NASA Tech Briefs

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National Aeronautics and
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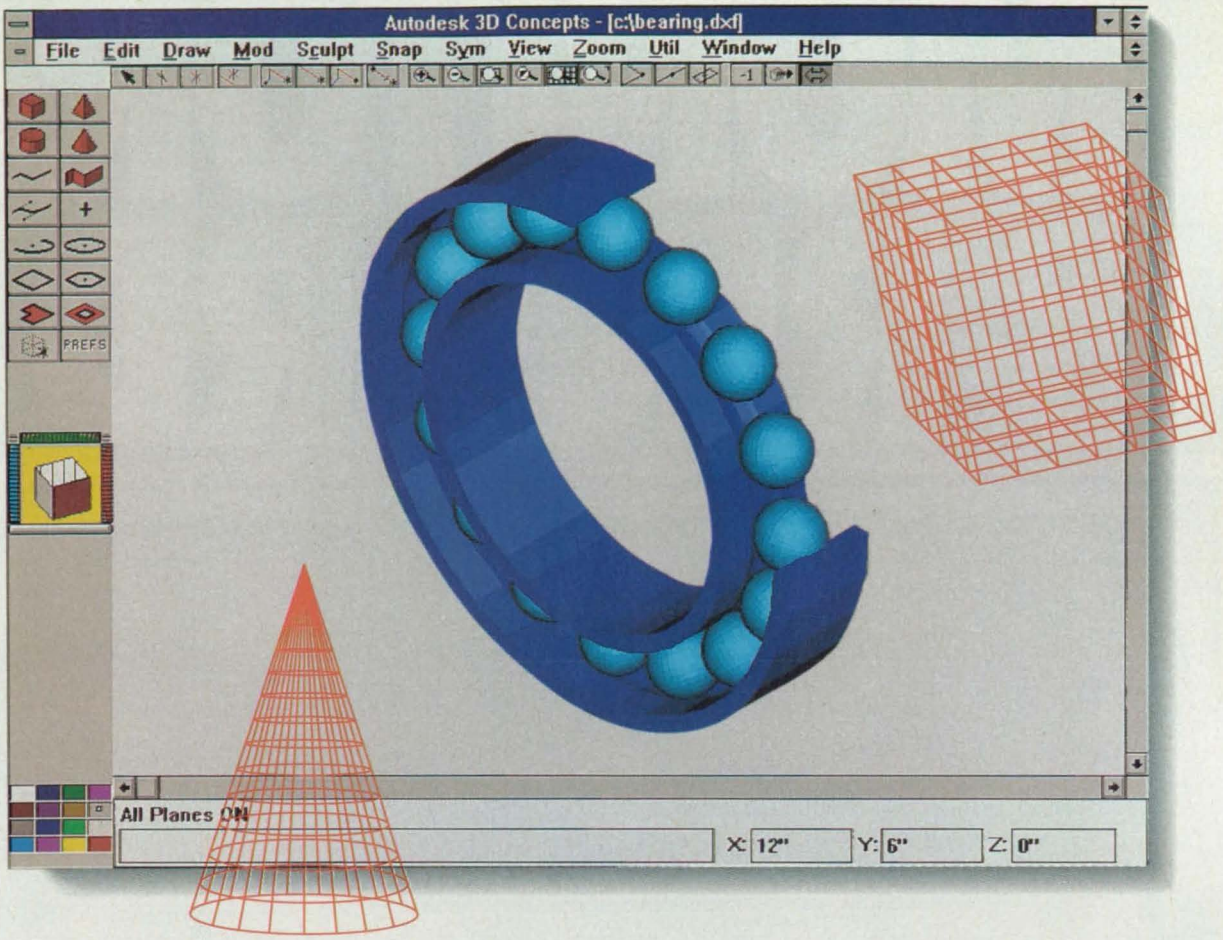

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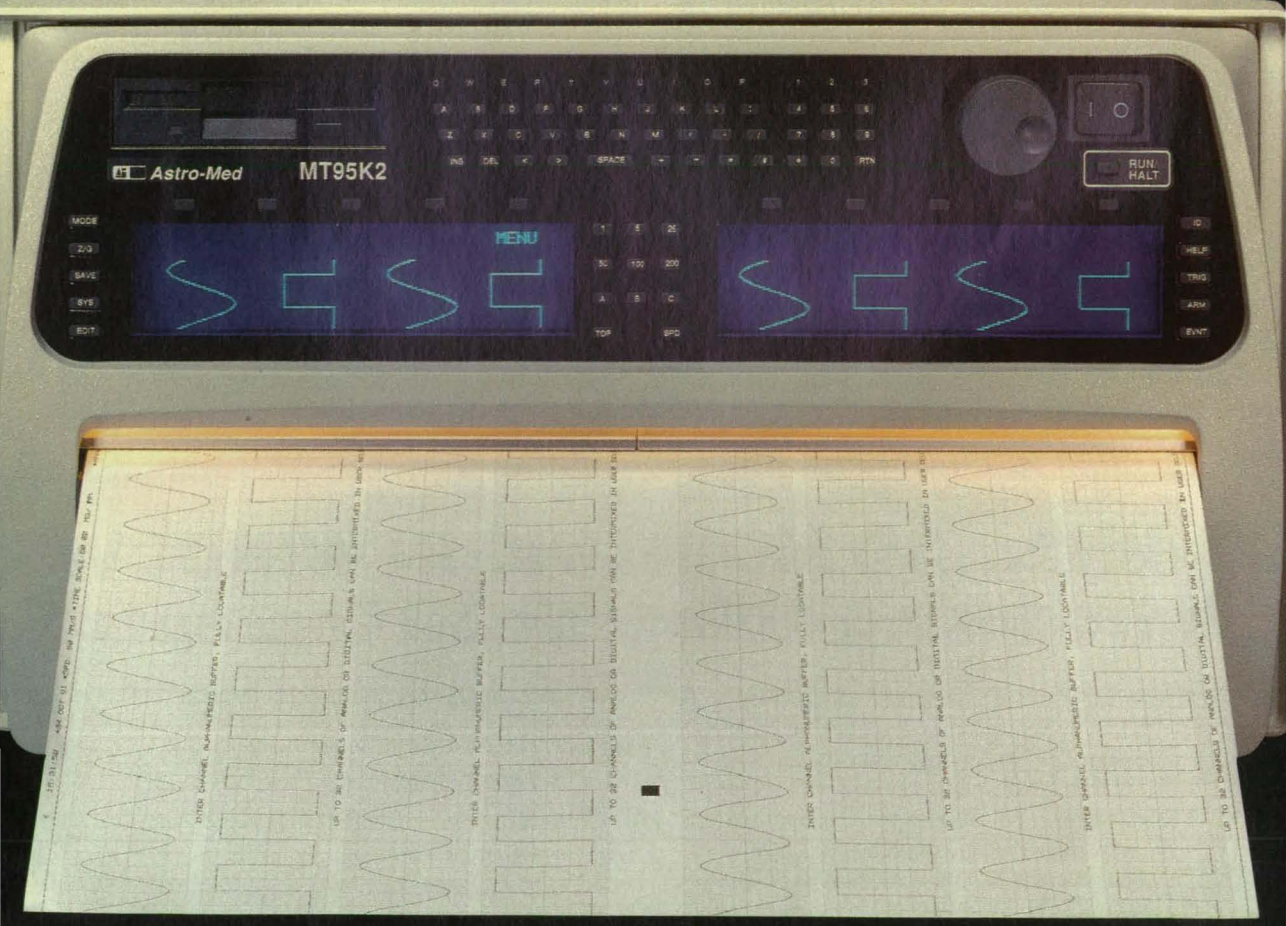

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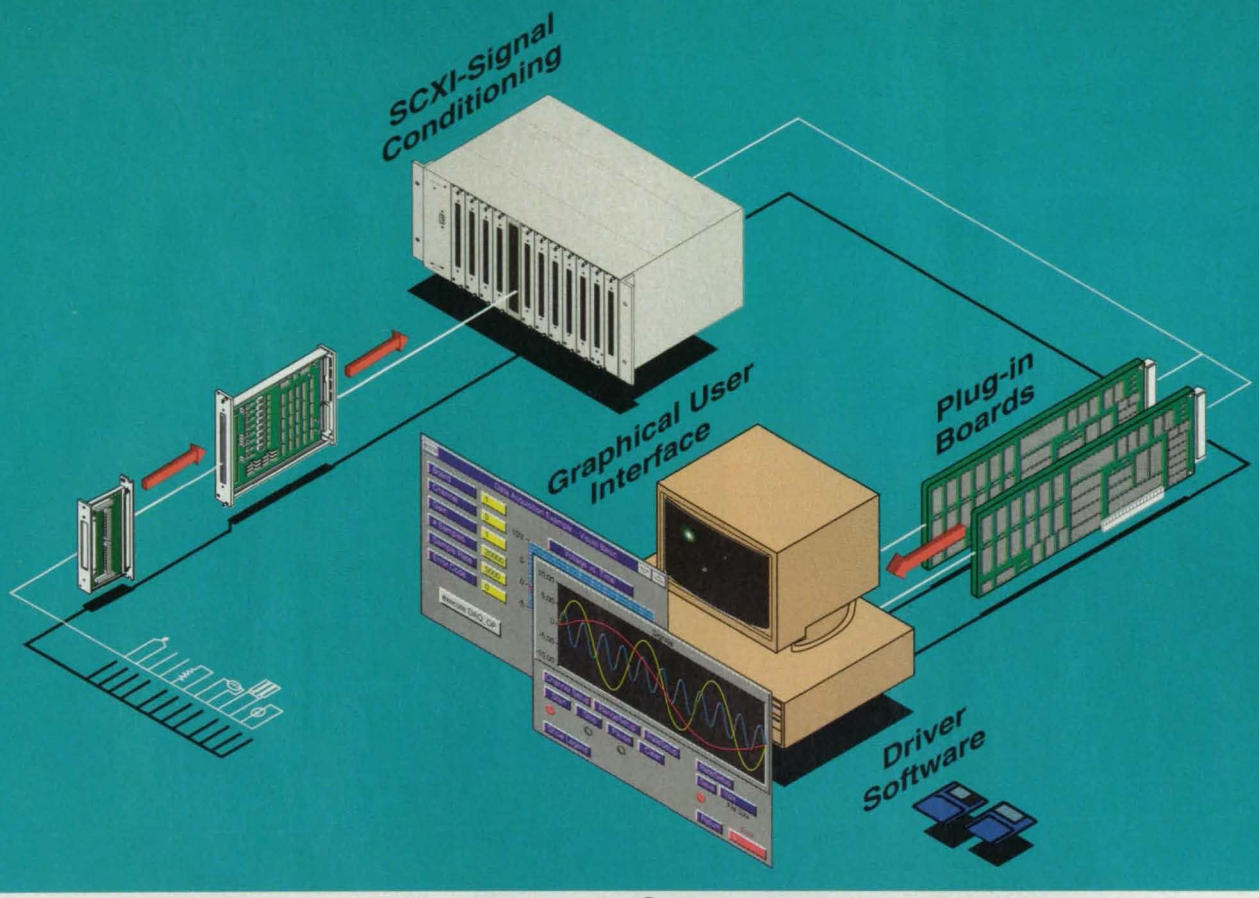

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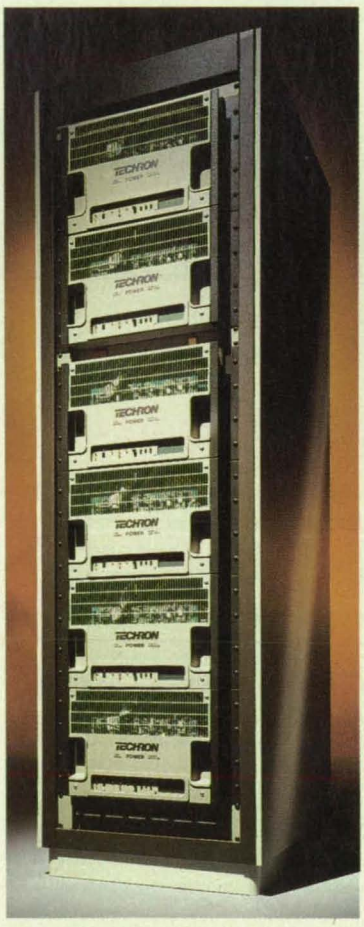

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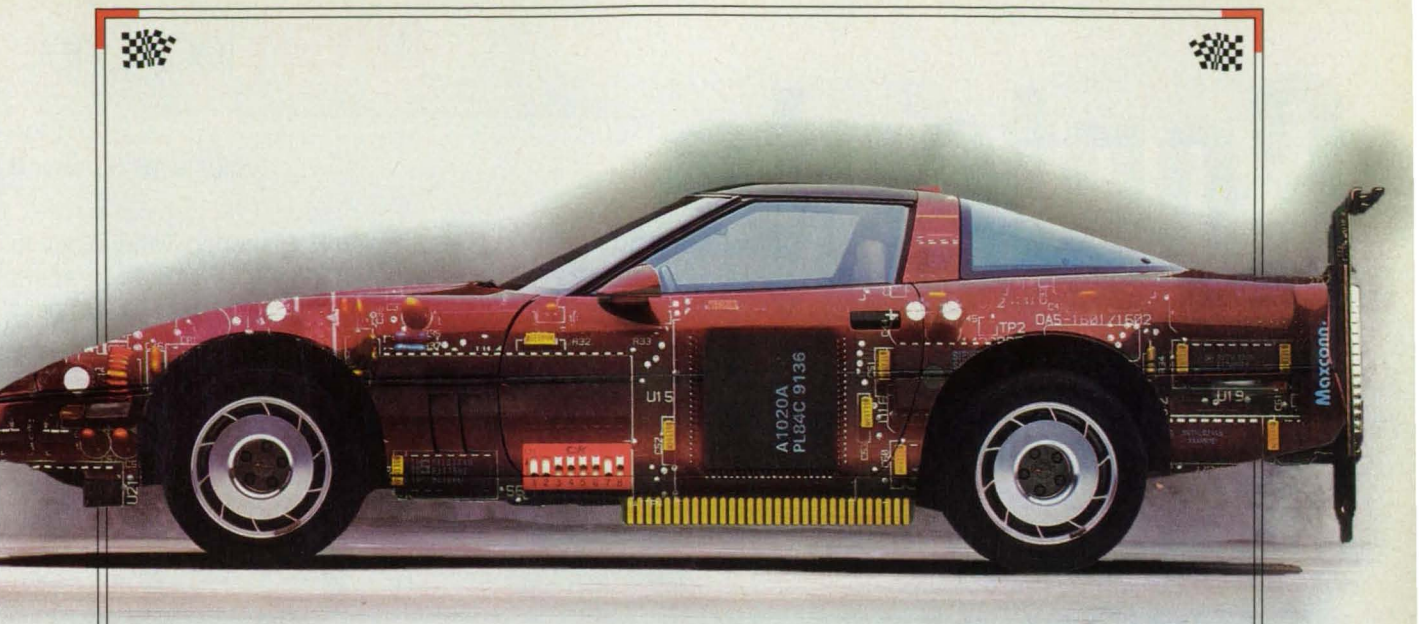

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NASA Tech Briefs

August 1992
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Transferring Engineering Technology to
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CAEM: Intelligent Computer Assistant for Engine Monitoring

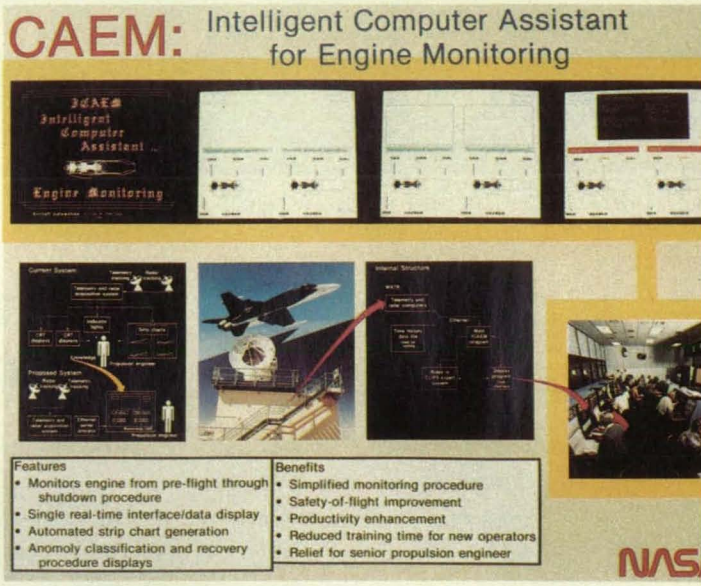

Photo courtesy NASA Ames

A new AI-based jet engine monitoring system developed at Ames Research Center promises to improve flight safety while saving engineering time. Turn to the tech brief on page 35.

48 Computer Programs

53 Mechanics

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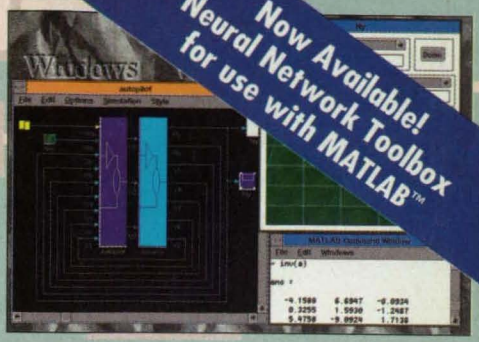
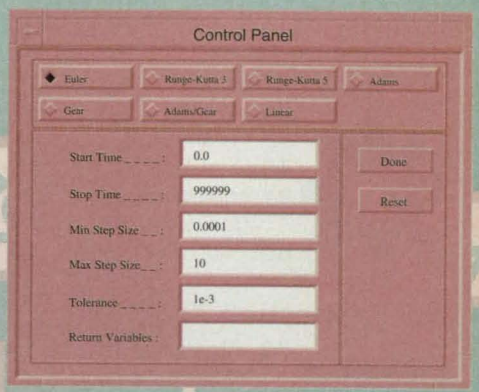
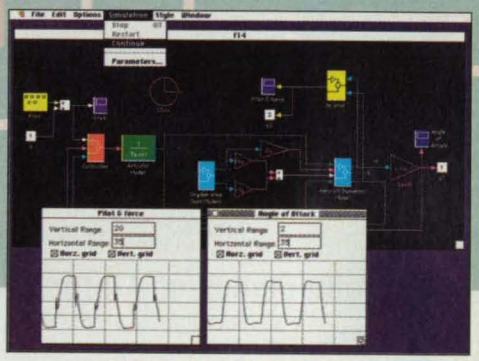
Block Diagram Software for Nonlinear Simulation of Dynamic Systems







(Top) Use the Scope block to see the "real-time" response of this autopilot model during the simulation; (Center) Specify simulation parameters via dialog boxes or the MATLAB command line; (Bottom) SIMULINK takes full advantage of the X Windows, OSF/Motif, Microsoft Windows, and Macintosh windowing systems.

SIMULINK, formerly named SIMULAB, is the next-generation software for modeling, analyzing, and simulating nonlinear systems. **SIMULINK** delivers a combination of flexibility, ease-of-use, and speed in a single package.

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Contents *(continued)*

Photo courtesy NASA Ames

The Plot4D computer program (page 54) creates animated pictures of unsteady and steady air flows—such as around this prolate spheroid—providing computational fluid dynamics researchers with a powerful new visualization tool.

DEPARTMENTS

on the cover:

A technician prepares to unlatch the door built into the guide vanes of the 16-Foot Transonic Wind Tunnel at NASA's Langley Research Center, which this year celebrates its 75th anniversary (see our report on page 14). The tunnel, built in 1939 and renovated in 1990, was recently used to develop two-dimensional nozzles that can deflect jet exhaust in any direction for increased maneuverability. This "thrust vectoring" may allow future military aircraft to be designed without traditional tail control surfaces or perhaps without the entire tail.
(Photo courtesy Langley Research Center)

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SCIENCE/SCOPE®

Now in its third cycle of mapping the surface of Venus, the spacecraft Magellan is close to its goal of producing a complete map of the planet. The key to gathering data is the Hughes Aircraft Company-built synthetic aperture radar, the sole scientific instrument aboard Magellan. Even before the first cycle ended, in mid-1991, Magellan had mapped 84% of Venus' surface, returning more digital data than all previous U.S. planetary missions combined, with resolutions 10 times better than those provided by earlier missions. To optimize radar performance, Hughes also designed a computer software program capable of handling the nearly 950 commands required per cycle. Each cycle takes one Venusian "day," the equivalent of 243 Earth-days.

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

Now, in times of disaster, even the most isolated outposts can be linked directly into the public telephone network. It's the result of portable versions of satellite earth stations called very small aperture terminals (VSATs), built by Hughes. VSATs played a vital role in three major relief efforts in 1991: the eruption of Mt. Pinatubo in the Philippines, the massive oil spill in Valdez, Alaska, and the 90,000-acre fire in the Idaho forest. VSATs can be shipped and assembled quickly and facilitate communications using more powerful antennas that are much smaller than conventional satellite dishes. The Hughes-designed networks' reliability and an availability rate of 99.5 percent make VSATs an excellent solution to conventional communications systems, which in disasters often experience serious degradation due to damage or overload.

Traffic managers will be better able to monitor, analyze, and control traffic flow, with the aid of Hughes' multi-spectral sensors and information management systems. These technologies will play an expanding role to help offset the increasing congestion on America's roads, by creating "smart highways." At a moment's notice, data could be gathered to help police, tow trucks, and ambulances respond to emergency crises. Understanding flow patterns and traffic composition would also help traffic engineers map out future traffic control strategies. The result of less traffic congestion will be billions of vehicle hours saved each year.

Some 700,000 school children experienced a field trip to the ocean floor off the Galapagos Islands, thanks in part to Hughes' SBS satellite. This high-technology journey was part of an unusual educational program — the JASON Project — which integrated the latest in marine science, videoteleconferencing, and satellite communications. Transmitted by Hughes' SBS satellite, video images of exotic underwater sea life flashed across large display screens, practically enveloping students in classrooms and auditoriums across the United States and Canada. The sharp, projected images were the result of Hughes' liquid crystal light valve technology.

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

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Editorial Notebook

New Directions, New Opportunities

As the aerospace and defense industries go through what has been referred to in the popular press as "downsizing," we are well aware that this euphemism for massive layoffs has caused pain and upheaval in many companies and lives.

Next month, in our September issue, we will feature the efforts being made by aerospace firms to expand beyond their traditional military/aerospace base into further-ranging commercial ventures. As you'll see, the approaches run the gamut from establishing technology licensing divisions—one aerospace contractor recently licensed a magnetic levitation technology to a company developing educational toys—to pursuing cooperative R&D agreements with commercial manufacturers.

As you see the new directions these companies are taking, we also hope you'll see employment opportunities for many of those whose lives have been short-circuited by this "downsizing." While most *NASA Tech Briefs* readers are employed, many of us know people who have been "downsized" and could use some help in finding new jobs. We hope you'll share the September issue with them, and also tell them about a new program we have initiated to help them in transition.

Beginning with the October issue, we will run two pages of "positions wanted" advertisements free for those engineers and scientists who are currently unemployed and actively seeking work. Economics force us to limit this effort to two pages and it will be first-come, first-served in the magazine. All you need to do is send us a resume and a 50-word synopsis of what you'd like to state in the ad. We'll provide a box number for anonymity if you prefer, rewrite the ad if needed, and send the resume to those who inquire. While this service will be free for the advertiser—the person looking for work—there will be a modest handling charge billed to companies who request resumes.

Send the resume and synopsis to: *NASA Tech Briefs*, Positions Wanted, 41 East 42nd St., # 921, New York, NY 10017.

Please, if you're currently employed but nervous, don't ask for the free service. We want to reserve the listings for those who need them most, and, unfortunately, we expect that there will be more requests for ads than we can fulfill at first, and not enough inquiries to make the effort budget-neutral, at least not in the beginning. We plan on running each ad once, but we will keep each resume on file and offer a synopsis of monthly ads to companies on request.

We keep hearing hints and seeing signs that things are getting better. While we're hoping they're all accurate, we're also hoping that these two ad pages will bring companies with needs together with people possessing the skills to fulfill those needs. ❑

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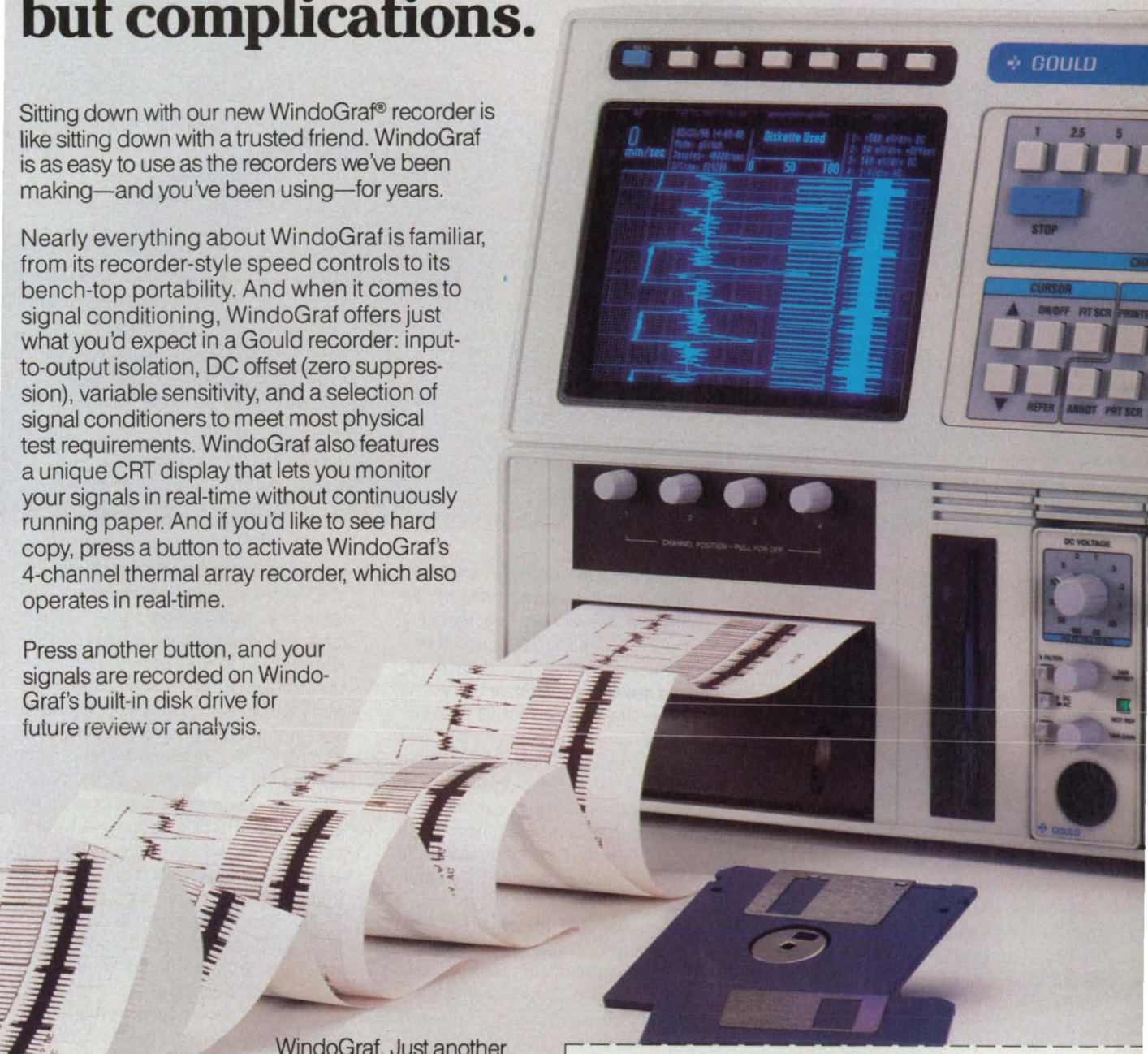

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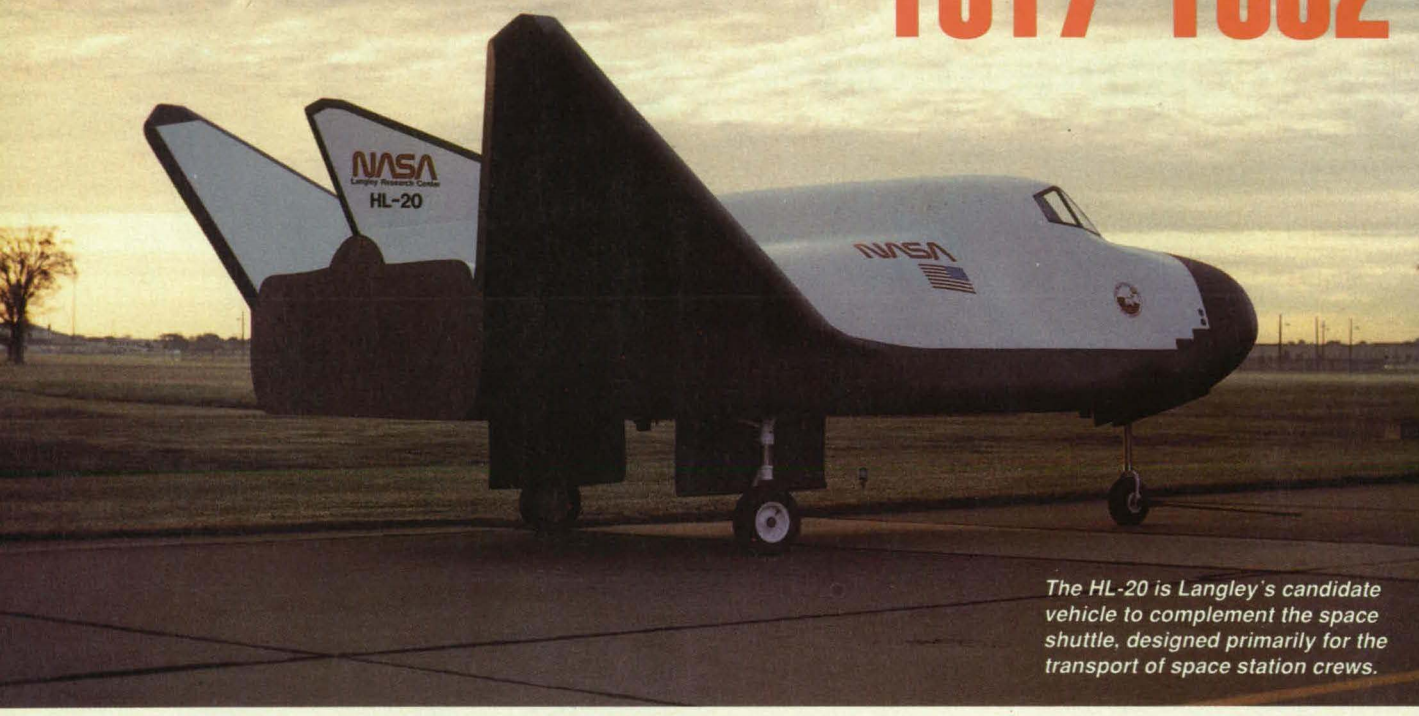


The HL-20 is Langley's candidate vehicle to complement the space shuttle, designed primarily for the transport of space station crews.

This year, NASA's Langley Research Center, Hampton, VA, celebrates 75 years as one of the world's premier aeronautical and aerospace research laboratories. The center's rich history spans the era of air and space travel to include such highlights as the first aircraft to break the sound barrier, landing a man on the moon, and the pioneering technology of the space shuttle.

The nation's first government-run civilian aeronautical laboratory began rather modestly on July 17, 1917. Initially called Langley Field, in honor of the aeronautical pioneer Samuel Pierpont Langley, it was the founding research facility of NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), formed in 1915 and funded by President Woodrow Wilson with just $5000. By the time its first wind tunnel was dedicated in 1920, Mr. Langley had died and the NACA facility became the Langley Memorial Aeronautical Laboratory. With NACA's formal abolishment in 1958 and the absorption of its facilities into the new National Aeronautics and Space Administration, the laboratory was renamed the Langley Research Center, as it is known today.

A consistent forerunner in wind tunnel design and research, the center constructed the world's first variable-density wind tunnel in 1923, which provided the primary source of data for the nation's growing aviation industry. The tunnel set the standard for all variable-density wind tunnels in use today, and was designated a National Historic Landmark in 1985. Building on its wind-tunnel supremacy, the center soon added a propeller research tunnel, a full-scale tunnel, and constructed the first transonic tunnel in 1950, featuring a slotted throat test section.

The center's engineers fostered both transfer of research findings and their own awareness of pressing problems by working closely with aircraft manufacturers and academic researchers. One of the center's most ingenious early designs, in response to broad-ranging requests for a means to reduce wind drag, was cowling in radial aircraft engines. The innovation won for NACA in 1929 the prestigious Collier trophy, recognizing the year's greatest aeronautical achievement. Engine cowling revolutionized aircraft design in the 1930s and saved the aviation industry millions of dollars.

During World War II, NACA researchers tested and boosted the performance of virtually every type of American combat plane, redesigning some 115 aircraft. The expertise gained was applied after the war to the challenges of high-speed flight. Langley scientists joined with the military in a supersonic aircraft development program that culminated in Charles E. Yeager's historic flight beyond the speed of sound on October 14, 1947. The program garnered Langley another Collier trophy, and provided a stepping stone to development of the X-15, America's first hypersonic transatmospheric vehicle.

Reducing aerodynamic drag to increase efficiency and performance persisted as a central focus of efforts to send aircraft soaring at ever-increasing speeds. Langley innovations that helped set the pace of high-speed aircraft development included laminar-flow airfoils and the swept wing in the 1940s, the variable-sweep wing in the 1950s, and the supercritical wing in the late 1960s. The transonic area rule, an innovative guide to shaping high-speed aircraft for optimum balance between wing and fuselage volume, allowed planes to safely pass through Mach 1 and won Langley yet another Collier in 1954.

Onward and Upward

Serving as the foundation of the newly-formed NASA at the end of the 1950s, Langley helped give birth to the space age. NASA's manned space program began at the center, where the original seven astronauts trained for Project Mercury. Langley also supported the subsequent manned space programs—Gemini, Apollo, Skylab—providing spacecraft design and testing, flight concept development, and mission planning. Notable successes included demonstrating for Project Apollo the feasibility of lunar-orbit rendezvous by employing a lunar landing module detachable from the mother ship. The concept expedited man's first moon landing which propelled the nation to the forefront of space technology.

Various unmanned space projects also relied on Langley ingenuity, including the Echo communications satellites, the Explorer, the Lunar Orbiter, and the more recent Long Duration Exposure Facility, a large satellite carrying 57 space experiments into orbit for six years. Since 1959, Langley has managed the Scout launch vehicle, designed for unmanned small satellite missions and high-altitude probes. Capable of launching a 385-pound satellite into a 500-mile orbit, the veteran Scout has had a success rate of 96 percent on 114 launches, thereby earning a spot at the National Air and Space Museum. On a larger scale, Langley managed the enormously fruitful Viking project, which landed two automated laboratories on Mars.

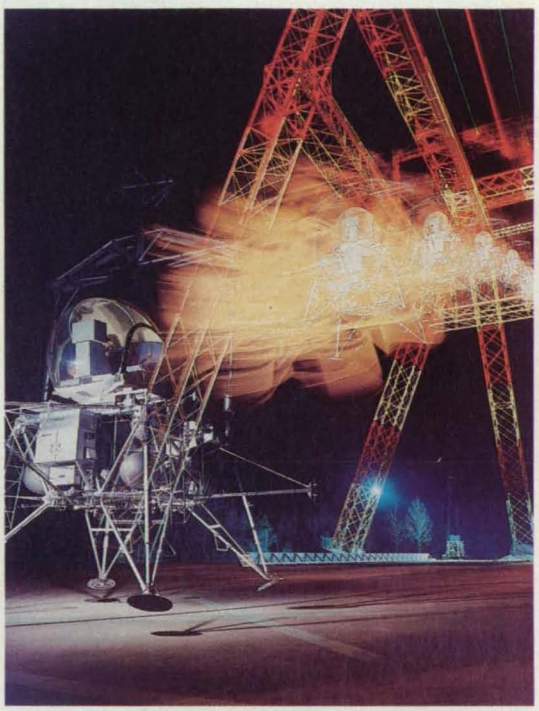
Langley's contributions to the ongoing space shuttle program included 60,000 wind-tunnel test hours to define vehicle flying characteristics, recommendation of the shuttle's delta wing shape, structural and materials evaluation, launch certification of the thermal protection system, and design and analysis of the flight control and guidance systems.

Langley Today

Langley Research Center currently employs approximately 5200 people and encompasses 203 buildings on nearly 800 acres of government land. Flight tests are conducted in over 40 wind tunnels that operate at speeds up to Mach 20. The newest asset is the National Transonic Facility, a large wind tunnel in which cryogenic nitrogen is pushed through the tunnel instead of air for a more realistic transonic flight simulation.

Langley's computer complex houses one of the world's fastest supercomputers and various sophisticated laboratories are equipped for research in fields ranging from computer science and advanced materials to acoustics and optics. Researchers design sensors, communications equipment, and data handling systems for space use; investigate the effects of heat, vacuum, noise, and meteoroid impact on space vehicles; and develop advanced composites, thermal control systems, and improved electronics. One result is the more than 500 technical reports and articles published by the center's researchers annually. Some of the center's current projects include:

National AeroSpace Plane (NASP) Development. This joint program of the Department of Defense, NASA, and US industry, supports development of a vehicle that will take off horizontally like an airplane, accelerate to about 17,500 mph (25 times the speed of sound) and reach low-Earth orbit. While in orbit, the plane could repair satellites or deploy payloads to the space station, and then return for a runway landing on Earth. Langley investigators employ supercomputer-generated simulations of high-speed wind tunnel tests to study engine nozzle performance and exhaust effects on tail surfaces.



A multiple exposure captures the movement of the Lunar Excursion Module, a manned simulator designed by Langley to train Apollo astronauts.

HL-20 Personnel Launch System. The HL-20 is Langley's candidate for a compact space vehicle to transport up to 10 astronauts and small cargo to and from low-Earth orbit, allowing rapid, affordable manned access to space. The vehicle is intended to complement the space shuttle and, as currently conceived, would be launched from an

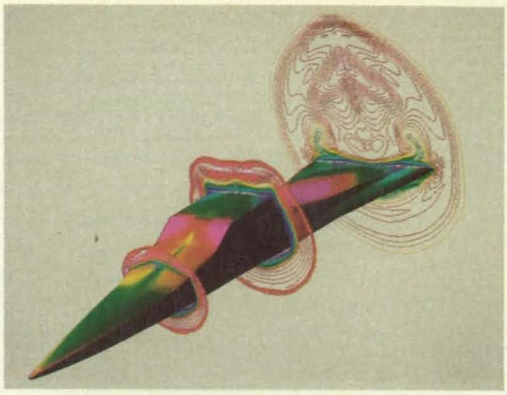
The cockpit of Langley's Transport Systems Research Vehicle displays data from an advanced-warning system for wind shear.

expendable booster and be capable of runway landings. With its wings folded, it could fit within the space shuttle's payload bay. Lacking the shuttle's main propulsion engines, the HL-20 would also offer enhanced crew safety.

Wind Shear Detection. Research at Langley's Wind Shear Program Office addresses the FAA mandate requiring all commercial aircraft to have onboard wind shear detection systems by the end of 1993. The FAA seeks sensors that will provide 20-40 second advanced warning of potentially dangerous wind shears caused by strong divergent winds, thereby allowing the aircraft's crew sufficient time to take corrective action. The office has flight-tested two forward-looking wind shear sensors based on Doppler radar and infrared technologies; tests of a third, laser-based LIDAR system are underway this summer in Denver, CO and Orlando, FL.

Wide-Screen Displays for Cockpit Research. Recent advances in computer graphics have made possible large-screen, integrated stereo displays useful in enhancing pilot and aircraft performance as well as safety. Langley has installed a 15" x 40" high-definition cockpit display in a ground simulator to assess pilot awareness.

Global Environment Studies. Major efforts are underway to analyze the global climate, focusing on such phenomena as holes in the ozone layer. Groundbreaking cloud radiation research included a Langley-led expedition this June by nearly 300 atmospheric scientists from eight countries to the Eastern Atlantic region between the Azores and Madeira Islands. Called the Atlantic Stratocumulus Transition Experiment (ASTEX), it collected information on the puffy, layered clouds in the region to assess their effects on the atmosphere and ocean. Analysis of the data is expected to yield refinements in computer models used to predict worldwide weather patterns.



Engine exhaust is modeled in this supercomputer-generated image of an aerospace vehicle as part of the National AeroSpace Plane (NASP) Program.

Langley researchers also devised the Halogen Occultation Experiment (HALOE), an atmospheric satellite deployed by the space shuttle in 1991. HALOE is intended to provide global-scale data on temperature, ozone, and other gases to better understand the chemistry, dynamics, and radiative processes of the middle atmosphere. Other atmospheric satellite studies include the Earth Radiation Budget Experiment, which gathers information on the radiation effects of clouds, and the Stratospheric Aerosol and Gas Experiment, which measures ozone and aerosol concentrations in the upper atmosphere. Langley researchers plan a number of future experiments for the Earth Observing System Polar Orbiting Satellite and the space station to further advance our knowledge of the global impact of natural and man-made phenomena. ❑

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.

Computer Jet-Engine-Monitoring System

A developmental system would reduce the difficulty of monitoring turbofan engines in flight. The system will distill and display critical engine data on one screen and would alert the engineer if abnormal conditions develop.
(See page 35)

Barrier/n/n+ Varactor Frequency Multipliers

These solid-state frequency multipliers would offer increased efficiency at millimeter and submillimeter wavelengths. The devices would feature Mott or heterojunction barriers and back-to-back diode configuration, which would make it possible to obtain symmetrical capacitance-versus-voltage characteristics with a high ratio between the maximum and minimum capacitances.
(See page 28)

Making Crystal Filaments From Extruded Ceramic Rods

Ceramic or metal fibers can be extruded into rods 0.01 to 0.05 in. (0.25 to 1.27 mm) in diameter at a significantly lower cost than in an earlier method of preparing the rods from hot-pressed full-density disk. The filaments can be used as reinforcing fibers in composite materials.
(See page 68)

Helicopter Rotor Blade With Free Tip

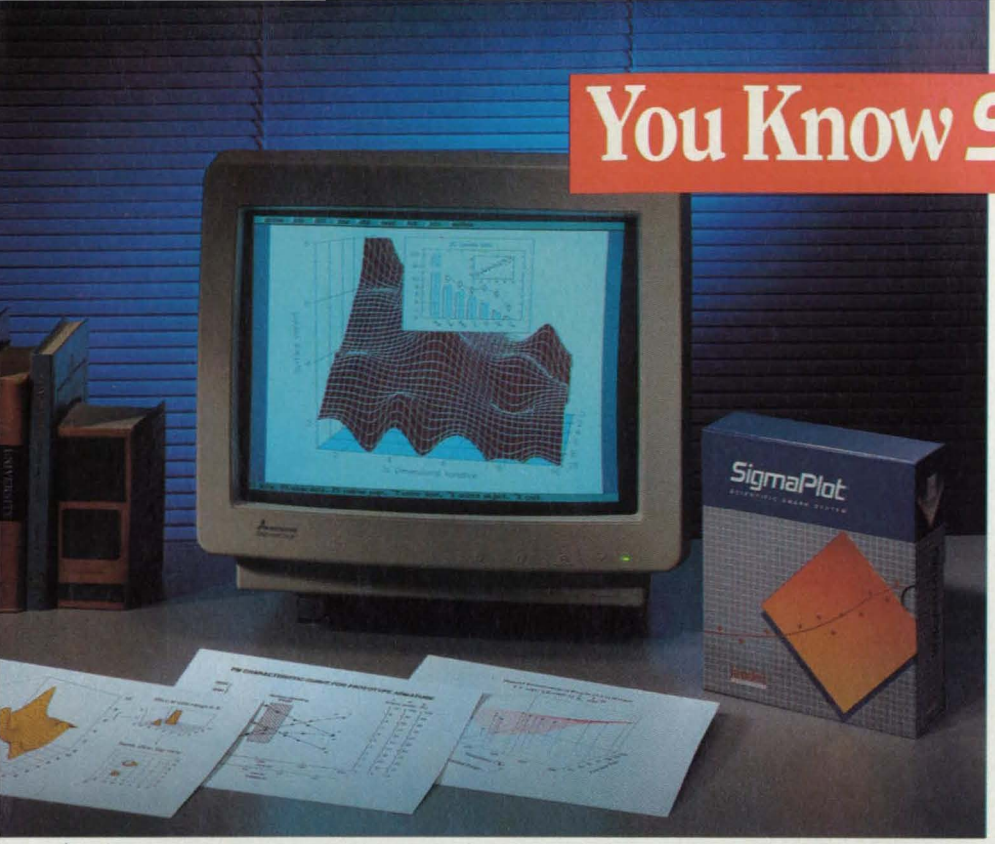
Free-tip rotor blades significantly improve fuel efficiency and other performance characteristics of helicopters. Tests on a scale model demonstrated 12 percent reduction in power requirement at cruise speeds. More savings are anticipated at higher speeds.
(See page 62)

Tangential-Entry Injector With Internal Reed Valve

A liquid-spray-injecting device features a designed pressure drop versus rate of flow to help in metering the flow. Potential application is in fuel-injection systems.
(See page 56)

Improved Raman-Emission Detector

Use of a paraboloidal mirror and collecting lens is one of several improvements that has increased the sensitivity of Raman-emission detector. The new detector also features improved flow geometry that reduces stabilization time.
(See page 41)



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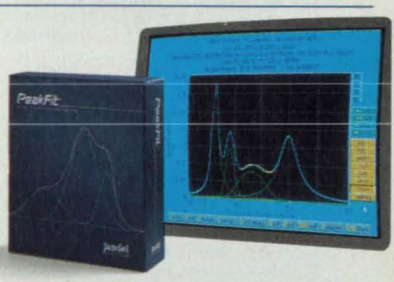

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If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low-and no-cost services provided by NASA's Technology Utilization (TU) Network. But a TECH BRIEFS subscription represents only a fraction of the technical information 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 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 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; *Dr. Doris Rouse, Director,* (919) 541-6980**

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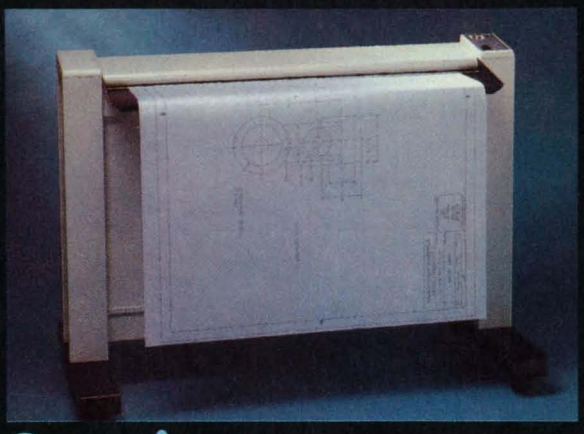

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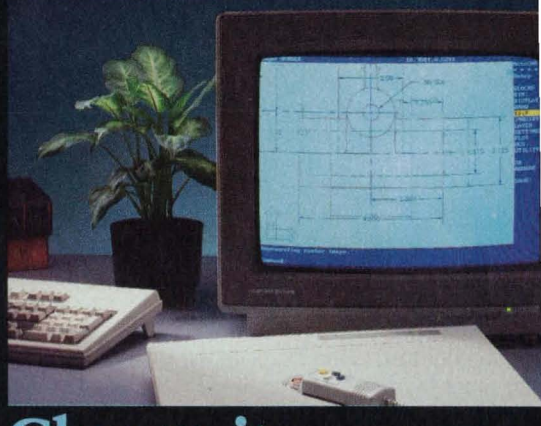

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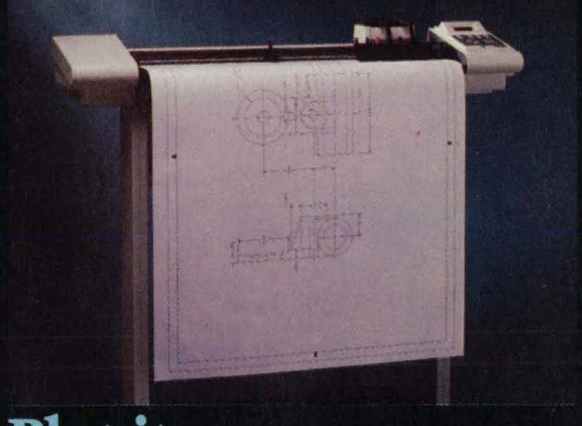

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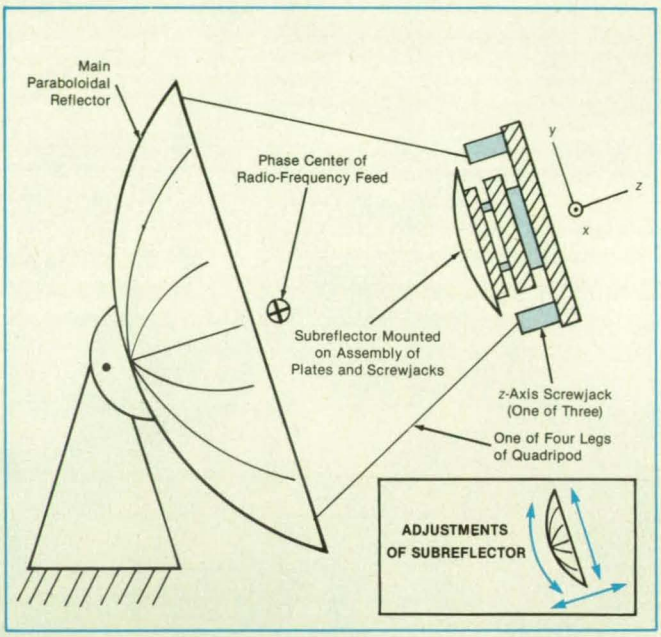
The subreflector is tilted and translated to compensate for gravitational distortions.

NASA's Jet Propulsion Laboratory, Pasadena, California

The subreflector of a 34-m-diameter paraboloidal radio-antenna reflector can be tilted and translated slightly to compensate partly for gravitational distortions of the antenna structure. The basic idea is simple and well known: one adjusts the position and orientation of the subreflector to focus it with respect to the phase center of the radio-frequency feed horn and the primary focus of the computed paraboloid that best fits the gravitationally distorted main paraboloidal reflector. By so doing, one restores some of the gain that is lost when the antenna is aimed at an elevation angle other than the design optimum elevation (which is 45° in this case).

The subreflector is located at the outer end of a quadripod mounted on the main reflector. The subreflector is mounted on the bottommost one of three plates, the topmost of which is connected to the quadripod at three corners by screwjacks that translate the corners along the *z* axis (see figure). Tilts are effected via differential *z* translations of the corners. The other two plates are connected to the top plate and to each other by slides and screwjacks that provide translations along the *x* and *y* axes.

Transducers indicate positions along the axes of the jacks, providing feedback for control of the position and orientation of the subreflector. A digital memory serves as an electronic lookup table that contains data on the required adjustments of the subreflector. These data are precomputed on the basis of measured and calculated gravitational distortions of the main reflector, quadripod, and other substructures as functions of the elevation angle. A signal indicative of the actual elevation angle is fed to a microprocessor, which uses the lookup table to generate control signals that, in turn, command the screwjacks to the required positions.



The **Position and Orientation of the Subreflector** are adjusted to compensate for gravitational distortions of the main reflector and other substructures when the elevation angle is changed. In the case of the 34-m antenna described in the text, typical adjustments upon change of elevation from 45° to 90° are of the order of millimeters.

This work was done by Masakazu S. Katow of Planning Research Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 163 on the TSP Request Card.* *NPO-18442*

Capacitive Proximity Sensor Has Longer Range

Sensitivity and range are increased by use of a driven shield.

Goddard Space Flight Center, Greenbelt, Maryland

Figure 1 illustrates a robot equipped with an improved capacitive sensor to detect a nearby object (which could be a person, conductor, or dielectric insulator). The output of the sensor is fed to the robot controller to prevent a collision between the robot and the object. Whereas prior capacitive proximity sensors for this purpose had to be mounted at typical standoff distances of 1 in. (2.5 cm) from the surfaces of robot arms, this sensor can be mounted more nearly flush and still achieve ranges in excess of 1 ft (30 cm), compared to the 1-in. (2.5-cm) range of comparable industrial sensors. The sensitivity and dynamic range also has a corresponding 12-to-1 improvement.

One essential element of the sensor is a thin sheet of conductive material mounted on a thin layer of electrical insulation on the electrically grounded robot arm. A second, much narrower sheet is similarly mounted on (and electrically insulated from) the first sheet. The second sheet serves as the capacitive sensing element, while the first sheet serves as an electrostatic shield between the sensing element and the robot arm. Through a voltage-follower circuit, the shield is driven at the same potential as that applied to the sensing element, without loading the source of the potential. As shown at the top of Figure 2, the driven shield alters the electric field around the sensing element. Instead of being concentrated in the gap between the sensing element and the grounded robot arm (as it would be in the absence of the driven shield), the field is effectively squeezed out of the gap and concentrated more in the exterior space to be probed.

As shown at the bottom of Figure 2, the sensing element is part of an oscillator circuit that operates at a typical frequency of about 20 kHz. The total capacitance between the sensing element and ground constitutes the tuning capacitance of the oscillator. This total capacitance includes the approximately fixed capacitance, C_{sg}, between the sensing element and ground. It also includes the series combination of (1) the variable capacitance, C_{so}, between the sensing element and the object and (2) the variable capacitance (if any), C_{og}, between the object and ground. The object is detected via the effect of C_{so} on the frequency of oscillation.

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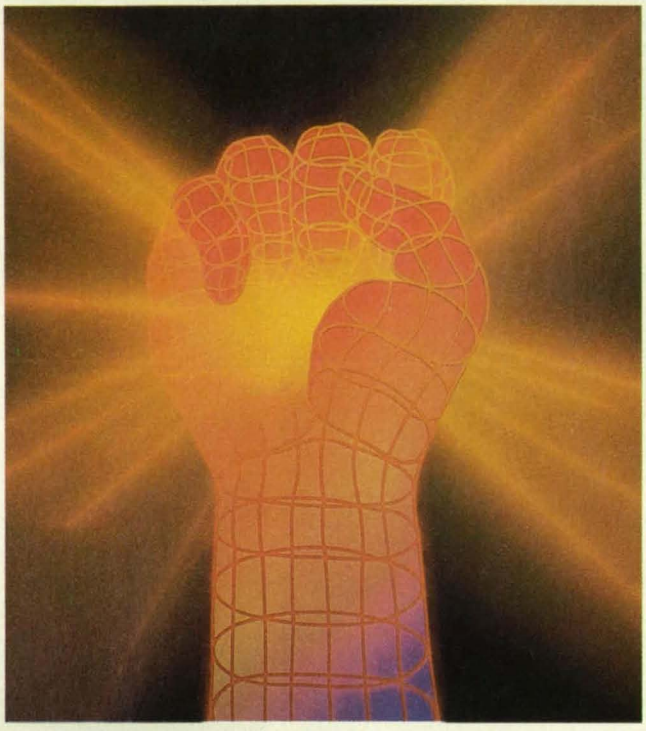

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Technology 2002 Program

Tuesday, Dec. 1

8:30 - 9:45 am	Welcome and Keynote Address
10:00 am - 12:00 pm	National Critical Technologies (6 Tracks)
1:00 - 3:00 pm	National Critical Technologies
4:00 - 6:00 pm	Workshop: How To Do Business With The U.S. Government

Wednesday, Dec. 2

8:30 - 8:55 am	Wednesday Keynote Address
9:00 - 11:00 am	National Critical Technologies (6 Tracks)
1:00 - 3:00 pm	National Critical Technologies
4:00 - 6:00 pm	University Technology Transfer Opportunities (Track #1) International Technology Forum (Track #2)
7:00 - 10:00 pm	Technology Transfer Awards Dinner

Thursday, Dec. 3

8:30 - 8:55 am	Thursday Keynote Address
9:00 - 11:00 am	National Critical Technologies (6 Tracks)
1:00 - 3:00 pm	University Technology Transfer Opportunities (Track #1) International Technology Forum (Track #2)

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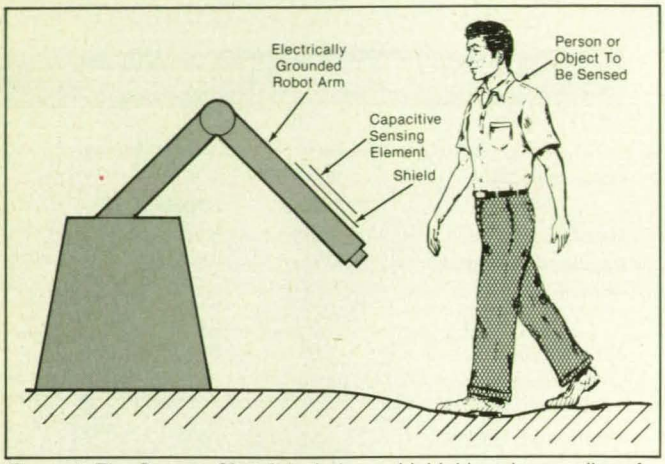
Figure 1. The **Capacitive Proximity Sensor** on the robot arm detects a nearby object (which could be a person) via the capacitive effect of the object on the frequency of an oscillator.



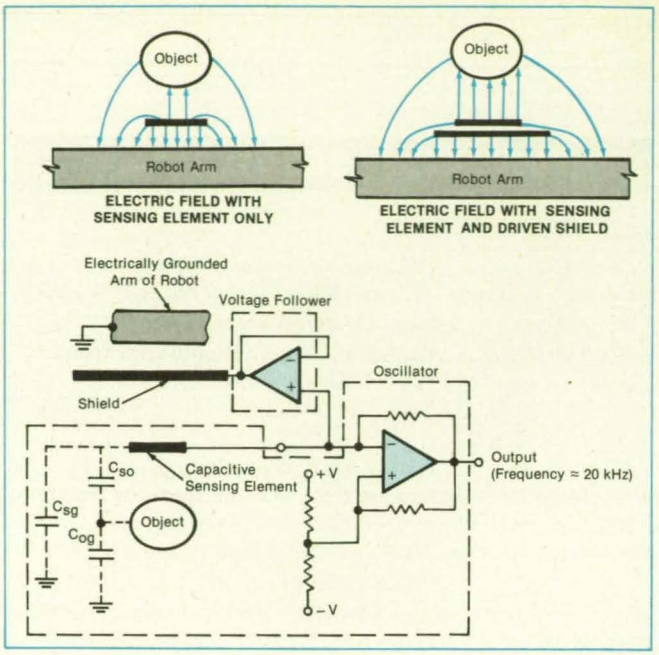


Figure 2. The **Sensor Circuit** includes a shield driven by a replica of the alternating voltage applied to the sensing element. The driven shield concentrates the sensing electrostatic field in the exterior region to enhance sensitivity to the object

The alteration of the electrostatic field greatly diminishes C_{sg} and increases C_{so} somewhat. Thus, C_{so} becomes a greater fraction of the total capacitance, with a correspondingly proportional increase in its effect on the frequency of oscillation. In a typical case, the result is an increase in the range at which an object can be sensed, from about 1 in. (2.5 cm) to about 12 in. (30 cm).

This work was done by John M. Vranish of **Goddard Space Flight Center**. *For further information, Circle 136 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-13377.

Determining Extinction Ratio of a Laser Diode

Background light and nonideality of laser pulses are taken into account.

Goddard Space Flight Center, Greenbelt, Maryland

An improved technique for determining the extinction ratio of a pulsed laser diode is based partly on a more-realistic definition of the extinction ratio applicable to nonideal laser pulses. Heretofore, most such determinations involved the assumption of ideal (that is square-wave) laser pulses, and, in some cases, neglect of the optical power from background light.

Figure 1 illustrates the ideal and nonideal cases. The extinction ratio, R, is defined by $R = (P_{on} - P_{bk})/(P_{off} - P_{bk})$, where P_{on} is the output power of the laser in a pulse of duration T, P_{off} is the output power of the laser in the absence of a pulse, and P_{bk} is the power of background light. These powers are computed from the corresponding output voltages V_{on}, V_{off}, and V_{bk} of an amplifier connected to a photodiode at which the laser beam is aimed.

Because the power fluctuates during a real pulse, it is more realistic to define the extinction ratio in terms of the energy obtained by integrating the power over the pulse interval (for P_{on}) of duration T, during an interval of duration T when the laser is operating under dc bias but the pulse is not applied (for P_{off}), and during an interval of T when the light from the laser is blocked, allowing the photodiode to receive only background light. Then the extinction ratio is defined by

$$R = \left[\int_T P_{on}(t)dt - \int_T P_{bk}(t)dt\right] \Big/ \left[\int_T P_{off}(t)dt - \int_T P_{bk}(t)dt\right]$$

where t = time. If P_{bk} and P_{off} are constant, then the equation becomes simply

$$R = \left[\frac{1}{T}\int_T P_{on}(t)dt - P_{bk}\right] \Big/ (P_{off} - P_{bk})$$

Figure 2 illustrates an apparatus used to measure the extinction ratio of a laser diode. The laser beam is directed through an interference filter (which transmits light in a passband centered on the laser wavelength), then focused by a lens onto a positive/intrinsic/negative photodiode. The pho-

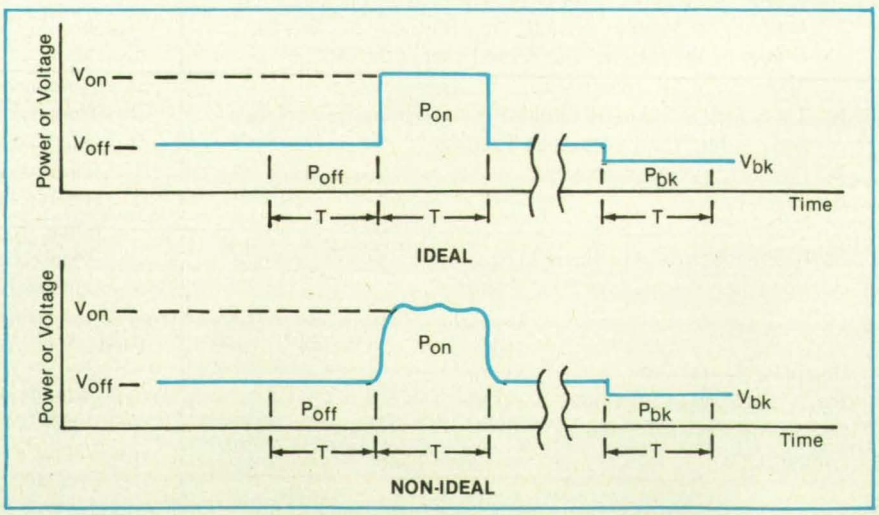


Figure 1. These **Ideal and Nonideal Waveforms** show the relationships among P_{on}, P_{off}, P_{bk} and the corresponding voltages V_{on}, V_{off}, and V_{bk}.

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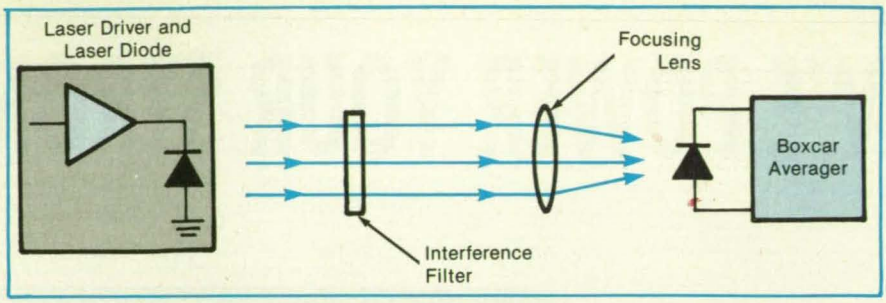


Figure 2. This **Apparatus Measures the Optical Energies** conveyed by the laser beam during pulse intervals T long, conveyed by the laser beam during no-pulse intervals T long, and conveyed by background light during intervals T long.

todiode is chosen to have a bandwidth (with respect to output electrical signals) greater than that of the amplitude modulation of the laser beam. A boxcar averager processes the output of the diode, integrating the appropriate amplified voltages over time to obtain $\int_T P_{on}(t)dt$, $\int_T P_{bk}(t)dt$, and $\int_T P_{bk}(t)dt$.

This work was done by Glenn L. Unger of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13413

Barrier/n/n$^+$ Varactor Frequency Multipliers

Solid-state frequency multipliers offer increased efficiency at millimeter and submillimeter wavelengths.

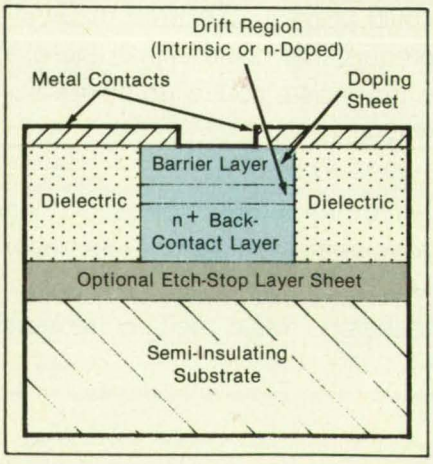
NASA's Jet Propulsion Laboratory, Pasadena, California

Barrier/n/n$^+$ (BNN+) varactor diodes are being developed for use as frequency multipliers at millimeter and submillimeter wavelengths. Typical devices of this type would be required to serve as frequency triplers or quintuplers to provide powers of the order of milliwatts at frequencies from 0.1 THz to about 1 THz.

The BNN+ concept is an extension of the barrier/intrinsic/n$^+$ (BIN+) concept described in "BIN Diode for Submillimeter Wavelengths" (NPO-17258), *NASA Tech Briefs*, Vol. 13, No. 1 (January 1989), page 24. Like BIN+ varactor diodes and unlike Schottky-barrier varactor diodes, the BNN+ devices feature Mott or heterojunction barriers and a back-to-back diode configuration, which make it possible to obtain symmetrical capacitance-versus-voltage characteristics with a high ratio between the maximum and minimum capacitances. This concept can be implemented by fabricating the back-to-back diodes in a planar configuration with no need to provide ohmic contacts between them and no need for bias voltage. In the version shown in the figure, each diode includes a barrier layer 20 to 30 nm thick, a drift layer 100 to 150 nm thick, and an n$^+$ layer, which serves as the back contact between the two diodes.

In the BIN+ case, the drift region is intrinsic, so that electrons injected from the n$^+$ back contact carry space-charge-limited current with a frequency response limited by transit time. In this case, the capacitance-versus-voltage characteristic includes a sharp transition between the maximum and minimum capacitances, enabling generation of high harmonic content suitable for triplers, quintuplers, and the like at low powers.

Numerical simulations have shown that the power would be maximized if the half width of the central peak in the capacitance-versus-voltage curve were about one-fifth of the maximum voltage. This could be achieved by proper sheet doping between the barrier and the drift re-



Back-to-Back BIN+ or BNN+ Diodes constitute a frequency-tripling varactor. In the BNN+ case, the drift region is n-doped. The optional etch-stop layer provides for the removal of the substrate to minimize the parasitic capacitance and the transmission-line losses of the leads.

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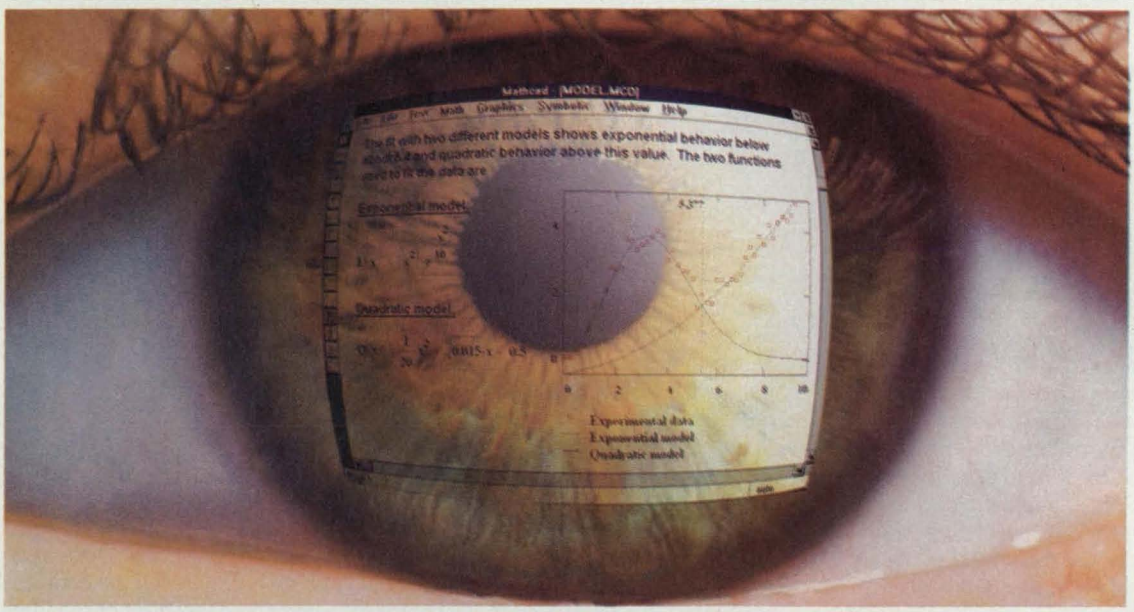

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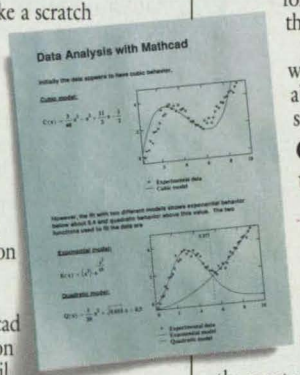

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gion. The maximum voltage is, in turn, determined by the onset of Fowler–Nordheim tunneling through the barrier, and this excludes the use of a simple Mott barrier for power applications.

The foregoing considerations led to the BNN+ concept, in which bulk doping (around $10^{17}/cm^3$) is added to the drift region. In this case, the current is no longer space-charge-limited and the frequency response is improved. The frequency response would approach the dielectric-relaxation limit, if it were not limited by the onset of electron-velocity saturation and the parasitic resistance of the n^+ region. The central peak in the capacitance-versus-voltage curve becomes less sharp than for the BIN diode, with slowly varying depletion tails. This situation is advantageous for high-power triplers.

Likely subjects for development in the near future include SiO_2/Si and $Al_xGa_{1-x}As$/GaAs devices to be tested as waveguide triplers to produce 5 mW at 200 GHz. A quasi-optically-coupled array of triplers integrated with an antenna structure has also been considered.

This work was done by Udo Lieneweg, Timo J. Tolmunen, Margaret A. Frerking, and Joseph Maserjian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 103 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-18428.

Equations for Designing Superconducting Transmission Lines

Characteristics of microwave circuits can be predicted accurately.

NASA's Jet Propulsion Laboratory, Pasadena, California

Equations for the propagation of quasi-transverse electric and magnetic (TEM) waves along thin films made of high-critical-temperature superconductors constitute the basis of a mathematical model useful in the design of coplanar-waveguide, microstrip, and stripline microwave circuits made with such films. The model can be incorporated readily into older commercial software for the computer-aided design of microwave circuits, which software was developed before the advent of high-critical-temperature superconductors.

The new model is needed because the electromagnetic characteristics of thin films of high-critical-temperature superconductors are more complicated than are those of ideal superconductors and of normal conductors. In particular, the major simplifying assumption that the depth of penetration of the electromagnetic wave is much less than the thickness of the film is not necessarily valid for a high-critical-temperature superconductor. The additional penetration can result in additional internal impedance and can affect such important externally measurable characteristics as input and output impedances, speed of propagation, electrical length, and attenuation. Even when the small-penetration-depth assumption is valid, high-temperature superconductors behave differently from ideal superconductors and normal superconductors: whereas the surface resistance of a normal conductor is proportional to the square root of the frequency, that of a superconductor is approximately proportional to the square of the frequency.

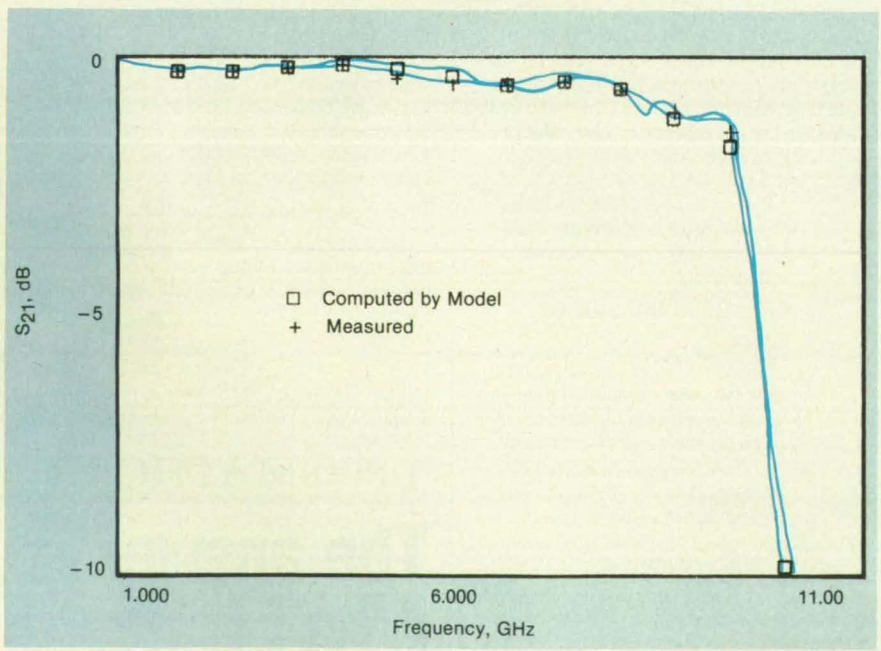
The new model is essentially an application of phenomenological loss-equivalence approximations to the London two-fluid mathematical model of superconductivity:

$$\sigma = \sigma_1 - j\,\sigma_2 = \sigma_n\left(\frac{T}{T_c}\right)^4 - j\frac{1-\left(\frac{T}{T_c}\right)^4}{2\pi f \mu_0 \lambda_0^2} \text{ at } T<T_c$$

where σ is the total conductivity, the imaginary part denotes the contribution of superconducting pairs of electrons, σ_n is the normal part of the conductivity (attributed to normal electrons), T is the absolute temperature, T_c is the critical temperature, f is the frequency, μ_0 is the magnetic permeability of free space, and λ_0 is the depth of penetration of the magnetic and electric fields into the superconductor at zero temperature. This equation for the complex conductivity can be used to derive equations for the real and imaginary components of the additional internal impedance, the attenuation, the effective wave-slowing factor (index of refraction), the corrected phase velocity of the waves, and the corrected effective dielectric constant (corrections being with respect to predictions of prior circuit theory).

The new model was tested by applying it to a low-pass filter made of yttrium barium copper oxide superconducting thin film on a lanthanum aluminate substrate. The figure gives an example of the close agreement between the predictions of the model and experimental values.

This work was done by Dimitrios Antsos of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 80 on the TSP Request Card.*
NPO-18418

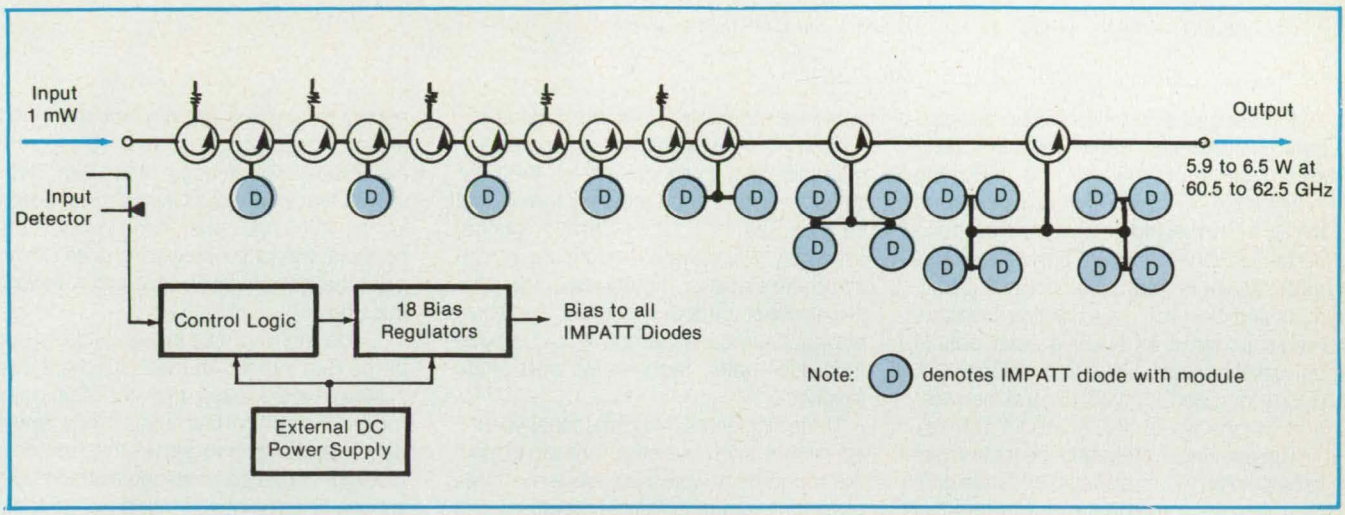


One of the Scattering Parameters (S_{21}, the coefficient of transmission from port 1 to port 2) of a low-pass filter as a function of frequency was computed by use of the model and measured.

Solid-State Power Amplifier for 61.5 GHz

Smaller, lighter units will replace larger, heavier traveling-wave-tube amplifiers.

Goddard Space Flight Center, Greenbelt, Maryland



This **Lightweight, Compact 60-GHz Amplifier** is a cascade of IMPATT-diode modules.

Power amplifiers based on impact-avalanche-transit-time (IMPATT) diodes are being developed for operation in communication systems at frequencies near 60 GHz. These solid-state amplifiers are intended to serve as replacements for the bulkier and heavier traveling-wave-tube amplifiers that, until recently, have been the only practical amplifiers available for this frequency range.

The figure shows the configuration of one of the new solid-state amplifiers. The amplifier is built in seven modular stages of one, two, four, and eight IMPATT diodes. Each diode and module can be regarded as a one-port active device that amplifies and reflects the incoming radio-frequency energy. Each of the first three stages contains one IMPATT diode and is optimized for high gain. The last four stages use modules that are optimized for high power at lower gain, and the number of modules per stage is doubled at each step (implying a gain of approximately 3 dB per each of these stages).

Power combining in the multiple diode stages is performed with a passive combiner plate. Power is transferred from stage to stage through sections of waveguide and isolator/circulator assemblies. The dc power is supplied to each IMPATT diode by a dedicated bias-regulating circuit. Each such circuit is turned on automatically by a controlling logic circuit when an input radio-frequency power of 1 mW is detected. At this input power, the amplifier outputs 5.9 to 6.5 W at frequencies from 60.5 to 62.5 GHz, representing dc-to-radio-frequency efficiencies of 3.8 to 4.2 percent.

This work was done by Michael K. Powers, James McClymonds, David Vye, and Thomas Arthur of **Goddard Space Flight Center**. *For further information, Circle 83 on the TSP Request Card.*
GSC-13465

Balloon-Borne System Would Aim Instrument Toward Sun

The system would provide initial coarse pointing, then maintain fine pointing.

Marshall Space Flight Center, Alabama

A proposed system including a digital control computer, control sensors, and control actuators would aim a telescope or other balloon-borne instrument toward the Sun. This would be a general-purpose system capable of providing three-axis (azimuth, elevation, and roll) or two-axis (azimuth and elevation only) pointing for instruments as large as NASA's solar optical universal polarimeter, which is about 6 ft. (1.8 m) long and 1.5 ft. (0.45 m) in diameter and weighs about 400 lb (about 180 kg).

The pointing system and the instrument to be pointed would be flown aboard a gondola, which would be suspended from a balloon by a cable. The pointing system would include a reaction wheel, which would apply azimuthal control torques to the gondola. A torque motor would apply additional low-frequency azimuthal torques between the gondola and the cable to keep the reaction wheel from saturating.

Three silicon solar cells mounted on the gondola 120° apart in azimuth would guide the azimuthal slew of the gondola in the initial acquisition of the view of the Sun. An elevation-gimbal assembly equipped with a torque motor, tachometer, and angle resolver would be mounted on the gondola. If only the azimuth and elevation were to be controlled, then the instrument could be mounted on an interface structure on this elevation-gimbal assembly. If roll were also to be controlled, then the instrument and interface structure would be mounted on a cross-elevation-gimbal assembly, which would, in turn, be mounted on the elevation-gimbal assembly. Like the elevation-gimbal assembly, the cross-elevation-gimbal assembly would include a torque motor, tachometer, and angle resolver.

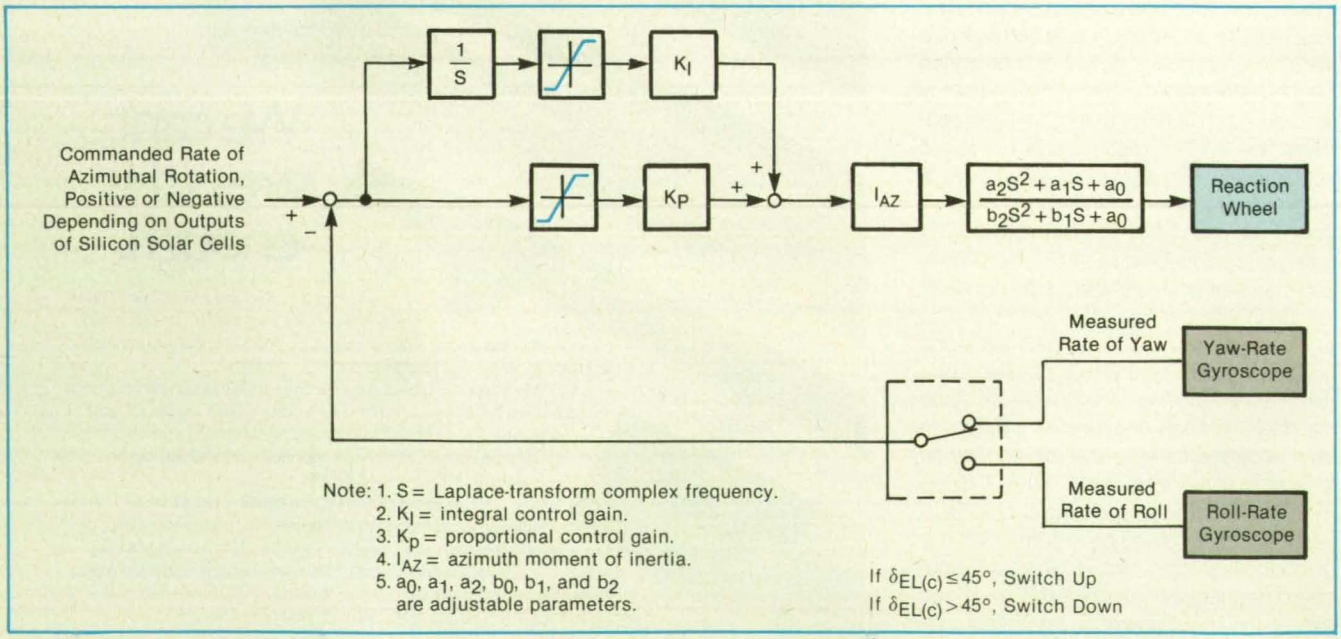
Three single-axis rate gyroscopes mounted on the interface structure along with the instrument would measure the rates of yaw (in azimuth), pitch (in elevation), and roll. An inclinometer on this structure would measure the roll angle. A two-axis Sun sensor mounted on the instrument would measure the deviation, in yaw and pitch, of the attitude of the instrument from the line to the apparent center of the Sun.

The control computer would preferably be readily programmable to adjust control-law parameters to suit whichever instrument is to be aimed. It would provide three modes of operation: (1) the gimbal-command mode, (2) the Sun-acquisition-slew mode, and (3) the Sun-point mode. Initially, the system would operate in the gimbal-command mode, in which the instrument would be brought to zero roll angle (if roll control were used) and to a predetermined elevation angle approximately equal to the expected elevation angle of the Sun. Then the system would pass into the Sun-acquisition-slew mode (see figure), in which the gondola would be slewed in azimuth to point the instrument approximately toward the Sun.

Once the Sun was in the field of view of the Sun sensor on the instrument, the system would pass into the Sun-point mode. The control law in this mode would be divided into two parts: the first part would generate commanded azimuth-, elevation-, and roll-acceleration commands; these commands would be fed to the second part, which would be a steering law that would generate the torque commands for the control actuators.

This work was done by M. E. Polites of **Marshall Space Flight Center**. *Further information may be found in NASA TP-3013 [N90-21219], "A General-Purpose Balloon-Borne Pointing System for Solar Scientific Instruments."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *MFS-28519*



The **Sun-Acquisition-Slew Mode** of the control system would command the azimuthal slewing of the instrument into initial approximate alignment with the line of sight to the Sun. The coefficients of the second-order transfer function would be chosen to assure stability and provide the required aiming performance for the specific instrument.

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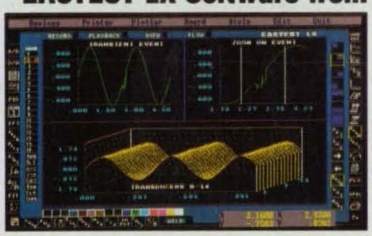

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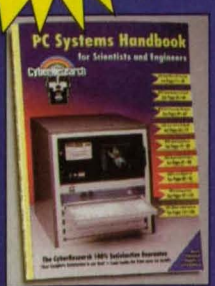
FREE PC Systems Handbook for Scientists & Engineers



This Combination Tutorial/Catalog Includes Many Examples of PC-based Systems

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GPS Measurement of Attitude

Orientations of ships, aircraft, and other objects can be determined with unusual accuracy.

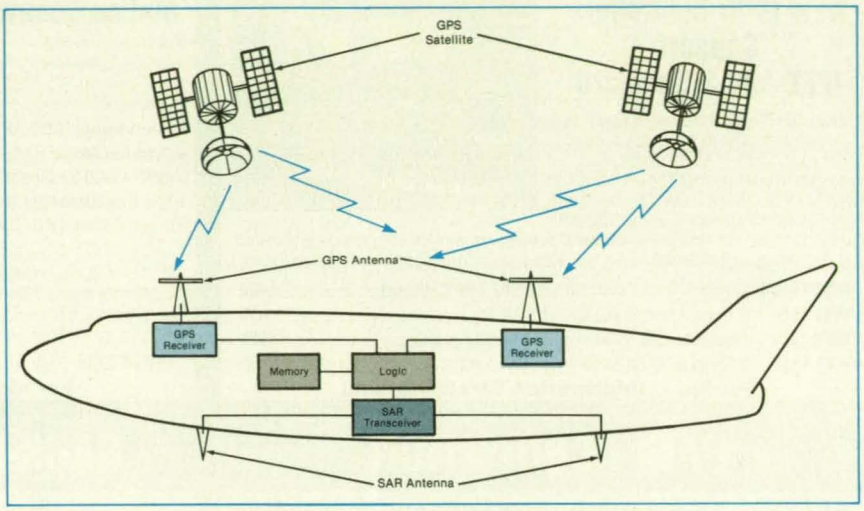
NASA's Jet Propulsion Laboratory, Pasadena, California

Signals transmitted by satellites of the Global Positioning System (GPS) can be used to measure the orientation of a baseline on a ship, aircraft, or other vehicle or platform with unusual accuracy. Combined with conventional GPS position and velocity data, the GPS orientation data allow more precise navigation and mapping and can also enhance calculations related to the performance and control of the vehicle or platform.

Though the details of implementation are complicated, the underlying concept is simple. Two GPS antennas, each connected to its own receiver, are placed at well separated points on the platform (see figure). The two GPS receivers then measure the positions of the ends of the baseline as functions of time. Conventional processing of the outputs of these receivers yields the platform's position and velocity. (Of course, one antenna and receiver would suffice for this purpose.) In addition, the output processor computes the vector difference between the two GPS positions and uses it to determine the orientation of the baseline.

Reliable implementation of the technique depends on the use of Rogue GPS receivers, which provide unusually precise GPS pseudorange. A straightforward least-squares algorithm calculates position and velocity, using as inputs the delay and the rate of change of delay for each satellite being tracked. The delay data are ionosphere-calibrated P-code pseudoranges, and the rates of change of delay are computed as differences of the ionosphere-calibrated carrier phase. As output, the algorithm gives the three-dimensional position and velocity of the receiver, along with the offset and rate of the receiver clock. Data from at least four satellites are needed to define a solution.

The orientation of the baseline is also calculated by a least-squares algorithm. For this calculation, the primary inputs are double-differenced carrier phases, and the outputs are the three vector components of the baseline. In the absence of other information, three double-differenced phases (implying four satellites) are required to specify a solution.



Two GPS Receivers yield differential measurements of position from which the orientation of the baseline between the antennas can be calculated.

The technique was tested aboard an aircraft carrying a synthetic-aperture radar (SAR), with a view toward using the GPS velocity and orientation data to correct for the effect of the attitude of the aircraft on SAR measurements of ocean-surface currents. Such a calibration is necessary when there is no land area in the SAR image to use as a zero-velocity reference. In this test, the technique was used to determine the orientation of a baseline between two antennas near the top of the fuselage, one just behind the cockpit and another about 23 m farther back. The two Rogue GPS receivers shared a rubidium frequency standard. They were configured to track four satellites simultaneously, computing the time-tagged GPS P1 and P2 pseudorange and L1 and L2 carrier phase along with signal-to-noise ratios. Once per second, these values were stored for later analysis. The uncertainties in the results were approximately 15 m in position, 0.015 m/s in velocity, 0.012° in azimuth, and 0.038° in pitch.

This work was done by S. J. DiNardo, E. L. Hushbeck, T. K. Meehan, T. N. Munson, G. H. Purcell, J. M. Srinivasan, L. E. Young, and T. P. Yunck of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 10 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-17937.

Transmission of Power Via Combined Laser Beams

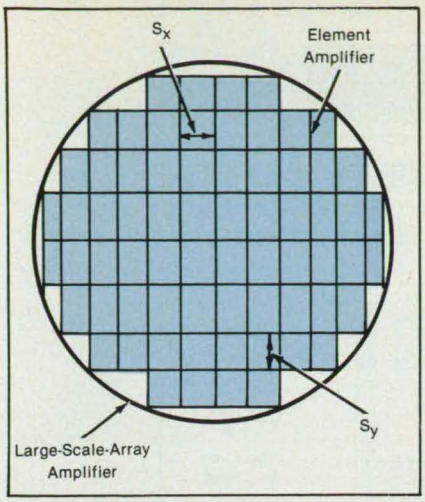
The combined beams would be suitable for transmission of power in outer space.

Langley Research Center, Hampton, Virginia

Lasers of high average power are now being considered for use as efficient means of transferring power from the Earth to satellites and between satellites. Of the various types of laser configurations, the laser-diode array (LDA) appears to be the most efficient in terms of mass and size. A study has been conducted on the far-field beam pattern and the power-collection efficiency of a multistage LDA amplifier consisting of about 200,000 5-W LDA amplifiers with random distributions of phase and orientation errors and random failures of diodes. Preliminary results indicate that such a system could be used to transmit power on laser beams in outer space.

To form a large-scale-array amplifier (LSAA), the element LDA's must generate well-defined diffraction-limited beams. Coherent matching of phases among the element LDA's is also critically important, enabling an LSAA system to generate a good beam pattern in the far field over thousands of kilometers. By passing a beam of high spectral and spatial quality from a master laser through a number of LDA amplifiers simultaneously, one can realize coherence among the amplified output beams.

The power in the far field of a beam dif-



One Megawatt of Power would be generated by use of 200,000 5-W LDA amplifiers.

fracted by a circular aperture is larger than that of the same beam diffracted by a square aperture of the same width. Therefore, to provide a conservative analysis, the overall shape of the LSAA is assumed to be circular. The elements of the LSAA are LDA amplifiers stacked inside the LSAA frame as shown in the figure, where horizontal and vertical widths after collimation are S_x and S_y, respectively. The amplifiers are assumed to generate diffraction-limited coherent collimated beams. Therefore, the full width at half maximum (FWHM) diffraction angle of the beam from the element LDA is typically about 0.16 mrad for a wavelength of 0.8 μm and $S_x \approx S_y \approx 1$ cm.

In the calculation of the far-field beam patterns and the power-collection efficiencies of the LSAA, the probable random phase errors and random failures of the individual amplifiers were taken into account. The power-collection efficiency is dependent on the size of the receiving aperture and on the pointing (that is, aiming) accuracy over a long distance. The best pointing accuracy to date has been shown to be 0.1 μrad, or about 50 cm at a transmission range of 5,000 km.

Preliminary calculations show that the LSAA could be used for the transmission of power in outer space with power-collection efficiency of approximately 80 percent into a receiver of moderate size (about 3 m in diameter) at a distance of 5,000 km. This approach could also offer the possibility of transmission of data at high rates by line-of-sight means rather than by fiber optics, while still offering the efficiency, compactness, and reliability of semiconductor lasers.

This work was done by Jin H. Kwon of Miami University and Ja H. Lee of **Langley Research Center**. *For further information, Circle 145 on the TSP Request Card.*
LAR-14389

Computer Jet-Engine-Monitoring System

Artificial intelligence distills and presents data on operation of engines.

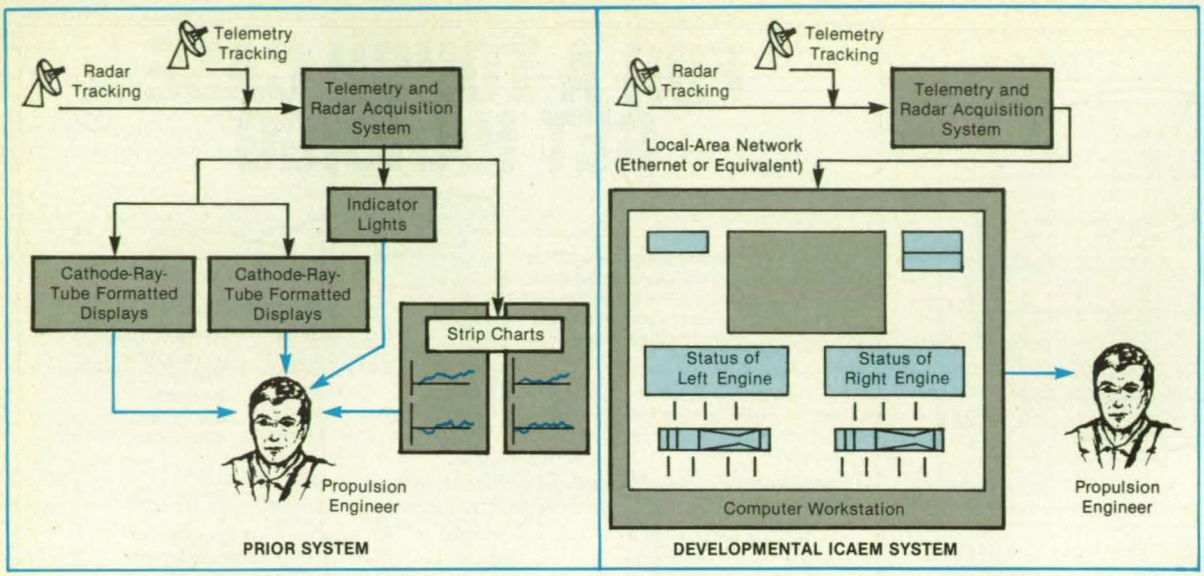
Ames Research Center, Moffett Field, California

A computer-based monitoring system is intended to distill and display data on the conditions of operation of the two turbofan engines of an F-18. The system, called the "Intelligent Computer Assistant for Engine Monitoring" (ICAEM) is in a preliminary state of development. The goals of the development project are to enhance safety of flight and to relieve propulsion engineers of the time-consuming but necessary task of monitoring propulsion systems in flight.

The ICAEM is designed to operate as an "expert aid" to an engineer, even an engineer who has little or no experience in monitoring propulsion systems. As telemetry data are received from the airplane, the ICAEM processes the mass of data into summary information on the status of the propulsion system and presents the information on a single video display at a computer workstation (see figure). The engineer can choose among a number of color graphical and textual displays to monitor the statuses of the left and right engines, instantaneous individual parameters (e.g., oil pressures or speeds of rotation), and/or histories of parameters (e.g., strip-chart displays). When a particular combination of parameters indicates an anomaly (e.g., stall), the ICAEM indicates the anomaly along with the recommended procedure (if any) to recover (e.g., to restart the engine).

The major part of the overall function of the ICAEM is effected by a computer program that acts as an interface between the incoming telemetry data and an expert-system computer program that codifies some of the expertise of propulsion-system engineers. Once given data, the expert system decides whether there exists an anomaly or other condition that the engineer needs to know. If so, that information is sent to another program that displays the necessary information to the engineer

When telemetry data are received, the



The **Developmental ICAEM System** reduces the burden on the propulsion engineer by providing a single display of summary information on the statuses of the engines and by alerting the engineer to anomalous conditions. In contrast, effective use of the prior engine-monitoring system requires continuous attention to multiple displays.

main program asserts a fact into a fact base in the expert-system program. Once enough facts are generated to match the conditions of a rule, the rule is "fired." The system must be able to identify a single-parameter anomaly (e.g., oil pressure too high) or an anomaly of the system that manifests itself via multiple parameters. As an example of the second type of anomaly, suppose that an attempt is being made to start the engine and the speed of rotation remains less than a specified allowable minimum during a specified time. In that case, the ICAEM processes the speed and time parameters into an indication of a "potential hung start."

This work was done by James D. Disbrow of PRC Systems, Inc., and Eugene L. Duke and Ronald J. Ray of **Ames Research Center**. *Further information may be found in NASA TM-101702 [N90-22322], "Preliminary Development of an Intelligent Computer Assistant for Engine Monitoring."*

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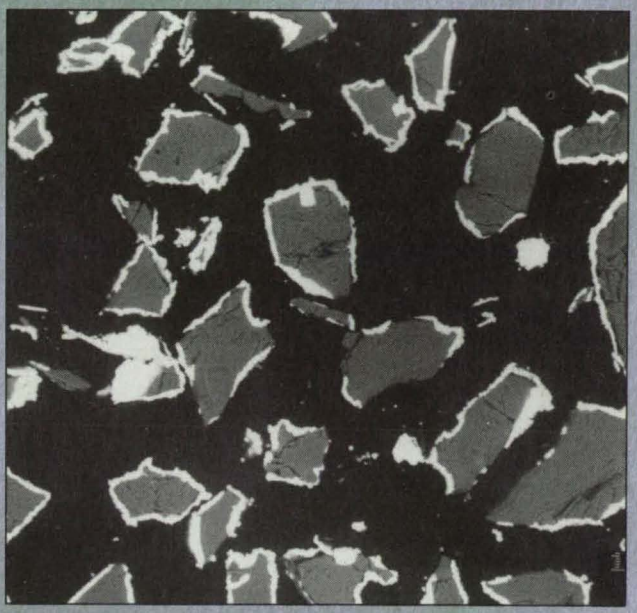

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Using Spectral Edge To Measure Doppler Shift

Frequency is inferred from relative amplitudes of the signal with and without filtering.

Goddard Space Flight Center, Greenbelt, Maryland

Pulsed-laser ranging systems of a new type implement a spectral-edge technique to make high-resolution measurements of the Doppler frequency shift in signals backscattered from targets. These systems are intended for use in measuring the velocities of both moving solid targets and diffuse moving targets like wind (via backscatter from aerosol particles and/or molecules), clouds, aerosols, or rain. Potential practical applications include measurements of wind shear from observation points at airports and aboard aircraft.

In designing a system of this type, one chooses a pulsed laser that emits at an ultraviolet, visible, or infrared wavelength suitable for generation of the desired hard-target or atmospheric backscatter. In conjunction with the laser, one selects or designs an optical filter (the "edge" filter) that has a sharp spectral transmission function such that the middle frequency of the laser emission lies on a steep portion of the slope (the "edge") on one side of the peak (see Figure 1).

Figure 2 helps to show how the lidar system uses the spectral properties of the laser and filter to measure the Doppler shift of the backscatter. A small fraction of the energy of each outgoing laser pulse is picked off by beam splitter 1, attenuated to about the level of the backscatter, and passed through an optical train to be sampled by a photodetector (called the "energy-monitor" photodetector). Part of the attenuated, picked-off fraction of the outgoing beam is also passed through the edge filter to a similar photodetector called the "edge-filter" photodetector. The backscatter signal is received by a telescope and sampled in the same manner as that of the picked-off, attenuated outgoing pulse. The outgoing-pulse and backscatter measurements are range-gated and digitized. The digitized values are then converted into normalized signal levels — ratios between the edge-filtered and energy monitor samples of the outgoing-pulse and backscatter signals. By use of the difference between the ratio of the backscatter samples and the ratio of the outgoing-pulse samples, the known edge-filter spectrum, and the spectrum of the laser emission, a processor computes the difference between the middle frequencies of the backscattered and outgoing pulses — that is, the Doppler shift.

A typical system of this type offers several advantages in comparison with prior Doppler lidar systems. It is not necessary to use diffraction-limited optics. It is not necessary to use a narrow-band laser; one can even use a laser that emits light in a spectral band 100 or more times as wide as the desired accuracy of the frequency measurement. The use of a differential-frequency-measurement technique with normalization anew on each pulse renders the measurement insensitive to jitter and drift in the laser frequency and in the spectral characteristics of the laser, provided that the laser width is narrow relative to the width of the edge filter and that the laser remains on the edge; that is, at or near the desired value about halfway down the peak of the filter spectrum. The signal normalization renders the measurement insensitive to variations in the amplitude of the outgoing and backscattered signals.

Furthermore, the spectral-edge technique enables the system to measure a small average Doppler shift caused by wind, even in the presence of much greater Doppler broadening caused by thermal motions of molecules.

This work was done by Lawrence Korb of **Goddard Space Flight Center**. *For further information, Circle 23 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-13343.

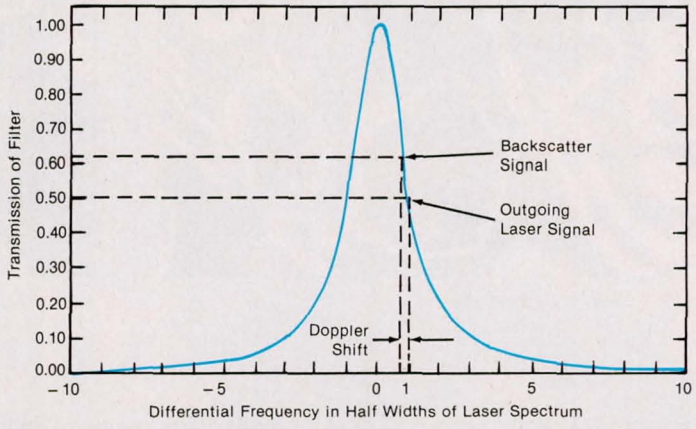


Figure 1. **Normalized Levels of Filtered Optical Signals** at two different frequencies depend on the transmission spectrum of the filter. The spectrum is chosen so that the frequencies of interest lie about halfway down from the peak on one side. The difference between the frequencies is computed from the slope of the spectrum and the difference between the levels.

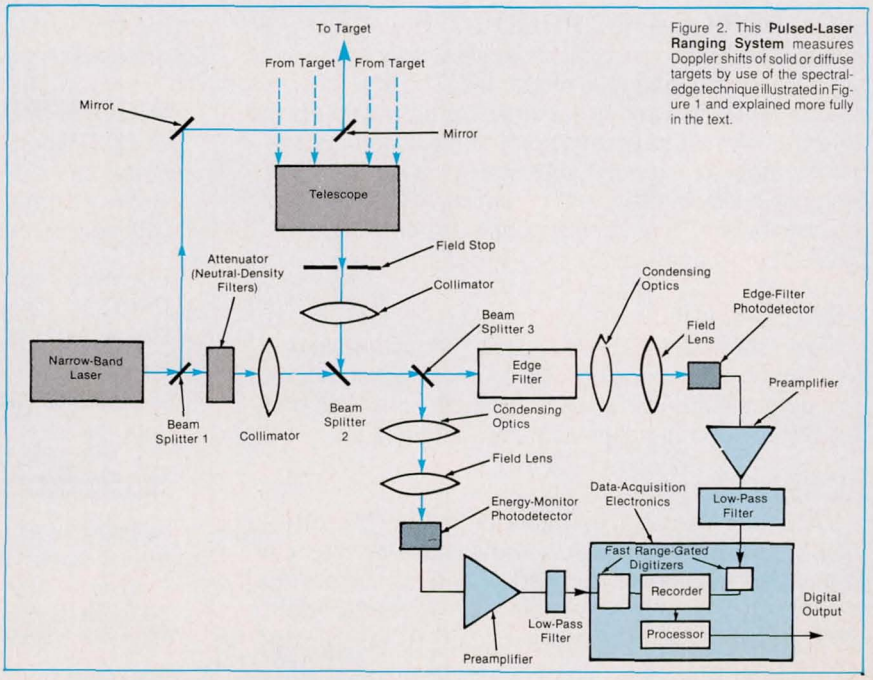


Figure 2. This **Pulsed-Laser Ranging System** measures Doppler shifts of solid or diffuse targets by use of the spectral-edge technique illustrated in Figure 1 and explained more fully in the text.

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.

Effects of Phase Jitter on Lock Detection in QPSK

Analyses are performed for three QPSK tracking loops.

A report presents a study of the performances of digital carrier-signal-tracking loops used in the reception of radio signals that contain quadrature-phase-shift-keyed (QPSK) modulation representing binary non-return-to-zero data. One of the important monitoring functions of a QPSK receiver — one that is necessary for automated operation — is the detection of lock on the carrier signal ("lock detection," for short). This study differs from prior studies (which involved the assumption of perfect carrier tracking) in that it includes the degrading effects of jitter in the phase of the carrier signal upon lock detection.

In most applications, it is valid to assume perfect carrier tracking as long as the loop signal-to-noise ratio (SNR) is sufficiently high or the period of estimation is sufficiently long. Under either condition, the degrading effect of phase jitter is not an issue; but where the loop SNR is low (because the received signal is weak) and the period of estimation has to be limited (to satisfy requirements upon the monitoring system), the degradation caused by phase jitter becomes significant and must be included in the calculations to predict performance accurately.

The report presents mathematical models of the received signal and of the noise, which is assumed to be white Gaussian. It describes the lock-detector algorithm and presents equations that characterize the lock-detection performance. Equations for the probabilities of lock detection and false indication of lock are derived. The degrading effect of phase jitter is then expressed as the ratio between the detector SNR in the presence of phase jitter and the detector SNR in the absence of phase jitter (or equivalently, assuming infinite SNR in the carrier-tracking loop).

The equations thus derived are applied in analyses of three QPSK carrier-tracking loops: the Costas crossover loop, the maximum a posteriori estimation loop, and the generalized Costas loop. The results of computer simulations are presented and found to agree substantially with the equations. Both the equations and the simulations are used to show that phase jitter can reduce the detector SNR by as much as 2 dB, especially when the loop SNR is low and the period of estimation is short.

This work was done by Alexander Mileant and Sami M. Hinedi of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "On the Effects of Phase Jitter in QPSK Lock Detection," Circle 87 on the TSP Request Card. NPO-18208*

Detection and Avoidance of Obstacles by Helicopters

Concepts of sensing and control are discussed.

A report discusses the general probems relevant to the design of control subsystems that would enable helicopters on nap-of-the-Earth flight paths to detect and avoid obstacles automatically. For the purpose of this study, it is assumed that a guidance or navigation subsystem has provided a nominal trajectory for a short distance ahead. Using information on obstacles provided in real time by the obstacle-detection subsystem, the obstacle-avoidance subsystem would adjust the flightpath about the nominal trajectory to obtain a safe trajectory.

The main text begins with an introduction that describes the helicopter obstacle-avoidance problem, indicating the similarities and differences between this problem and the obstacle-avoidance problem of industrial mobile robots. One notable similarity is that the domain of action is predominantly two-dimensional in the sense that nap-of-the-Earth flight is predominantly ground-hugging with lateral maneuvers, as are the movements of a mobile robot around the floor of a factory or laboratory. A previous paper on the helicopter obstacle-avoidance problem restricted the concept to the two-dimensional framework, and one of the considerations in the present study is how to extend the concept to the full three dimensions.

The problem is discussed under two different assumed circumstances. The first circumstance is that a full range map is available, regardless of whether the map data are collected from a passive or an active sensor. Two different approaches are proposed to extend the previous two-dimensional obstacle-avoidance concept to three dimensions, exploiting the predominantly lateral-maneuvering characteristics of nap-of-the-Earth flight. The first approach involves a direct search of the three-dimensional range-map data for indications of openings between obstacles.The second approach involves compression of the three-dimensional data into a two-dimensional map for a two-dimensional path search. Both approaches remain to be tested in realistic simulations.

The second circumstance is that a passive sensor, which is the preferred primary sensor, provides only a sparse range map. In this case, an integrated approach is proposed to augment the passive sensor with an active sensor, which would be driven by the obstacle-avoidance subsystem to probe the environment selectively for supplemental range data. This approach raises the issue of the fusion of data, and two data-base formats are proposed to provide the uniformity required for this purpose. Both formats involve quantization of the horizontal components of range. One also involves quantization of the vertical component, enabling the representation of overhanging objects, at the cost of additional memory and, potentially, additional computation.

This work was done by Victor H. L. Cheng and Banavar Sridhar of **Ames Research Center**. *To obtain a copy of the report. "Integration of Active and Passive Sensors for Obstacle Avoidance," Circle 37 on the TSP Request Card. ARC-12825*

Measuring Hydrogen Plumes With Raman Lidar

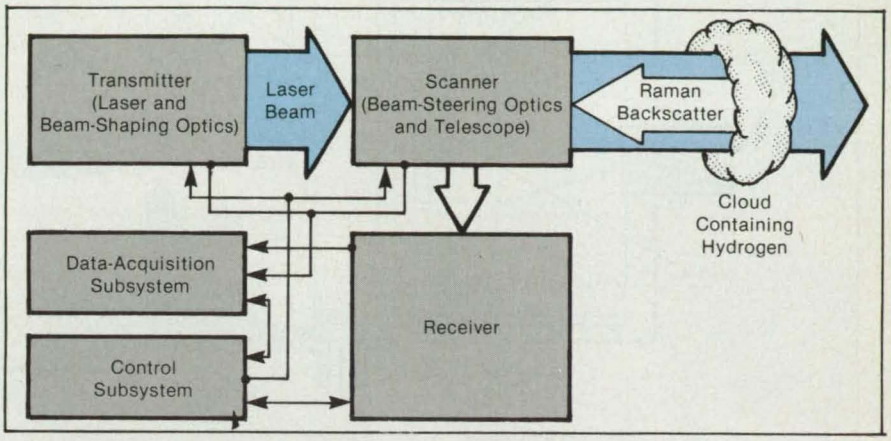
Concentrations below the lower limit for flammability can be measured.

John F. Kennedy Space Center, Florida

A prototype Raman lidar system measures the concentration of hydrogen gas in the atmosphere as a function of position, with a range resolution of 3 ft (about 0.9 m) over a range of 3,000 ft (about 0.9 km). It is sensitive to concentrations smaller than 0.5 percent, which is 10 times below the minimum flammable concentration. The system is being developed for use as a safety monitor and to study the dispersion of hydrogen gas that leaks into the atmosphere.

Prior Raman lidar systems have been developed to detect methane and light hydrocarbons in refineries. The basic principle of operation is straightforward (see figure): A pulsed ultraviolet laser beam is directed through beam-shaping and beam-steering optics along the desired line of sight into the atmosphere. The beam excites Raman emissions from the molecules to be detected (in this case, hydrogen and nitrogen). The backscattered light is collected by the telescope, band-pass-filtered at the appropriate hydrogen and nitrogen Raman wavelengths, and sent to photodetectors.

The outputs of the hydrogen-wavelength and nitrogen-wavelength channels are digitized and range-gated according to the round-trip pulse-travel times. For each range, the relative concentration of hydrogen is computed from the ratio between the hydrogen- and nitrogen-backscatter signals. The concentration and range data can be correlated with scan-angle data to obtain a color graphic display of concentration as a function of position in three dimensions.



The **Scanning Lidar System** measures the space-resolved concentration of hydrogen in the atmosphere via Raman backscatter from a pulsed laser beam.

The principal sources of error in the prototype system are liquid water (rain or spray) and sunlight. Another Raman lidar channel could be added to measure the water content and use it to correct the hydrogen content. The effect of sunlight can be totally eliminated through the use of a special dielectric coating on the telescope mirrors, which serve as sunfilters.

This work was done by Bernard Caputo of Computer Genetics Corp. for **Kennedy Space Center**. *For further information, Circle 63 on the TSP Request Card.*
KSC-11459

Improved Raman-Emission Detector

Sensitivity is increased by several novel design features.

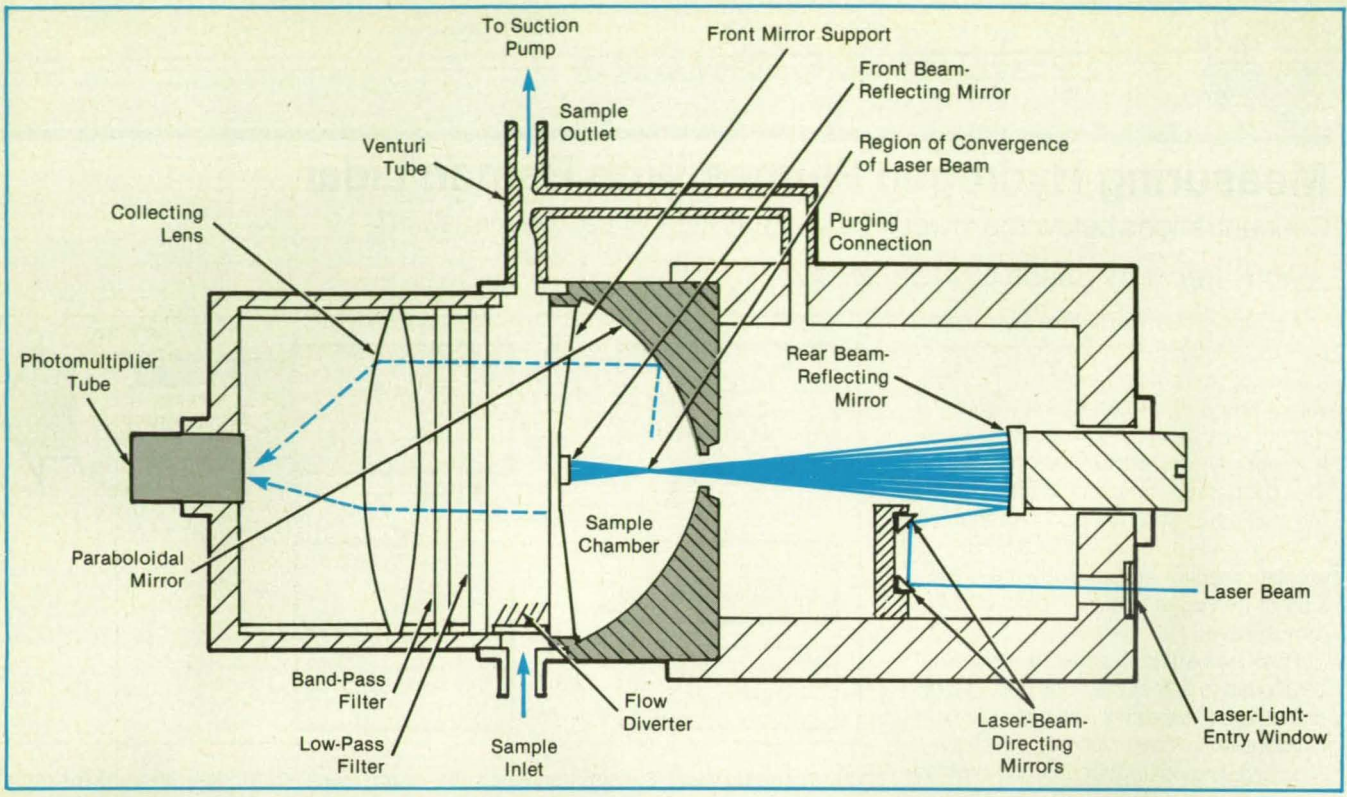
John F. Kennedy Space Center, Florida

The figure illustrates an improved apparatus that excites and detects Raman emissions (optical emissions from rotationally and vibrationally excited molecules) in a sample gas mixture. The emissions at the known Raman wavelength of a given molecular species are used to measure the concentration of that species in the mixture. This apparatus features several changes in design that result in sensitivity greater than that of a prior Raman-emission detector: most notably, increasing the collection of Raman emissions by use of a paraboloidal reflector and collecting lens coaxial with the illuminating beam instead of a spherical reflector and condensing lens on an optical axis perpendicular to the illuminating beam.

An argon-ion laser beam is used to excite the molecules of the sample gas. The beam enters the apparatus through a window and is directed to bounce back and forth between two concave mirrors. These mirrors are configured so that the multiply reflected beam converges to a waist at and near the focal point of the paraboloidal reflector. Thus, the Raman emission comes predominantly from the narrow waist region and is, therefore, collimated by the paraboloidal reflector. The collimated light is passed through a low-pass filter, which reduces noise by suppressing both scattered light at the original laser frequency and undesired ultraviolet fluorescence excited by the laser beam. The collimated light is then sent through a band-pass filter to select only light of the desired Raman wavelength. The filtered light is then focused by the collecting lens onto a photomultiplier tube.

The volume partially enclosed by the paraboloidal reflector and the low-pass filter constitutes the sample chamber. The sample gas flows through this chamber from an inlet to an outlet and then to a suction pump. This flow continually purges the chamber. The gas mixture is made to flow through a venturi tube at the outlet to generate additional suction, which is used to reduce the pressure in the cavity shown in the figure to the right of the sample chamber. A set of vanes at the inlet diverts the flow in such a way as to reduce the time needed to flush out any previous sample gas and stabilize the composition of the present sample gas in the chamber.

This work was done by Gary N. McKinney of Lockheed Space Operations Co. for **Kennedy Space Center**. *For further informa-*



This **Raman-Emission Detector** features an improved Raman-light-collection scheme that increases sensitivity and an improved flow geometry that reduces stabilization time.

tion, Circle 66 on the TSP Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11521.

Acousto-Optical Imaging Spectropolarimeter

This robust instrument takes polarization-specific images of solid surfaces and atmospheric sources.

Goddard Space Flight Center, Greenbelt, Maryland

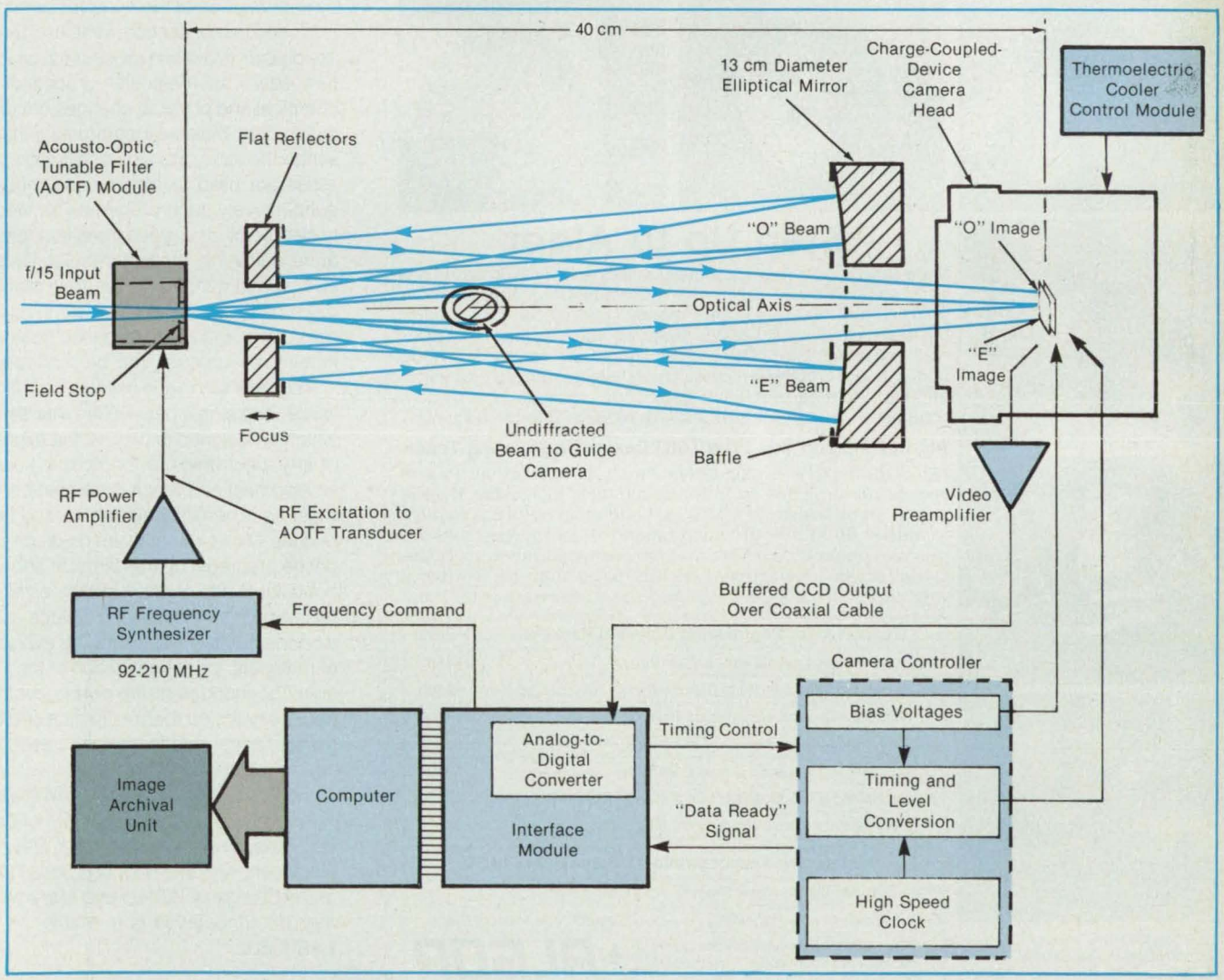
The figure is a schematic diagram of an imaging spectropolarimeter designed around an acousto-optical tunable filter (AOTF). This is a robust instrument designed for use on the ground and aboard aircraft. It takes polarization-specific spectral images of terrestrial and nonterrestrial sources, including solid surfaces, aerosols, and absorption and emission phenomena in the gas phase, at wavelengths from 500 to 1,000 nm.

A tunable solid-state filter operates on the principle of acousto-optical diffraction in a birefringent medium. The spatial period of the diffraction grating in the medium is the wavelength of a radio-frequency acoustic excitation introduced into the medium via a transducer. The spectral passband of the filter can be tuned rapidly by changing the frequency of the acoustic excitation.

From the perspective of designing an imaging spectropolarimeter, an acousto-optical tunable filter offers multiple advantages over more conventional optical filters that are made adjustable or selectable by mounting them in filter wheels. These advantages include higher spectral resolving power, highly specific selection of polarization, larger optical aperture, all-solid-state operation (no sliding or rotating parts), and faster tunability.

The tunable acousto-optical filter in the GSFC imaging spectropolarimeter is made of TeO_2, a birefringent material that has desirable acousto-optical properties, including a relatively high figure of merit, which provides high throughput and spectral resolving power. The filter is said to be noncollinear, meaning that the acoustical and optical signals do not propagate collinearly everywhere within the TeO_2 medium; noncollinearity offers some flexibility in design. The instrument includes an all-reflective optical relay assembly that includes a single ellipsoidal mirror. The combination of the filter and relay optics forms side-by-side, orthogonally polarized spectral images on a charge-coupled-device camera. The spectral coverage of the instrument is limited by the spectral response of the charge-coupled device and the frequency limitations of the radio-frequency matching network at the transducer.

This work was done by Babak Saif, David Glenar, Robert Zimmerman, and Bernard Seery of **Goddard Space Flight Center**. *For further information, Circle 29 on the TSP Request Card.*
GSC-13461



The **Acousto-optical Imaging Spectropolarimeter** produces side-by-side spectral images in two mutually perpendicular polarizations, one corresponding to the ordinary ("O"), the other corresponding to the extraordinary ("E") waves in the acousto-optical material. This instrument offers a relatively large aperture, high resolving power, and rapid tunability, with no moving parts.

Monitoring Polymer Curing Via Electromagnetic Impedance

Continuous frequency-dependent measurement and analysis are performed during the curing cycle.

Langley Research Center, Hampton, Virginia

A new nondestructive in-situ electromagnetic-impedance measurement technique has been developed, as both a research and production tool, for sensing the cure-processing properties of high-temperature, high-performance thermoset and thermoplastic resins. Frequency-dependent impedance measurements are of particular importance in assuring the quality of a polymer resin and controlling the resin-curing processes. This type of technique is one of only a few instrumental techniques available for monitoring and measuring the molecular properties of a polymeric resin in both the liquid and solid states. This technique is advantageous in its ability to study the curing process in both laboratory and production settings, and it can be used to examine properties continuously as the resin transforms from a monomeric liquid of varying viscosity to a cross-linked insoluble, high-temperature solid.

The technique emphasizes continuous frequency-dependent measurement and analysis throughout the cure cycle. The instrumentation can measure the complex permittivity, an intrinsic polymer property, over nine orders of magnitude (10^{-3} to 10^{6}) and six decades of frequency (Hz to MHz) at temperatures up to 400 °C. The Hz-to-MHz frequency range is advantageous as it senses both ionic and dipolar diffusion processes and minimizes electrode-polarization problems. The frequency dependence of the complex permittivity is used to monitor both ionic and Debye-like dipolar relaxation processes, which in turn serve as molecular probes of the chemical and physical changes occurring during cure. Molecular parameters that describe the ionic and dipolar diffusion processes are used to monitor and measure quantitatively such properties as viscosity, degree of cure, glass-transition temperature, softening, melting, recrystallization, and solvent content. Moisture contents in thermosets and thermoplastics can be measured, and changes due to heating or long-term exposure can be monitored.

This new technique uses a commercially licensed single passive laminar sensor, which is designed to prevent the exposure of any electronics to the hostile sensing environment and which is compatible with most commercially available impedance bridges. Measurements are made on composite prepregs, on thin films, in adhesive bond lines, and on thick laminates at various positions. Applications include use as a nondestructive means for the evaluation of materials, for determination of the "window" boundaries of the curing cycles of newly developed thermoplastics and thermoset resins, and for online, closed-loop control of curing cycles.

This work was done by William T. Freeman and John C. Covington of **Langley Research Center** *and David E. Kranbuehl, Melanie Hoff, and Susan Delos of the College of William and Mary. No further documentation is available.*
LAR-13802

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.

Physical Models in GPSOMC Software

Contributions to range and phase observables and the partial derivatives thereof are described.

A report describes the physical models incorporated into GPSOMC, the modeling module of the GIPSY software, which processes geodetic measurements in the Global Positioning Satellite (GPS) system. This report is a corrected, expanded, and updated version of JPL Publication 87-21, which was dated September 15, 1987.

A detailed explanation of the special meanings of "observables" and variants thereof in the special context of the report is essential to a description of the report. In the GPS system, distances (called "ranges") from GPS satellites are measured on the basis of detected phases of electromagnetic signals. In a given instance, the "physical observable" is the difference between the reference phase of the transmitter at the instant of emission and the reference phase of the receiver at the instant of reception. An "observed observable" is one that is related in a prescribed way to the physically detected phase. A "computed observable," closely related to a physical observable, is one that is defined in terms of differences between clocks, e.g., the difference between the reference phase defined, in turn, by the station clock at the receiver and the reference phase defined, in turn, by the clock in the orbiting transmitter.

In interpreting measurements of range from GPS satellites, the observables are passed through a multiparameter estimation routine ("filter") to estimate the parameters of models. These models describe the spacecraft orbits and the motions of the receivers fixed to the Earth. The model also supplies, to the filter, a-priori values of computed observables and the partial derivatives of the computed observables with respect to the parameters of the models. The report describes the portion of the software that models the locations of the receivers and the motions of the whole Earth and computes the observables and partial derivatives.

The major components of the models are discussed in sections 2 through 5 of the report. Section 2 defines the coordinate frame for the model and establishes methods for calculating the position of the receiver in that frame by use of the best current models of the motions of the whole Earth and of local tidal deformations. Section 3 defines the observables and the intimately associated models of the behaviors of the clocks in GPS satellites and receiving ground stations. Section 4 presents the model used to describe the passage of GPS signals through the troposphere. All the partial derivatives of observables with respect to parameters of the models are given in section 5. Values of the physical constants used in the GPSOMC software and a complete list of the parameters available for adjustment are given in the appendixes.

This work was done by Ojars J. Sovers and James S. Border of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Observation Model and Parameter Partials for the JPL Geodetic GPS Modeling Software GPSOMC," Circle 71 on the TSP Request Card. NPO-18241*

Soot-Free Combustion of Methane and LNG

No soot builds up when these fuels are burned with liquid oxygen.

Experiments have shown that neither methane nor liquefied natural gas (LNG) produces soot when burned in a turbine simulator with liquid oxygen under conditions like those in the gas-generator section of a rocket engine. The experiments were conducted to determine whether these fuels behave similarly to some other hydrocarbon fuels, which give off soot that coats turbomachinery and reduces performance.

The fuels were burned at various combinations of fuel/oxygen-mixture ratio, chamber pressure, and rate of flow. LNG (about 92 percent of which was methane) was tested at mixture ratios from 0.24 to 0.58, chamber pressures from 840 to 1,370 psia (5.8 to 9.4 MPa), and a total-mass-flow rate of about 1.5 lb/s (about 0.7 kg/s) with a fine-pattern triplet injector to examine the effect of low-purity methane on the deposition of carbon. Seven tests were made, each lasting 200 s. No appreciable buildup of carbon was found in the small-scale turbine simulator.

Pure methane was tested at mixture ratios from 0.23 to 0.81, chamber pressures from 925 to 2,210 psia (6.4 to 15.2 MPa) and a total-mass-flow rate of about 14 lb/s (about 6.4 kg/s). To examine the effect of injection densities of methane representative of those of a full-scale engine, a coarse-pattern triplet injector was used. As in the nine tests of LNG, no appreciable buildup of carbon was detected.

This work was done by John Bossard of Aerojet TechSystems for **Marshall Space Flight Center**. *To obtain a copy of the report, "Soot Free Operation of LOX-Methane Gas Generators," Circle 124 on the TSP Request Card. MFS-28561*

Nearly Azeotropic Mixtures To Replace Refrigerant 12

These mixtures would cause less damage to the ozone layer of the atmosphere.

NASA's Jet Propulsion Laboratory, Pasadena, California

Measurements have indicated that a number of nearly azeotropic fluid mixtures have saturation pressures similar to that of Refrigerant 12 (R12, dichlorodifluoromethane, CCl_2F_2) while being about 2% as damaging as R12 is to the ozone layer in the atmosphere. Moreover, these mixtures are of low toxicity, are nonflammable, and are more compatible with conventional lubricating oils than is Refrigerant 134a (R134a, 1,1,1,2-tetrafluoroethane, CH_2FCF_3; boiling temperature −27.89 °C), which is now the leading replacement for R12. The mixtures may be usable in commercial, automotive, and household refrigerators and air conditioners.

R12, now used in many refrigerators and air conditioners, is known to leak from these machines and ascend into the upper atmosphere, where it damages the ozone layer. One of the proposed replacements, R134a, does not damage the ozone layer because it contains no chlorine. But because of its lack of chlorine, conventional lubricating oils do not dissolve as well in it, and consequently compressors are likely to fail prematurely through nonlubricated wear. Dupont has recently patented an oil-compatible ternary mixture of R22 (chlorodifluoromethane, $CHClF_2$; boiling temperature −40.76 °C), R152a (1,1-difluoroethane, CHF_2CH_3; boiling temperature −25.00 °C), and R124 (2-chloro-1,1,1,2-tetrafluoroethane, $CHClFCF_3$; boiling temperature −12.00 °C). Because the boiling temperatures of these three fluids differ significantly, and because the mixture of them is not azeotropic, leaks could substantially change the composition and, thereby, the pressure characteristics of this fluid.

A thorough search of fluids and hundreds of measurements provided five nearly azeotropic mixtures (see table) of R134a, R152a, R124, and R142b (chlorodifluoroethane, CH_3CClF_2; boiling temperature −9.70 °C) that have low boiling-point spreads, low toxicity, and low ozone-damaging capability, that are nonflammable, and that are more compatible with conventional oils than is R134a. The data from the tests indicate that the pressure of any of the combinations in the table is nearly equal to the pressure of R12, and thus the mixtures may be a good "drop-in substitute" for R12. Because the mixtures are nearly azeotropic, the overall composition should not be significantly altered by leakage.

In addition to R134a, R152a also has no ozone-depletion potential. R124 and R142b both have ozone-depletion potentials that are less than 5 percent of that of R12. Thus all five of the mixtures of the table have ozone-depletion potentials about 2% that of R12. The five mixtures are nonflammable, although R152a and R142b by themselves are flammable. Because R124 and R142b both contain chlorine, they are expected to dissolve oil more effectively than R134a does; the addition of them to R134a is therefore expected to help R134a dissolve conventional lubricating oils.

This work was done by Jack A. Jones of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 122 on the TSP Request Card.*

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

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

Refer to NPO-18030, volume and number of this NASA Tech Briefs *issue, and the page number.*

MIXTURES

Mixture Number	Component A	Component B*	Component C*
1	0.5 < R134a < 1.0	R124 < 0.5	
2	0.5 < R134a < 1.0	R142b < 0.5	
3	0.5 < R134a < 1.0	R124 < 0.5	R142b < 0.5
4	0.5 < R134a < 1.0	R152a < 0.5	R124 < 0.5
5	0.5 < R134a < 1.0	R152a < 0.5	R142b < 0.5

*0.0 < (B + C) < 0.2
Proportions of component refrigerants are given in mole fractions.

These **Binary and Ternary Nearly Azeotropic Mixtures** of liquids are potential replacements for Refrigerant 12, which is now commonly used. Each of these mixtures has an ozone-depletion potential less than one-hundredth that of Refrigerant 12.

IDENTIFICATION OF COMPONENT REFRIGERANTS

Refrigerant	Formula	Name	Normal Boiling Temperature, °C
R134a	CH_2FCF_3	1,1,1,2-Tetrafluoroethane	−27.89
R152a	CHF_2CH_3	1,1-Difluoroethane	−25.00
R124	$CHClFCF_3$	2-Chloro-1,1,1,2-tetrafluoroethane	−12.00
R142b	CH_3CClF_2	Chlorodifluoroethane	−9.70

Removing Undesired Fine Powder From Silicon Reactor

The flow of gas from a fluidized bed sweeps the smallest particles away.

NASA's Jet Propulsion Laboratory, Pasadena, California

The fluidized-bed reactor shown in the figure is designed to produce highly pure polycrystalline silicon particles that have diameters $\geq$ 400 μm. The reactor operates by the pyrolysis of silane in a reaction zone, which is a bed of silicon seed particles (diameters 50 to 400 μm) fluidized by the flow of silane and possibly a carrier gas. Above the reaction zone lies an entrainment zone, where the gas mixture flows rapidly enough to entrain a significant proportion of the silicon powders, (particles that have diameters less than a few microns) — but not a significant proportion of the larger seed and product silicon particles. The entrained particles are swept out of the reactor by the fluidizing gas. The concept may also be applicable to such other processes as the production of fine metal and ceramic powders in which careful control of the sizes of product particles is needed.

Usually, the highly pure polycrystalline silicon product particles are intended to serve as the starting material for the preparation of single crystals of silicon by the single-crystal-pulling technique. Silicon powder is undesirable in this application because instead of melting readily, the powder floats on the surface and deposits around the newly formed single-crystal rod. Furthermore, the powder particles are more susceptible to contamination than the larger particles are because the powder particles have more surface area per unit mass. Finally, it is difficult to handle micron-to-submicron-sized particles of silicon powder.

Silicon powder results from the homogeneous decomposition of silane (direct decomposition of silane into silicon and hydrogen from within the gas phase) rather than from the heterogeneous decomposition of silane (decomposition of silane by deposition of silicon onto the surfaces of silicon particles). This undesired homogeneous decomposition can be lessened by reducing the temperature of the reaction zone or by maintaining a low concentration of silane in the reaction zone. However, these measures would also slow the desired heterogeneous decomposition. The use of the entrainment zone makes it possible to maintain conditions for more-efficient heterogeneous decomposition in the reaction zone, while removing the undesired silicon powder from the fluidized bed.

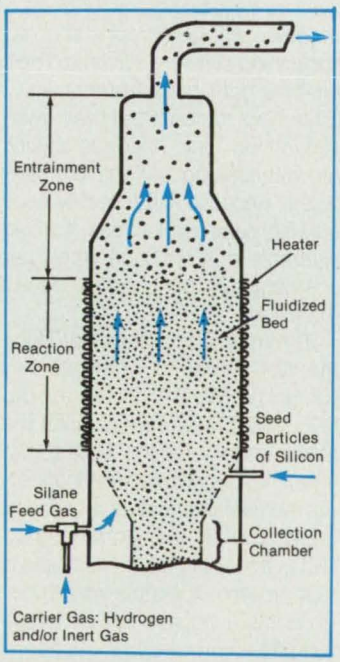
The required velocity of flow in the entrainment zone can be calculated from such parameters as the density and viscosity of the gas and the sizes, shapes, and void fractions of the particles. The required flow in the entrainment zone can then be maintained by use of a suitable input flow of silane and carrier gases and/or by a suitable decrease in the cross section of the reactor in the entrainment zone. Typically, flow speeds of 0.1 to 4.8 ft/s (0.03 to 1.5 m/s) should suffice to remove at least 50 percent of the silicon powder but not to entrain a significant amount of the larger product silicon particles.

This work was done by Robert N. Flagella of Union Carbide Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 120 on the TSP Request Card.*

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

Morris N. Reinisch
Union Carbide, Inc.
Law Dept. — Patent Section
39 Old Ridgebury Road
Danbury, CT 06817–0001

Refer to NPO-18323, volume and number of this NASA Tech Briefs *issue, and the page number.*



This **Fluidized-Bed Reactor** includes an entrainment zone above the fluidized-bed reaction zone. The fluidizing gas flows rapidly enough in the entrainment zone to carry away fine particles of silicon.

Computer Programs

COSMIC: Transferring NASA Software

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

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

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

COSMIC is part of NASA's Technology Utilization Network.

COSMIC® *John A. Gibson, Director,*
Phone (706) 542-3265 ; FAX (706) 542-4807
The University of Georgia, 382 East Broad Street, Athens, Georgia 30602

Computer Programs

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

Mathematics and Information Sciences

Transportable Applications Environment Plus

Users can construct custom user interfaces for their own application programs.

Transportable Applications Environment Plus (TAE+) is an integrated, portable computer program that provides an environment for developing and running interactive window, text, and graphical object-based application software systems. The program enables both programmers and nonprogrammers to construct their own custom application user interface easily and to move those applications to different computers. Because TAE+ can be used repeatedly for many applications, it provides considerable cost savings when used as a company's primary user interface development tool.

The main components of TAE+ are (1) the WorkBench, a what-you-see-is-what-you-get (WYSIWYG) tool for the design and layout of a user interface; (2) the WPT's (Window Programming Tools) software package, a set of callable subroutines that control the user interface of an application program; and (3) TAE Command Language (TCL), an easy-to-learn command language that provides a simple way to develop an executable application prototype with a run-time-interpreted language.

The WorkBench enables the developer of an application program to construct the layout of the display screen interactively by manipulating a set of interaction objects, including such input items as buttons, icons, and scrolling lists. Also included are such data-driven graphical objects as dials, thermometers, and strip charts, which TAE+ updates as the values of the data change. The WorkBench includes drawing tools for creating icons and the graphics associated with data-driven objects. As a developer's tool, it also provides the capability to define "connections" between interaction objects dynamically, rehearse the designed user interface, save the user interface details in a resource file, and generate fully annotated and operational source code (in C, Ada, FORTRAN, and TCL). This WorkBench-generated code includes calls to the TAE+ runtime services (WPT's), which use the details saved in the resource file to control the entire user interface and, thus, supply a bridge between the development and runtime environment. Since the WPT's access the resource file during execution, the user interface details remain independent from the application code, allowing changes (e.g., color, front screen location, type of object) to be made easily without recompiling or relinking the application software.

In addition to WPT's, TAE+ offers control of interaction objects from the interpreted TAE Command Language. TCL provides an extremely powerful means for the more experienced developer to develop quickly a prototype of an application's user interface without the overhead of compiling or linking.

TAE+ uses the MIT X-Window System as the underlying windowing standard. The WorkBench and WPT's are written in C++, and the remaining code is written in C. TAE+ is available by license for an unlimited time. The licensed program product includes the TAE+ source code and one set of supporting documentation. Recommended minimum memories of 8 MB and 50 MB in disk space are required to load the TAE+ TAR tape. This tape includes the Free Software Foundation's C++ compiler (GNU's C++). TAE+ was developed in 1989.

TAE+ is available in a form suitable for six different groups of computers: (1) DEC, VAX station and other VMS VAX'es (specify TK50 or 9-track VMS Backup format), (2)

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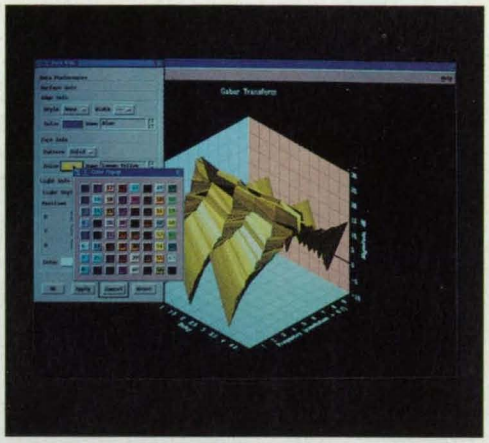

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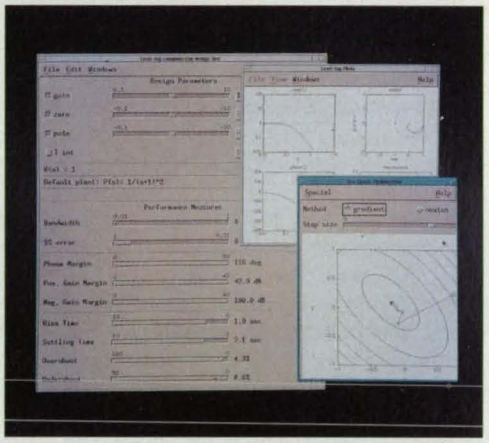

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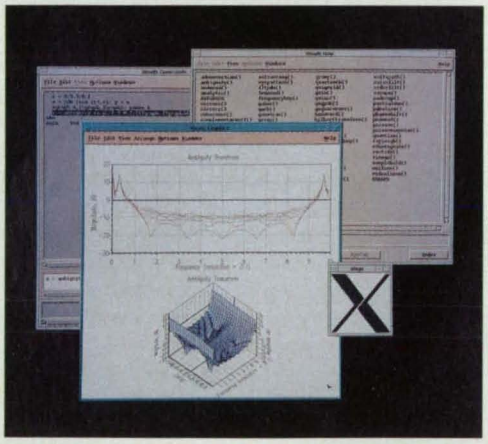

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Object-oriented Analysis For Signal Processsing. Xmath

Macintosh II computers running AUX [on ¼-in. (6.35-mm) miniature tape cartridge in Unix TAR format], (3) Apollo Domain Series 3000 [on ¼-in. (6.35-mm) cartridge in TAR format], (4) DEC VAX and RISC workstations running Ultrix (TK50 in TAR format), (5) Sun 3- and 4-series work stations running Sun OS and IBM RT/PC's and PS/2's running AIX [on ¼-in. (6.35-mm) Sun cartridge in TAR format], and (6) HP 9000 Series 800 workstations (HP preformatted, 16-track cartridge tape in TAR format).

This program was developed by the Data Systems Technology Division of **Goddard Space Flight Center**. *For further information, Circle 19 on the TSP Request Card.*
GSC-13277/78

Curvilinear-Interpolation Program

INTERP2 performs a polynomial interpolation based on the true relationship among known values.

Determining the value of a function at a point between points specifically defined in a table is a common task for scientists and engineers. This process, called interpolation, ranges from the simplicity of linear regression to the complexity of time-consuming algorithms, depending on the accuracy required. INTERP2 is an interactive, easy-to-use computer program that uses the speed of a computer to execute a complicated mathematical process that solves interpolation problems quickly and accurately.

Interpolation based on a straight-line correlation among the given data points ignores all but two data points close to the unknown point, and is therefore unable to account for any effects of curvature. This is why curvilinear interpolation, a complicated method, is often necessary when a highly accurate value is required. INTERP2 solves for an unknown value based on the true relationship among given values, whether that relationship is linear or nonlinear. Using the technique of the Lagrange interpolating polynomial, INTERP2 "draws" a curve through the input data points and then interpolates to obtain the unknown $f(x)$ for a known x expediently.

INTERP2 is written in BASIC for an IBM-PC-compatible computer running the MS-DOS operating system. A short explanatory text file and the executable code are included with the source code. INTERP2 was developed in 1989 and requires 37 KB of memory.

IBM and IBM PC are registered trademarks of International Business Machines. MS-DOS is a registered trademark of the Microsoft Corp.

This program was written by Michael J. Coppi of Lockheed Space Operations Co. for **Kennedy Space Center**. *For further information, Circle 14 on the TSP Request Card.*
KSC-11497

Software for Integer Programming

IESIP implements an improved exploratory-search technique for pure integer linear-programming problems.

The Improved Exploratory Search Technique for Pure Integer Linear Programming Problems (IESIP) computer program addresses the problem of optimizing an objective function of one or more variables subject to a set of confining functions or constraints, by use of a method called discrete optimization or integer programming. Integer programming is based on a specific form of the general linear-programming problem in which all variables in the objective function and all variables in the constraints are integers. While more difficult, integer programming is required for accuracy in the mathematical modeling of systems that contain small numbers of components, such as in the distribution of goods, scheduling operations on machine tools, and scheduling production in general.

IESIP establishes a new methodology for solving pure integer-programming problems by utilizing a modified version of the univariate exploratory move developed by Robert Hooke and T. A. Jeeves. IESIP also takes some of its technique from the greedy procedure and the idea of unit neighborhoods. A rounding scheme involves the use of a continuous solution found by a traditional method (simplex or other suitable technique) and creates a feasible integer starting point. The Hook-and-Jeeves exploratory search is modified to accommodate integers and constraints and is then employed to determine an optimal integer solution from the feasible starting solution. The user-friendly IESIP enables the rapid solution of problems up to 10 variables in size (limited by DOS allocation). Sample problems compare IESIP solutions with the traditional branch-and-bound approach.

IESIP is written in Borland's TURBO Pascal for IBM PC-series computers and compatibles running DOS. Source code and an executable code are provided. The main memory requirement for execution is 25K. This program is available on a 5.25-in. (13.34-cm), 360K MS DOS format diskette. IESIP was developed in 1990.

IBM is a trademark of International Business Machines Corp. TURBO Pascal is registered by Borland International.

This program was written by F. R. Fogle of **Marshall Space Flight Center**. *For further information, Circle 152 on the TSP Request Card.*
MFS-27260

Program Models Propagation of Failures

FIRM represents a hybrid between schematic-diagram and fault-tree approaches.

The FIRM computer program is a software tool for the identification of failures and the management of risk. FIRM is based on the directed-graph ("digraph") approach, which can be considered a hybrid between an approach based on schematic diagrams of systems and an approach based on fault trees. In a digraph model of failure, nodes are used to represent failures of components or functions, and connections between nodes are used to represent the propagation of failures among components or functions.

Failure is defined in terms of "reachability" of a component or process. The program can determine either reachability to a target or reachability from a source. Any node in the digraph can be chosen as a source, and FIRM will identify all nodes (singletons) or combinations of 2 (doubletons) or 3 (tripletons) nodes that can reach the target. FIRM can also identify loops in digraphs and display the direct failure paths between any two nodes.

The three core algorithms in FIRM are optimized for processing singletons and doubletons and can also handle tripletons. A unique feature is that FIRM solves for reachability for a given node without computing reachability for the entire digraph. No matrix computation methods are used. The algorithm thus implements essentially a real-time approach that enables the user to modify the digraph and immediately observe any changes in reachability for nodes of interest. The ability of FIRM to detect and print loops in digraphs enables users to develop large digraphs more easily. Its ability to display all direct failure paths between any two selected nodes in a digraph is useful in investigating failure-propagation scenarios contained in digraphs.

FIRM is written to be highly portable. It is written in C and can run on any computer that includes an ANSI standard C compiler. FIRM has been installed on Macintosh, IBM PC-series, DEC VAX, Amdahl, and Cray computers. The program can solve problems of unlimited size, depending only on the memory resources of the host computer. The memory required for the executable code ranges from 56 Kb on the Macintosh computer to 198 Kb on the Cray computer. Mathematical models require approximately 68 bytes per node. The program is available on a 5.25-in.

(13.34-cm) 360K MS-DOS-format diskette (standard medium) or a 3.5-in. (8.89-cm) Macintosh-format diskette. FIRM was developed in 1990.

Cray is a trademark of Cray Research, Inc. Amdahl is a trademark of Amdahl Corp. IBM PC is a trademark of International Business Machines. DEC and VAX are trademarks of Digital Equipment Corp. Macintosh is a trademark of Apple Computer, Inc.

This program was written by Donald B. Hackler, David T. Bui, and Fred J. Becker of Lockheed Engineering & Sciences Co. for **Johnson Space Center**. *For further information, Circle 2 on the TSP Request Card.*
MSC-21860

Program Handles Environmental-Test Data

S3DACS assists in the acquisition, recording, processing, and display of test data.

The S3 Data Acquisition and Control System, (S3DACS) computer program was developed for the Environmental Test Laboratory and Space Simulator at NASA's Jet Propulsion Laboratory. The program is used for monitoring, controlling, and recording information acquired during tests and presenting this information in various formats for easy access by a large number of users.

All testing is initiated by a setup procedure that defines what will be tested, limits to be checked, formulas to use, and the like. The results of tests (e.g., temperature, resistance) are then automatically stored in a data base for display in real time and for future reference. Measurement data thus obtained can be used in various computations defined for the test and selectively presented in tabular, graphical, or electronic form. Reports can be made to show current or historical events.

The S3DACS network software is written in FoxPro/LAN 1.02 and 80386 Assembler for IBM PC and compatible computers running MS-DOS 3.31 or higher. Required computing equipment includes the following: an 80386 33-MHz processor with 10 Mb of random-access memory (RAM) set up as a file server, an 80386 33-MHz processor with 4 Mb of RAM connected to a FLUKE 2240B or 2280 data-acquisition device, and an 80386 20-MHz processor with 5 Mb of RAM used as a workstation. Also needed is National Instruments circuit board that is compatible with a general-purpose interface bus (GPIB) to enable S3DACS to communicate with IEEE-488 control instruments.

Required software includes the following: Novell Netware 386 for management of the network; FoxPro/LAN 1.02 for management of the data base; Version 5.0 of QEMM 386 for management of the memory; and Version 4 of DGE, Saywhat, Viewlib, and DBSHOW for graphics and screen displays. The equipment listed in the preceding paragraph is the minimum that will allow installation of S3. Workstations and data-acquisition devices can be added transparently.

S3DACS is distributed on seven 5.25-in. (13.34-cm), 1.2-Mb MS-DOS-format diskettes. The extensive documentation includes a quick-reference guide, a software user's manual, a computer-systems-operator's manual, and a software programmer's manual. The source code is provided in PKZIP format, and the PKUNZIP utility is included. Compilation of the assembler source code requires version 5.10 of Microsoft's Assembler. Because of the complexity of this software package, COSMIC strongly recommends the purchase and review of the documentation prior to the purchase of the program. S3DACS was developed in 1990. S3DACS is a copyrighted work with all copyright vested in NASA.

All trade names used are the property of their respective corporate owners.

This program was written by Frances de Freitas Bart, Terry C. Fisher, and Claudia de Luna of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 20 on the TSP Request Card.*
NPO-18508

Program for Logarithmic Interpolation of Test Data

DATASPACE interpolates to the logarithmically increasing intervals that are preferred in some analyses.

Scientists and engineers work with the reduction, analysis, and manipulation of data. In many instances, the recorded data must meet certain requirements before standard numerical techniques can be used to interpret them. For example, the analysis of a linear viscoelastic material requires knowledge of one of two time-dependent properties — the stress-relaxation modulus $E(t)$ or the creep compliance $D(t)$ (when t = time) — one of which can be derived from the other by a numerical method if the recorded data points are evenly spaced or increasingly spaced with respect to the time coordinate. The difficulty is caused by the fact that most laboratory data are variably spaced, making the use of numerical techniques difficult. To reduce this difficulty in the case of the analysis of stress-relaxation data, NASA scientists developed the DATASPACE computer program to establish a logarithmically increasing time interval in the relaxation data. The program is generally applicable

to any situation in which there is a need for increasingly spaced abscissa values in a set of data.

DATASPACE first takes the logarithm of the abscissa values, then uses a cubic-spline interpolation routine (which minimizes interpolation error) to create an evenly spaced array from the log values. This array is returned from the log abscissa domain to the abscissa domain and written to an output file for further manipulation. As a result of the interpolation in the log abscissa domain, the data are increasingly spaced. Stress-relaxation data processed in this way are spaced closely at short times and widely at long times, thus making it possible to avoid the distortion inherent in evenly spaced time coordinates. The interpolation routine gives results that compare favorably with the recorded data. The experimental data curve is retained, and the interpolated points reflect the desired spacing.

DATASPACE is written in FORTRAN 77 for IBM PC-compatible computers with math coprocessors running MS-DOS and for Apple Macintosh computers running MacOS. With minor modifications, the source code is portable to any computer that supports an ANSI FORTRAN 77 compiler. MicroSoft FORTRAN v2.1 is required for the Macintosh version. An executable code is included with the PC version. DATASPACE is available on a 5.25-in. (13.34-cm) 360K MS-DOS format diskette (standard distribution) or on a 3.5-in. (8.89-cm) 800K Macintosh format diskette. This program was developed in 1991.

IBM PC is a trademark of International Business Machines Corp. MS-DOS is a registered trademark of Microsoft Corp. Macintosh and MacOS are trademarks of Apple Computer, Inc.

This program was written by Frank E. Ledbetter II of **Marshall Space Flight Center**. *For further information, Circle 150 on the TSP Request Card.*
MFS-28551

Benchmark Lisp and Ada Programs

These programs can be used in several different ways to measure computational efficiency.

Some of the research of the Information Sciences Division at NASA Ames Research Center is devoted to the analysis and enhancement of processors and advanced computer architectures, specifically in support of automation and robotic systems. To compare the abilities of computers to process efficiently by use of the Lisp and Ada computing languages, scientists at Ames Research Center have developed a suite of nonparallel benchmark programs called ELAPSE. The benchmark suite was designed to be used in any or all of the following three tests: (1) comparing the efficiency of one computer processing via Lisp vs. processing via Ada; (2) comparing the efficiencies of several computers processing via Lisp; or (3) comparing several computers processing via Ada.

ELAPSE tests the efficiency with which a computer can execute the various routines in each language. The sample routines are based on manipulations of numbers and symbols and include two-dimensional fast Fourier transformations, Cholesky decomposition and substitution, Gaussian elimination, high-level data processing, and symbol-list references. Also included is a routine based on a Bayesian classification program that sorts data into optimized groups.

The ELAPSE benchmark programs are available for any computer equipped with a validated Ada compiler and/or Common Lisp system. Of the 18 routines in ELAPSE, 14 were developed or translated at Ames. The others are readily available through literature. The benchmark program that requires the most memory is CHOLESKY.ADA. Under VAX/VMS, CHOLESKY.ADA requires 760K of main memory. ELAPSE is available on either two 5.25-in. (13.34-cm), 360K MS-DOS format diskettes (standard distribution) or a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in ASCII CARD IMAGE format. The contents of the diskettes are compressed by use of the PKWARE archiving software tools. The utility program PKUNZIP.EXE, which decompresses the files from the archival format, is included. The ELAPSE benchmark programs were written in 1990.

VAX and VMS are trademarks of Digital Equipment Corp. MS-DOS is a registered trademark of Microsoft Corp.

This program was written by Gloria Davis, David Galant, Raymond Lim, and John Stutz of **Ames Research Center**; *J. Gibson of RECON Software; B. Raghavan of F.C.C.D.; P. Cheesema of Riacs-USRA; and W. Taylor of Sterling Software. For further information, Circle 109 on the TSP Request Card.*
ARC-12980

Software Operates on Bit-Map Images

Thirteen programs enable the user to create, alter, and store images.

PIXTOOLS is a package of software for the Silicon Graphics IRIS consisting of thirteen programs plus a library for operating on bit-map images. The image data structure is denoted as a "PIXIMAGE." The programs enable the IRIS user to create and edit high-resolution images from the Sharp JX450 scanner and to save such images in the forms in which they are displayed on video screens, resize them, and capture them.

Images can be sent to the QMS laser printer, the Tektronix 4693 color thermal printer, and the Matrix QCRZ film recorder. In addition, images in PIX format can be converted to images in SGI format (and vice versa) or converted to images in PostScript format. Images in PIX or SGI format can be converted to ".ras" files, which can be read by the "rasp" routine in the PLOT3D/AMES program (available from COSMIC), and ".ras" files can be converted to PIX files.

Eleven of the programs print information and read and write files. Two of the programs — namely, PIXSCAN and PIXEDIT — offer graphical interfaces. PIXEDIT uses the full IRIS screen as a drawing area, and pop-up menus are available. The menus enable manipulation of images and background color and saving of an image on a screen to a file. PIXSCAN is the user interface to the Sharp JX450 scanner. This program enables the user to do a preliminary scan of an image at low resolution and then select an area to rescan in higher resolution into a file. To be able to use PIXSCAN, the user must have the general-purpose interface bus (GPIB) circuit board (IEEE 488) and the "libgpib.a" library of software from Silicon Graphics, Inc. Instructions in the use of all the programs are provided in the form of UNIX on-line manual pages.

The PIXTOOLS programs are written in C language for execution on SGI IRIS 4D-series workstations running IRIX 3.2 or later. PIXEDIT (the largest program) requires 840K of main memory. The programs with graphical interfaces require that the IRIS have at least 24 bit planes. The package of programs is available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. A README file and UNIX manual pages provide information regarding installation and use of the PIXTOOLS programs. A nine-page manual that provides slightly more detailed information may be purchased separately. PIXTOOLS was developed in 1990 and updated in 1991.

SGI, IRIS 4D, and IRIX are trademarks of Silicon Graphics, Inc. PostScript is a registered trademark of Adobe Systems Inc. UNIX is a registered trademark of AT&T.

This program was written by Diana Choi of **Ames Research Center**. *For further information, Circle 72 on the TSP Request Card.*
ARC-12830

Simple, Lightweight, Thermomechanical Coupling

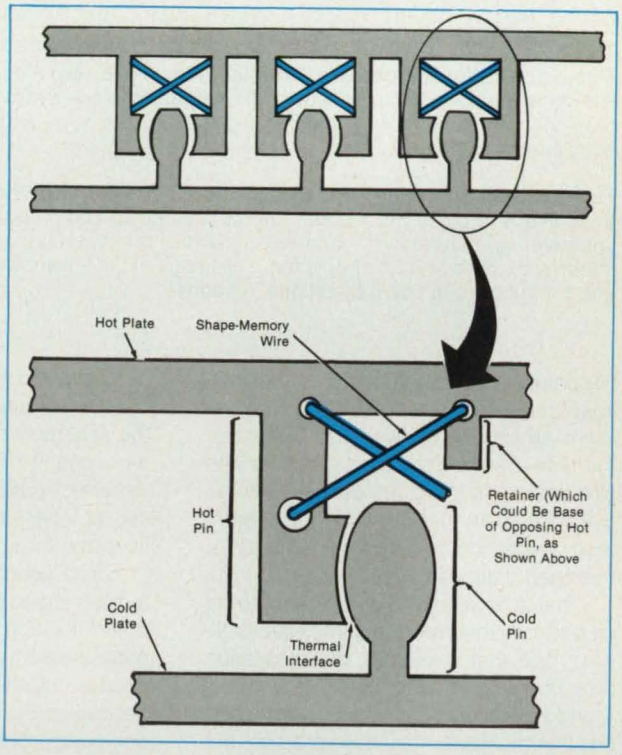
Temperature-sensitive shape-memory wire activates cantilevered thermal contacts.

Goddard Space Flight Center, Greenbelt, Maryland

A self-actuating thermal coupling device is light in weight and transfers heat efficiently. The coupling is thermostatic, making and breaking thermal contact as necessary to maintain a nearly steady temperature at the hot side of the interface.

Unlike in some other heat-transfer devices, the heat is not transferred by direct contact between the hot and cold plates; instead, the heat is transferred via contact pins perpendicular to the hot and cold plates. The pins can be designed to provide a larger total cross-sectional area for transfer than do the plates; transfer thus proceeds more efficiently. Thermal conductance can be 5 to 20 times as great. Moreover, it is easier to fabricate the smoothly polished surfaces that are desirable for efficient transfer on the many small areas of the pins than on the large areas of the hot and cold plates. In addition, the new device does not require large, externally applied forces to maintain thermal contact between the hot and cold plates. It therefore does not need a large and massive supporting structure. Moreover, inasmuch as fluids are not used to transfer heat, there is no risk of spillage during connection and disconnection of the hot and cold assemblies, and the need for the elaborate seals and tight alignment tolerances of fluid couplings is eliminated.

The device includes many pins extending from the hot and cold plates. The contour of the thermal interface on a hot pin matches that of the thermal interface on the mating cold pin (see figure). A loop of wire made of a nickel/titanium or other alloy that has a shape memory links each hot pin with a retainer. When the temperature of the shape-memory wire rises above a critical value, the wire shrinks, pulling the hot pin against the cold pin. When the temperature falls below the critical level, the wire expands to its original length, allowing the hot pin to pull away from the cold pin. The critical temperature is determined by the composition of the alloy.



One of Many Hot Pins on a hot plate is poised near a cold pin, its cold-plate counterpart. As the temperature of the hot plate rises, the shape-memory wire contracts, drawing the hot pin against the cold pin.

Thus, when heat flowing into the hot plate (from electronic circuitry, for example) raises the temperature of the hot plate above the critical temperature, the hot and cold pins come into contact and heat then flows into the cold plate, which may be connected to a radiator, heat exchanger, or conductor. The hot pins are held firmly against the cold pins until the temperature of the hot plate drops sufficiently to relax the wire. Then the pins separate and the transfer of heat stops. When the temperature of the hot plate again rises, the cycle resumes.

This work was done by M. Bruce Milam of **Goddard Space Flight Center**. *For further information, Circle 39 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-13251.

Measuring Streamwise Momentum and Cross-Stream Turbulence

Probes can be shaped to obtain the desired directional responses.

Ames Research Center, Moffett Field, California

New shapes for the tips of Pitot probes have been proposed to enable measurement of time-averaged streamwise momentum densities and time-averaged intensities of cross-stream turbulence in subsonic flows. Pitot probes are tubular pressure probes designed to face upstream, across the stream, or at intermediate angles; the response of such a probe depends on the direction of flow with respect to its axis. The new shapes would be tailored to yield specific directional responses.

Figure 1 illustrates schematically a probe in a turbulent flow. The probe is axisymmetric, and its x axis is aligned with the time-averaged direction of the stream. The flow is assumed to be in the low-subsonic range, so that the effect of compressibility can be neglected. It is also assumed that viscosity, if present, exerts a negligible effect. Under these conditions, a relatively simple analysis based on the fundamental equations of flow shows that the component of dynamic pressure attributable to cross-stream turbulence equals the difference between the time-averaged stagnation pressure based on the streamwise

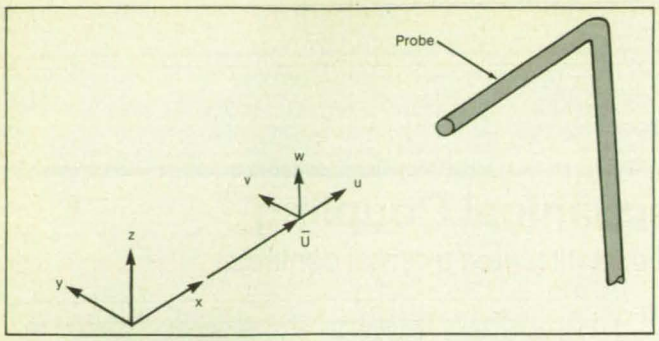


Figure 1. A **Tubular Probe in a Turbulent Flow Field** responds to the static and dynamic pressures. The response to the dynamic pressure can depend in a complicated way on the x, y, and z components of velocity.

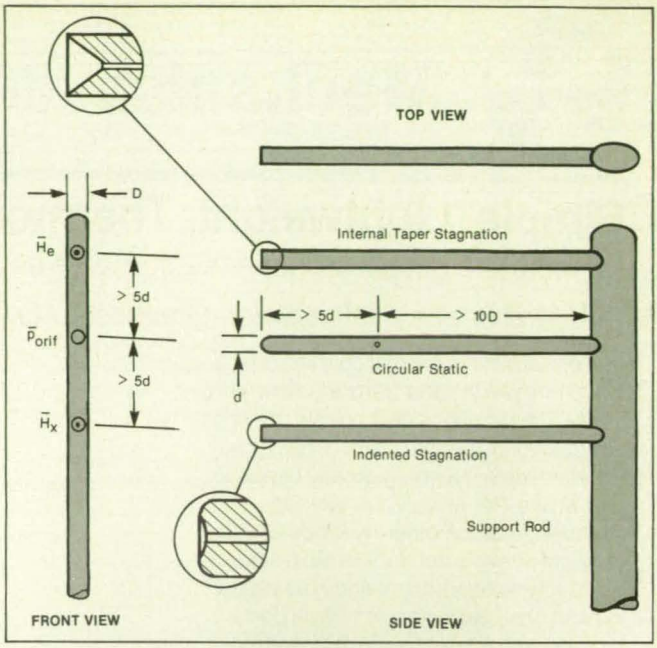


Figure 2. **Two Stagnation-Pressure Probes Plus a Static-Pressure Probe** provide the measurements needed to compute the time-averaged streamwise momentum density and time-average intensity of cross-stream turbulence. The shape of the lower probe gives it the desired $\cos^2 a$ directional response.

(x) component of velocity and the time-averaged stagnation pressured based on the entire velocity. The analysis also shows that the time-averaged dynamic pressure and streamwise momentum density can be calculated from the time-averaged streamwise stagnation pressure and the time-averaged static pressure.

What is required, then, is a set of three probes: one that measures the static pressure; one that measures the stagnation pressure and is equally sensitive to the x, y, and z components of flow velocity; and one that measures stagnation pressure but is sensitive to the x component of velocity only (see Figure 2). The requirement upon the third-mentioned probe is equivalent to the requirement that its response to dynamic pressure be proportional to $\cos^2\alpha$, where α is the angle between the flow and the axis of the probe.

The directional response of a probe of a given shape can be calculated from potential-flow theory by use of suitable computer programs. Such calculations can be iterated until the response approaches the desired $\cos^2\alpha$ response to an acceptable degree of precision. There is no unique solution; one might wish to investigate several shapes to determine which is the least sensitive to errors in construction.

This work was done by Vernon J. Rossow of **Ames Research Center**. *For further information, Circle 58 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, Ames Research Center [see page 20]. Refer to ARC-11934.

Improved Depiction of Computed Unsteady Flows

Animated pictures of flow variables and smoke and dye streaks assist in analyses and comparisons.

Ames Research Center, Moffett Field, California

The PLOT4D and STREAKER computer programs increase the ease of production and utility of animated depictions of unsteady flows that have been simulated numerically by advanced techniques of computational fluid dynamics. Given the practical limitations of computer memories, these programs were developed with a view toward maximizing the amount of information displayed while minimizing the amount stored. By enabling the user to make (and, if necessary, change) choices from a variety of options, these programs enhance the visualization and analysis of computed flows.

PLOT4D is an extended version of PLOT3D, which has been used widely to depict steady three-dimensional flows. (The "4" distinguishes PLOT4D by emphasizing that time is treated as a fourth dimension.) PLOT4D retains the capabilities and ease of use of PLOT3D, but incorporates additional features that make it more computationally efficient to use PLOT4D than to visualize an unsteady flow as a succes-

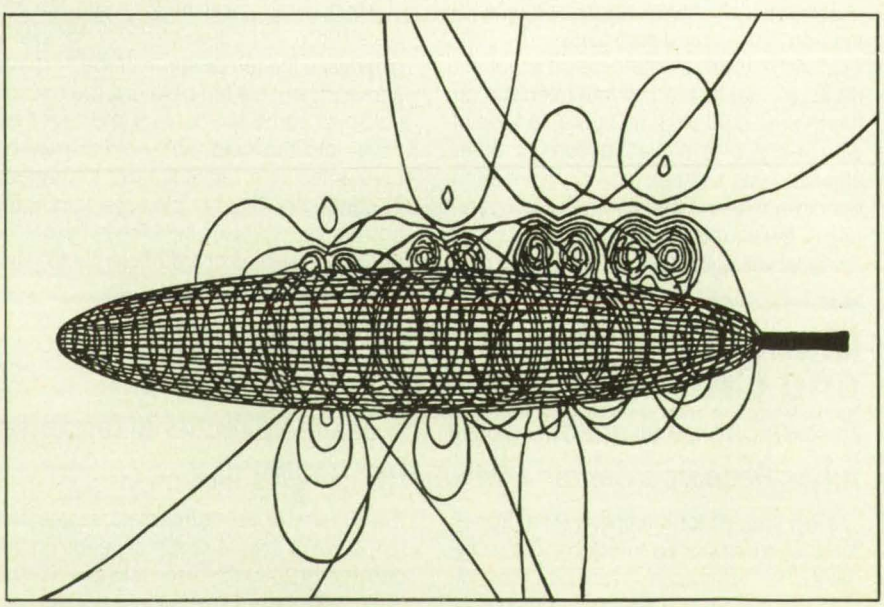


Figure 1. These **Density Contours** around a prolate spheroid in a flow at an angle of attack of 30° were plotted by PLOT4D. This picture represents a steady flow, for example only; PLOT4D is designed primarily for but not limited to the depiction of unsteady flow.

sion of steady flows, animating frame by frame via PLOT3D.

PLOT4D postprocesses the numerical output of a fluid-dynamical computation into maps of flow quantities on two-coordinate surfaces that depict a cut through the flow field or conform to a body surface. Also, multiple surfaces can be animated; in the extreme case, a full three-dimensional grid can be represented as a stack of two-coordinate surfaces.

The animation capabilities of PLOT4D require only a one-time input of a given three-dimensional flow configuration in the form of sets of three-coordinate data. These data consist of the flow variables in two-coordinate computational planes with time as the third coordinate. From five basic flow variables (density, the three components of momentum, and internal energy), PLOT4D calculates any of the 57 available scalar or vector quantities at each time step. The requested graphical representation is then stored in a memory buffer that enables the subsequent sequential display of the images on a video monitor. In this manner, all of the images are created before the animation is displayed. With a few quick commands in PLOT4D, various contours that depict the flow (see Figure 1) can be shown in sequence. The animation can be run forward, backward, slowly, or quickly; stopped; and restarted.

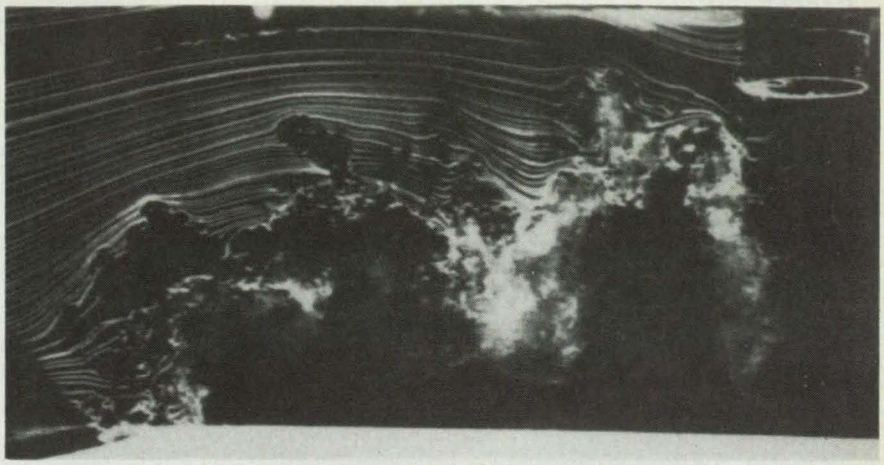
The STREAKER program generates streaklines, which are close approximations of the patterns that would be traced out by streams of dye or smoke released into the simulated flows at designated positions. Streaklines can be compared directly with smoke and dye traces in flow experiments to obtain qualitative indications of the validity of fluid-dynamical computations rapidly. It is important to distinguish among streaklines, streamlines, and the pathlines of individual particles. While they are identical in steady flow, they differ in unsteady flow (see Figure 2). Thus, the streamline-tracing subroutines of prior flow-visualization programs cannot be used to simulate smoke and dye traces in unsteady flow.

A streakline can be defined via the spatial succession of endpoints, at the given time step, of pathlines of massless particles released into the flow at some position at previous time steps. STREAKER computes the endpoints of such pathlines by fourth-order Runge–Kutta integration of velocity vectors. The streamlines will be broken if the distance between consecutive points exceeds a user-defined value.

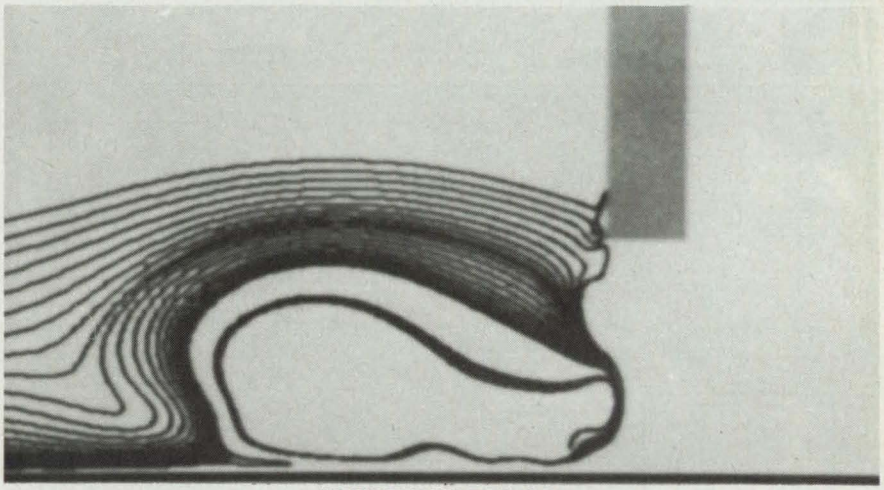
This work was done by Merritt H. Smith, William R. Van Dalsem, and Pieter G. Buning of **Ames Research Center** *and F. Carroll Dougherty of the University of Colorado. Further information may be found in AIAA paper 89A-25122, "Analysis and Visualization of Complex Unsteady Three-Dimensional Flows."*

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

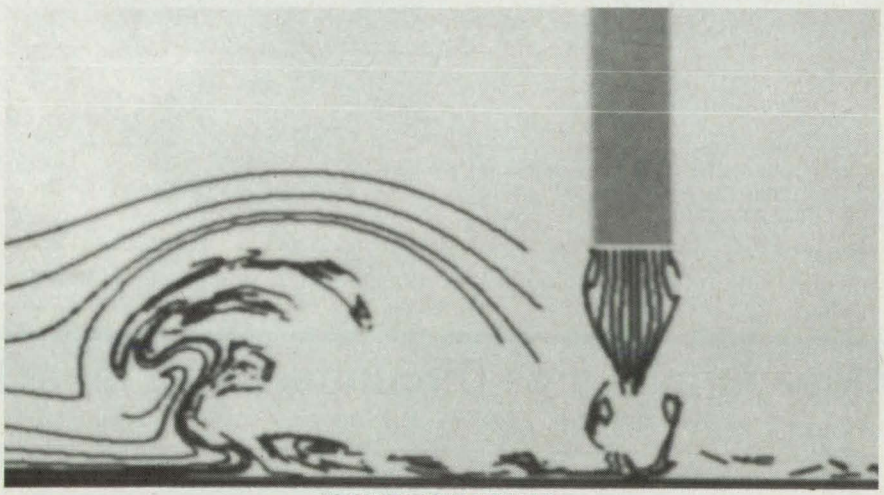
ARC-12677



EXPERIMENT WITH SMOKE TRACES



COMPUTED STREAMLINES



COMPUTED STREAKLINES

Figure 2. A **Jet Aimed at the Ground With a Crossflow** was photographed in an experiment with smoke tracers. It was also simulated numerically and is depicted here with streamlines and streaklines. The streaklines clearly resemble the smoke traces more closely than the streamlines do.

Tangential-Entry Injector With Internal Reed Valve

The pressure drop as a function of flow can be changed by design.

Marshall Space Flight Center, Alabama

A liquid-spray-injecting device provides a designed pressure drop versus rate of flow to help in metering the flow. The device can be used, for example, to provide a wide range of throttleability for liquid fuel injected into a combustion chamber or engine.

The device includes a cylinder with tangential entry slots and an internal reed valve (see Figure 1). The tangential entry imparts a swirling motion to the liquid, resulting in a finely atomized liquid spray when the liquid reaches the discharge end of the injector. The reeds in the reed valve vary the cross-sectional flow areas of the tangential entry slots by deflecting in response to the pressure of the flowing liquid. This variation alters the pressure-versus-flow characteristic.

The reed valve is a thin sheet of metal with partial cutouts, rolled up into a cylinder. The partial cutouts define the reeds. Windows at the ends of the reeds provide fixed minimum cross sections for flow. In fabrication, the reed valve is inserted in the cylinder that has the tangential entry slots, and a cover is brazed onto one end of the cylinder.

At low pressure drop, the reeds remain undeflected, so that the windows predominate as the flow-metering cross sections. When the pressure exceeds a specified first design value, the reeds deflect, providing varying flow-metering cross sections. When the pressure drop reaches a second, higher design value, the reeds attain maximum deflection, and any further increase in pressure drop fails to cause further deflection because the metering cross section shifts from the reeds to the tangential entry slots.

Figure 2 shows the pressure-vs.-flow characteristics of this device and of a comparable device of fixed cross section. The pressure drop varies with the square of the flow below the first and above the second design value, and linearly with the flow between these two design values.

This work was done by George B. Cox, Jr., of Pratt & Whitney for **Marshall Space Flight Center**. *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, Marshall Space Flight Center *[see page 20]*. *Refer to MFS-28547.*

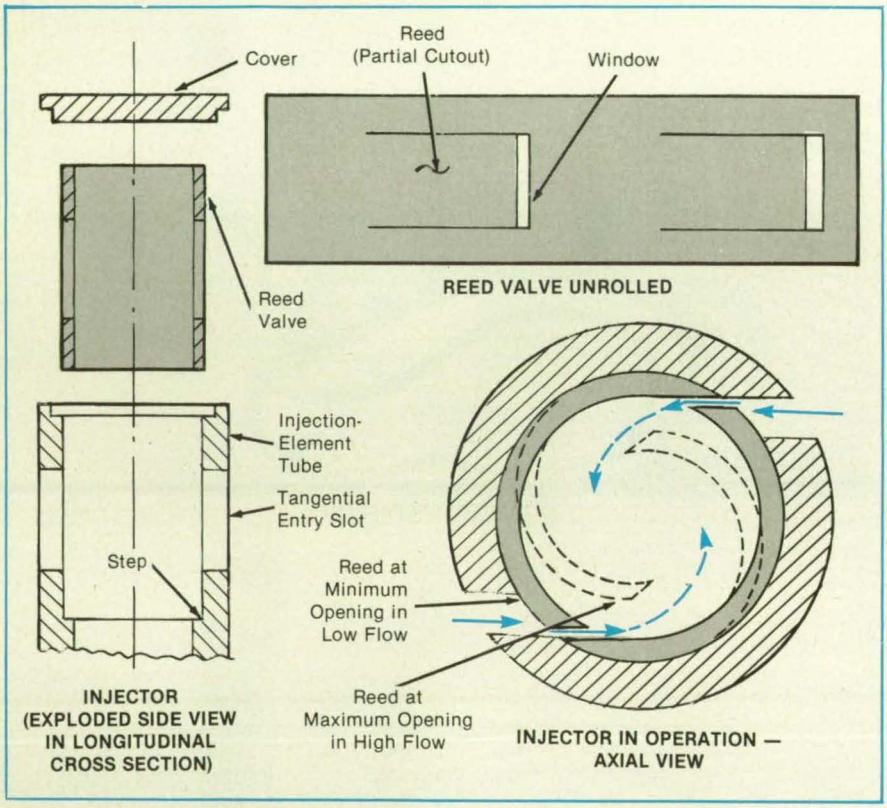


Figure 1. A **Reed Valve** is placed inside a tangential-entry flow injector to provide a variable orifice.

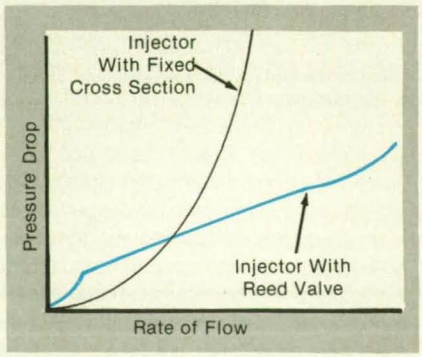


Figure 2. The **Pressure-vs.-Flow Characteristic** of the device of Figure 1 can be chosen by design to provide a wide range of throttleability.

Measuring Large Circumferences More Precisely

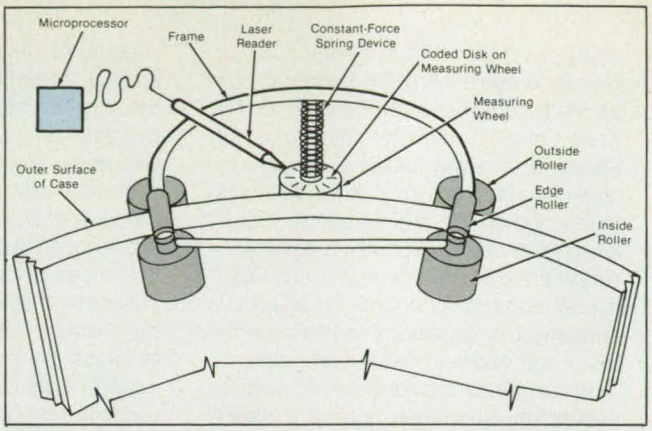
Potentially attainable precision exceeds that of a measuring tape or micrometer.

Marshall Space Flight Center, Alabama

An optoelectromechanical gauge measures the circumference of a large object with a resolution of about 10^{-4} in. (about 2.5 μm). It was designed to measure circumferences of large solid-rocket-motor cases precisely but can just as well be used to measure circumferences of other large, round objects like tanks. It could also measure the distance between two marks on the edge of a plate or along a beam or track.

The figure illustrates the gauge mounted on the upper rim of a large, vertically oriented round cylinder. The gauge frame rests on the rim or on optional edge rollers that, in turn, rest on the rim. A measuring wheel is held by a constant-force spring device against the cylindrical surface, the circumference of which is to be measured. Two inside rollers and two outside rollers provide rolling contact with the cylinder and help to guide it around the rim. The inside, outside, and edge rollers are mounted in fixed positions on the frame.

A disk like those used in compact-disk recording marked in an angular-position-indicating code is mounted on the side of the measuring wheel. A laser reader mounted on the frame senses the passage of the marks as the disk rolls along the surface. The reader sends the code signals to a microprocessor, which counts each mark, records the direction of rota-



The **Laser Reader Detects Code Marks** on the side of the measuring wheel. The passage of the marks indicates the distance traveled by the wheel as it moves around the circumference of the cylinder. The principle can be used to measure the inside as well as the outside circumference.

tion, and computes the distance traveled. The distance is displayed electronically and/or printed on paper.

This work was done by Louis E. Moore and Ernest E. Rogers of Thiokol 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-28564.

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.

Studies of Positive-Position-Feedback Control

Damping of vibrations was increased substantially in experiments.

A report discusses theoretical and experimental studies of positive-position-feedback control, a technique intended primarily for use in suppressing vibrations in large flexible structures. Positive-position-feedback control involves the placement of actuators and position or strain sensors (e.g., piezoelectric transducers), possibly collocated in pairs, at a number of points on a structure; control voltages are applied to the actuators in response to the outputs of the sensors processed via a compensator algorithm. The compensator algorithm implements second-order differential filter equations of the same form as those that describe the vibrations of the structure. The coupling between the structure and compensator is called "positive position feedback" because the forcing terms in the differential equations for the vibration-mode position coordinates of the structure and filter, respectively, are proportional to the vibration-mode position coordinates of the filter and structure, respectively.

One of the advantages of positive position feedback is that it provides global stability conditions that are independent of the dynamical characteristics of the structure; that is, vibrational modes that are not controlled or not represented in the mathematical model of the structure do not destabilize the system. Furthermore, positive-position-feedback control is not destabilized by the finite dynamics of the actuators.

This study focused on an aluminum cantilever beam 12.5 in. (31.8 cm) long, 0.648 in. (1.65 cm) wide, and 9.5 mils (0.24 mm) thick, equipped with two actuator/sensor pairs near its clamped end. Vibrations were excited by shaking the clamped end. Equations for the dynamics of the beam were derived, and the corresponding filter parameters were extracted. Several experiments were performed: In one experiment, one sensor/actuator pair was used, and one filter was tuned to control the first bending mode at about 5 Hz. In another experiment, one sensor/actuator pair was used, and three filters were used to control the first three modes. In yet another experiment, one actuator/sensor pair and one filter were used to control the first, second, and third bending modes, while the other sensor/actuator pair and another filter were used to control the fourth, fifth, and sixth bending modes.

The results of the experiments demonstrate that it is feasible to suppress vibrations by use of positive position feedback and that the spillover of vibrational energy into uncontrolled modes can have a stabilizing effect if the control gain is sufficiently small. The experimental positive-position-feedback control of the cantilever beam was found to multiply its damping ratios in various bending modes by factors that ranged from 2 to 130.

This work was done by James L. Fanson and Thomas K. Caughey of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Positive Position Feedback Control for Large Space Structures," Circle 76 on the TSP Request Card.*
NPO-18074

CFD Simulations of Sonic Booms in Near and Mid Fields

Experiments confirm the accuracy of simulations.

A report discusses the use of computational fluid dynamics (CFD) to simulate numerically the generation and propagation of sonic booms in the near- and mid-field regions of supersonic flows about simplified bodies representative of advanced airplanes. The principal motivation for this study lies in the need to design such airplanes to minimize sonic booms experienced by observers on the ground. The design strategy calls for shaping an airplane in such a way that the mid-field pressure disturbance (e.g., a finite-rise shock) is retained on the ground before it turns into an N-shaped overpressure-versus-time disturbance of the type that is characteristic of noisy sonic booms. To effect this strategy, it is necessary to compute the near- and mid-field flows accurately.

In this study, the parabolized Navier–Stokes equations were applied to steady supersonic flows about a cone/cylinder body, a low-aspect-ratio wing, and a thin fuselage-like body with a sharp nose and two delta wings. The parabolized Navier–Stokes equations in these cases offer two important advantages: (1) The required computing time and computer memory are reduced below what would otherwise be needed because the equations can be solved by a space-marching rather than by a time-relaxation technique, and (2) because the parabolized Navier–Stokes equations are valid in both the viscous and inviscid regions of the flow field, the interactions between these regions are taken into account automatically.

Two limitations arise from "parabolization" of the full Navier–Stokes equations. The first is that the streamwise viscous terms are neglected. The second is that the streamwise component of velocity must be positive everywhere: this excludes streamwise separation of flow but still permits crossflow separation.

The parabolized Navier–Stokes equations were integrated by use of an implicit, approximate-factorization, finite-volume algorithm in which the crossflow inviscid fluxes were evaluated by Roe's flux-difference-splitting scheme. First, the near-field solutions were obtained by applying the algorithm to the flows immediately surrounding the bodies. These solutions were transferred to computer codes based on Whitham's *F*-function theory (in which *F* is an integral that represents a distribution of sources that causes a given isentropic axisymmetric flow at a given distance from the airplane) for extrapolation to the far field.

These computations were performed on grids of various degrees of fineness and compared with data from wind-tunnel experiments performed with the three bodies in question. It was observed that a large number of grid points was needed to resolve the interactions between the tail shocks and the fan expansions, and that adequate resolution of these two regions of the flows near the bodies was necessary for accurate representations of the far-field overpressures. Consequently, thereafter a solution-adaptive-grid procedure was used and found to produce accurate solutions with half as many grid points.

This work was done by Samson H. Cheung of MCAT Institute and Thomas A. Edwards and Scott L. Lawrence of **Ames Research Center**. *Further information may be found in AIAA paper 91A-12512, "Application of CFD to Sonic Boom Near- and Mid-Field Prediction."*

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

ARC-12855

Bearing Cartridge Designed To Reduce Wear

Independent preloads would be applied to two races.

Marshall Space Flight Center, Alabama

A bearing cartridge that holds the outer races of two ball bearings in a turbopump is designed to prevent unloading of the bearings during operating transients. The cartridge and bearings are intended to replace two ball bearings, the outer races of which are mounted in a cylinder called the "isolator" and which are preloaded by a single spring mount that holds the isolator and reacts radial loads.

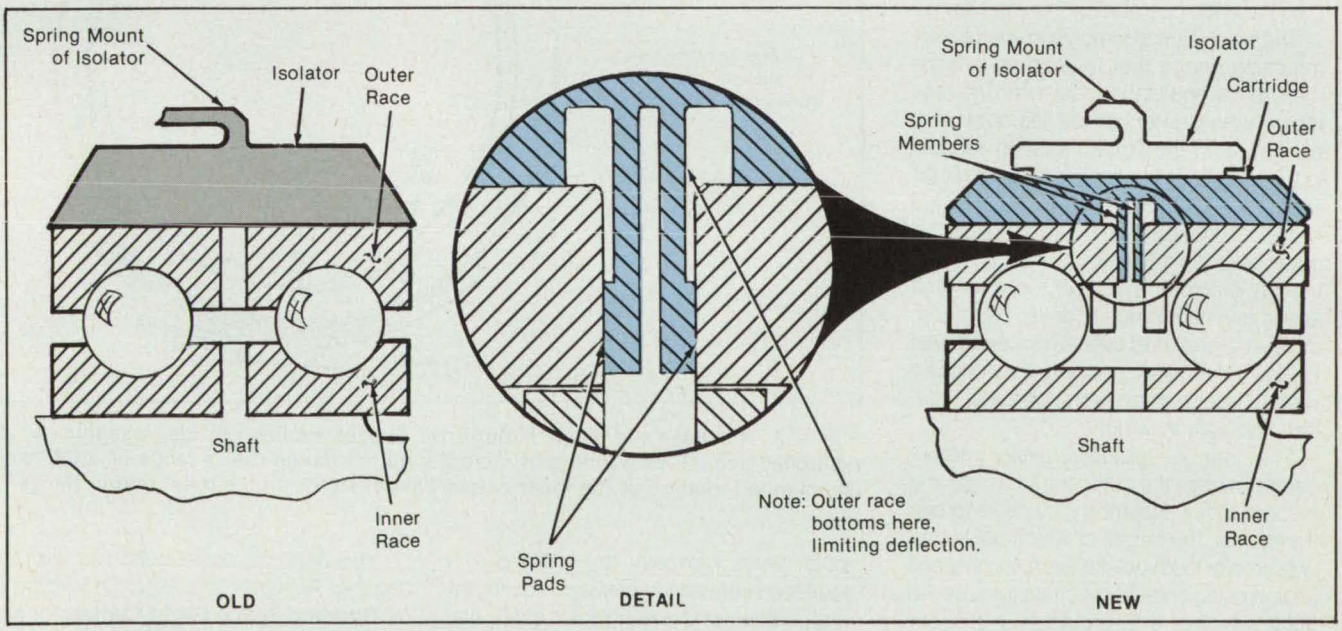
The figure shows the old and the proposed new designs. In the old design, the bearings can become unloaded when the pair of bearings slides axially in the bore of the isolator during axial transients of the shaft and inner races mounted on the shaft. The moment applied to an outer race as it moves along the isolator may cause unloading or excessive excursion of the balls on the side opposite that of the loaded balls. It is necessary to eliminate unloading because unloading has been found to initiate wear.

In the new design, the outer races would be mounted in a cartridge that would slide axially in the bore of the isolator during transients and that would force the outer races to move with it as a pair. The cartridge would include two integral seal-type spring members that would apply independent preloads to the two outer races. The outer surface of the cartridge would be barreled slightly to allow the bearings to be loaded nearly evenly in the presence of misalignment between the shaft and the components that support the bearings.

The spring members in the cartridge would be able to undergo twice as much deflection as does a beam spring in the old design, without requiring additional space. At a sufficiently large deflection, the point of contact between the affected spring and outer race would move from the spring pad to a point on the member closer to the bore of the cartridge, thereby effectively shortening the spring and making it stiffer so that it would offer a greater impediment to further travel. In other words, the affected bearing would "bottom" in the cartridge before the other one would become unloaded.

Another advantage of independent preloads on the two bearings is that deflections of one bearing would not affect the other bearing directly. In comparison, bearings preloaded against each other impose unwanted moments on each other, resulting in misalignment. Another advantage of independent preloads is that the influences of differences between the internal clearances in the two bearings (caused by differences between temperatures) and of differences between the radial loads on the two bearings would be eliminated.

This work was done by Eric J. Krieg of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 52 on the TSP Request Card. MFS-29807*



In the **Old Design**, the bearings can become unloaded during axial transients of the shaft and inner races. In the new design, one bearing would "bottom" in the cartridge before the other would become unloaded.

Dual-Roll Robotic Wrist-Joint Assembly

The joint provides two concentric rotations: one limited, the other unlimited.

Goddard Space Flight Center, Greenbelt, Maryland

A compact robotic wrist-joint assembly (see Figure 1) includes two motor subassemblies (see Figure 2) that provide two concentric output rotations about the axis of the wrist:

1. An outer output flange on the front face

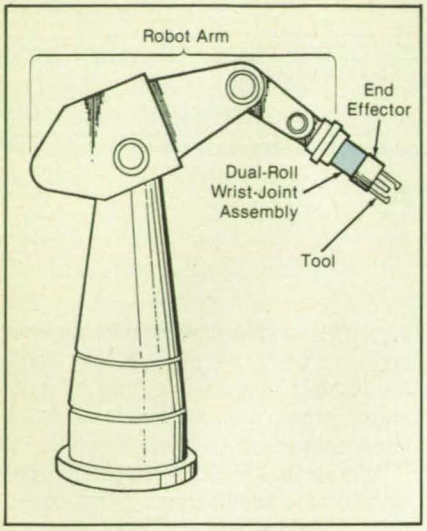


Figure 1. The **Dual-Roll Wrist-Joint Assembly** is mounted on the end of a robot arm.

of the wrist-joint assembly is rotated to, and held at, any predetermined roll angle within a limited range of ±180°. This motion provides the required roll orientation to the end effector of the robot, which is mounted on the outer flange.

2. An inner output flange concentric with the outer output flange is capable of unlimited rotation relative to the outer flange. This motion is used to drive a rotary tool (e.g., a milling cutter or a nut runner like the one shown in Figure 1) in conjunction with the operation of the end effector.

The wrist-joint assembly includes a rear mounting flange that is used for attachment to the end of the robot arm. The rear motor subassembly drives the outer output flange in the limited rotation relative to the rear mounting flange; the front motor subassembly drives the inner output flange in the unlimited rotation relative to the outer output flange. Each motor subassembly includes a concentric rotor and stator and a harmonic drive. Harmonic drives are preferred over other gear drives for this mechanism because they operate without backlash and are compact, reliable, and light in weight.

The train of torque-coupling components between the outer output flange and the rear motor assembly includes a torque transducer, the output of which could provide control feedback for such applications as tightening bolts to specified torques. An angle resolver at the output of the rear motor subassembly provides feedback for control of the roll angle of the outer flange. A flat, flexible cable provides the electrical connections between the stationary housing and the front motor, which rotates with the outer flange. The cable is wound in a spiral that provides enough slack to accommodate the ±180° range of rotation of the outer output flange.

A brake disk is connected to the rear motor shaft. Normally, the brake disk is squeezed between two brake pads to prevent rotation of the rear motor shaft, harmonic drive, and outer output flange. To free the rear motor subassembly for rotation to a new commanded roll angle, a brake solenoid is energized to pull on an armature that, in turn, pulls one of the brake pads away from the brake disk. Once the outer output flange reaches the new commanded roll angle, as sensed by the angle resolver, the solenoid is deenergized and the brake applied.

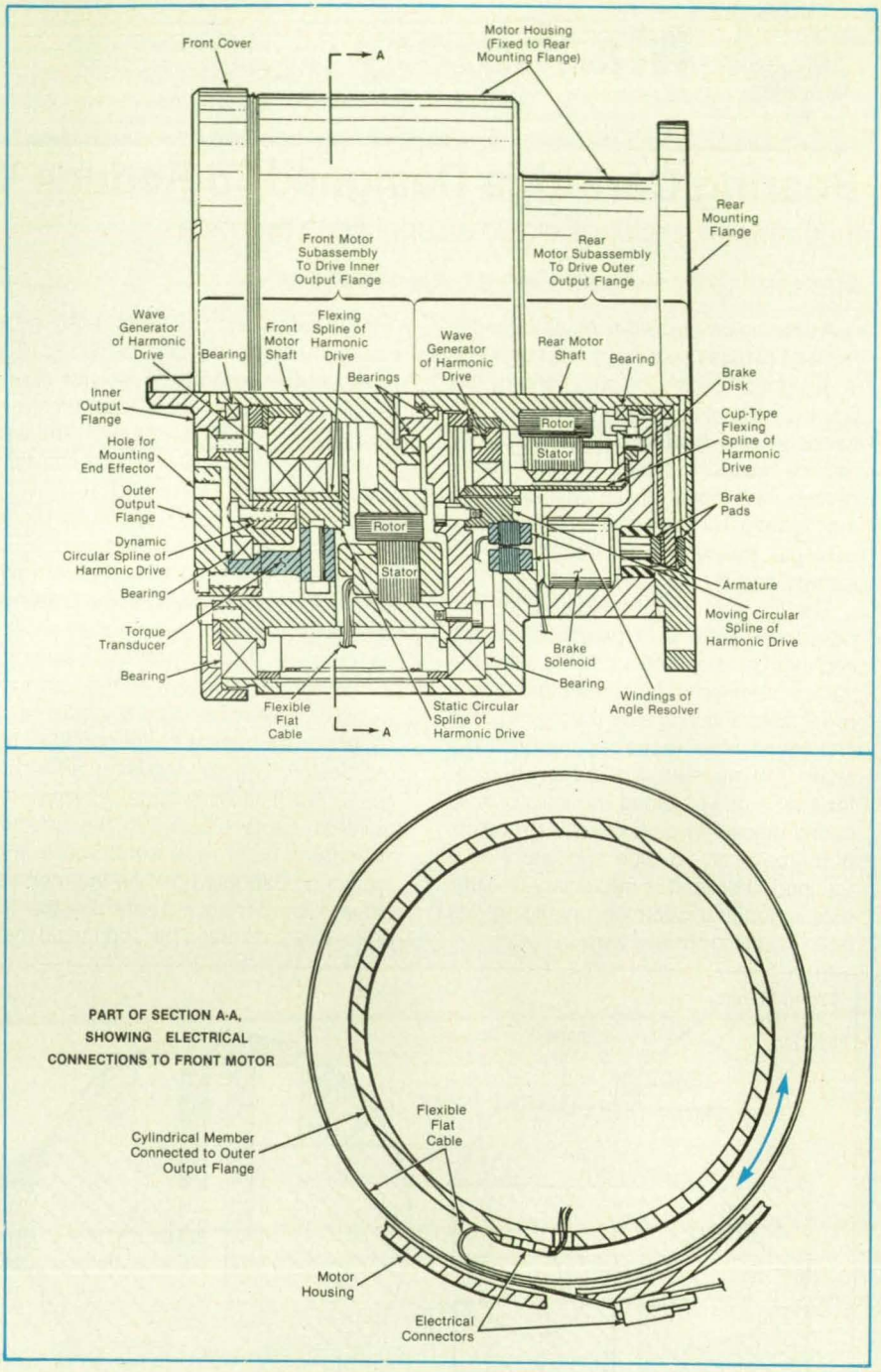


Figure 2. The **Rear and Front Motor-Drive Subassemblies** provide, respectively, (1) controlled angular positioning of the outer output flange over a range of ±180° and (2) unlimited rotation of the inner output flange relative to the outer output flange.

This work was done by John M. Vranish, Paul W. Richards, and Peter D. Spidaliere of **Goddard Space Flight Center**. *For further information, Circle 4 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13307.

Improved Regenerative Sorbent-Compressor Refrigerator

The efficiency of the regenerative portion of the cooling cycle would be increased.

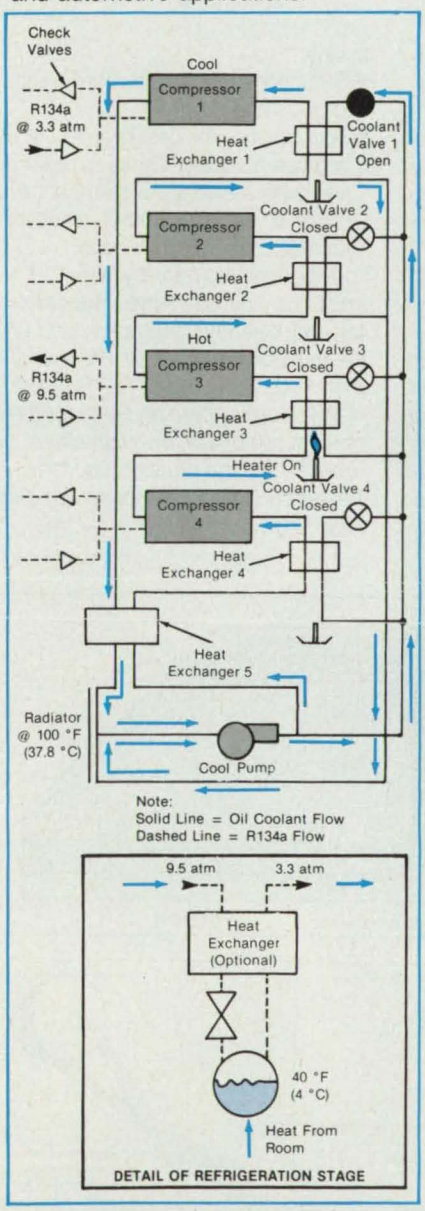
NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptual regenerative sorbent-compressor refrigerator would attain a regeneration efficiency and, therefore, an overall power efficiency and coefficient of performance greater than those of many conventional refrigerators.

The improved refrigerator could be powered by electricity, oil, gas, solar heat, or even waste heat. The concept has been partly verified by computer simulation, and tests have been started. Refrigeration systems designed according to this concept could be used as air conditioners, refrigerators, and heat pumps in industrial, home, and automotive applications.

The refrigerator would include two fluid loops. In one loop, a non-ozone damaging working fluid, CH_2FCF_3 (also known as Refrigerant 134a or R134a), would be circulated by physical adsorption and desorption in four activated-charcoal sorption compressors. In the other loop, a liquid or gas coolant (e.g., oil) would be circulated by a pump. The coolant loop would be used to pass hot and cold wavefronts through the sorption compressors, thus regenerating almost all of their sensible heat and about half of their heats of adsorption. This system has very little thermal gradient in the heated and cooled compressors, and thus is more efficient than previous regenerative sorption system.

The figure illustrates schematically the operation at one of four phases of the operating cycle. (The phases propagate in sequence among the four sorption compres-



A Wave of Regenerative Heating and Cooling would propagate cyclically like a peristaltic wave among the four sorption compressors and their associated heat exchangers.

sors.) In this phase, the heater under heat exchanger 4 would be turned on to heat compressor 3 to a temperature of about 400 °F (204 °C) while coolant valve 1 would be opened to cool compressor 1 to about 100 °F (38 °C).

The heating in compressor 3 would cause the working fluid to be desorbed at a pressure of about 9.5 atm (0.96 MPa), while the cooling in compressor 1 would cause the working fluid to be resorbed down to a pressure of about 3.3 atm (0.33 MPa). Thus, the working fluid would flow from compressor 3 through an expansion valve where the fluid is cooled and accepts heat from a room (air conditioning), and finally to compressor 1.

Based on actual adsorption data, the cooling coefficient of performance is estimated to be about 1.5, which is about half the efficiency of an electrical vapor-compression cycle. Gas heat, however, costs 4 times less than electrical power, primarily because power-generation cycles are so inefficient. Thus, this improved refrigeration system should cost about half as much to operate as traditional refrigeration systems do, and, including power generating costs, it should consume noticeably less energy.

This work was done by Jack A. Jones of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 128 on the TSP Request Card.*

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

Edward Ansell
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
120i East California Boulevard
Pasadena, CA 91125

Refer to NPO-18211, volume and number of this NASA Tech Briefs *issue, and the page number.*

Helicopter Rotor Blade With Free Tip

Vibrations are reduced while efficiency is increased.

Ames Research Center, Moffett Field, California

Free-tip rotor blades can improve significantly the fuel efficiency and other performance characteristics of helicopters. Rotor free tips resemble the free-tip winglets that have resulted in improved performance when added to fixed wings. The application of the free-tip concept to helicopter rotors was proposed in 1980, and tests indicate no technical impediment to further development.

The free-tip rotor concept is so called because the outermost portion of the rotor blade pivots independently with respect to the inboard portion of the blade about a pitch axis parallel to the blade axis, located slightly forward of the aerodynamic center of the tip (see figure). The centrifugal force of the tip acts on a tension/torsion strap made of wire wrapped repeatedly around two spools. The tension and the elasticity of the wires make the device act as a torsion spring that biases the tip nose-up. The relative airstream tends to turn the tip nose-down, and the balance of torques causes the tip to "weathervane" to an intermediate angular position that results in a net positive aerodynamic lift.

The tension/torsion strap can be modified easily to obtain numerous torque-vs.-angle relationships. It is designed to apply a nearly constant pitch moment that causes the tip to generate a nearly constant lift as it travels around the azimuth. This reduces the fluctuation in lift, with two major beneficial effects: Flapwise vibratory loads on the blade and vibratory loads on the blade pitch-control mechanisms are reduced, while the negative lift produced by an advancing fixed tip is eliminated, thus reducing the amount of power required to achieve the same overall lift.

A scale-model four-blade rotor of 2.546-m radius with free tips at the outer 10 percent of the radius was tested in a wind tunnel, both with the tip free and with the tip locked to simulate a fixed-tip blade. At cruise speeds, the blade consumed 12 percent less power in the free-tip condition than in the locked condition; at higher speeds, a reduction in the effects of compressibility reduces the power consumption even more.

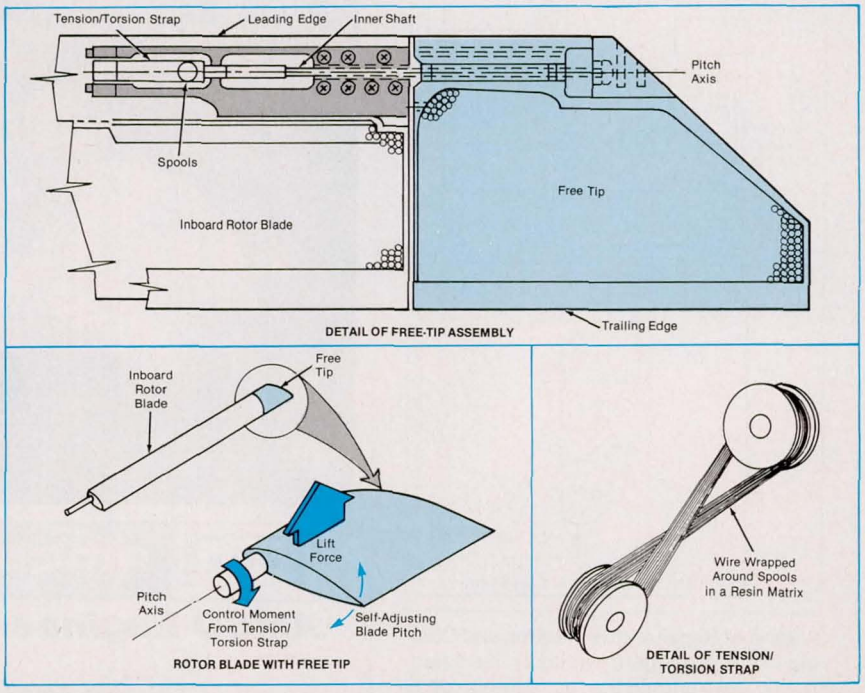
The peak vibratory flapwise blade-bending moments and the oscillatory loads going into the control system were 40 and 70 percent less, respectively, in the free-tip than in the fixed-tip condition. These large reductions are attributed to the fact that the outer 10 percent of the blade span sweeps through 57 percent of the area of the rotor disk that makes the dominant contribution to the oscillatory blade loads.

Free-tip technology can be applied to tilt rotors and tail rotors as well as to helicopter rotors. Other benefits include the following:

- Reduction of 15 to 20 percent in sensitivity to gusts and
- Opportunities for design as in the use of thin tips for lower compressibility power and suppression of noise and in the use of highly swept tips without resultant high control loads at high speeds.

This work was done by Robert H. Stroub and Larry Young of **Ames Research Center** *and Matthew Cawthorne and Charles Keys of Boeing Vertol Co. For further information, Circle 21 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-12151.



The **Free Tip** on a helicopter rotor blade pivots about a pitch axis near the leading edge. It provides a nearly steady lift, thereby reducing vibrations and power consumption.

Ultrasonic Probe for In Situ Inspection of Welds

Defects can be detected while the workpiece is still mounted for welding.

Marshall Space Flight Center, Alabama

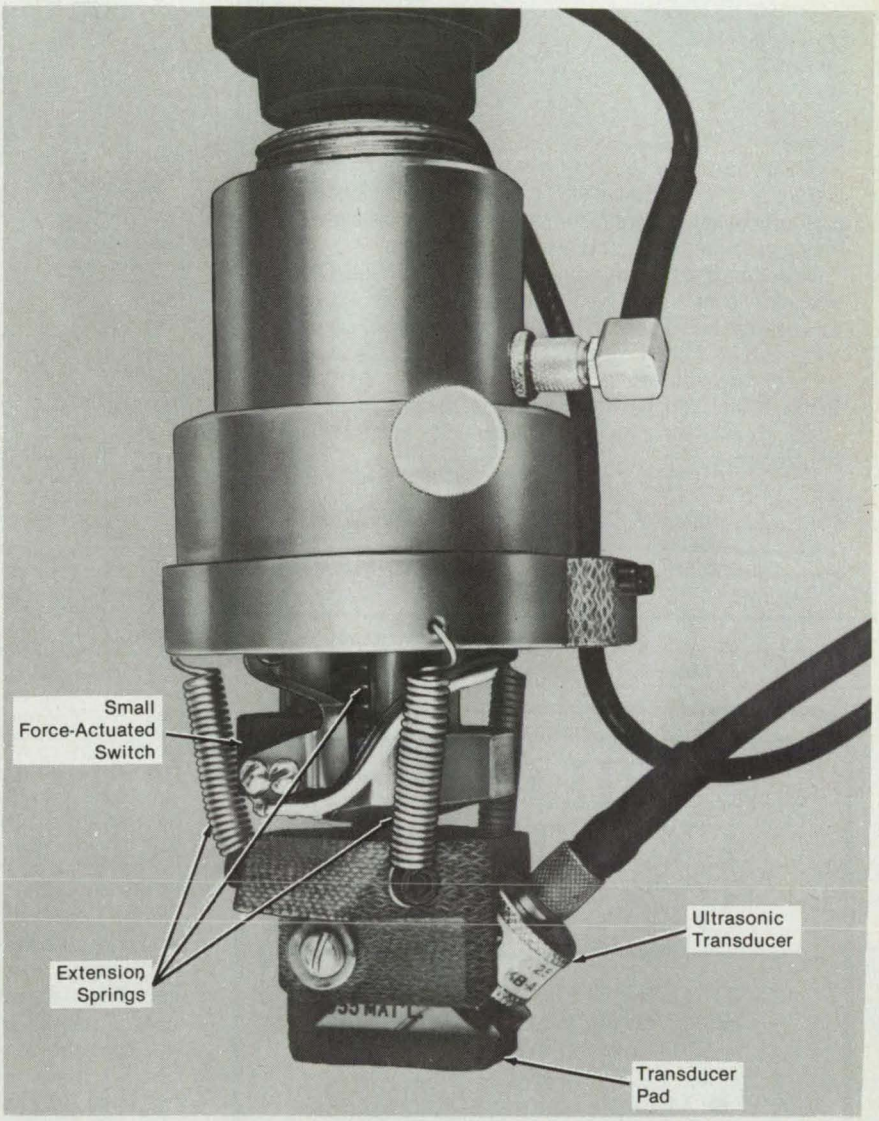
An end effector on a welding robot contains an ultrasonic transducer for inspection of the welds. An ultrasonic transducer detects such flaws as tungsten inclusions and lack of penetration of the weld. The end effector is used to determine the quality of a weld immediately after the weld has been made, while the workpiece is still mounted on the welding apparatus; the weld can be reworked in place, if necessary. The delay caused by the paperwork and setup involved in returning the workpiece for rework is thereby avoided.

The end effector can be mounted on any standard gas/tungsten arc-welding torch, including one equipped with a through-the-torch vision system. Its length is the same as that of a long gas cup with electrode.

A set of extension springs stabilizes the transducer and ensures that its elastomeric dry-couplant pad sits squarely on the weldment surface. The transducer can be rotated 360° and locked into alignment with the weld bead. A small force-actuated switch halts downward travel of the robot arm toward the workpiece and sets the force of contact between the transducer and the workpiece.

This work was done by Jeffrey L. Gilbert and Vincent Y. Paternoster of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 110 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29842.



The **Ultrasonic End Effector** is installed on the welding torch in place of the gas cup and electrode, and used to inspect the weld. The elastomer-covered transducer makes contact with the weld bead.

Vacuum Plasma Spraying Replaces Electrodeposition

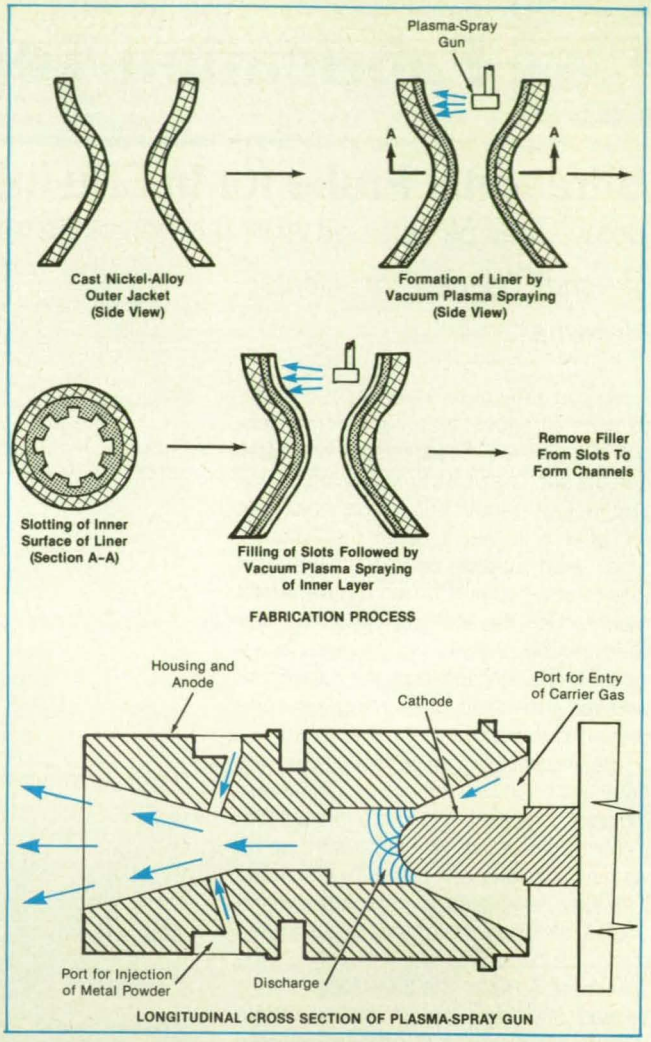
Fabrication times and costs are reduced.

Marshall Space Flight Center, Alabama

Vacuum plasma spraying can be used to fabricate large parts that have complicated contours and inner structures, without uninspectable welds. The technique greatly reduces both the time and the expense of fabrication. In the case of the Space Shuttle main engine combustion chamber, for example, it has been estimated that vacuum plasma spraying will reduce the cost of fabrication by about $1.7 million and the time required for fabrication by 2 years. [Fabrication of the combustion chamber by the older method costs $4 million (1990 dollars) and takes 4 years.]

Although this particular combustion chamber is an extreme case, it serves to illustrate the advantages of the vacuum-plasma-spraying method for the fabrication of complicated machine and instrument parts in general.

In the first step of the older method, a spin-cast Narloy-Z (or equivalent) billet is forged into an hourglass to form the liner



The **Wall of a Combustion Chamber** is built up on the inside of an outer nickel-alloy jacket by plasma spraying. Particles of the metal to be sprayed are partially melted in the plasma gun and thrown out at supersonic speed toward the deposition surface.

of the combustion chamber. Axial cooling channels are machined into the liner, then filled with wax. The filled channels and adjacent surfaces are covered with a thin layer of electrodeposited copper, on which a thicker layer of nickel is electrodeposited. The electrodeposition of nickel can take as long as 2,000 person-hours.

When the deposition of the nickel wall has been completed and the wax channel filler melted away, the halves of a thick forged nickel-alloy "clamshell" are attached by electron-beam and tungsten/inert-gas welding. The clamshell is attached to the liner by brazing. Then the coolant manifolds are welded to the top and the bottom of the combustion chamber.

In the newer method (see figure), the chamber is formed from the outside in, instead of from the inside out as in the older method. A layer of Narloy-Z is plasma-sprayed on the inner surface of a nickel-alloy outer jacket. Cooling channels are machined into the layer, and a temporary filler material is placed in the channels. Then plasma spraying is resumed to cover the channels and form the inner wall of the chamber.

This filler material is removed by etching. Mild steel is a promising filler. It leaves smooth channels and can be etched away by use of hydrochloric, phosphoric, or sulfuric acid, which does not attack Narloy-Z.

In comparison with the older method, the vacuum plasma-spray method produces a much stronger bond between the grooves and the covering layer that completes the channels and the wall of the combustion chamber. In burst tests, the bond withstood a pressure of 20 kpsi (about 140 MPa)—three times the allowable limit for units made by the old method.

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This work was done by Richard R. Holmes, Chris Power, David H. Burns, Ron Daniel, and Timothy N. McKechnie of **Marshall Space Flight Center**. *For further information, Circle 27 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-28569.

Tape-Smoothing Tool for Adhesion Tests

A hand-held device assists in the application of the correct pressure.

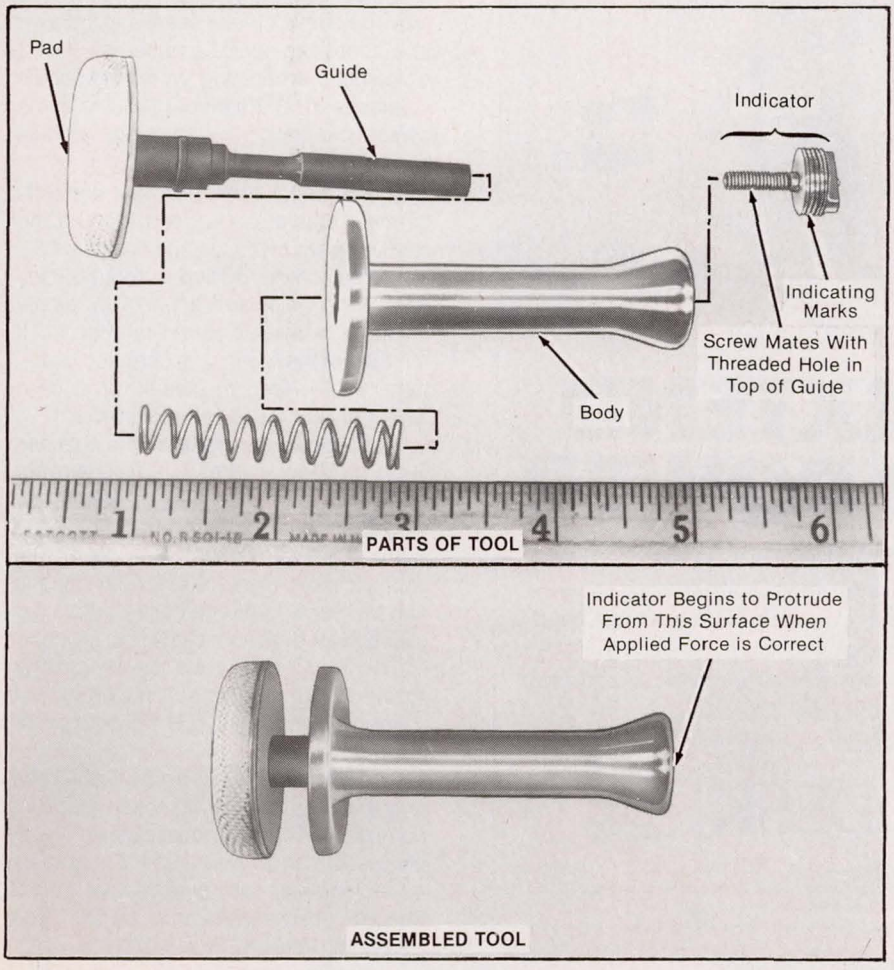
Marshall Space Flight Center, Alabama

A small tool (see figure) helps to smooth out an adhesive tape uniformly to ensure consistency and repeatability of tape-peel tests of the adhesion of paint to a substrate. The tool, about the size of a cigarette lighter, is designed for ease of holding and handling.

The part of the tool that presses on the tape is a ring-shaped pad of soft polyurethane covered with an ultra-high-molecular-weight polyethylene fabric that resists wear and allows the tool to slide easily. An internal spring helps to regulate the force applied by the pad to the tape. Before use, the tool is calibrated with a 5-lb (2.3-kg) weight. The threaded indicator button is turned until the spring just begins to yield under this weight.

To perform the tape-peel test, the technician first applies a strip of masking tape 6 in. (15.2 cm) wide to the surface to be tested. The technician presses the pad of the tool against the tape so that the indicator button shows that the calibrated force is being applied, then passes the tool twice along the tape. Finally, the tape is pulled away from the surface at an angle of 90°.

This work was done by Peter B. Allen of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 50 on the TSP Request Card. MFS-28599*



This **Mushroom-Shaped Tool** includes a resilient pad covered with a tough, smooth fabric. When its indicator button projects above the stem, the correct force is being applied.

Making Crystal Filaments From Extruded Ceramic Rods

Ceramic or metal fibers can be produced at low cost.

Lewis Research Center, Cleveland, Ohio

A process produces single-crystal fibers of ceramic or metal, at a cost lower than that of previous methods. In the new process, a single-crystal filament is drawn from the tip of an extruded polycrystalline rod. The filaments can be used as reinforcing fibers in composite materials.

Previously, the rods were prepared from hot-pressed full-density disks. The disks were cut into small slices that were ground into rods precisely square in cross section. Each rod was ≤ 4 in. (10 cm) long. Each cost about $200 (1989 prices) and took 4 to 5 weeks to purchase.

In contrast, the extrusion process produces 20 or more rods in about an hour and saves an estimated $100,000 per year. It produces longer rods from which longer fibers can be drawn. Moreover, it can potentially feed the single crystal fiber drawing process directly. Continuous filaments can be made, and the material will not be subjected to contamination from storage and transfer to the drawing machine.

In the new process, ceramic or metal powder is mixed with solvent and a binder and extruded into rods 0.01 to 0.05 in. (0.25 to 1.27 mm) in diameter. The rods are heated as they are extruded to evaporate the solvent and possibly to sinter the ceramic powder.

The rod is fed into a float-zone apparatus in which a pair of focused laser beams melt the tip of the rod. Since a rod is smoothly handled by the feed mechanism and is rigid, it can be precisely positioned in the laser beams. The heat of the lasers drives off the volatile binder from the material and sinters it just before it melts. An oriented single-crystal seed fiber of the same material as that of the feed rod is brought in contact with the moltens feed rod tip, forming a stable liquid zone between the single crystal seed and the feed rod. The single crystal seed is withdrawn at a controlled speed and carries with it a filament emanating from the single crystal seed. The filament has the same crystal orientation as the single crystal fiber drawing.

The diameter of the filament depends on the diameter of the feed rod and the relative speed of the rod and fiber. A 0.030-in. diameter feed rod that is about 60 percent dense will form a 0.023 in. single crystal at a relative-speed ratio of 1:1. If the ratio of the motions is changed to 4:2, the 0.030-in. feed rod would produce a single crystal 0.016 in. in diameter.

Alternatively, the extrusion material can be formulated so that it is flexible after being extruded and dried. It can then be wound on spools and uncoiled as it is fed to the drawing machine. A single-crystal filament more than 1,000 ft (300 m) long can be drawn from one coil. A patent application for this technology is in process.

This work was done by Leonard J. Westfall of **Lewis Research Center**. *For further information, Circle 125 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 20]. Refer to LEW-14921.

Obtaining Patterns of Holes in Directional Couplers

Impressions of holes are taken in talcum powder.

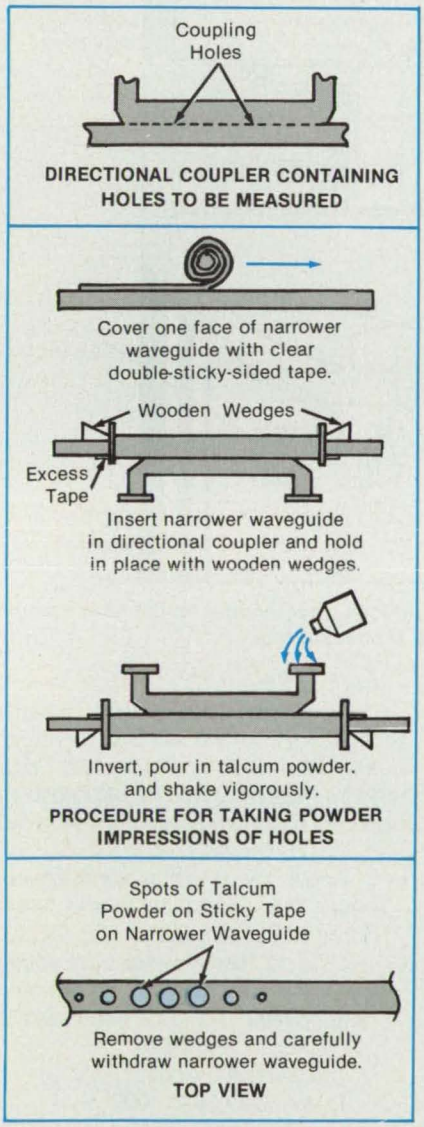
NASA's Jet Propulsion Laboratory, Pasadena, California

A simple technique enables the reproduction of the pattern of holes in the hidden common wall of a microwave directional coupler. The technique is also applicable to other equipment that contains inaccessible holes in a common wall between adjacent tubes. The tubes can be cylinders of round, rectangular, or otherwise-shaped cross section. To enable the use of the technique, at least one of the tubes must be straight.

One surface of a section of waveguide narrower than the interior of the straight section of the directional coupler is covered with clear double-sided adhesive tape. This section is inserted in the straight section of the coupler, and held in place with wood wedges (see figure). Talcum powder is poured into a port of the bent section of the coupler, and the assembly is shaken vigorously to distribute the powder. The wedges are removed, and the inserted section of waveguide is carefully withdrawn from the straight section. The double-sided tape now contains an accurate reproduction, in talc, of the hidden coupling holes.

This work was done by Raul M. Perez of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 86 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-18454.



The **Talcum-Dusting Procedure** yields a pattern of powder on adhesive tape that shows the sizes of distances between interior holes. Later, the microwave coupler can be cleaned with water or compressed air.

Lunar Habitat Would Be Assembled in Space

Living quarters for a crew of 12 would be built into a used propellant tank.

Langley Research Center, Hampton, Virginia

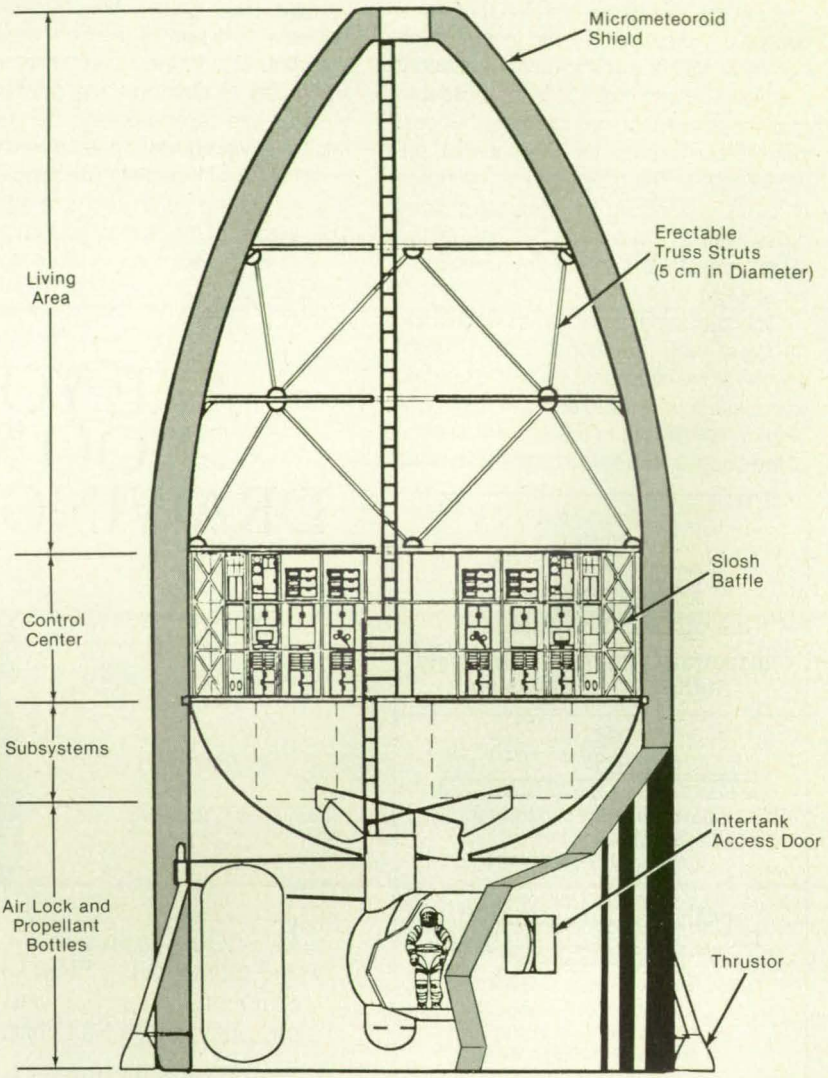
A conceptual lunar habitat would be built inside an external tank from the National Space Transportation System (NSTS) spacecraft. The NSTS spacecraft consists of an orbiter, external tank, and two solid rocket boosters. The solid rocket boosters are used for approximately 2 minutes during each launch and are recovered for reuse. The external tank is an expendable structure used for approximately 8½ minutes during each launch to provide enough liquid oxygen and liquid hydrogen to the main engines of the orbiter to place the orbiter into low orbit around the Earth.

Heretofore, the external tanks have been jettisoned immediately prior to insertion into low orbits around the Earth. The tanks have subsequently tumbled and broken up in the atmosphere before falling over open seas. In the lunar-habitat concept, the external tank would be placed in orbit and the hydrogen tank would be separated from the intertank, leaving a unit consisting of the liquid-oxygen tank and the intertank that could be outfitted as a lunar habitat (see figure).

The tank would be inserted into low orbit around the Earth, where it would be partially disassembled and outfitted as a 12-person lunar habitat. The modifications to the liquid-oxygen-tank-intertank unit would utilize existing structures and openings for access by humans without compromising the structural integrity of the tank. The modifications would include the installation of living quarters, instrumentation, and an air lock. Thermal-control, environmental-control life-support, and propulsion systems would also be added.

The habitat would be designed for unmanned transport to low orbit around the Moon and autonomous soft landing on the surface of the moon. At Space Station *Freedom*, a resource node, an air lock, and environmental-control and life-support modules would be added to enable the maximum use of intravehicular activity. Additional aids for assembling the habitat at the Space Station *Freedom* would include an orbital maneuvering vehicle and a mobile servicing center with robotic end effectors, which would minimize the amount of extravehicular activity required to outfit the habitat.

Post-landing operations prior to occupancy would include erection of a radiator panel, the installation of an auxiliary power system, and the addition of a regolith for shielding against solar energetic particles and galactic cosmic radiation. The regolith could be added to the cavity between the micrometeoroid shield and the wall of the tank. The regolith would also provide additional thermal insulation and protection against meteoroids. The radiator panels would be positioned vertically, approximately 15 m from and connected to the lunar habitat, and oriented parallel to the plane of the solar ecliptic.



The Lunar Habitat, shown here as it would look after landing on the Moon, would be made by outfitting a used NSTS external propellant tank.

The habitat would then be ready to house a crew of 12 for as long as 70 days between resupply missions. The lunar habitat is expected to become feasible by the year 2000 with the concurrent development of a space transfer vehicle and manned cargo lander for exchange of crews and resupply.

This work was done by Charles B. King, Ansel J. Butterfield, and Warren D. Hypes of Bionetics Corp.; Lisa C. Simonsen of Planning Research Corp.; and John B. Hall, Jr., A. Don Scott, Jr., and John E. Nealy of **Langley Research Center**. *Further information may be found in NASA TM-4212 [N91-14251], "Single Launch Lunar Habitat Derived From NSTS External Tank."*

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.

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

Charles H. Burr, Esq.
The Bionetics Corp.
Tenth Floor, Suite 1000
Harbour Centre Building
2 Eaton Street
Hampton, VA 23669

Refer to LAR-14234, volume and number of this NASA Tech Briefs issue, and the page number.

Recognizing Patterns in Log-Polar Coordinates

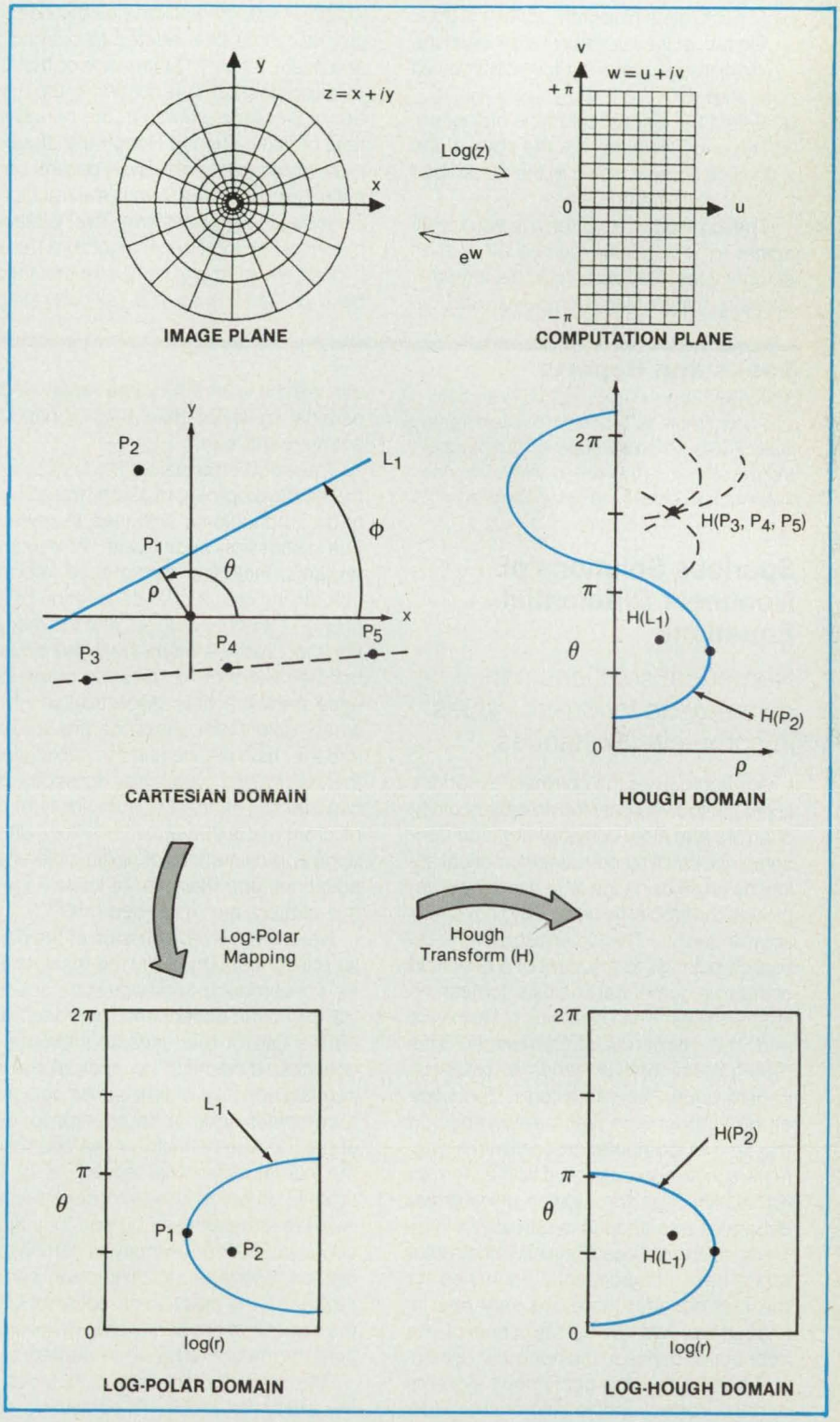
The log-Hough-transform method offers economy of representation and computation.

Lyndon B. Johnson Space Center, Houston, Texas

The log-Hough transform is the basis of an improved method for the recognition of patterns — particularly, straight lines — in noisy images. The log-Hough transform is so named because it is derived by synthesis of a modified Hough transform with a log-polar coordinate system that is used to represent the raw image data. The resulting unification of the iconic and Hough domains simplifies computations in the recognition of lines and eliminates the erroneous quantization of slopes attributable to the finite spacing of the Cartesian coordinate grid of the classical Hough transform. The method can be implemented in hardware and/or software.

The log-polar representation is already well established in imaging technology and science: Log-polar coordinates are the ray-ring coordinates of experimental polar-exponential image arrays of charge-coupled-device (CCD) photodetectors. NASA's Johnson Space Center has several varieties of video remappers, which can convert image data from Cartesian CCD arrays to the log-polar representation at video frame rates. The eye-to-brain mapping is log-polar except in the fovea. The in-place-processing and scale-invariant properties of the log-Hough transform may well have significance for the neurophysiological architecture of human vision.

The definition of some terms and a description of the modified Hough transform are prerequisite to an explanation of the new method. A straight line in the image or in the Cartesian representation of the image becomes a curved line in the log-polar domain (see figure). This curved line is denoted the "log line" for short. The leftmost point of the curve, called its "apex," represents the point of closest approach of the Cartesian straight line to the origin of the Cartesian coordinates. The Cartesian straight line through a given point of closest approach to the origin is called the "apical line" of that point, and the log line of which a given point is the apex is called the "apical log line" of that point. The scale invariance of the log-polar representation manifests itself in the identical shape and orientation of all log lines; log lines differ from each other only in location. The modified Hough transform of a Cartesian straight line is its apex in the log-polar domain. The modified Hough transform of a Cartesian point is the mirror image, reflected about a vertical line through the point in the log-polar do-



The **Log-Hough Transform** takes advantage of the rotational and scale invariance of the mapping from Cartesian to log-polar coordinates.

main, of the apical log line of that point.

The new method prescribes the following algorithm for the recognition of a straight line.

(1) By edge detection or other suitable means, select candidate points in the log-polar image that may lie on edges or lines.
(2) Construct the mirror image of the apical log line of every candidate point (the modified Hough transform of every candidate point).
(3) Accumulate a histogram, in the log-polar domain, of the intersections between the mirror-image apical log lines constructed in step 2.
(4) Select the highest bin in the histogram. The underlying point is the apex of the log line corresponding to the recognized Cartesian straight line.

The log-Hough transform is equally efficient in recognizing curves other than straight lines. For example, in the log-polar domain, hyperbolas, parabolas, and circles are copies of the log line respectively scaled by the factors ½, 2, and −1. Log-Hough algorithms for recognizing these figures are thus identical to the algorithm described above, with appropriate scaling of construction templates. Generalization to other geometric entities requires proper interpretation of their log-polar transforms. Regardless of the patterns to be recognized, scale and rotation invariance are automatic in this coordinate system.

The rotation and scale invariance of the log-polar mapping eliminates the need to process most data related to orientation and scale. Another advantage of the log-polar domain is the reduction in the number of picture elements in the peripheral field of view. The log-Hough transform is more amenable to massively parallel computing architectures than is the traditional Cartesian Hough transform. The "in-place" nature of the log-Hough algorithm makes it possible to apply local pixel-neighborhood processing as in a "silicon retina." No buses are required to export data off-retina to an external Hough domain. In-place "drawing" of log-line templates would consist of enabling nearest-neighbor excitation paths. Histogram bins could be implemented via analog aggregation circuits.

This work was done by Carl F. R. Weiman of Transitions Research Corp. for **Johnson Space Center**. *For further information, Circle 105 on the TSP Request Card.*

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

Dr. John Evans, President
Transitions Research Corp.
15 Great Pasture Road
Danbury, CN 06810

Refer to MSC-21758, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books and Reports

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

Spurious Solutions of Nonlinear Differential Equations

Numerical solutions can converge to incorrect values in some circumstances.

A report utilizes the nonlinear-dynamics approach to investigate the possible sources of errors and slow convergence and nonconvergence of steady-state numerical solutions when using the time-dependent approach for problems containing nonlinear source terms. This interdisciplinary research belongs to a subset of a new field of study in numerical analysis sometimes referred to as "The Dynamics of Numerics and The Numerics of Dynamics". This report is the first of series of research papers under the same topic. The hope of the authors is to reach researchers in the field of computational sciences and, in particular, computational fluid dynamics (CFD). Although the studies of nonlinear dynamics and chaotic dynamics for nonlinear differential equations and for discrete maps have independently flourished for the last decade, there are very few investigators addressing the issue of the connection between the nonlinear dynamical behavior of the continuous systems and the corresponding discrete map (difference equation) resulting from finite-difference discretizations. It is important to realize that these nonlinear discrete maps can exhibit a much richer range of dynamical behavior than their continuum counterparts can.

The report emphasizes the implications for the development of algorithms in CFD and computational sciences in general. The discussion begins with introductory remarks, including background information, definitions, a brief description of the phenomena to be studied, and the motivations for studying them. Next, the dynamical behaviors of the discrete maps that arise from the time discretization of ordinary differential equations are studied, and the main results and the implications thereof for computational sciences are described. The level of complexity of the discrete maps that arise from finite-difference approximations of partial differential equations and the state of knowledge of this subject are described briefly.

Next, there is a discussion of the popular misconceptions of (1) the residual test for convergence in steady-state solution via the "time-dependent" approach and (2) the use of the "inverse problems of nonlinear dynamics" to analyze the dynamical behavior of time-series data from a computer code in an attempt to learn about the true behavior of the solution of the partial differential equations of the system of which the time series is the discrete-time-sampled output. This application of time-series analysis can be misleading, and a wrong conclusion can be reached if the practitioner does not know the solution of the partial differential equations by means other than numerical.

The main fundamental conclusion of the study for problems containing nonlinear source terms is that, even in the absence of truncation and round-off errors, there are qualitative features of the nonlinear differential equations that cannot be adequately represented by the finite-difference method and vice versa. The discrete maps that result from finite discretizations can exhibit a range of dynamical behavior much richer than that of the continuum counterparts of these discrete maps. Spurious stable as well as unstable steady-state numerical solutions, spurious asymptotic numerical solutions of higher period, and even stable chaotic behavior can occur in finite-difference solutions. A typical feature is the existence of spurious numerical asymptotes that can interfere with stability, accuracy, and basins of attraction of the true physics of the continuum.

The occurrence of spurious asymptotes is independent of whether the nonlinear differential equation in question has a unique steady-state solution or additional periodic solutions and/or exhibits chaotic phenomena. The form of the nonlinear differential equation and the type of numerical solution scheme are the determining factors. In the past, there was a tendency to ignore spurious asymptotes on the assumption that they all lie beyond the linearized stability limits of the time step. In this study, it is shown that bifurcations to and from spurious asymptotic solutions, and transitions to computational instability, not only are highly dependent on the problem and the solution scheme but are also dependent on initial data and boundary conditions and not limited to time steps that are beyond the linearized stability limit.

For these reasons, it is essential for practitioners in computational sciences to be knowledgeable about the dynamical behaviors of finite-difference methods for the solution of nonlinear scalar differential equations before applying these methods to practical computations. It is also im-

portant to change the traditional way of thinking and practices when dealing with genuinely nonlinear problems.

This work was done by H. C. Yee of **Ames Research Center**, *P. K. Sweby of the University of Reading, and D. F. Griffiths of the University of Dundee. Further information may be found in NASA TM-102820 [N90-22339], "Dynamical Approach Study of Spurious Steady-State Numerical Solutions of Nonlinear Differential Equations, Part I — The ODE Connection and Its Implications for Algorithm Development in Computational Fluid Dynamics."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12770

Software for Computing Selected Functions

Routines in the Ada language support scientific and engineering functions.

A NASA technical memorandum presents a collection of software packages in the Ada computing language that implement selected mathematical functions used in science and engineering. It provides the Ada programmer with the mathematical-function support found in the Pascal and FORTRAN computing languages, plus support for extended-precision arithmetic and complex arithmetic.

The software packages were developed as infrastructure for programs to be used in testing a new computer. They were written under the assumption that the computer conforms to the Institute of Electrical and Electronics Engineers 754-1985 standard for single binary floating-point arithmetic and can handle 32-bit integers. The results of computations with these software packages should be the same on the original intended computer or on any other computer that satisfies these requirements; this universality makes the software valuable for testing new computers in general, writing computer code for general distribution, or possibly developing new computing integrated circuits.

The extended-precision-arithmetic software package provides accuracy to 47 bits in multiplication, 46.5 bits in division, and 48 bits in addition (single-precision arithmetic in the IEEE 754-1985 standard is accurate to 24 bits at most). The complex-arithmetic software package implements Cartesian complex arithmetic in floating-point numbers; a complex absolute-value function and a complex square-root function are included.

There are two mathematical-function software packages: one for basic and one for transcendental functions. The basic functions are floor (nearest integer less than or equal to), ceiling (nearest integer greater than or equal to), truncation (round toward zero to integer), modulo, and pseudorandom number. The transcendental functions are the sine, cosine, exponential, natural logarithm, square root, arc tangent, and proper-quadrant arc tangent (the arc tangent of x/y in the proper quadrant of Cartesian coordinates x, y).

The document includes brief descriptions of the algorithms implemented by the software packages, with analyses of errors. The software packages are presented in appendixes.

This work was done by David C. Grant of **Ames Research Center**. *Further information may be found in NASA TM-102256 [N90-16423], "Basic Mathematical Function Libraries for Scientific Computation."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-13117

Life Sciences

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.

Efflux of Nitrate From Hydroponically Grown Wheat

Increasing the concentration of nitrate in the nutrient solution increases the efflux of nitrate.

A report describes experiments to measure the influx of nitrate into, and the efflux of nitrate from, hydroponically grown wheat seedlings. Because the influx of nitrate requires adenosine triphosphate and thus costs energy, finding conditions that reduce this efflux could lead to more-efficient utilization of nitrogen by crop plants. This would be particularly important for the production of crops in a spacecraft on an extended mission — where available energy would be limited.

In the experiments, wheat seedlings were grown hydroponically in a ¼-strength Hoagland's solution for 8 days in an environmentally controlled growth chamber at 400 $\mu E/m^2s$, at temperature of 18 °C and 80 percent relative humidity. On the 7th day, they were transferred into ¼-strength Hoagland's solution (loading solution) containing nitrate (plus, in some cases, chlorate) at the concentration specified for each experiment. After removal from the loading solution, 10 seedlings were rinsed in 300 mL of the efflux solution and then placed in 60 mL of this solution for specified times. The amount of nitrate released in each such time was measured by use of high-performance liquid chromatography. Rates of uptake of nitrate and chlorate were determined from the rates of depletion of these ions from substrate solutions.

The results of the experiments showed that the ratio between the efflux and influx of nitrate was greater in darkness than in light and increased with the concentration of nitrate in the nutrient solution. On the basis of these experiments, the authors suggest that a nutrient solution should be optimized at the lowest possible concentration of nitrate.

The feasibility of using chlorate as a trapping agent (that is, as a competitive inhibitor of uptake of nitrate) for effluxed nitrate was assessed, and its toxicity determined. The toxicity of chlorate was apparent after 1 h, but little toxicity was observed during nitrate-efflux experiments that lasted up to 20 min. Higher rates of efflux of nitrate were detected as the concentration of chlorate was increased in the efflux solution — perhaps because chlorate served as a trapping agent for effluxed nitrate.

This work was done by R. C. Huffaker, M. Aslam, and M. R. Ward of the University of California at Davis for **Ames Research Center**. *Further information may be found in NASA CR-177534 [N89-27346], "Efficiency of N Use by Wheat as a Function of Influx and Efflux of NO_3^-."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12628

Air-Traffic Controllers Evaluate the Descent Advisor

An automation aid is found to assist controllers without restricting them unduly.

A report describes a study of the performance of the Descent Advisor algorithm, a software automation aid intended to assist air-traffic controllers in efficiently spacing traffic and meeting specified times of arrival at designated positions (called "metering fixes") in the sky. The Descent Advisor is based partly on mathematical models of weather conditions and the performances of aircraft. It generates suggested clearances, including top-of-descent points and speed-profile data, for one or more aircraft to attain specific time or separation-distance objectives. The interface between the Descent Advisor and the controller is a mouse-based, menu-driven computer-terminal display that enables the controller to use the predictive capability of the Descent Advisor to resolve conflicts and issue advisory notices to the pilots of arriving aircraft.

This study focused on the operational characteristics of the Descent Advisor, with specific attention to how the Descent Advisor can be used for the intended purposes of prediction, spacing, and metering. The experimental part of the study involved the use of the Descent Advisor by both currently employed and retired air-traffic controllers in a computer simulation of air traffic approaching Denver's Stapleton International Airport. Controllers followed the procedures of the Denver Air Route Traffic Control Center and operated in teams of two as they do at present — one monitoring a radar display of traffic, the other entering information onto flight strips and operating the computer keyboard. When using the Descent Advisor, the controller who normally operated the keyboard used the mouse instead.

Evaluations by the controllers indicated considerable enthusiasm for the Descent Advisor and provided specific recommendations for using it effectively. One member of the two-member controller team for each arrival sector used clearances generated by the Descent Advisor, while the other used manual flight strips as in current practice. When the controllers encountered problems that fell outside the domain of the Descent Advisor, they used conventional vectoring techniques to establish the desired spacings, then resumed the use of the Descent Advisor without difficulty.

Controllers used the Descent Advisor in various ways, some relying heavily on time-line data, others concentrating on the auxiliary information provided directly on maps. Thus, even in the initial evaluation, operation was sufficiently flexible that controllers did not feel that the Descent Advisor restricted them.

One major issue in the continued development of the Descent Advisor and other automation aids is the need for adequate training to ensure that evaluations by controllers are meaningful. The Descent Advisor as evaluated is not simple; nor are the controllers accustomed to the sophisticated display format in which it was presented. Adequate time should be allowed for training, and there is a need for the development of a step-by-step training strategy. In addition, it was found that working with a group of controllers for a considerable time was effective in enabling these controllers to train other controllers to serve as subjects in the simulations.

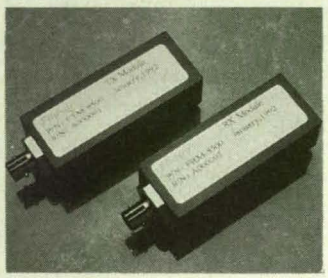
This work was done by Leonard Tobias, Uwe Volckers, and Heinz Erzberger of **Ames Research Center**. *Further information may be found in NASA TM-102197 [N89-25981], "Controller Evaluations of the Descent Advisor Automation Aid."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12622

New on the Market

Omega Engineering Inc., Stamford, CT, has released IPC-XPERT, **data acquisition software** that transforms a PC into a process monitor and control workstation. The IPC-XPERT icon-driven graphical interface can display data as bar graphs, radial or linear meters, trend lines, digital indicators, or animated process diagrams. The system supports analog and digital I/O, thermocouples, RTDs, strain gauges, and advanced mathematical functions.
For More Information Circle No. 800

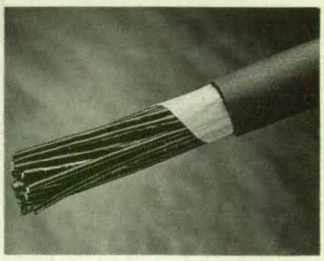
Advanced Technology Materials Inc., Danbury, CT, has introduced a line of **semiconducting diamond thin films** that offer extreme hardness, thermal conductivity, resistance to heat and cold, and the ability to adhere to various substrates. The materials can be used in high-voltage photoconductive switches that allow precise impulse radar imaging, diamond transistors for high-temperature and high-radiation environments, particle detectors, and clinical radiation dosimeters.
For More Information Circle No. 798



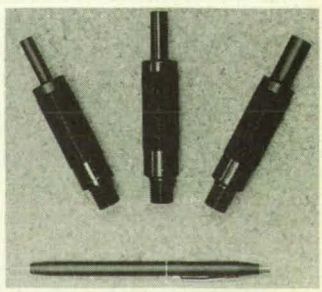
Finisar Corp., Menlo Park, CA, has applied innovative laser physics technology in the development of the first practical gigabit-rate **data communications links** that run over multimode fiber. Utilizing ordinary CD lasers, the components allow designers to build network adapters that can transmit data up to 1.5 Gbits/sec. for under $1000 with low bit error rates, thereby enabling ultra-high-performance configurations never before economical.
For More Information Circle No. 796

The latest version of SmartCAM Advanced Fabrication™ from Point Control Co., Eugene, OR, is designed to **model and optimize CNC manufacturing processes** for turret punch presses and plasma, laser, and waterjet cutters. The software replaces traditional CNC programming procedures with interactive modeling techniques, allowing the user to swiftly create, optimize, and alter CNC processes.
For More Information Circle No. 790

An affordable **3D mouse** for CAD applications has been introduced by Multipoint Technology Corp., Westford, MA. The MULTIPOINT Z™ mouse integrates the features of a conventional mouse with an innovative 3-axis trackball and Z thumbwheel to provide six degrees of freedom for easy manipulation of 3D CAD images.
For More Information Circle No. 794



Olflex Wire & Cable Inc., Fairfield, NJ, has announced ROBOT 900, a multiconductor, elastomeric-insulated **cable** designed for use in severe tortional applications. The cable features unique stranding and a specially-formulated polyurethane jacket for increased mechanical protection and resistance to mineral and synthetic oils.
For More Information Circle No. 792

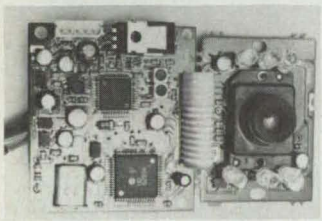


ScanTech Corp., Breckenridge, CO, has developed a patented **sensing technology** that can see through nonferrous housings such as plastic, aluminum, brass, and titanium to monitor the motion and position of internal components. The technology, which is incorporated into ScanTech's MDS-750 series sensors, uses standard data acquisition methods and requires no human intervention, complex computer algorithms, or special lighting.
For More Information Circle No. 788

New on the Market

The Starburst™, a unique high-resolution **printer** introduced by Lasertechnics, Albuquerque, NM, can produce either continuous-tone images using dye diffusion thermal transfer or dithered images using thermal wax transfer. It can also generate black and white prints or transparencies in both modes and is PostScript-compatible. The Starburst has application in CAD/CAM, presentation graphics, environmental sciences, industrial design, and medical imaging.
For More Information Circle No. 776

A credit-card-size, solid-state **camera** for monitoring industrial and scientific tasks has been introduced by Marshall Electronics Inc., Culver City, CA. The monochrome video camera has a wide-angle lens, 1/3" sensor, 240-line resolution, and auto-electronic light adjustment. Small enough to be hidden in walls, built into machines, or mounted on enclosures, the Model V-1203 camera is suitable for remote monitoring of toxic or dangerous environments and wherever visibility is impeded.
For More Information Circle No. 780



Solid oxide fuel cell (SOFC) technology developed by Ceramatec Inc., Salt Lake City, UT, promises cost-efficient, environmentally-safe energy sources scaleable to both commercial and household applications. Ceramatec's new planar fuel cell utilizes a ceramic conductor to convert methane into electricity and is virtually noise-, vibration-, and maintenance-free.
For More Information Circle No. 786

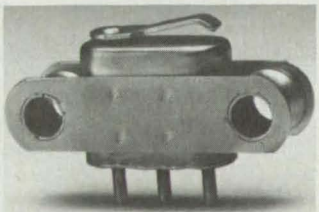
Cyberware, Monterey, CA, has introduced a **3D scanner** that offers 75 points/inch resolution to capture minute details of an object's shape and color. Images are captured in 13 seconds without touching the object and displayed instantly on a graphics workstation. Dubbed the 3030/HIREZ, the scanner enables novel applications in such fields as package modeling, reconstructive surgery, and medical appliance design. Researchers can study highly-accurate 3D images of fragile objects rather than the objects themselves.
For More Information Circle No. 772

The MathWorks Inc., Natick, MA, has announced a Windows version of SIMULINK (previously known as SIMULAB), its highly-interactive **CAE tool** for simulation of nonlinear dynamic systems. SIMULINK can be used to model real-world, time-varying systems in electrical, mechanical, chemical, aerospace, and automotive engineering applications.
For More Information Circle No. 782

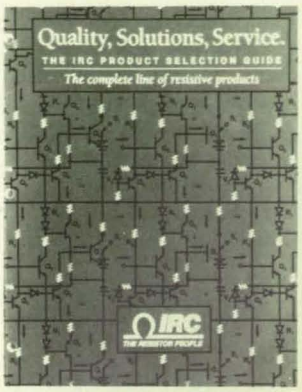
LABTECH, Wilmington, MA, has announced real-time multitasking for Windows with its NOTEBOOK and NOTEBOOK/XE **software**. A user can collect data, display it in real time, simultaneously log the data to a disk, and perform triggering and control decisions based on the data. Since they provide gap-free sampling, both programs are suitable for applications where I/O points must be monitored and updated continuously.
For More Information Circle No. 774

Engis Corp., Wheeling, IL, has developed a quick two-step process for **scratch-free, stress-free finishes on advanced ceramic parts**. Titanium-carbides, 95%+ alumina ceramics, aluminum oxide-titanium carbides, and silicon require such finishes for electronics and other high-tech applications. The process, which reduces cycle times by half, utilizes a micron-size diamond slurry to establish surface flatness and a colloidal polish to prevent scratches.
For More Information Circle No. 784

Haydon Switch and Instrument Inc., Waterbury, CT, reports that patented technology used in its 6200 series switch has quadrupled the life expectancy of **sealed switches** to more than 100,000 cycles. Employing a one-piece switch blade and special alloy contacts, the switches are available with several contact materials to accommodate high current and/or low current and with a choice of actuators and electrical terminations.
For More Information Circle No. 778



New Literature



Resistive products are featured in a databook from IRC Inc., Boone, NC. It includes a surface mount cylindrical CHP resistor; TaNFilm surface mount, SIP, and DIP precision resistors and network;, and high-voltage precision resistors. Also described are special-purpose products such as line feed resistors for telecommunications, and circuit-protection, current-sensing, and fuse resistors.
For More Information Circle No. 712

Literature from Saguaro Scientific Corp., Tucson, AZ, describes its integrated **fiber optics communications and electro-optics instruction kit**. Called the Laser Tools and Technics LF-4310, the kit's 20 labs address basic principles from cutting fiber to use of lock-in amplifiers and interferometers.
For More Information Circle No. 708

Small Parts Inc., Miami Lakes, FL, has published a 272-page catalog of hard-to-find **components, materials, and tools for R&D applications**. Featured items include hypodermic tubing in 304 or 316 stainless steel in most gauges from six to 33, Teflon tubing in standard and thin wall, shrink Teflon tubing in two shrink ratios, and stainless steel guide wire. New items include stainless steel TORXZ screws in inch and metric sizes and tapered and metric-sized dowel pins.
For More Information Circle No. 704

Auerback Publications, New York, NY, has released *Technology Management: Case Studies in Innovation*, a collection of 34 hands-on case studies analyzing the range of issues that must be addressed for productive, profitable **technology development and transfer**. Thirty industry experts explain the technology management strategies and techniques used by today's most successful companies.
For More Information Circle No. 710

A 64-page catalog from Analogic Corp., Peabody, MA, describes **data acquisition products** ranging from those with 12- to 16-bit accuracies at 50 kHz throughput to those providing true 16-bit accuracies at acquisition speeds up to 1 MHz. Many of the acquisition boards contain analog output capabilities, counter-timers, and digital I/O. Also featured are expansion, analog output, and signal conditioning boards.
For More Information Circle No. 702

Newport Corp., Fountain Valley, CA, has published a 550-page **precision laboratory products** catalog highlighting 30 new products, including the Liquid-Crystal Light Control System, the ULTRAlign™ family of stainless steel positioners, optical meters and detectors, and the PMC400 advanced multi-axis motion controller. Fiber optics, electronic instruments, and vibration control table systems are also described.
For More Information Circle No. 714

The new **data acquisition** catalog from Keithley Instruments Inc., Taunton, MA, includes boards sold under the Keithley MetroByte brand name, Keithley Asyst software, and WORK-HORSE™ industrial acquisition and control products. The 288-page catalog features 24 new products, including the DAS-1600, a 100 ksample/sec analog I/O board with expanded digital and analog output capability, and the 8-channel, 1 MS/s A/D DAS-58 offering simultaneous sample and hold and 1 megaword on-board memory.
For More Information Circle No. 706

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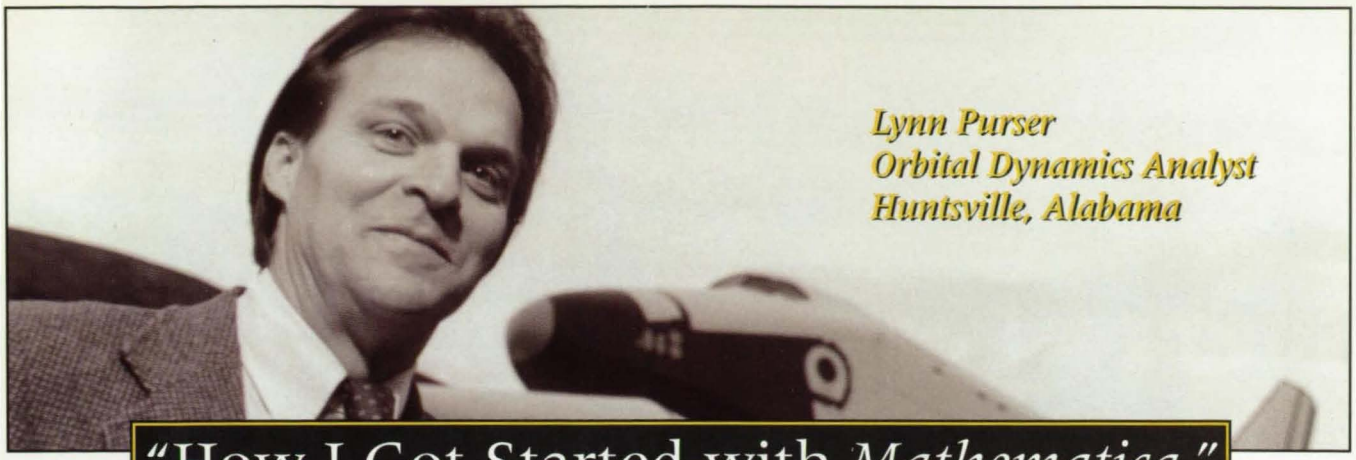


Lynn Purser
Orbital Dynamics Analyst
Huntsville, Alabama

"How I Got Started with *Mathematica*®"

I admit, when I first read about *Mathematica*, I was a little skeptical. I guess mathematicians are like anybody else. Sort of like auto workers being replaced by robots—some mathematicians were skeptical of something that might replace them. So when my firm offered an in-house training seminar on *Mathematica*, I decided to see what all the talk was about.

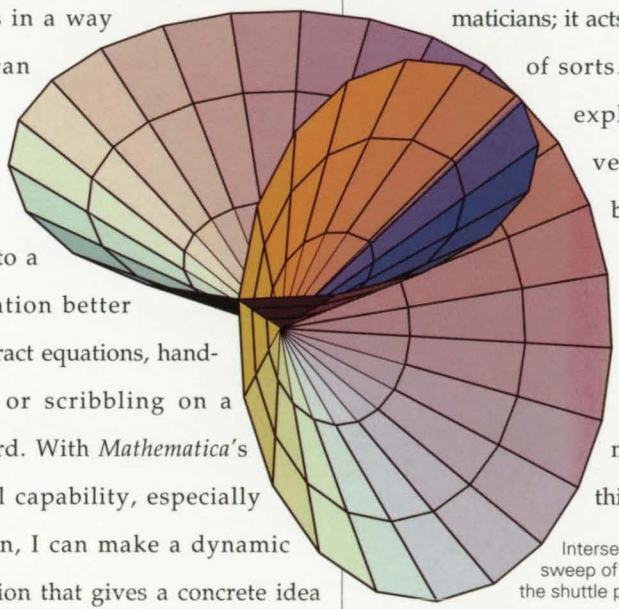
Photo Courtesy of NASA

That class was fun. I tried to do things beyond what the teacher was covering—the rudimentary stuff about *Mathematica* syntax. I wanted to do animation and play with the graphics. I was taken with the visual dimension of it.

Working on NASA projects, I have to solve problems and present my solutions in a way others can understand. People respond to a visualization better than abstract equations, hand-waving, or scribbling on a blackboard. With *Mathematica*'s graphical capability, especially animation, I can make a dynamic presentation that gives a concrete idea of what I'm talking about.

Then there's the symbolic power. For example, the first project I tackled with *Mathematica* involved a nasty algebraic equation. I solved it on my own and then let *Mathematica* solve it. We both came up with the same answer. But my solution took a few hours and *Mathematica*'s took a few minutes.

Now I use *Mathematica* regularly. I don't think it will ever replace mathematicians; it acts as an assistant of sorts. It helps you explore and develop concepts, by handling the tedious details. In that way, you're free to concentrate on more important things.



Intersection of fields of sweep of two sensors in the shuttle payload bay.

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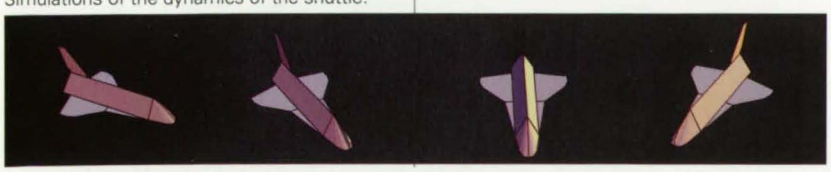
Simulations of the dynamics of the shuttle.



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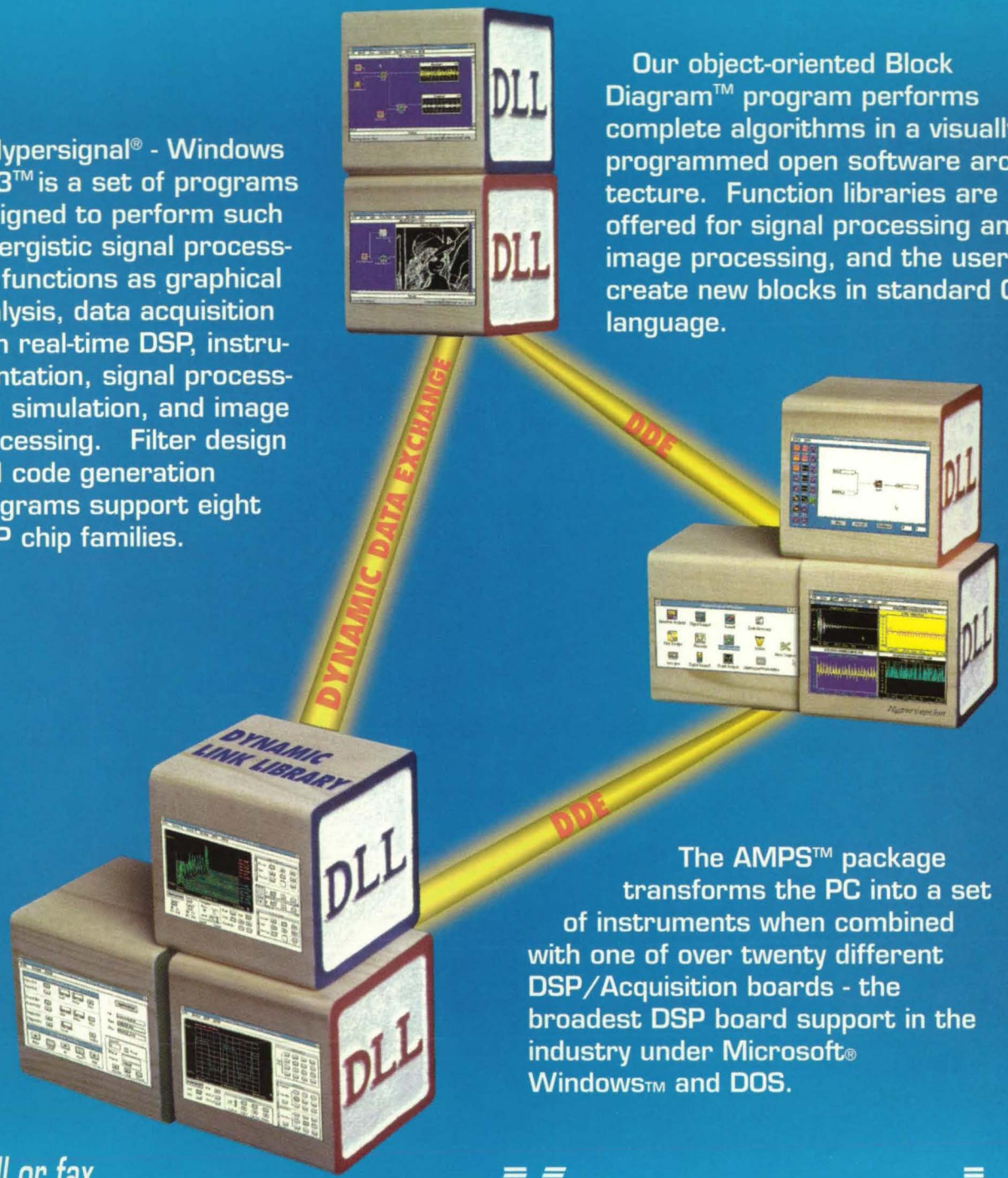

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