NASA Tech Briefs

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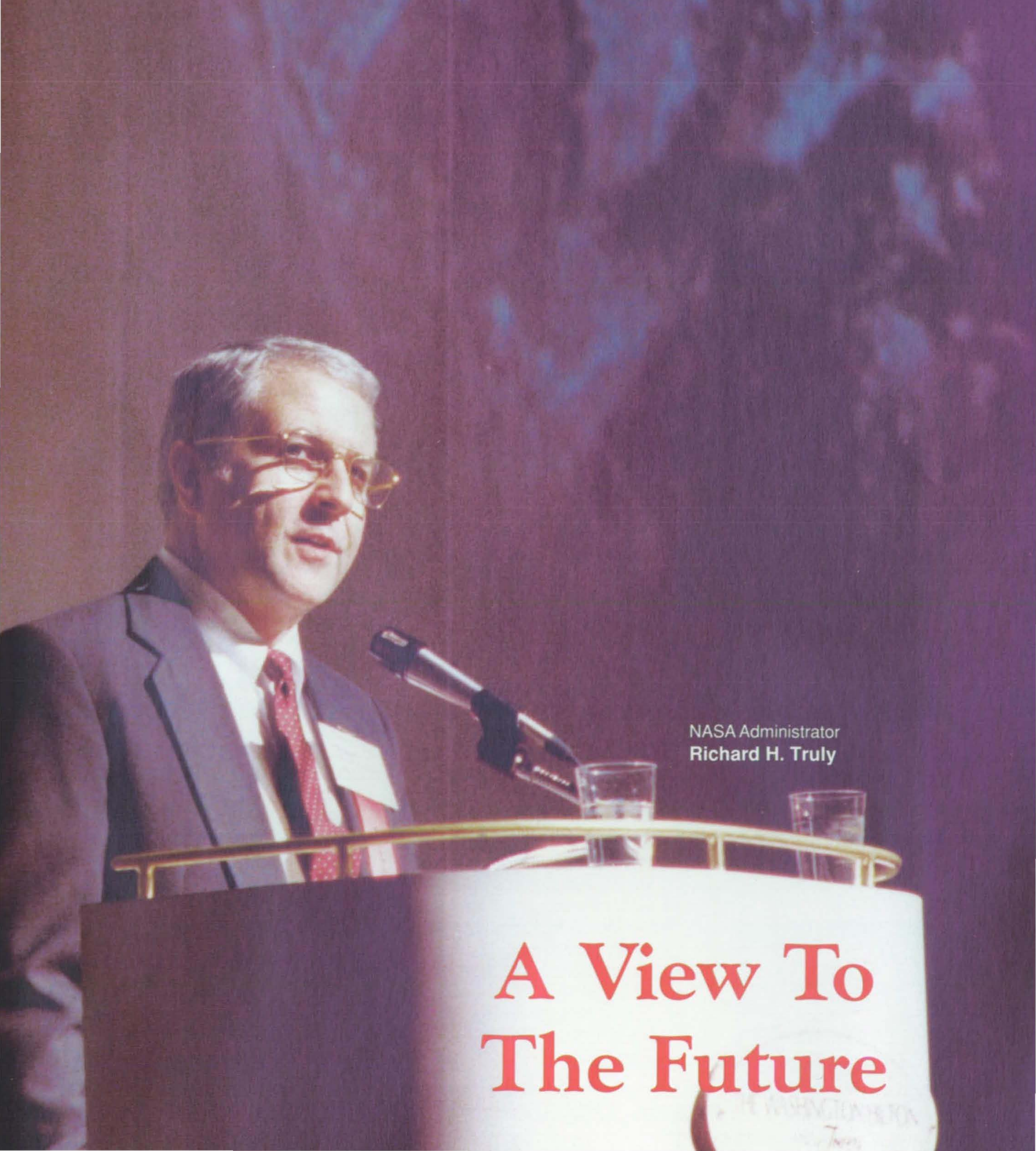
Volume 15 Number 1

Transferring Technology
to Industry and
Government
January 1991



NASA Administrator
Richard H. Truly

A View To The Future

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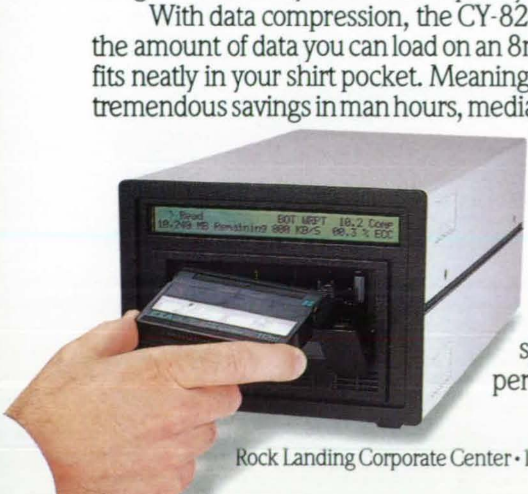

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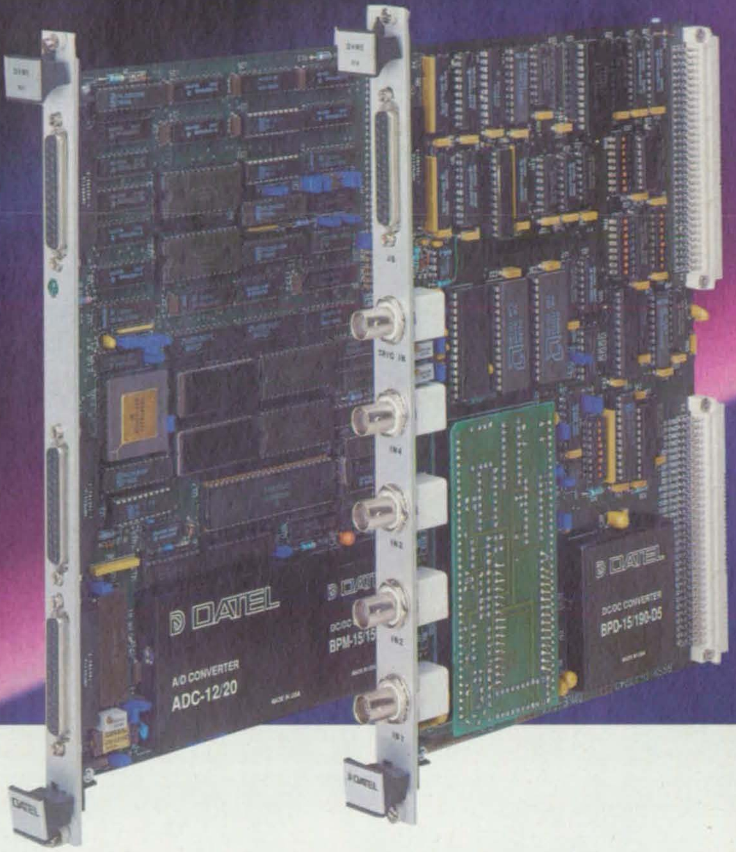

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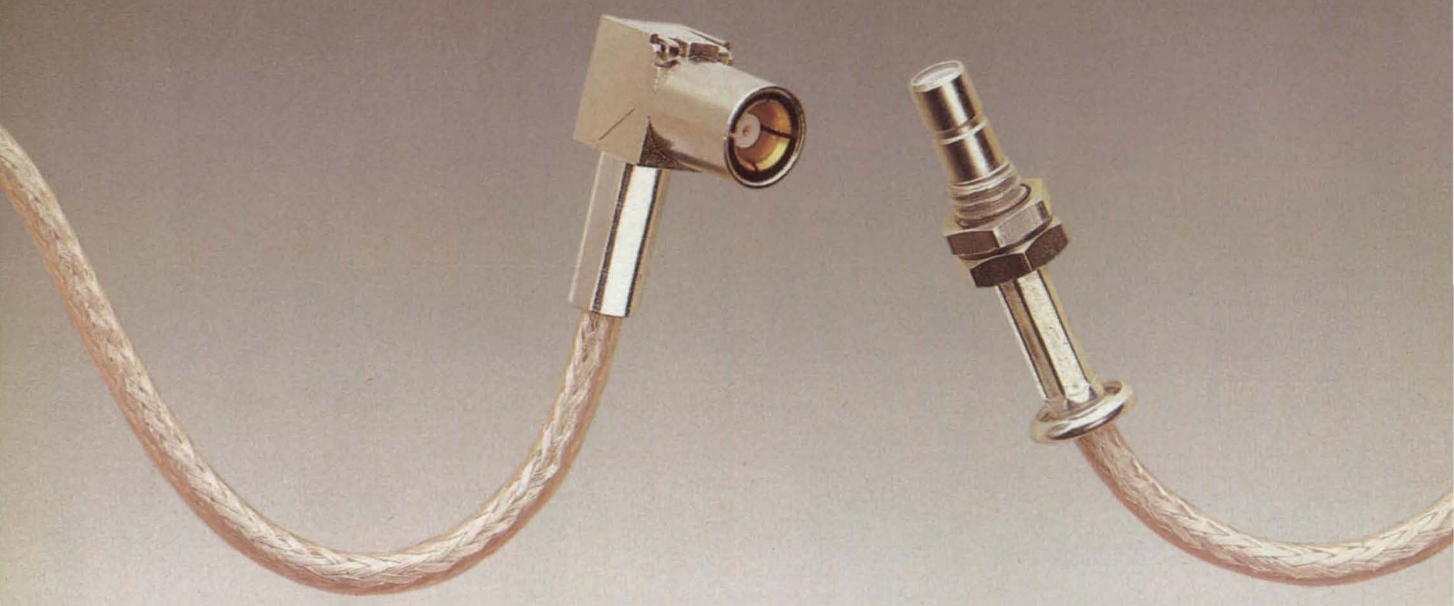

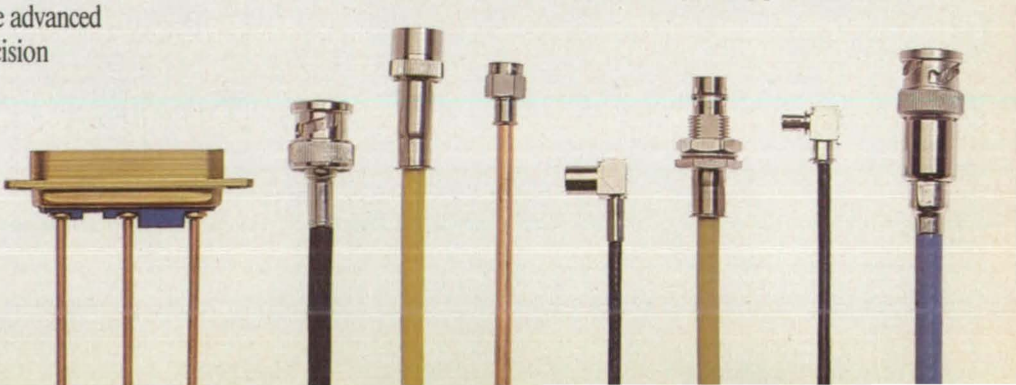

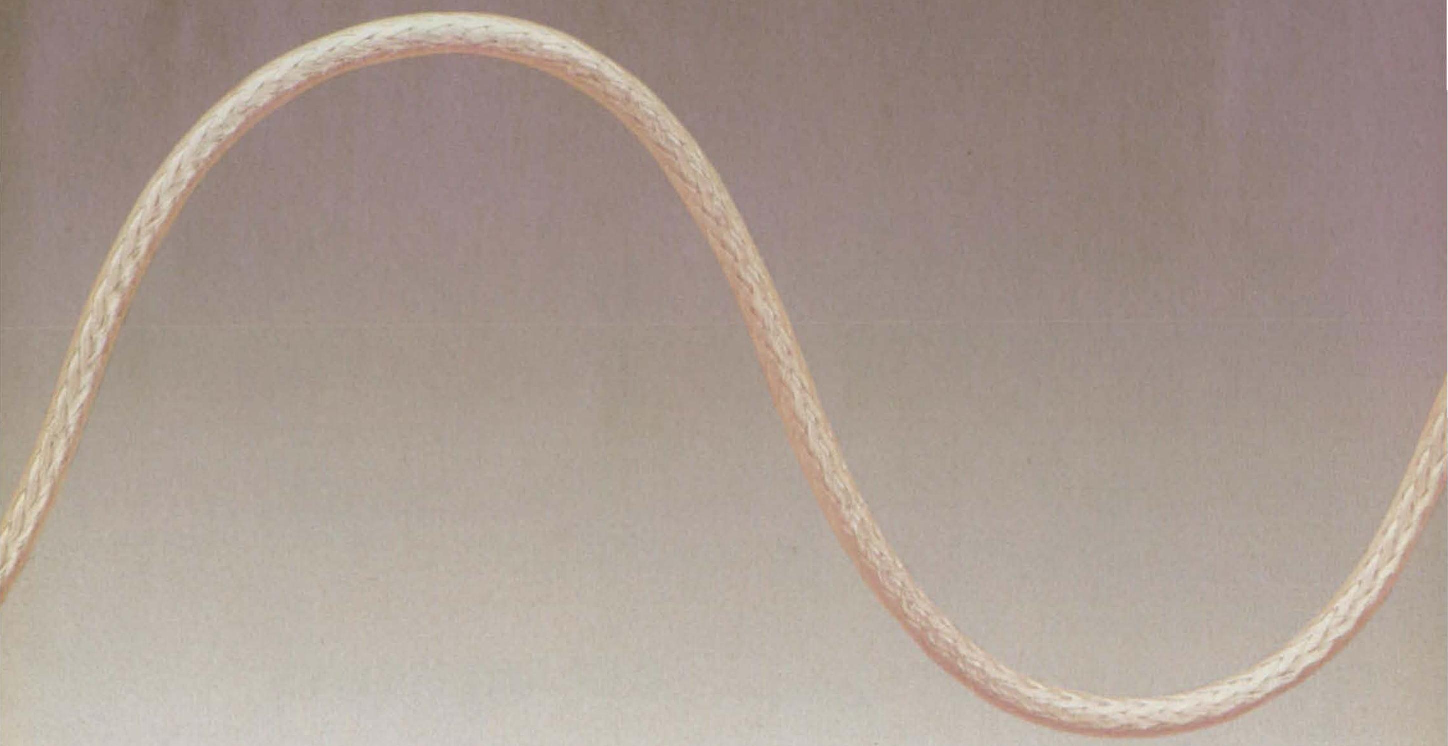

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ABP BPA

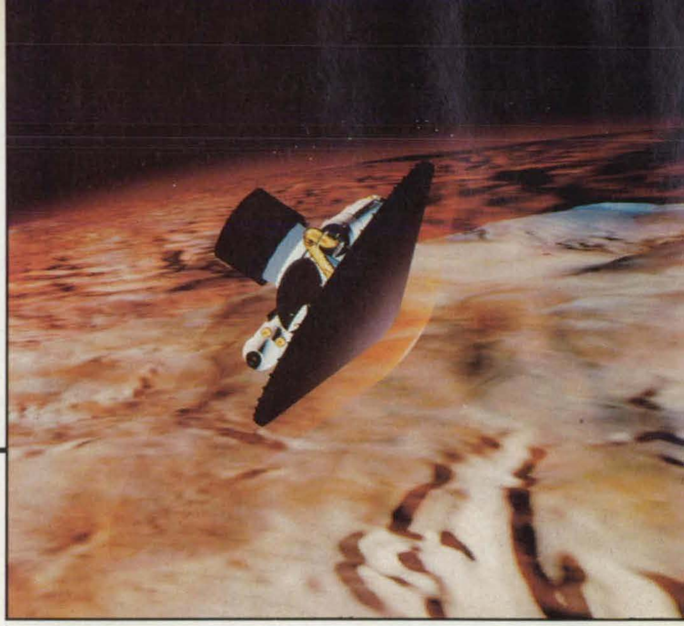

Photo courtesy NASA

A piloted spacecraft performs an aerobrake maneuver over Martian terrain in this conceptual image. The digital model of Mars' surface was generated using data from the 1970s Viking missions. The development of new concepts for transfer and landing vehicles is a key part of the Space Exploration Initiative, described on page 12.

SPECIAL FEATURES

TECHNICAL SECTION

DEPARTMENTS

On The Cover: NASA Administrator Richard H. Truly opened Technology 2000, the first-ever national technology transfer conference and exposition, held in Washington, D.C. November 27-28. Our show coverage begins on page 8.

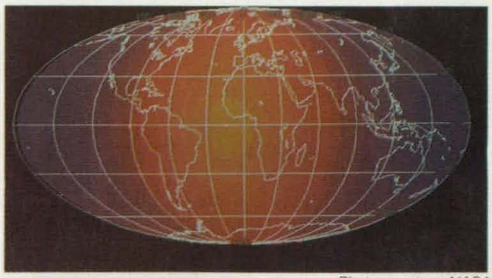

Photo courtesy NASA

NASA's Marshall Space Flight Center has created a computer program to study atmospheric pressures, densities, temperatures, and winds. This plot was generated to analyze the upper atmosphere's response to a solar storm. Turn to page 35.

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Editorial Notebook

An Overwhelming Success

When you initiate the first-ever national technology transfer conference and exposition, you're not sure what to expect. You know that you'll feature the work of NASA's best and brightest minds, thanks to the support of top NASA management, but there are still butterflies as you go into the show. What happens if you give the party and nobody comes?

Well, you came. As NASA Administrator Richard Truly stated in his remarks opening the conference, the response to Technology 2000 was "overwhelming." Some 2500 of the nation's leading technical minds came to listen, learn, and present. More than 90 papers were presented in two days, covering a wide array of innovative technologies with commercial potential. In the exhibit area, NASA's field centers, other government agencies, and some 150 high-tech companies showcased technologies for transfer, services to help industry access and use technology, and examples of successful spinoffs.

Administrator Truly set the tone for Technology 2000 in his plenary session speech:

"We are having this conference to do our part to accelerate the time period from technology generation to technology application. Too many times in the past we have waited until the technology generated for NASA missions was placed on the shelf before secondary or commercial application was sought and found. This process often took a decade or more. Given the fast pace at which technology development is now moving, and the competitiveness from other nations to capitalize on these developments, that traditional approach is simply no longer acceptable.

"At this conference, you will be exposed to some of the developments under way at NASA, so you may begin to imagine their commercial applications and get a jump start on our competitors. You will also be exposed to the many mechanisms we have for assisting you in this process. NASA is dedicated to keeping 'made in the USA' synonymous with the finest aeronautical, space-related, and high-technology products in the world."

Technology 2000 not only featured the transfer of technology from NASA to industry, but from other government agencies to the private sector. . . and from industry back to government and from company to company.

We received extensive media coverage of Technology 2000, not just in the business and technical press, but also in *USA Today*, the *Baltimore Sun*, and a host of other newspapers, as well as on network and cable television. We were surprised and frankly delighted to have 119 members of the working media register for the conference.

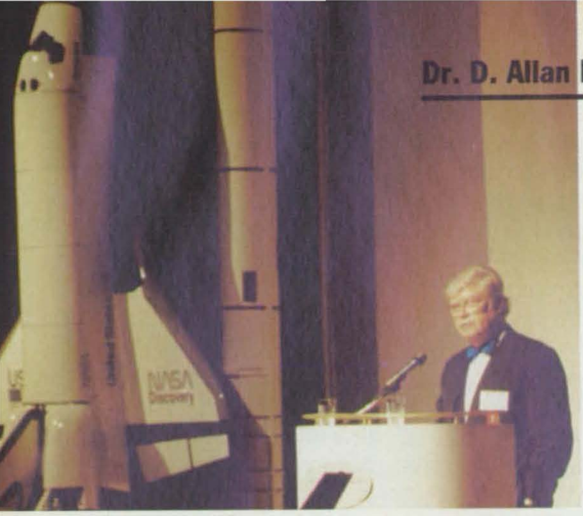
As successful as Technology 2000 was, as excited as we all were and are, we know it was just the beginning. We've already started planning for Technology 2001, which will be held at the new convention center in San Jose, CA, Dec. 3-5, 1991. We've added a third day to the conference and tripled the size of the exhibit and meeting areas. From the interest we saw on the part of exhibitors and attendees at Technology 2000, we think we'll need every inch.

We're planning an even more extensive collection of symposia for Technology 2001 and a wide range of program innovations. We will keep you apprised in this space.

For all of you who came and participated, our heartfelt thanks. It couldn't have happened without you. For those of you who wished to come but for whatever reasons couldn't, I'm sorry you missed an exciting event. To everybody. . . see you in San Jose in 1991.

The 176 exhibit booths at Technology 2000 featured a wide array of government- and-industry-developed innovations, including improved prosthetic devices for amputees (above), a new material mixing technique (below), and a dynamic positioning system (left).

For information on obtaining the complete proceedings of Technology 2000 technical sessions, see page 24.



Dr. D. Allan Bromley:

Technology Is Key To Economic Leadership

Following are excerpts from the Technology 2000 keynote address by Dr. D. Allan Bromley, Assistant to the President for Science and Technology.

Today, more than ever before, the key determinant of the strength of a nation's economy is the efficiency of that nation's technology. The difference between success and failure in our marketplace today often comes down to who has the better technology. If this country is going to remain an economic leader, then we must retain our leadership in technology. In those areas where our activities do not define the frontiers of technology, it is essential that we be close enough to those frontiers so that we are able to exploit new discoveries whenever, wherever they are made.

I don't believe we have lost our lead in technology, although you frequently hear that point made. On the contrary, I would maintain that the United States has built the strongest science and technology enterprise the world has ever seen. An excellent example of our continued preeminence is provided by our host organization (for Technology 2000), by NASA. In the last two years, NASA has had a few highly publicized mishaps. But mishaps are expected whenever you are pushing the frontiers of science and technology. There is no doubt whatsoever that NASA remains far ahead of any other national space program. It has had a dramatic impact on this country, through its activities and through the way it has changed how we think about ourselves. A few thousand years from now, when historians and archeologists look back on this century, the one thing they remember may very well be that wonderful picture of our planet taken on the way to the moon. That photograph has made clear to all of us that we share a small planet which is ours to cherish, ours to destroy.

A Restless Society

The United States has a restless society that prizes and rewards innovation. Our business culture encourages the formation of new companies, and allows successful companies to grow quickly and with minimal interference. The rapid growth of the biotechnology industry is a case in point. In the 1980s alone, over 400 firms were founded in the biotechnology area. These typically small firms with less than 500 employees generate a vastly disproportionate share of the new ideas, products, and jobs in the U.S.

It is important to recognize that we live in an age characterized by change. In the future the spoils are going to go to the quick, the smart, the tenacious. The massive production lines for which we have become justly famous are no longer going to be looked on as the paragon. What we need instead is greater flexibility, greater ability to match changing customer demands, particularly in the international marketplace.

We need to take greater advantage of the enormous resource that resides in the roughly 725 national laboratories we support. We have a tremendous challenge to get the technological know-how that exists in our laboratories into the private sector. One way to go about this is through our support of organizations like Sematech, which is jointly funded by the federal government and private industry at a level of $200 million a year to develop advanced manufacturing technology in the semiconductor industry.

Both the Administration and the vast majority of the House and Senate are convinced that we in this country are seriously underinvesting in R&D, in technology. This is something that by working together, even in difficult financial times, we can improve.

There has never been any question about the role of the federal government in supporting basic research. It has been clear since the early days following World War II that no single institution could hope to gain a sufficient amount of the benefit from any basic research program to justify the investment on its own, which leaves the federal government as the appropriate supporter for much of the basic research done in this country.

It is in taking the basic research through to an effective product or process that we have not fared as well in the competitive marketplace as we should. The Bush Administration feels very strongly that the federal government has a major role to play in working with industry to take those basic discoveries and move them through the precompetitive development phase for a whole array of generic technologies, because there too no single institution can hope to gain sufficient benefit, sufficient profit to justify their sole support of the development that's required. By sharing the risks, we can speed up the process and enable our industry to compete on a more level playing field with the rest of the world.

Long-Range Planning Needed

An important activity in my office right now is the work of the National Critical Technologies Panel, which has been tasked with merging the two lists of critical technologies released during the past year by the Defense and Commerce departments. The panel has been asked to specify where we are with respect to the rest of the world in each of these technologies, and then to make recommendations for action that should be taken to improve our relative stance, to improve our utilization of these technologies, and to more effectively take advantage of areas where we have leading positions.

In the federal government and in the private sector, our long-range strategic thinking is not as well-developed as it should be. We're prepared in the Bush Administration to help, and we look on industrial competitiveness as one of the most pressing of the nation's problems. But we deeply believe that we as government are not nearly as well qualified to make the strategic decisions for industry as is industry itself, nor do we believe that economic transfusions in the absence of such strategic plans are any solution at all. ❑

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Dr. Jeffrey Rosendahl

A View To The Future

In the plenary session entitled "A View to the Future," NASA managers described prime space missions that will be generating new technologies for the 21st century. Following are excerpts from Dr. Jeffrey Rosendahl's talk on the Space Exploration Initiative (SEI), which looks to the establishment of a moon base followed by a piloted mission to Mars. Dr. Rosendahl is deputy director of NASA's Office of Exploration.

On July 20, 1989, President Bush, speaking on the twentieth anniversary of the Apollo moon landing, established a major new direction for the U.S. space program when he offered the challenge to NASA and the nation to return to the moon—this time to stay—and then to journey into tomorrow with a manned mission to Mars.

What is it going to take to accomplish all this? First, we are going to have to be able to get off the ground. The space shuttle will continue to play an important role in the program as a transporter of people, but we're going to have to learn how to get very large pieces of cargo into orbit. Heavy-lift launch capability is going to be an important element in implementing the Space Exploration Initiative. Some of the current types of expendable launch vehicles are going to play an important role as well.

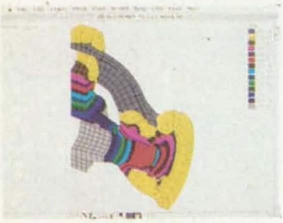
There are a variety of things we will need to be able to do in low-Earth orbit, some involving research in space medicine, in qualifying humans for long-duration space flight, using the space station. If we are going to Mars, we'll have to develop measures to deal with the problems of adapting to the low-gravity environment, or we're going to have to use artificial gravity. There are all sorts of interesting medical questions that could have spinoff in understanding basic questions in medical techniques here on Earth.

We're also going to have to validate servicing, replacement, and maintenance techniques. We may wind up evolving the space station to carry out a variety of tasks in assembly and maintenance. The station may prove critical for the assembly of transfer vehicles which would provide routine transit between the moon and

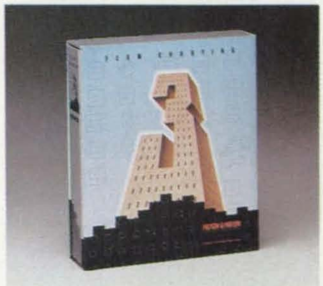
(Continued on page 60)

Technology Showcase

A sample of the more than 200 innovative products featured at Technology 2000



Structural Research and Analysis Corp., Santa Monica, CA, demonstrated a Macintosh version of the COSMOS/M® **finite element analysis system.** Version 1.61 allows analysis on models with up to 15,000 nodes and 60,000 degrees of freedom. The system offers increased analysis capability with two new modules: ESTAR for electromagnetic analysis, and FLOWSTAR for fluid flow analysis.



A new **flowcharting software program for IBM PCs** displayed by Patton & Patton Software Corp., Morgan Hill, CA, allows creation of 300 dpi printer output in normal, compressed, or ultra-compressed chart densities. Flow Charting 3 features "point and shoot" file management, and on-line help screens. The software requires 512K of memory and a CGA, EGA, VGA, or Hercules Graphics card.

High Tech Basic (HTBasic), a **PC-based engineering BASIC** displayed by TransEra Corp., Provo, UT, offers high-level graphic capabilities, GPIB and printer support, and HP BASIC compatibility while running at speeds comparable to higher-priced workstations. HTBasic 3.0 features BASIC-compatible instrument and program commands, complex numbers, loadable device drivers, international character support, and syntax extensions.

The Phototron®, **a biological water and air reclamation and recycling chamber**, was presented by Pyraponic Industries Inc., San Diego, CA. The system produces potable water and food using the natural filtering of plants; it can manufacture one gallon of potable water every 24 hours. Proposed for use on space station Freedom, the Phototron could help sustain human life in space over long periods by recycling urine through plant transpiration to produce pure drinking water.

Tiodize Co., Inc., Huntington Beach, CA, presented a **self-lubricating composite material** with long wear life, low coefficient of friction, and no creep at 30,000 psi/600° F loads. Suited for bearings, bushings, thrust washers, wear pads, and other applications, TRIBO/COMP® TDF is one-fifth the weight of steel and one-half the weight of aluminum.

Claritek, San Diego, CA, exhibited the Heartlink™ system which provides for the **real-time transfer of doppler ultrasound (cardiac)** in the video format across standard telephone lines. Available for integration into medical institutions, Heartlink is compatible with Microsoft's Excel 2.2®, Microsoft Word 4.0®, and PowerPoint 2.0® for use in a PACS environment.

Nicolet Test Instruments, Madison, WI, demonstrated NIC500 version 6.0, a Microsoft Windows 3.0-based **software application for the System 500** multichannel waveform acquisition and analysis system. Nicolet also showcased **TACT™ software for the 400 Series oscilloscope**. The TACT programming system consists of a LEARN function, built-in BASIC language, and a full-screen editor.

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 sections 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 18). NASA's patent-licensing program to encourage commercial development is described on page 18.

Multiple-Quantum-Well Intersubband Infrared Detector

A proposed multiple-quantum-well device would be a stack of substacks, each of which would contain quantum-well layers sensitive to a different narrow band of wavelengths. The device would detect photons over a broader range of wavelengths than present multiple-quantum-well infrared detectors.
(See page 25)

Polyphenylquinoxalines via Aromatic Nucleophilic Displacement

A process for the synthesis of polyphenylquinoxalines (PPQ's) involves nucleophilic displacement reactions of di(hydroxyphenyl) quinoxaline monomers with activated aromatic dihalides. The process facilitates the synthesis of new PPQ's, which are useful as adhesives, coatings, films, membranes, and matrices for composites.
(See page 32)

Membrane Bioreactor With Pressure Cycle

An improved class of multilayer membrane bioreactors uses convection forced by differences in pressure to overcome some of the diffusional limitations of prior bioreactors. In new reactors, a flow of nutrient solution reduces adverse gradients of concentration, keeps cells supplied with fresh nutrient, and sweeps away the products faster than in bioreactors using diffusion.
(See page 55)

Heterojunction-Internal-Photoemission Infrared Detectors

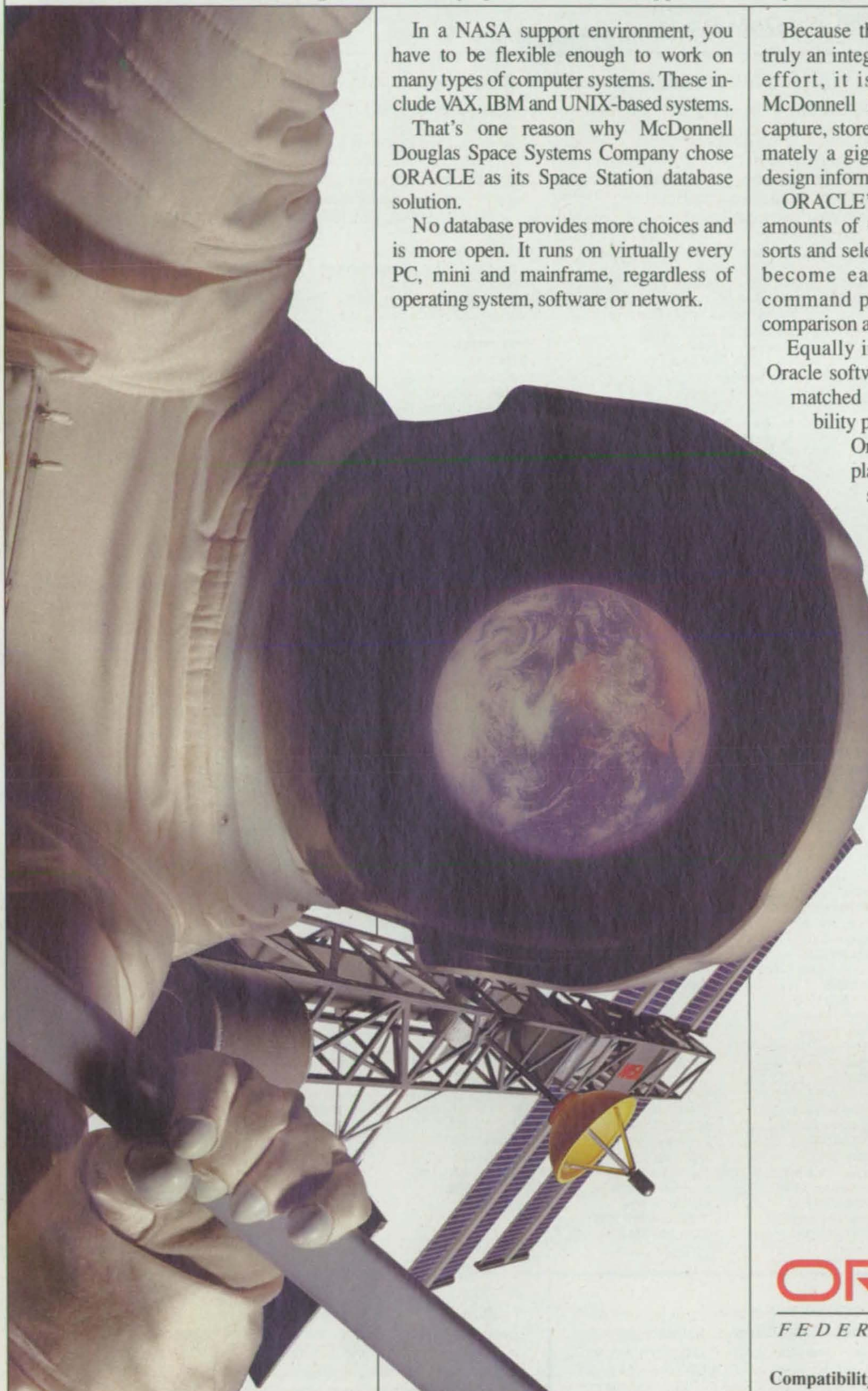
Heterojunction-internal-photoemission infrared photodetectors have been proposed for incorporation into planar arrays in imaging devices that are required to function well at wavelengths from 8 to 17 μm and at temperatures above 65 K. The proposed photodetectors would add new options to the design of imaging devices and could be built into integrated circuits that also include silicon multiplexer/readout circuits.
(See page 22)

Lightweight Substrates for Mirrors

A conventional quasi-isotropic fabric laminate with a surfacing layer of carbon-fiber paper consisting of randomly oriented chopped carbon fibers is proposed as new mirror substrate for space-based instruments. The substrate is lightweight, thermally and mechanically stable, and resistant to degradation from radiation.
(See page 32)

Open World, Open Database

McDonnell Douglas selects truly open database to support NASA Space Station effort.



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Electronic Components and Circuits

Hardware, Techniques, and Processes

Reinforced Positive Filler Paste for Lead/Acid Batteries

Lead-coated glass fibers would extend the battery life.

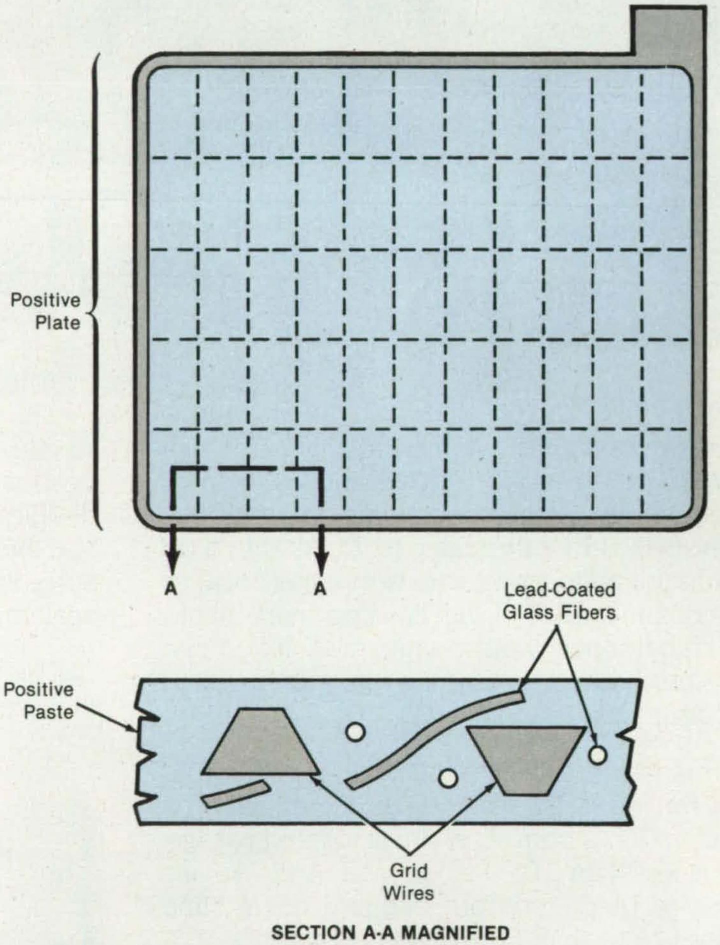
NASA's Jet Propulsion Laboratory, Pasadena, California

Lead-coated glass fibers have been proposed as an additive to the positive paste used in lead/acid batteries. The fibers are expected to improve both the electrical and the mechanical properties of the positive battery electrodes, thus extending the lives of batteries during repeated charge/discharge cycles.

The positive electrode is the plate that normally fails in deep-cycle applications. As the battery is cycled, the positive paste softens and eventually causes the battery to fail. In the proposed scheme, the lead-coated glass fibers would be mixed with the paste before the paste is applied to the positive electrode. After the electrode is cured, the fibers would reinforce the electrode, somewhat like the steel rods in reinforced concrete. The fibers would also provide electrical paths in a discharged electrode, thus preventing the poorly conducting discharged active material from becoming electrically isolated.

Shown in the figure is the cross section of a typical positive battery plate pasted with a mixture of lead-coated glass fibers and active material. The fibers would be distributed uniformly throughout the 0.1-in. (2.5-mm) thickness of the plate.

The distance between the grid wires of the plate would be 0.2 in. (5 mm). The diameter of the glass fibers with lead coating would be 0.01 in. (0.25 mm), while the diameter of the glass fibers without the lead coat would be 0.004 in. (0.1 mm). The fibers, chopped to an average length of 0.1 in. (2.5 mm), would occupy about 2 percent of the volume of the active material. A pellet of active material between the grid wires would contain approximately 25 fibers.



A **Mixture of Lead-Coated Glass Fibers and Positive Paste** would form pellets of active material between the grid wires of the positive battery electrode. The fibers would contribute to the charge capacity, electrical conductivity, and mechanical stability of the electrode.

The addition of fibers to the positive paste could be beneficial in several ways. One result could be a reduction in weight obtained by an increase in the distance between the grid wires of the positive plate. The fibers would reduce the electrical resistance of the plate so that a greater portion of the plate could be converted to lead dioxide. Because lead on the fibers would be charged during the formation of the plate, a corrosion layer of lead dioxide would form on the fibers. The corrosion layer would act to provide a good electrical and mechanical interface with the active material.

This work was done by Dean B. Edwards and Wally E. Rippel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 51 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

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Refer to NPO-16991, volume and number of this NASA Tech Briefs *issue, and the page number.*

Heterojunction-Internal-Photoemission Infrared Detectors

A new type of photodetector would add options for the design of imaging devices.

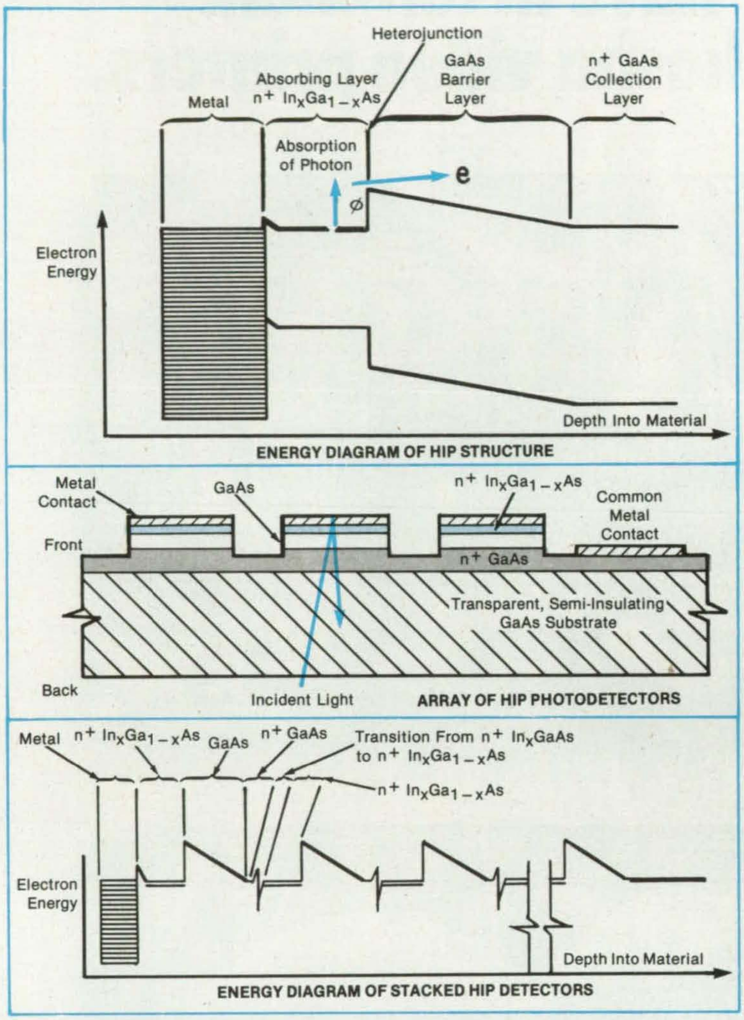
NASA's Jet Propulsion Laboratory, Pasadena, California

Heterojunction-internal-photoemission (HIP) infrared photodetectors have been proposed for incorporation into planar arrays in imaging devices that are required to function well at wavelengths from 8 to 17 μm and at temperatures above 65 K. The ability to fabricate specially tailored heterostructures containing elements from groups III and V of the periodic table has opened up the possibility of making these and other new optoelectronic devices. The proposed photodetectors could be built into integrated circuits that also include silicon multiplexer/readout circuits.

Detection would occur via photoemission of electrons over heterojunction barriers. In a representative detector of this type, the heterojunction would be incorporated into an appropriately doped structure. The heterojunction could be formed, for example, between heavily electron-donor-doped (n^+) $In_xGa_{1-x}As$ and GaAs (see figure). By selection of the composition x one could set the height, ϕ, of the energy barrier for electrons and make it correspond to the cutoff wavelength, λ_c, according to $\lambda_c = hc/\phi$, where h is Planck's constant and c is the speed of light. For operation in the long-wavelength infrared region of interest, one would typically choose $x \approx 0.1$.

Unlike some quantum-well infrared detectors, the proposed devices could detect radiation that impinged perpendicularly to the plane of the heterojunction. Incident photons would excite free electrons from the occupied energy states of the degenerate n^+ $In_xGa_{1-x}As$ layer to the higher energy states in the continuum of the conduction energy band. If the distance between a photoexcited electron and the barrier were of the order of a mean free path for inelastic scattering and the electron were excited with an energy $> \phi$, then there would be a high probability that the electron would cross the barrier and be collected.

The undoped GaAs layer adjacent to the heterojunction would constitute a barrier region with a built-in electrostatic field that would terminate at an interface with an n^+ GaAs layer. The electrons that cross the barrier would be swept by this field into the n^+ GaAs layer, where they would be collected. This effect would be identical to the photovoltaic effect in p/n-junction or Schottky-barrier devices. Therefore, with the addition of suitable contacts, photodetectors of this type could be operated as photovoltaic detectors, and imaging arrays of them could provide direct outputs to multiplexer/readout circuits, without having to apply bias voltages to the arrays.



In an HIP Infrared Photodetector, photoexcited electrons would cross an energy barrier at a heterojunction and be swept toward a collection layer. An array of such detectors could be made by etching mesa structures. HIP layers could be stacked to increase quantum efficiency.

It would be relatively easy to form the electrical contact between the $In_xGa_{1-x}As$ layer and an outer metal layer, especially if the composition x were increased near the metal/semiconductor interface to make an ohmic contact of low resistance. The thickness of the n^+ $In_xGa_{1-x}As$ layer should be kept approximately at the electron-scattering mean free path to maximize the quantum efficiency. An array of mesa picture-element detectors could be etched by standard photolithography, as shown in the middle of the figure. In this configuration, radiation may be incident from the back side of the transparent, semi-insulating GaAs substrate and be reflected from the front metal contacts, thus providing two passes through the absorbing n^+ $In_xGa_{1-x}As$ layer. The common contact to the GaAs n layer could be placed at a peripheral point from the front side.

The quantum efficiency of an HIP infrared detector would be limited by the thinness of a single n^+ $In_xGa_{1-x}As$ absorbing layer. With suitable doping and matching of layers, detectors could be stacked to increase quantum efficiency, as shown at the bottom of the figure.

This work was done by Joseph Maserjian of **NASA's Jet Propulsion Laboratory**, *Center for Space Microelectronics Technology. For further information, Circle 122 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-17879

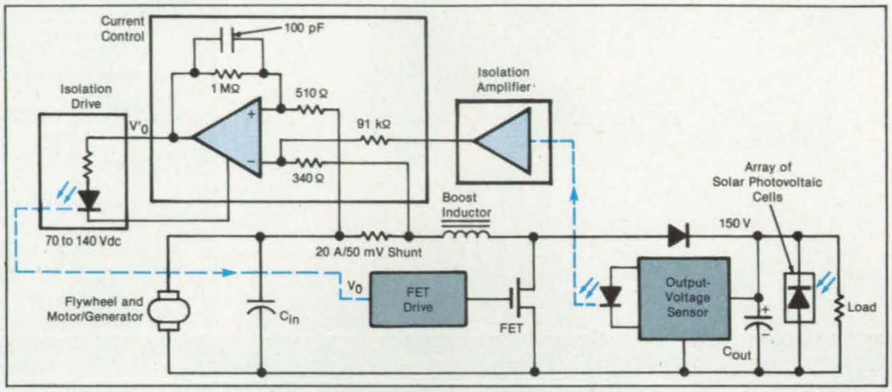
Self-Oscillating Inductive Boost Regulator

Features include optical coupling and rapid response.

Goddard Space Flight Center, Greenbelt, Maryland

An improved voltage regulator is designed for use in a solar photovoltaic dc power system utilizing a flywheel for energy storage. The voltage regulator includes a self-oscillating inductive voltage-boosting circuit, which regulates the withdrawal of energy from the flywheel and motor/generator when the output of the solar cells is insufficient to maintain the load voltage at the specified level of 150 Vdc.

The voltage-boosting circuit (see figure) increases the load voltage by supplementing it with the rectified ripple current in the boost inductor. The ripple is generated by periodically connecting the output end of the boost inductor to ground via a field-effect-transistor (FET) switch. The switching of the FET's and, therefore, the magnitude and frequency of the ripple are controlled by the current-controlling portion of the circuit, which contains a hysteretic voltage comparator. A resistive voltage-divider network feeds, to the input terminals of the comparator, a combination voltage derived partly from a shunt that senses the current in the boost inductor and partly from a control signal representative of the output voltage. The output-voltage and the FET-switching signals are transmitted to and from the current-controlling circuitry, respectively, via optoisolators, so that the isolation of relatively low control voltages from relatively high common-mode power-supply voltages presents no major problem.



The **Self-Oscillating Boost Regulator** senses the output voltage and the current in the boost industor and accordingly turns the FET switch on and off periodically to maintain the output voltage as close as possible to 150 V.

The resistive voltage-divider network is designed to turn the FET switch off whenever the current in the boost inductor reaches a maximum safe value. Below that limit, the current-controlling circuitry continuously regulates the magnitude of the boost inductor current in response to the sensed output voltage to keep that voltage at 150 V. The circuit is self-oscillating in the sense that the FET's are turned on and off only in response to sensed current and voltage. This feature enables the circuit to respond faster to a change in the load than can a prior type of boost regulator that operates partly under control of a fixed-frequency clock signal and must wait until the next clock pulse to turn the FET switch on, no matter how much the load may change during the "off" part of the cycle.

This work was done by John Paulkovich, G. Ernest Rodriguez, and Vickie Eakin of **Goddard Space Flight Center.** *For further information, Circle 165 on the TSP Request Card.*
GSC-13305

Multiple-Quantum-Well Intersubband Infrared Detector

Bandwidth and detectivity would be increased.

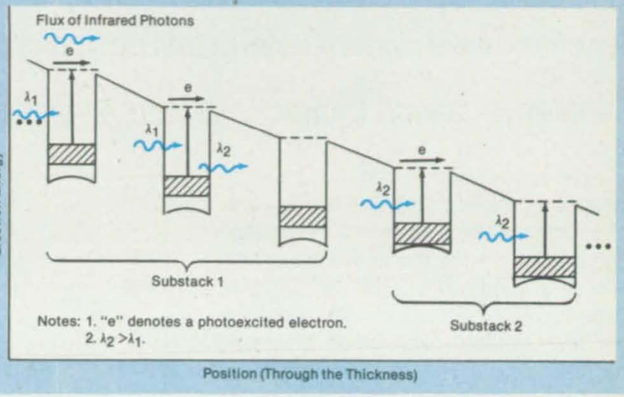
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed multiple-quantum-well intersubband semiconductor device would detect photons over a broader range of wavelengths than present multiple-quantum-well infrared detectors can now accommodate. The structure of the detector would resemble that of other multiple-quantum-well devices reported in previous issues of *NASA Tech Briefs*, but would differ in the numbers, thicknesses, and proportions of the semiconductor elements in its layers.

The device would be a stack of multiple substacks within each of which there would be multiple barrier layers of $Al_xGa_{1-x}As$ alternating with quantum-well layers of GaAs or In_yGa_yAs (see figure). Each quantum well would support two quantum states: a lower state bound in the well, and an upper, slightly-bound state with an energy slightly above the barrier (and, therefore, in the continuum of energy levels in the conduction band). In present multiple-quantum-well devices, the upper states are below the barriers, so that the photoexcited electrons have to undergo quantum-mechanical tunneling and the consequent attenuation to leave the wells. In the proposed device, the higher energy of the upper state would enable the photoexcited electrons to cross the barriers without tunneling. In addition, the oscillator strength of the upper states would be high with respect to that of the lower states, resulting in a high probability of absorption of photon energy between the lower states and the continuum. These features would contribute to the detectivity of the device.

Within the *n*th substack, the compositions and thicknesses of the layers would be chosen so that the quantum wells in that substack would be sensitive to a certain narrow band of wavelengths around a middle wavelength of λ_n. The wide-band response would be achieved by making the quantum wells in each succeeding substack slightly wider and shallower than those of the preceding substack. By this design, the first substack would absorb the photons of highest energy (shortest wavelength, λ_1), the second substack would absorb photons of the next highest energy (slightly longer wavelength λ_2), and so on. Because the quantum efficiency of the device would decrease with an increasing number of quantum wells, this design would involve an engineering compromise between bandwidth and quantum efficiency.

The **Proposed Multiple-Quantum-Well Device** would be a stack of substacks, each of which would contain quantum-well layers sensitive to a different narrow band of wavelengths. The energy levels shown here include the effect of the bias voltage applied to the device.



This work was done by Shmuel I. Borenstain of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 155 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 18]. Refer to NPO-17962.

Electro-optical Position-Measuring System

A nonintrusive system determines positions of models within the test section of a wind tunnel.

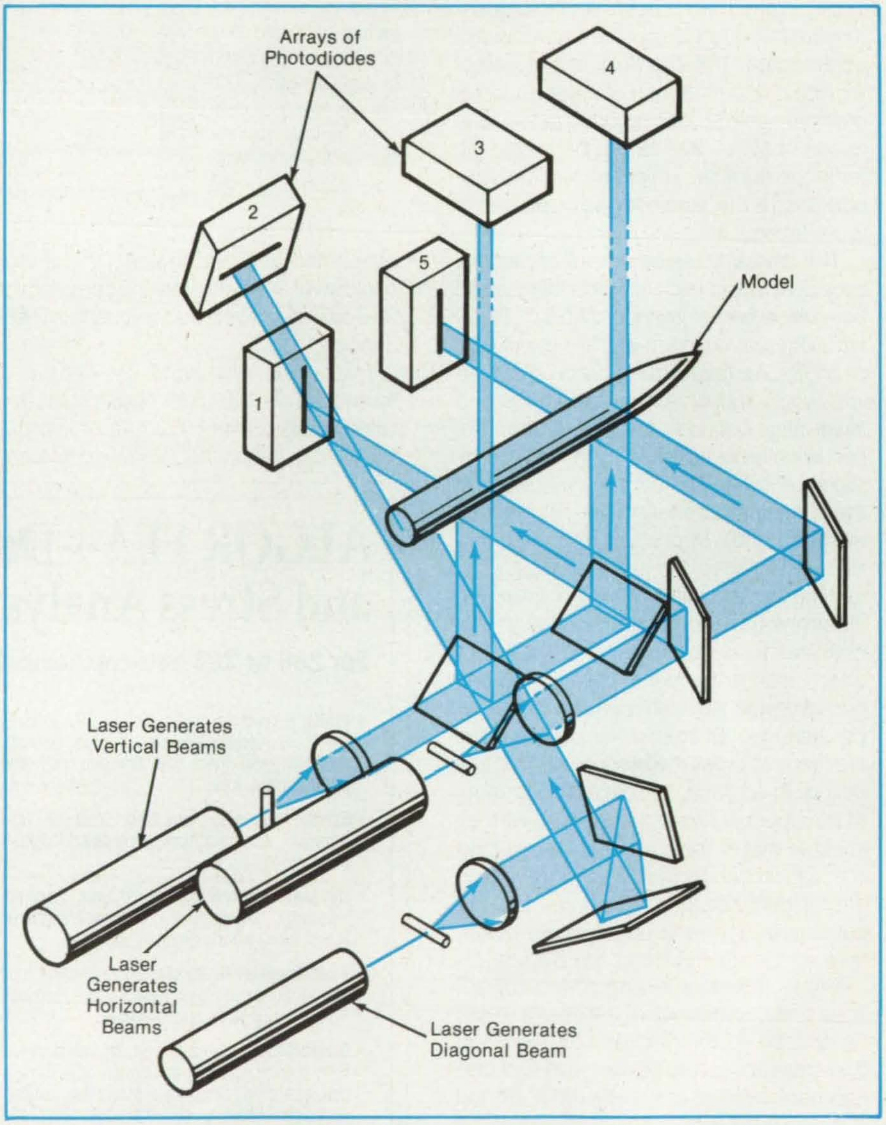
Langley Research Center, Hampton, Virginia

An electro-optical system has been developed to measure the five components of coordinates that represent the position and orientation of a model in the test section of a wind tunnel. This nonintrusive system, which is located entirely outside the test section, uses small lasers as sources of light and self-scanning linear photodiode arrays (LPDA's) as the sensing elements.

The optics of the system are arranged along the perimeter of the test section on adjustable rails to accommodate various models. The laser beams are shaped into sheets of light by small glass rods and collimated by plano-convex cylindrical lenses. A combination of plate beam splitters and first-surface mirrors at 45° are used in two of the optical paths, producing four sheets of light orthogonal to the test section. One pair of sheets of light is reflected from underneath the test section onto LPDA's 3 and 4 (see figure) for measurements of sideways position and yaw. Another pair of sheets is reflected across the test section onto LPDA's 1 and 5 for measurements of lift and pitch. The third sheet of light is reflected diagonally through the test section onto LPDA 2 for measurements of axial position. The LPDA's have 1-in. (2.54-cm) apertures and contain 1,024 discrete photodiodes each.

Each LPDA produces a video signal consisting of a train of recharge pulses proportional to the intensity of incident light on each of its 1,024 photodiodes. A signal conditioner converts only the pulses from saturated photodiodes into transistor/transistor-logic (TTL) form, ignoring anything below a predetermined level. Processing circuitry counts the TTL pulses and produces both binary and analog representations. The counters are updated at a rate of 256 Hz. When no model is present in the test section, all the LPDA's are fully illuminated, resulting in a count of 1,024 for each one. However, when a model obstructs the sheets of light, the locations of the resulting shadows on the LPDA's are used to determine the position of the model.

The system has been successfully installed and is currently operational in the 13-in. (33-cm) Magnetic Suspension and Balance System (MSBS) at NASA Langley Research Center. The useful full-scale ranges of the system are ±0.45 in. (±11.4 mm) and ±8° for linear and angular displacements, respectively. The system has an overall precision of ±0.002 in. (0.05 mm) and ±0.02° in linear and angular measurements, respectively. With improvements in measuring ranges, this type of electro-optical system can be adapted for use in other aerodynamic applications.



This **Electro-optical Five-Component Position-Measuring System** is used in the 13-in. Magnetic Suspension and Balance System at Langley Research Center.

This work was done by Ping Tcheng and Timothy D. Schott of **Langley Research Center**. *For further information, Circle 49 on the TSP Request Card. LAR-13840*

Multistage Estimation of Frequency and Phase

Each stage would refine the estimate further.

NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptual two-stage software scheme serves as a prototype of a multistage scheme for digital estimation of the phase, frequency, and the rate of change of frequency ("Doppler rate," for short) of a possibly phase-modulated received sinusoidal signal in a communication system in which the transmitter and/or the receiver is (are) traveling rapidly, accelerating, and/or jerking severely. Although the scheme was conceived for use in estimating the parameters of signals from spacecraft and the high dynamic GPS signal parameters, it is also applicable, at least in principle, to terrestrial stationary/mobile (e.g., cellular radio) and land-mobile/satellite communication systems.

The conceptual multistage estimation scheme stands in contrast to the prior single-stage schemes (phase-locked loop, conventional cross-product automatic frequency-control loop, Kalman filter, and the like). The concept embraces many variations in the number, types, and parameters of the stages. In general, the successive stages yield increasingly refined estimates (see figure), and each succeeding stage operates within a bandwidth smaller than that of the preceding stage.

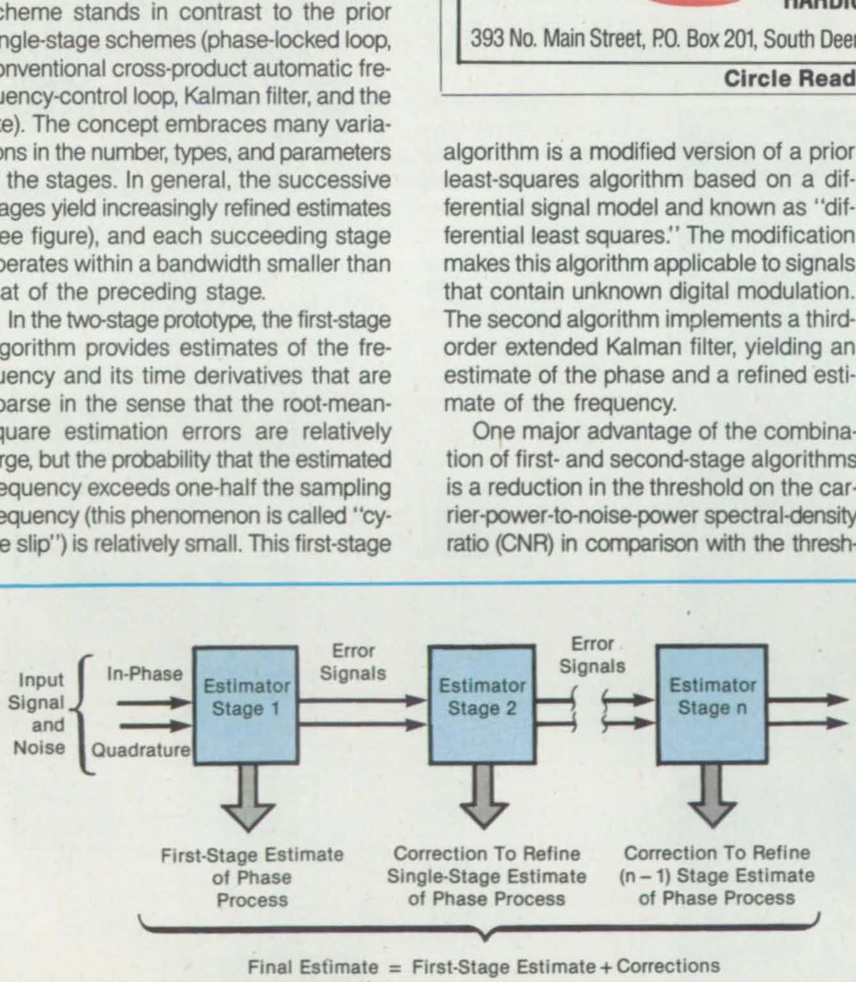
In the two-stage prototype, the first-stage algorithm provides estimates of the frequency and its time derivatives that are coarse in the sense that the root-mean-square estimation errors are relatively large, but the probability that the estimated frequency exceeds one-half the sampling frequency (this phenomenon is called "cycle slip") is relatively small. This first-stage algorithm is a modified version of a prior least-squares algorithm based on a differential signal model and known as "differential least squares." The modification makes this algorithm applicable to signals that contain unknown digital modulation. The second algorithm implements a third-order extended Kalman filter, yielding an estimate of the phase and a refined estimate of the frequency.

One major advantage of the combination of first- and second-stage algorithms is a reduction in the threshold on the carrier-power-to-noise-power spectral-density ratio (CNR) in comparison with the threshold CNR achievable by either algorithm alone. Indeed, from computer simulations designed to test the performance of the two-stage scheme, it appears that for an unmodulated carrier, the scheme achieves the same threshold CNR as that of an almost exact and computationally intensive implementation of a maximum-likelihood estimator. The simulations also show that where digital modulation is present, the threshold CNR of this scheme is about 6 dB below that of a previous approximate maximum-likelihood-estimator (AMLE) scheme.

The overall complexity of the scheme is about twice that of a third-order Kalman filter or of a single fourth-order extended Kalman filter. Of course, one could reduce the threshold CNR and the rms estimation errors further by use of a more complicated set of algorithms that implement three or more stages of estimation.

This work was done by Rajendra Kumar of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 94 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-17911.



Each Additional Stage of a multistage scheme would provide an increasingly refined estimate of the frequency and phase of a signal.

Simultaneous Detection and Estimation Amid Strong Dynamical Effects

The effective signal-to-noise ratio is several decibels greater than in previous schemes.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed scheme for the digital processing of a received noisy, binary-phase-modulated radio signal provides for the simultaneous detection of the binary modulation and estimation of the Doppler phase, frequency, and frequency derivative. The scheme is intended for use where the relative motion between the transmitter and receiver can include large velocities, strong accelerations, and/or intense jerks, resulting in possibly large Doppler frequency shifts with respect to time. It could improve reception in radar, mobile/satellite communications, and navigation systems.

The scheme (see figure) starts with estimation of the local parameters (those that depend on the momentary state of the binary modulation) of the received signal, followed by detection of a possible jump in these parameters. A jump signifies a data-bit transition in the modulation and is mathematically separated from the received signal, thereby effectively demodulating the signal. The effectively demodulated signal is then processed to obtain estimates of the global parameters (those phase and frequency parameters, including the Doppler parameters, that do not depend on the modulation) of the received signal. The estimates of the global parameters are also used to improve the estimates of the local parameters during subsequent bit periods.

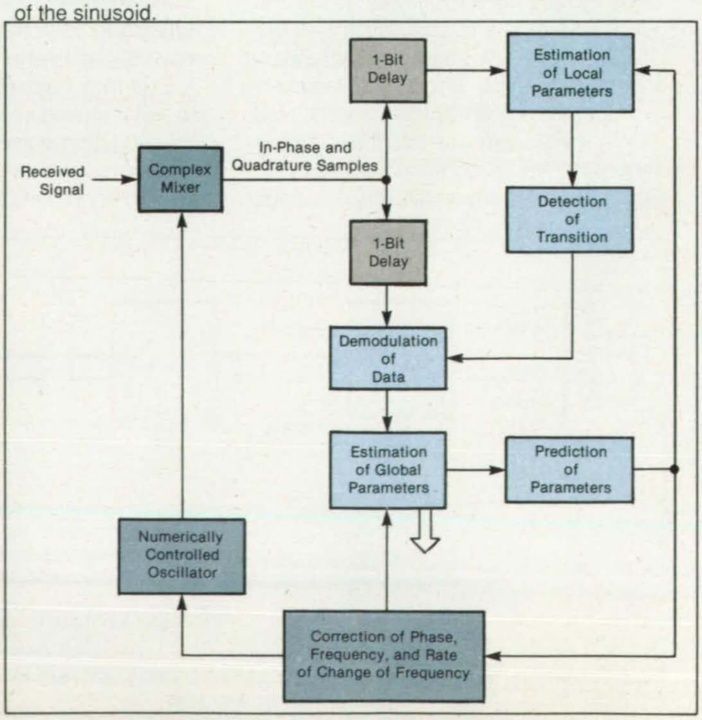
The scheme incorporates either of two different but equivalent algorithms for the estimation of both the local and global parameters. The algorithms are improved versions of the Kalman filter. For the local parameters, it is necessary to use a subalgorithm capable of estimating both the phase and the frequency. However, for the global parameters, it is not necessary to estimate the phase, and, therefore, a frequency-estimating algorithm can be substituted for the Kalman filter, resulting in a marginal reduction of the required P/N_0 (where P = the received carrier power and N_0 = the power spectral density of the noise).

Either of the two algorithms can provide an improvement of up to 3 dB (according to computer simulations) over the Kalman filter (and over a phase- or frequency-locked loop) in the estimation of phase and frequency when the signal-to-noise ratio (SNR) is low. Both algorithms are based upon the recognition of two available error signals with nearly independent noise. In conventional implementations, one of these error signals is simply ignored.

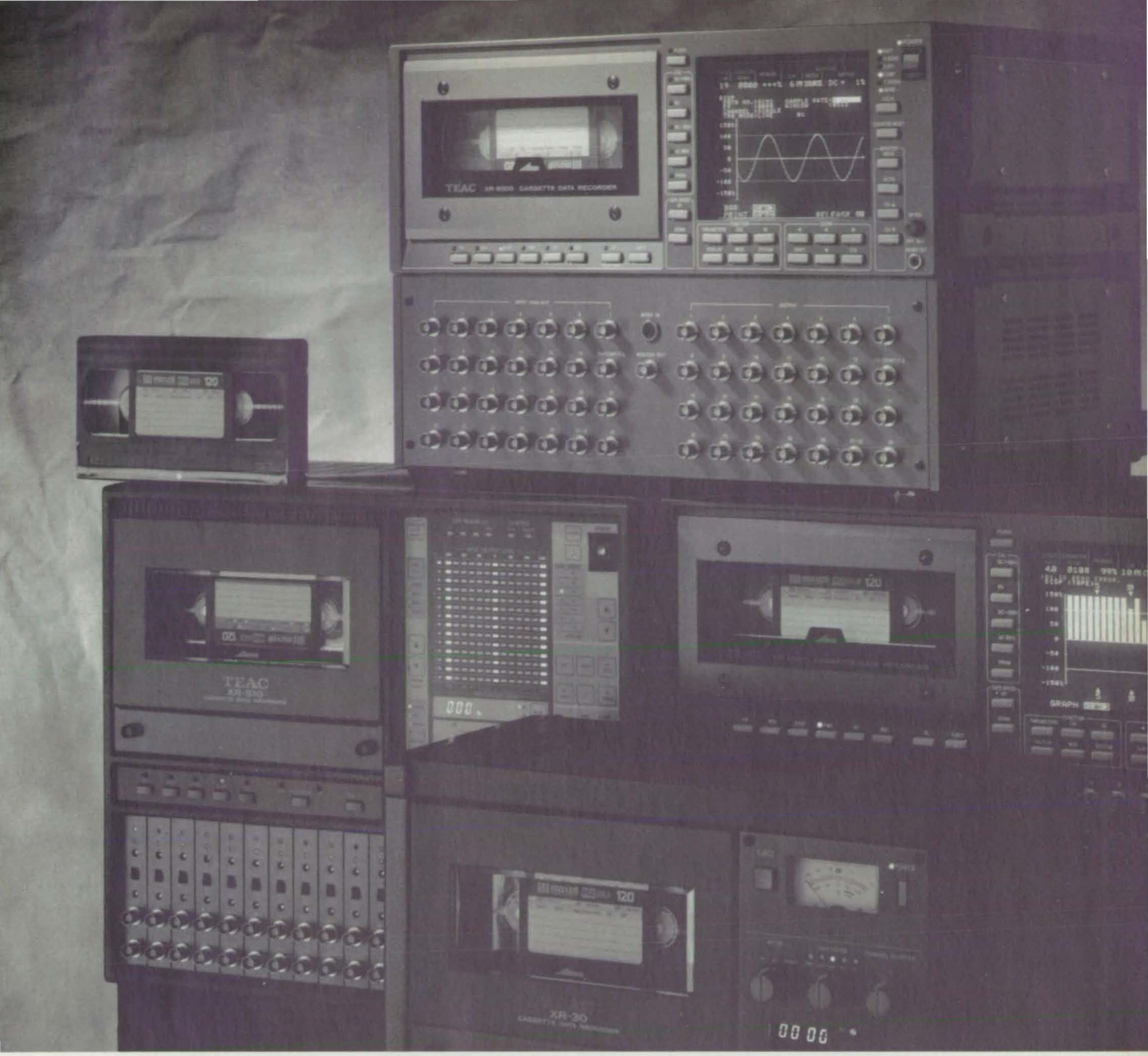
In one algorithm, the observations are reprocessed over an optimally selected period, making it possible to exploit the other error signal as well. The improvement in this scheme is not due to better linearization as in an iterated Kalman filter (where the improvement increases with the iteration interval) but, rather, is due to the fact that if the reprocessing interval is optimal, the two sets of measurements are nearly independent, resulting in an improvement of nearly 3 dB (according to computer simulations) under a low SNR. In the other algorithm, which is relevant to classical phase-locked loops, an adaptive Hilbert-transform technique results in similar improvements.

This work was done by Rajendra Kumar of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 156 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 18]. Refer to NPO-17820.



The **Proposed Estimation/Detection Scheme** provides for the digital processing of a binary-phase-modulated, noisy sinusoid to obtain both the binary signal and estimates of the phase and frequency parameters of the sinusoid.



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Physical 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.

Real-Gas Properties of Air and Air-Plus-Hydrogen Mixtures

Properties related to chemical reactivity are calculated from first principles.

The report presents some calculated chemical, physical, and spectroscopic properties of nitrogen, oxygen, hydrogen, and compounds thereof. The data are needed particularly in numerical simulations of the heating, radiative properties, and chemical reactions of molecular species in the air flowing through jet engines and around spacecraft. These real-gas properties (as distinguished from the ideal-gas properties used in simplifying assumptions) are often difficult or impossible to measure and are best obtained via state-of-the-art quantum-chemical calculations on advanced computers.

The report includes three main sections and an appendix. Section I discusses the electronic-transition moments (proportional to the probabilities of radiative transitions) of 13 molecular species found in air. For each species, there is a brief narrative summary of the literature, the status of calculations to date, and the recommended values. The transition moments of some species are plotted as functions of bond lengths. An appendix discusses the relationships between transition moments and other quantities that appear in quantum-mechanical calculations of radiative intensities and lifetimes.

Section II discusses the constants of proportionality to the rates of selected chemical reactions among some of the species. Calculations of these constants are continuing, and values available thus far are presented. Each such calculation requires a three-step process: (1) The potential-energy surface that represents the energy of interaction between the species in question at any geometrical arrangement of the atoms must be calculated. This surface is related to a map of the forces between the species during a collision that leads to the reaction in question. (2) The data generated in step 1 must be fitted to an equation that can be used to calculate the interaction energy of the system for any geometrical arrangement of the atoms. (3) A large number of collisions between reactants is simultated by classical mechanics, using the equation derived in step 2. The results are averaged to obtain cross sections and rate constants.

Section III discusses the use of potential-energy curves and collision integrals to calculate the transport properties of hot air. Potential energies of O_2, N_2, NO, N_2^+, and O_2^+ are plotted as functions of intermolecular separations. Some viscosities, thermal conductivities, and diffusion coefficients are plotted as functions of temperature.

This work was done by David M. Cooper, Richard L. Jaffe, Stephen R. Langhoff, and Harry Partridge, III of **Ames Research Center**. *To obtain a copy of the report, "Real Gas Properties of Air and Air Plus Hydrogen Mixtures," Circle 123 on the TSP Request Card.*
ARC-12275

Status of Imaging Radar Polarimetry

Topics include theory, equipment, and experimental data.

A report pulls together information on imaging radar polarimetry from a variety of sources. It reviews the state of the art, examines current applicable developments in radar equipment, describes the recording and processing of radar polarimetric measurements, and discusses the interpretation and application of the resulting polarimetric images.

Imaging radar polarimetry is a synthetic-aperture-radar technique in which the complete amplitude and phase response of each picture or resolution element of the target is recorded for both horizontal and vertical reflected polarizations, in response to both horizontal and vertical transmitted polarizations. Thus, the basic polarimetric data about each picture element have to be expressed as a complex-number scattering matrix. This stands in contrast to conventional radar imaging, in which polarization is ignored and each picture element is characterized by a simple scalar amplitude. In return for increased complexity, imaging polarimetry yields more detailed information about the target — for example, making it possible to distinguish between forested or treeless landscape.

The report begins with a brief history of imaging radar polarimetry. This is followed by the first section of the main text, which discusses the fundamental theory of radar polarimetry. Topics include the basic equations for back-scattering, the scattering matrix, Stokes-matrix representations of scattering matrices, polarization signatures of target areas, and development of mathematical models of polarimetric properties of different types of terrain. The modeling effort is particularly significant in that it enables the comparison of measured and predicted properties, thus providing the means for interpretation of remote-sensing data in ways that were not possible before the emergence of radar polarimetry.

The next section describes the implementation of imaging radar polarimeters. It includes a section on the radar equipment carried aboard several research airplanes and to be carried aboard future spacecraft, a section on the recording and digital processing of polarimetric measurements, a section on phase calibration of the polarimetric data, and a section on compression of the data to manageable volumes for storage and analysis.

The third section describes the experimental polarimetric scattering characteristics of several different kinds of terrain. It presents images and polarization signatures of San Francisco (including ocean, urban development, city parks, and natural terrain), the Pisgah lava flow in the Mojave desert, a forested area near Mt. Shasta, and ice floating in the Beaufort sea. The fourth and last section is a brief summary.

This work was done by Jakob J. van Zyl and Howard A. Zebker of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Radar Imaging Polarimetry," Circle 107 on the TSP Request Card.*
NPO-17890

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Materials

Hardware, Techniques and Processes

Books and Reports

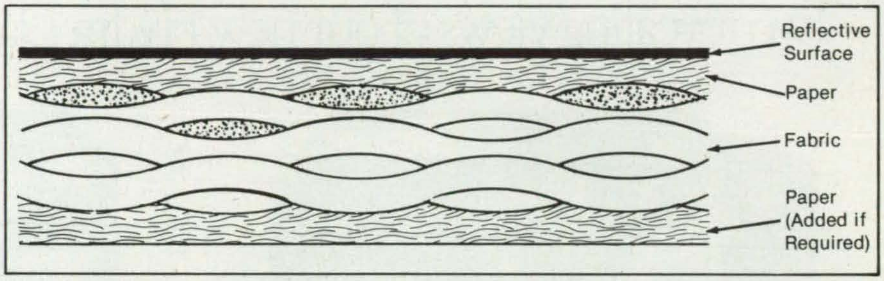
Lightweight Substrates for Mirrors

Layered structures would be made of carbon/carbon material.

NASA's Jet Propulsion Laboratory, Pasadena, California

Mirror substrates for space-based instruments are required to be lightweight, thermally and mechanically stable, and resistant to degradation from radiation. Carbon/carbon composites are ideally suited to this application, but the state of the art utilizes thick, three-dimensionally woven substrates having high areal weights.

A new substrate uses a conventional quasi-isotropic fabric laminate with a surfacing layer of carbon-fiber paper consisting of randomly oriented chopped carbon fibers. The carbon paper serves as a machinable layer, allowing the correct optical figure to be machined into the substrate. This provides the polishable surface and serves to fill in the print-through of the underlying fabric. The paper layer, being of random orientation, also removes the regular crack structure of the fabric and is therefore more readily densified into a smooth homogeneous surface layer. Substrates of this type can be made quite thin, thus keeping areal weights to a minimum. Mirrors of this type could be made faster, and would cost less, than their predecessors.



The **Layered Structure** of fabric and paper would be relatively easy to manufacture. When impregnated with carbon, the structure would be rigid and stable.

This work was done by D. Kyle Brown of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 63 on the TSP Request Card.*
NPO-17854

Polyphenylquinoxalines via Aromatic Nucleophilic Displacement

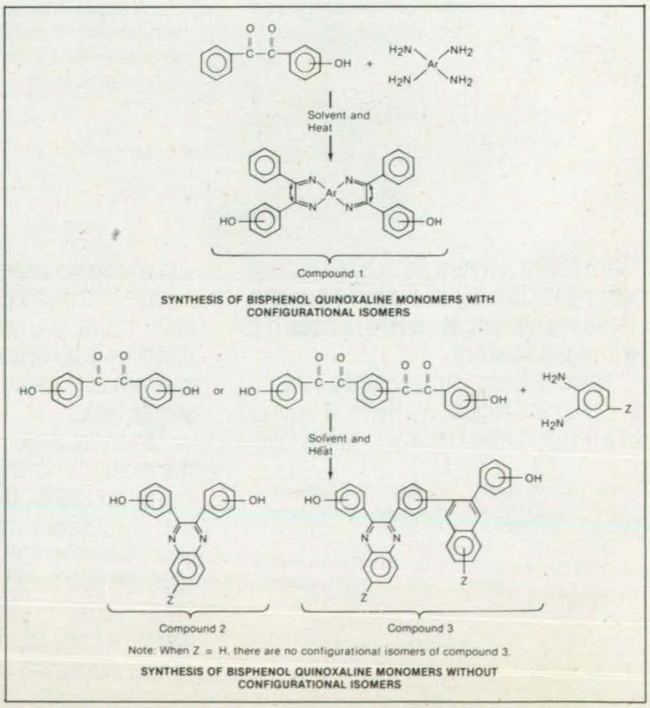
A new reaction sequence costs less and provides for a variety of molecular structures.

Langley Research Center, Hampton, Virginia

A process for the synthesis of polyphenylquinoxalines (PPQ's) involves nucleophilic displacement reactions of di(hydroxyphenyl) quinoxaline monomers with activated aromatic dihalides. The new process costs less than do other processes for the synthesis of PPQ's. In addition, because of the availability of a large variety of activated aromatic dihalides, the new process facilitates the synthesis of PPQ's of new and varied molecular structures. The new PPQ's are useful as adhesives, coatings, films, membranes, and matrices for composites.

Conventional PPQ's, prepared from bis(phenyl-α-diketones) and bis(ortho diamines), are configurationally unordered, with three possible isomers distributed randomly along the backbones of these polymers. This dissymmetry contributes to the amorphous character, high solubilities, and limited tensile moduli observed in these materials. On the other hand, the incorpora-

Figure 1. **Bisphenol Quinoxaline Monomers** can be synthesized with or without configurational isomers.



tion of crystallinity into the backbone of a polymer enhances its mechanical properties and its resistance to solvents. The new process can synthesize configurationally ordered semicrystalline PPQ's.

In tests of the new process, the synthesis of the PPQ's involved the use of two different types of bisphenol quinoxaline monomers; those with and those without configurational isomers. The PPQ's prepared from monomers with configurational isomers had essentially the same physical and mechanical properties as those of PPQ's prepared via the conventional process. Some PPQ's prepared from monomers without configurational isomers were semicrystalline, as evidenced by differential scanning calorimetry and wide-angle x-ray diffraction.

The top part of Figure 1 illustrates the synthesis of bisphenol quinoxaline monomers that have configurational isomers. The symbol Ar represents a radical of 1,2,4,5-tetrasubstituted benzene, 3,3',4,4'-tetrasubstituted benzene, biphenyl, diphenylether, diphenylmethane, diphenylketone, diphenylsulfone, diphenylthioether, or any appropriate bis(ortho diamine), or a mixture of any of these compounds. The bottom part of Figure 1 illustrates the synthesis of the monomers without configurational isomers. The symbol Z represents H, Cl, Br, OCH_3, CH_3, CH_2CH_3, phenyl, or other groups. In both sequences, the catenation of the hydroxy groups can be meta meta, para para, meta para, or mixtures thereof.

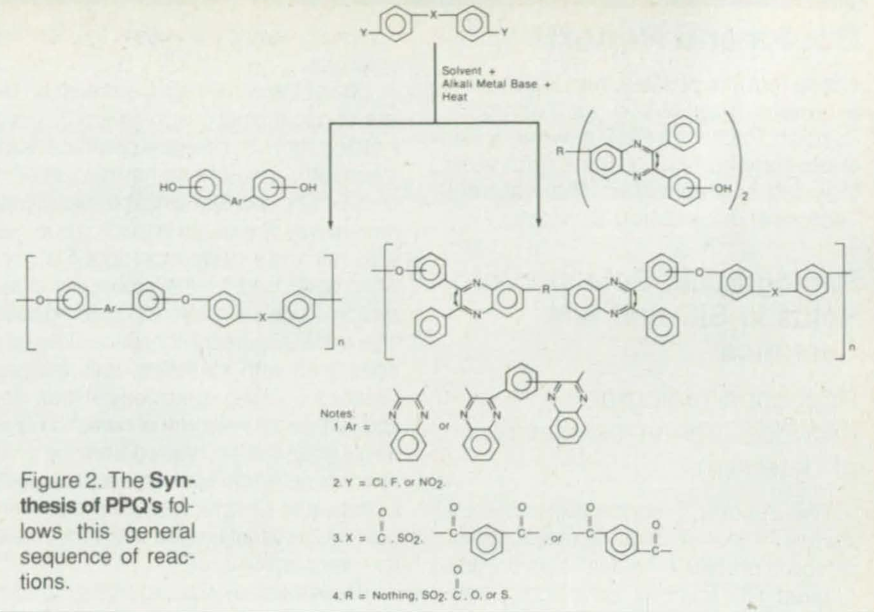


Figure 2. The **Synthesis of PPQ's** follows this general sequence of reactions.

Figure 2 illustrates the synthesis of a PPQ. The reactions are carried out in a polar aprotic solvent, possibly N,N-dimethylacetamide, sulfolane, N-methylpryrrolidone, or diphenylsulfone, using an alkali metal base, at an elevated temperature, under a nitrogen atmosphere.

This work was done by Paul M. Hergenrother and John W. Connell of **Langley Research Center**. *For further information, Circle 27 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-13988.

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.

Radiographic Detection of Voids in SiC and SiN Ceramics

Projection radiography provides greater sensitivity of detection.

Two reports describe experimental studies of the efficacy of radiographic detection of voids in "green" (unfired) and sintered SiC and SiN ceramics. These studies were motivated by the need for a nondestructive technique to detect flaws that limit the strengths of sintered structural ceramic components.

In the experiments, solid precursors of surface and internal voids were introduced artificially by seeding green specimens of the ceramics with styrene divinyl benzene microspheres. The specimens were compacted and sintered to form the ceramics. The high sintering temperatures (above 2,100 °C) caused the microspheres to decompose, leaving the voids in the resulting ceramics.

One of the studies concentrated on the use of microfocus (magnifying projection) x-radiography to detect subsurface voids made with microspheres having diameters of 200, 321, and 528 μm. The microfocus system was operated with photon energies ≤ 20 keV and a 10-μm focal spot. Statistics were developed for the probability of detection of voids in green and sintered specimens at a 95-percent confidence level and compared with statistics obtained previously for similar specimens. It was also shown that the reliability of detection of internal voids can be inferred from the probability-of-detection curves of surface voids in the same ceramic, provided that there are no local variations in density and chemical composition.

The other study was undertaken to compare the reliabilities of the microfocus and the conventional (nonmagnifying or contact) radiography in the detection of voids. In this study, the specimens were seeded with microspheres having diameters of 50, 80, and 115 μm. The conventional x-ray system, with a tungsten target and a 400-μm focal spot, was operated at 25 to 75 kV and a beam current of 5 to 8 mA. The microfocus system, with a molybdenum target, was operated at 30 to 60 kV with a beam current of 0.25 to 0.32 mA.

The sensitivity of detection of voids by microfocus radiography at a 90-percent probability of detection and a 95-percent confidence level was found to be 1.5 percent of the thickness of the specimen in both ceramics. The corresponding figure for conventional radiography was found to be 2.5 percent of the thickness of the specimen. Thus, it appears that microfocus (projection) radiography is preferable to conventional (contact) radiography when increased sensitivity is required and the additional time and effort necessary to set up the microfocus apparatus can be tolerated.

This work was done by George Y. Baaklini, James D. Kiser, and Don J. Roth of **Lewis Research Center**. *Further information may be found in*

NASA TM-86945 [N85-21674], "Radiographic Detectability Limits for Seeded Voids in Sintered Silicon Carbide and Silicon Nitride," and

NASA TM-87164 [N86-13749], "Probability of Detection of Internal Voids in Structural Ceramics Using Microfocus Radiography."

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14881

Computer Programs

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

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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.

Physical Sciences

Global Reference Atmosphere Model-1988

A composite empirical mathematical model gives pressures, densities, temperatures, and winds.

The Four-D Global Reference Atmosphere computer program (GRAM) was developed from an empirical mathematical model of the atmosphere that generates values for pressure, density, temperature, and winds from the surface level to orbital altitudes. This program can generate altitude profiles of parameters of the atmosphere along any simulated trajectory through the atmosphere. The program was developed from design applications in the Space Shuttle program; for example, the simulation of reentry trajectories for the external tanks. Other potential applications include studies of global circulation and diffusion and the generation of profiles for comparison with results of other atmospheric-measurement techniques such as satellite-measured temperature profiles and wind profiles from infrasonic measurements.

GRAM-88 is the latest version of the GRAM software. The GRAM-88 software contains a number of changes that have improved the model statistics; in particular, the small-scale-density-perturbation statistics. It also corrected a low latitude grid problem as well as the SCIDAT data base. Furthermore, GRAM-88 now uses the 1976 U.S. Standard Atmosphere as a comparison standard rather than the US62 used in other versions.

The program is based on an amalgamation of two empirical mathematical models for the low (27 km) and the high (90 km) atmosphere, with a newly developed latitude-and longitude-dependent model for the middle atmosphere. The Jacchia (1970) model simulates the high atmospheric region above 115 km. The Jacchia sections of the program are in separate subroutines so that other thermospheric exospheric models could easily be adapted if required for special applications. The improved code eliminated the calculation of geostrophic winds above 125 km altitude from the model. The region of the atmosphere between 30 km and 90 km is simulated by a latitude- and longitude-dependent empirically modified version of the latitude-dependent empirical model of Groves (1971). A fairing technique between 90 km and 115 km accomplished a smooth transition between the modified Groves values and the Jacchia values.

Below 25 km, the parameters of the atmosphere are computed by the four-dimensional worldwide model of the atmosphere devised by Spiegler and Fowler (1972). This set of data is not included. GRAM-88 incorporates a hydrostatic/gas-law check in the altitude range of 0 to 30 km to flag and change any bad data points. Between 5 km and 30 km, an interpolation scheme is used between the results of the four-dimensional model and the modified Groves values. The output parameters consist of components for (1) latitude-, longitude-, and altitude-dependent monthly and annual means; (2) quasi-biennial oscillations (QBO); and (3) random perturbations to simulate partially the variability due to synoptic, diurnal, planetary-wave, and gravity-wave variations. Quasi-biennial and random-variation perturbations are computed from parameters determined by various empirical studies and are added to the monthly mean values.

The GRAM-88 program is intended for batch execution on the IBM 3084 computer. It is written in STANDARD FORTRAN 77 under the MVS/XA operating system. The IBM DISPLA graphics routines are necessary for graphical output. The program was developed in 1988.

This program was written by D. L. Johnson and Rhonda Blocker of **Marshall Space Flight Center** *and C. G. Justus of Georgia Institute of Technology. For further information, Circle 161 on the TSP Request Card.*

MFS-28397

Mechanics

Program Analyzes Errors in STAGS

This program assists in scrutiny of the output of the STAGS finite-element program for plates.

Estimation of the accuracies of stresses and deflections computed by the finite-element method is a common problem that arises with each new application of the method. The EAC computer program is designed for analysis of the errors in the results of the STAGS computer program (COSMIC Program HQN-10967), which is a finite-element code, for a shell unit consisting of a rectangular orthotropic plate. EAC requires input data for the geometry of the plate, the properties of the material, and a set of boundary conditions. These input data come from the STAGS code. (The specific link between the input and output data from STAGS and the input data for EAC is POSTP, the postprocessor program in the STAGS processors.) EAC computes a continuous solution from the discrete results of STAGS in order to estimate the error of the results of STAGS.

Currently, EAC can handle only one plate unit, at one load step of the execution of STAGS, using the noncorotation option. The finite-element-method solution from STAGS is assumed to be a valid zeroth approximation for starting the iterative solution of the shell equations. This solution forms the first step of execution of EAC, during the first phase of which the resulting general solution in the form of Fourier coefficients and constants of integration (generalized coordinates) are written to a temporary file. During the second phase, these data are read and are used to generate results at specified points on the plate, or over a grid defined by the user.

An option in EAC enables the user to reuse the data from this file saved from a previous execution of EAC to generate output data over a different output grid or at selected points on the plate unit. The results are written to two files. One file is used as the input data file for a contour-plotting postprocessor for EAC. The generalized coordinates allow for the computation of a continuous solution for the plate equations. The continuous solution has the obvious advantage that resultant stresses and deflections can be computed at any point on the plate and not only at grid points in STAGS. However, the main advantage of the continuous solution is that a measure of its error can be computed. The output of the code includes this measure of the error in the continuous solution, which is also an indirect measure of the error in the finite-element results in STAGS.

EAC has been implemented on a DEC MICROVAX II computer under VMS 4.7. It is written in FORTRAN 77 and has a central-memory requirement of 1369 kbytes. EAC was developed in 1988.

This program was written by Gaylen A. Thurston and Nancy Jane C. Bains of **Langley Research Center** *and Rajaram Sistla of Analytical Services & Materials, Inc. For further information, Circle 103 on the TSP Request Card.*
LAR-14063

Mathematics and Information Sciences

Programs for Modeling Fault-Tolerant Computing Systems

One program uses a Pade approximation; the other uses a Taylor-series solution technique.

The Pade Approximation with Scaling, (PAWS) and Scaling Taylor Exponential Matrix (STEM) computer programs are software tools for design and validation. These programs provide a flexible, user-friendly, language-based interface for the input of Markov mathematical models that describe the behaviors of fault-tolerant computer systems. Markov models can include both the recovery from faults via reconfiguration and the behaviors of such systems when faults occur. PAWS and STEM produce exact solutions of the probability of system failure and provide a conservative estimate of the number of significant digits in the solution.

The calculation of the probability of entering a death state of a Markov model, i.e., the state that represents the failure of a system, requires the solution of a set of coupled differential equations. Because of the large disparity between the rates of arrivals of faults and recoveries of the system, models of fault-tolerant architectures inevitably lead to numerically stiff differential equations. PAWS uses a Pade approximation as a solution technique; STEM uses a Taylor-series solution technique. Both programs can solve numerically stiff models. PAWS and STEM possess complementary properties with regard to their input space; and additional strength of these programs is that they accept input compatible to the Semi-Markov Unreliability Range Evaluator (SURE) program (COSMIC program number LAR-13789).

The mathematical approach chosen to solve a reliability problem may vary with the size and nature of the problem. Although different solution techniques are used in different programs, it is possible to have a common input language.

The Systems Validation Methods group at NASA Langley Research Center has created a set of programs that form the basis for a "reliability analysis" workstation. The components are as follows: SURE itself, the PAWS/STEM reliability-analysis programs based upon the SURE input language, and the Abstract Semi-Markov Specification Interface to SURE Tool (ASSIST) program (COSMIC program number LAR-14193). ASSIST automatically generates Markov/semi-Markov model descriptions in the SURE input language from an abstract language.

PAWS and STEM are written in PASCAL and FORTRAN for interactive execution and have been implemented on a DEC VAX computer operating under VMS 4.7 with a virtual-memory requirement of approximately 292K of 8-bit bytes. For graphical output, the graphics library TEMPLATE is required. However, both PAWS and STEM can be used without graphical input. PAWS and STEM were developed in 1988.

This program was written by Ricky W. Butler of **Langley Research Center**. *For further information, Circle 86 on the TSP Request Card.*
LAR-14165

Program Generates Images of Solid Surfaces

Various shapes can be constructed and viewed from several perspectives.

The Solid Surface Modeler (SSM) computer program generates three-dimensional computer models of solid surfaces for use in visual analysis and animation. In addition to such basic software tools as Box and Cylinder, SSM provides advanced functions, including Constructive Solid Geometry, Skin Construction, Tube Construction, Material Property Editing, and Texture Map Tools. SSM allows a user to change such attributes as color, reflectivity, smoothing, and position of the object easily. The model can then be saved in ASCII or binary format for use in another program or saved in edit format for reloading in SSM.

When fully installed, SSM is menu-driven and can be run from any directory. The user can elect to use a mouse or a keyboard interface. Viewing choices include wire frame, solid surface, one-window orthographic, or four-window orthographic and perspective.

SSM was written in standard C with Silicon Graphic's Iris Graphics Library calls and AT&T PicLib calls. The program can be run with a minimum of 8 MB of random-access memory although 16 MB are recommended. SSM source and executable codes require a minimum memory of 3,346K bytes. The program is available for the Silicon Graphics IRIS workstation running version 3.1 of IRIX, and a Sun workstation with AT&T PXM964 running 4.2 bsd. Documentation is included on the tape. SSM was developed in 1989.

This program was written by Sharon P. Goza of **Johnson Space Center** *and Bradley Bell and David Shores of Barrios Technology. For further information, Circle 20 on the TSP Request Card.*
MSC-21630/49

Mechanics

Hardware, Techniques, and Processes

Computer Programs

Improved Computation of Dynamic Stresses

The cost of computation is reduced.

Marshall Space Flight Center, Alabama

A method that combines a modified computational procedure with a preprocessing and a postprocessing program yields additional data and reduces the time and cost of using the DYNRE1 module of the STARDYNE computer program to compute distributions of stresses in machinery under dynamic loads. The development of the method was motivated by some of the limitations of DYNRE1; namely, (1) it can compute no more than 500 components of stress in one run, (2) it does not compute von Mises stresses and (3) it does not compute frequencies.

Heretofore, because of limitation 1, it was necessary to make several relatively expensive DYNRE1 runs for each operating speed of the machine in question when the number of components of stress to be computed was large. With the modified procedure and the additional programs, only one DYNRE1 run is needed for each operating speed. The postprocessing program, which costs much less to execute, computes the additional components of stress. The new method also overcomes limitations 2 and 3 by computing von Mises stresses and the frequencies of the components of stress.

The first step of the procedure is to use the preprocessing program (called "PROGS3") to modify the dynamic-characteristics file (called "TAPE4") in the STARDYNE code. PROGS3 adds dummy nodes and the consequent dummy degrees of freedom and dummy modal displacements and stores the results in a new file (called "TAPE44").

In the second step of the procedure, one uses TAPE44 from the first step as input to DYNRE1 and runs DYNRE1 to compute the displacement history for each dummy node and degree of freedom. These displacements represent the contribution of each mode at each time point of the computation. They are used as input for the postprocessing program.

In the third step, the postprocessing program (called "PROGS4") performs matrix multiplication of the dummy displacement histories by the appropriate modal stresses to obtain stress histories. From the average number of zero crossings of each component of stress per unit time, PROGS4 computes its frequency. From the components of stress in any element at a given time, PROGS4 computes the von Mises stress history of that element.

This work was done by Tarun K. Ghosh of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information, Circle 7 on the TSP Request Card. MFS-29745*

Measuring Adhesion and Friction Forces

The Cavendish balance is adapted to a new purpose.

Lewis Research Center, Cleveland, Ohio

An apparatus has been developed which measures the forces of adhesion and friction between specimens of solid materials in a vacuum at temperatures from ambient to 900 °C. It is intended primarily for use in studying the adhesion properties of ceramics and metals, including silicon carbide, aluminum oxide, and iron-base amorphous alloys.

The apparatus is mounted in an ultrahigh-vacuum system that also contains equipment for x-ray photoelectron spectroscopy. The portion of the apparatus that measures adhesion is based on the principle of the Cavendish balance. A pin specimen is mounted at one end of an arm that is suspended on a vertical torsion wire (see Figure 1). The other end of the arm holds the magnetic core of a linear variable-differential transformer that is used to measure the angular deflection of the arm.

A flat specimen is pushed slowly against the pin specimen until it turns the beam and twists the torsion wire through a small angle. The flat specimen is then pulled back slowly until it separates from the pin specimen. The difference between the angular positions at which the specimens make and break contact gives a measure of the force of adhesion between them. If, for example, there is no adhesion, then the specimens make and break contact at the same position. If there is adhesion, then the receding flat specimen pulls the pin specimen out beyond the point of initial contact.

Inasmuch as the pulloff (adhesion) force is measured in terms of the torsion in the wire, the force can be calibrated in three ways: (1) by calculation from the length and diameter of the wire; (2) by calculation with measured values of natural periods of har-

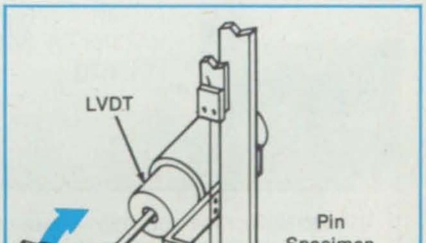

Figure 1. A **Modified Cavendish Balance** instrumented with a linear variable-differential transformer (LVDT) is used to measure adhesion between pin and flat specimens.

monic motions of the arm when the arm is freely oscillating; and (3) by direct comparison of microforce to standard weight when the arm and torsion wire are held horizontally. The values of pulloff force determined by all three methods of calibration have been found to be nearly the same.

For the measurement of friction force, a pin specimen is mounted on the end of a beam that is, in turn, mounted on a micrometer-type manipulator. The beam includes two mutually perpendicular flats instrumented with strain gauges (see Figure 2). A flat specimen is mounted on a vertical beam on another micrometer-type manipulator. The flat and pin specimens are pressed together, and the manipulators used to slide them horizontally or vertically against each other. The load (pressing) force and the sliding (frictional) force are measured by the strain gauges.

This work was done by Kazuhisa Miyoshi of **Lewis Research Center**. *Further information may be found in*

NASA TM-101959 [N89-20253], "Design, Development, and Applications of Novel Techniques for Studying Surface Mechanical Properties;"

NASA TM-100799 [N88-20454], "Development of a Torsion Balance for Adhesion Measurements;"

NASA TM-101377 [N89-11913], "Adhesion, Friction, and Wear of Plasma-Deposited Thin Silicon Nitride Films at Temperatures to 700°C;" and

NASA TP-2449 [N85-21359], "Humidity Effects on Adhesion of Nickel-Zinc Ferrite in Elastic Contact With Magnetic Tape and Itself."

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LEW-14903

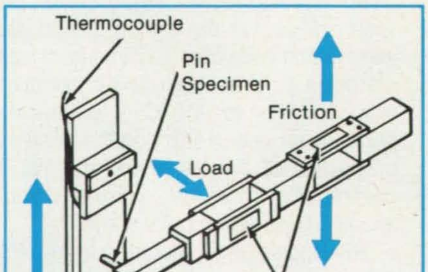

Figure 2. **Strain Gauges Measure Pressing and Sliding Forces** as pin and flat specimens are rubbed against each other.

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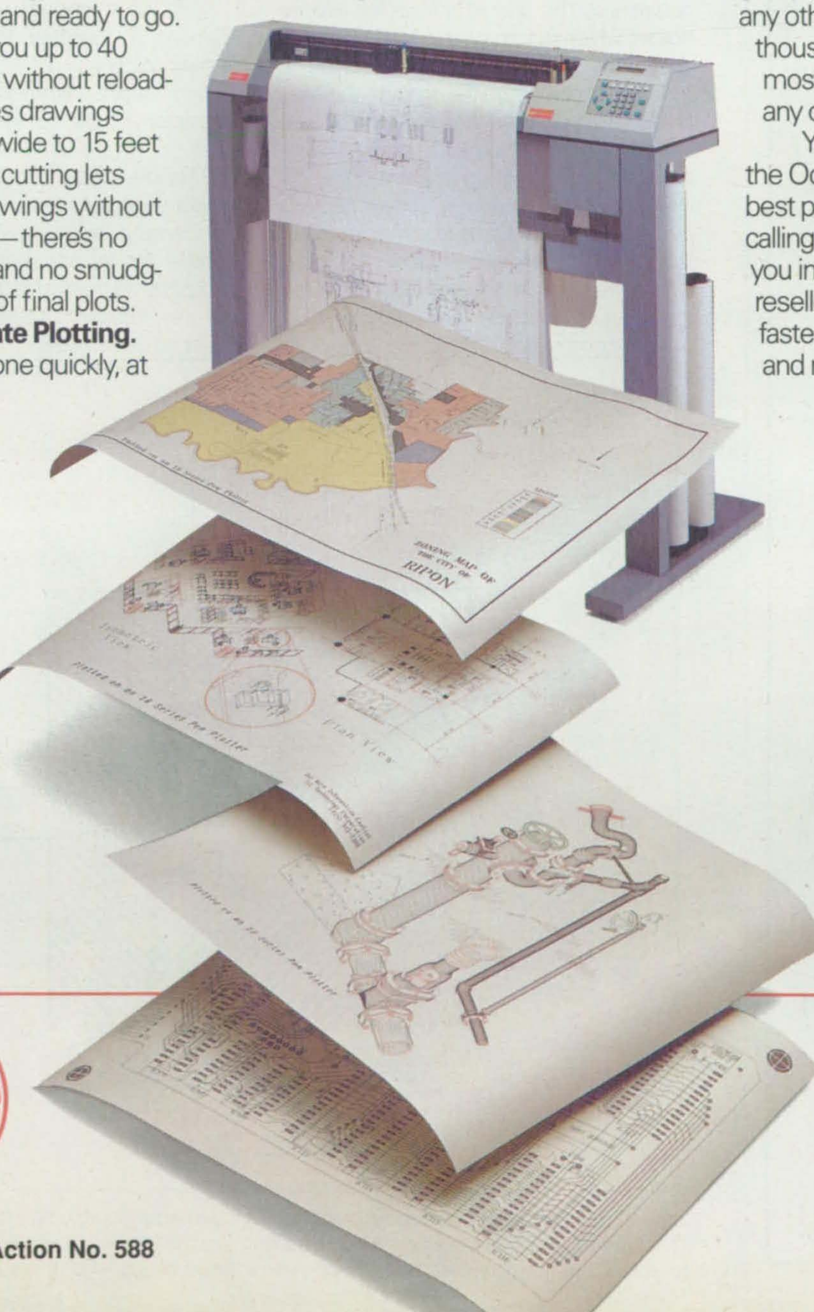

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Apparatus for Tests of Percussion Primers

Tests are conducted under realistic conditions.

Langley Research Center, Hampton, Virginia

A test apparatus and method have been developed to measure the ignition capability of percussion primers. Since the 1815 invention of percussion primers, no test method has been generally accepted for measuring their output performance. Consequently, no specification, military or commercial, contains any requirements for this output.

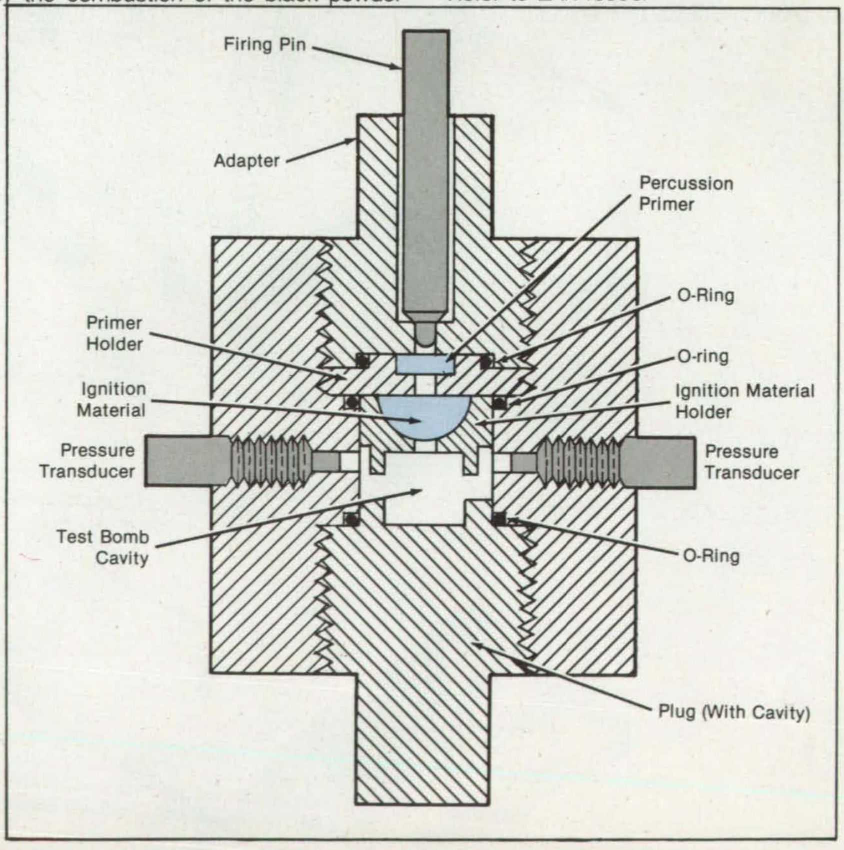
The test method fills this technology void by providing an approach to quantify the ability of primers to ignite a small quantity of ignition material. This method closely simulates actual conditions and interfaces encountered in such applications as in munitions and rocket motors.

The figure, showing a cross section of the test chamber (bomb) illustrates the test conditions. The primer is installed into its holder, which in turn is held in place by an adapter. A 200-mg charge of FFG black powder is placed in the ignition-material holder, which is then inserted into the test cavity and held in place with a plug. A weight dropped onto the firing pin drives the pin into and ignites the primer. The primer output (heat, gas, light, and burning particles) is directed onto and ignites the black powder within the small volume of the cup in the ignition-material holder. The gas generated by the combustion of the black powder vents through six small holes from the cup into the test bomb cavity, where the resulting pressure is measured by the pressure transducers.

The firing-pin impact and pressure traces, recorded by a high-response tape deck, are analyzed to determine the function times and characterize the output performances of different types of percussion primers. The rate at which the flame spreads through, and combustion occurs in, the black powder is directly relatable to the type of primer. A "hot" output of high-pressure gases and burning particles produces a much faster burning of the black powder than does a "soft" output of low-pressure gases and no burning particles.

This work was done by Laurence J. Bement of **Langley Research Center** *James W. Bailey of PRC, and Morry L. Schimmel of Schimmel Co. For further information, Circle 98 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-13996.



The **Ignitability-Testing Apparatus** is a small bomb instrumented with pressure transducers. The sizes, shapes, and positions of bomb components and materials under test can be selected to obtain quantitative data on ignition over a range of realistic operating conditions.

Machinery

Hardware, Techniques, and Processes

Model of Bearing With Hydrostatic Damper

The model accurately represents the nonlinear aspects of the dynamics.

Marshall Space Flight Center, Alabama

An improved mathematical model of the rotational and vibrational dynamics of a bearing package in a turbopump incorporates the effects of a hydrostatic damper. This model is part of a larger finite-element model that represents the rotational and vibrational dynamics of the rotor and housing of the pump. The previous mathematical model did not contain enough detail of the bearing package to define the effects of the hydrostatic damper explicitly. The improved model includes representations of the deadband and the nonlinear stiffness and damping of the ball bearings, the nonlinear stiffness and damping of the hydrostatic film, and the stiffness of the bearing support.

The hydrostatic damper is a stiff hydrostatic film that forms in the ~0.001-in. (~0.025-mm) radial gap between the outer surface of the cartridge and the inner backup support that holds the cartridge. There is a 0.0005-in. (0.013-mm) radial deadband between the outer races of the ball bearings and the mating inner cylindrical surfaces of the cartridge (see Figure 1). In normal operation, fixed loads on the rotor exceed the dynamic loads, and the bearing package operates fully engaged at one side of the deadband clearance.

The mathematical model of the bearing package incorporates nonlinearity through piecewise-linear representations of the coefficients of stiffness (K) and damping (C) as functions of deflections of the various components. For each segment of the piecewise-linear representation of the overall equivalent stiffness ($K_{equivalent}$), the stiffnesses of the ball bearings, hydrostatic film, and backup support are combined as though these components were springs in series (see Figure 2). The relative deflections of components of the bearing package at which changes in stiffness occur are then defined.

The amount of radial deflection between the rotor and the housing is related to the deflection of the damper via the bottom equation in Figure 2. The deflection required to "bottom out" the hydrostatic damper can be determined from this equation. For deflections greater than this value, the piecewise-linear curve of equivalent stiffness is then defined by combining only the stiffnesses of the ball bearings and backup support (that is, by treating the stiffness of the hydrostatic damper as though it were infinite).

The improved mathematical model enables the incorporation of the effects of the hydrostatic damper into the overall rotordynamic mathematical model without the addition of a mathematical submodel of a major substructure. The improved model was used in an analysis that led to a proposed design in which the damping of rotor vibrations was increased significantly over that of the current design. In the proposed design, the dynamic loads on the bearing would be reduced by as much as 70 percent and the worst-case stability-threshold speed would be increased from 38,200 rpm to more than 50,000 rpm.

This work was done by David G. Goggin of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information, Circle 3 on the TSP Request Card.*
MFS-29654

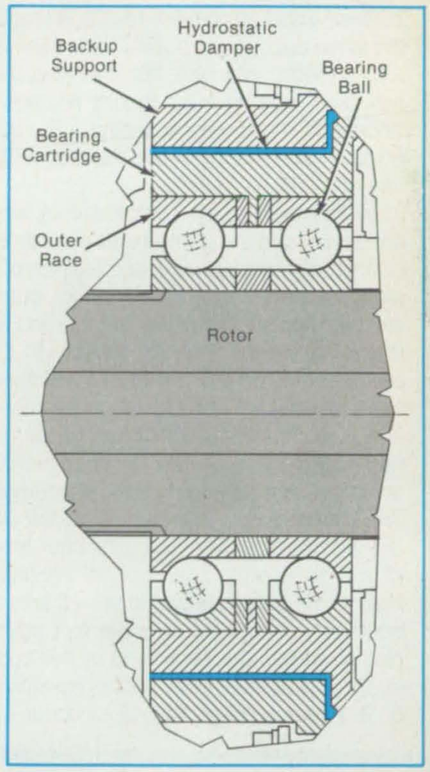


Figure 1. The **Bearing Package**, shown here in simplified form, supports the rotor shaft.

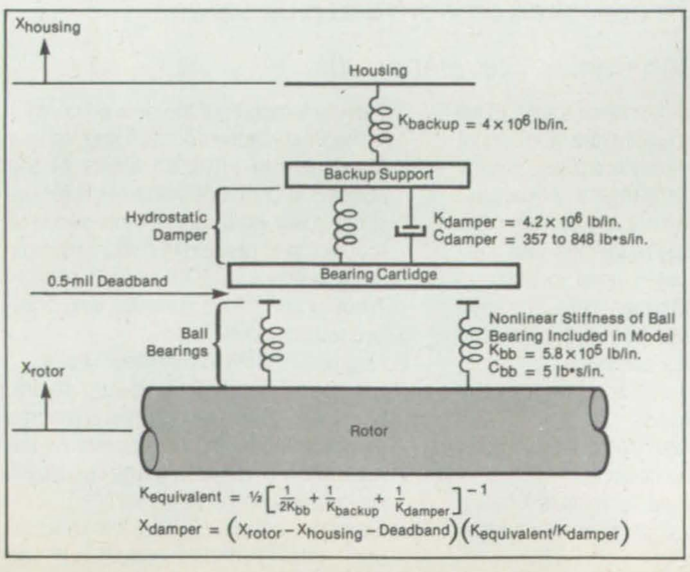


Figure 2. The **Mathematical Model of the Bearing Package** represents the stiffness, damping, and deadband characteristics of the bearing and hydrostatic damper.

Fabrication Technology

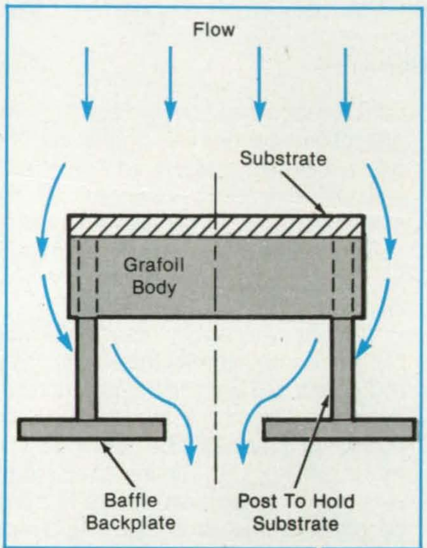
Preventing Vapor Deposition of the Backs of Substrates

This technique has been applied in the selective deposition of silicon on silicon carbide.

Langley Research Center, Hampton, Virginia

A technique that prevents back-side deposition on substrates in an impinging chemical-vapor deposition (CVD) system has been developed. If not prevented, back-side deposition often results in cracking of the deposit and makes replication in a CVD reactor difficult to achieve. Also, the new technique does not require any post-deposition machining to separate the deposited substrate from the deposition fixture.

In this technique, a substrate of any shape and size is mounted on a number of pillars made of graphite or some other material compatible with the deposition process (see figure). The pillars are bonded to the substrate as close as possible to its periphery. A hollow structure, which is open on one side and closed on the other and is compatible with the substrate, is fabricated from Grafoil (or equivalent), using graphite cement to bond it together. The structure is then mounted on the pillars with the open side facing the back side of the substrate. This side is pressed against the substrate and is sealed with a bonding agent. This arrangement completely covers the back side of the substrate and prevents any vapor deposition on it. However, deposition does occur on the Grafoil body.



The **Back Side of the Substrate Is Covered Completely**, allowing vapor deposition only on the Grafoil body.

Typically, this approach is used when a SiC substrate is being coated with Si. Since Grafoil is quite flexible, the Si-coated Grafoil is readily broken into small pieces for removal from the substrate by use of a piercing tool and a pair of pliers. Because the substrate is perpendicular to the Grafoil body and the flexible Grafoil deforms as stresses develop (due to growth of material and mismatch of thermal expansion), the cracks do not propagate into the substrate.

This technique is inexpensive, does not require any machining to remove excess material, and is easy to use. It has been used successfully in the selective deposition of SiC and Si in a CVD reactor.

This work was done by Jitendra S. Goela, Roy Jaworski, and Raymond L. Taylor of Morton Thiokol, Inc./CVD Inc. for **Langley Research Center**. *No further documentation is available.*

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

Gerald K. White, Esq.
Director, Patents and Trademarks
Morton Thiokol, Inc.
110 North Wacker Drive
Chicago, IL 60606-1560

Refer to LAR-14071, volume and number of this NASA Tech Briefs *issue, and the page number.*

Plasma Spraying Reclaims Compressor Housings

Metal coats are deposited on worn and pitted areas.

Lewis Research Center, Cleveland, Ohio

Plasma spraying has been found to be an effective technique for the addition of metal to out-of-tolerance magnesium-alloy turbine-engine compressor housings. Without the plasma-spraying process, the housings could not be reclaimed. The plasma-spraying process is used to build up material in worn and pitted areas. The newly applied material is then remachined to the specified surface contours.

The reclamation procedure can be summarized as follows:

1. Disassemble, clean, remove paint from, and degrease the housing.
2. Place the housing on a suitable locating fixture on a vertical turret lathe or equivalent machine tool.
3. Place a template of the desired contour in the trace section of the turret lathe.
4. Machine the affected areas of the housing to contours that provide for the subsequent plasma spraying and final machining to result in minimum plasma-spray buildups of 0.017 in. (0.43 mm).
5. Treat all machined surfaces with chromic acid solution.
6. Degrease in trichloroethylene vapor.
7. Set the plasma-spraying gun to the specified current, voltage, gas pressures and other operating parameters for the application of a Ni-5Al (parts by weight) composite bond coat.
8. Blast the affected areas with angular steel grit. Remove residual grit and foreign particles with clean, dry air.
9. Apply the specified tape or brush-on maskant to prevent deposition on the areas not to be built up.
10. Position the plasma-spray gun 5 in. (12.7 cm) from and aimed perpendicularly at the surface to be treated. Load the powder feeder with the powdered-metal ingredients of the bond coat.
11. Plasma-spray the bond coat at a rate of 0.0004 to 0.0006 in. (0.01 to 0.015 mm) per pass to obtain a buildup of 0.004 to 0.006 in. (0.1 to 0.15 mm).
12. Set the gun to the specified operating parameters for the application of a Al-12 Si alloy (parts by weight) overcoat. Load the powder feeder with the powdered-metal ingredients of this coat.
13. Plasma-spray the overcoat at 0.004 to 0.006 in. (0.1 to 0.15 mm) per pass until

the final thickness is 0.015 to 0.020 in. (0.38 to 0.51 mm) greater than the specified final thickness.

14. Machine the built-up areas to the specified final dimensions.
15. Treat all reworked aluminum and magnesium surfaces with corrosion-prevention solutions.

To assess the reclamation process, tensile-strength tests were conducted on specimens that had been plasma-sprayed to coating thicknesses of 0.020 to 0.100 in. (0.51 to 2.54 mm). The specimens were also thermally cycled. The results showed that thermal cycling did not reduce tensile strength. Furthermore, compressor housings were plasma-sprayed and thermally cycled in 150-h engine tests and 200-h flight tests, during which the turbine engine was operated at a variety of loads, speeds, and torques. The plasma-sprayed coats showed no evidence of degradation or delamination from the compressor housings.

This work was done by George W. Leissler of Sverdrup Technology, Inc., and John S. Yuhas of the U.S. Army Aviation Research and Technology Activity (AVSCOM) for **Lewis Research Center**. *Further information may be found in NASA TM-101310 [N89-10156], "T55-L-712 Turbine Engine Compressor Housing Refurbishment-Plasma Spray Project."*

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

LEW-14899

Eliminating Unbonded Edges in Explosive Bonding

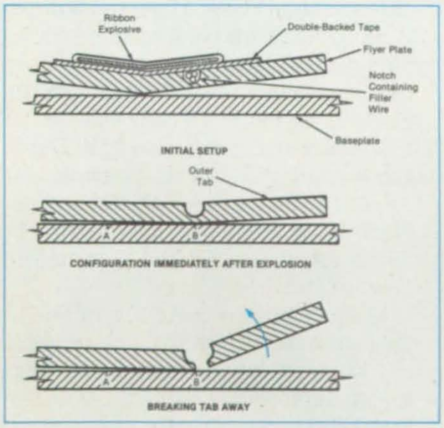
A notch in the flyer plate eases removal of unbonded material.

Langley Research Center, Hampton, Virginia

An explosive-bonding technique eliminates the sharp unbonded notch that normally occurs between the flyer plate and baseplate. The new technique makes it possible to simply break away the unbonded outer extremity of the flyer plate; it is no longer necessary to grind away the unbonded edge to prevent the collection of corrosive contaminants in edge voids.

In the previous standard explosive-bonding method, the limit of the bonded area is not well defined; in repeated bonding cycles in the same setup, the bonded area varies, and its edge cannot be predicted precisely. To be sure that the bonded area extends at least to the prescribed limit, the flyer plate must overlap the baseplate well beyond that limit. Then, after bonding, nondestructive ultrasonic inspection is used to determine where the limit of the bonded area actually lies, and the unbonded edge of the flyer plate is ground away to that point.

In the new method, a notch is cut in the flyer plate and filled with a material that has properties similar to those of the flyer plate (see figure). The filler is held in place by an adhesive. As is usual in Langley Research Center's explosive seam-welding process, the flyer plate is prebent to give it the optimum high-velocity collision angle. Double-backed tape holds the ribbon explosive in place, centered over the bend line.



The **Bent, Notched Flyer Plate** is set up for explosive bonding (top). After detonation, thenotch is empty, and the flyer plate is bonded to the baseplate between points A and B (center). The outer part ofthe flyer plate is bent like a lever to separate it from the bonded part (bottom). The ribbon explosive (and the bond) extend perpendicularly to the plane of the paper.

When the explosion in the ribbon is detonated, it generates a pressure wave that drives the flyer plate against the baseplate so that the plates bond between edges A and B. The force of the explosion fractures the adhesive and jettisons the filler material, leaving an empty notch. The loose edge of the flyer plate can now be bent so that it breaks at the base of the notch, which coincides with the limit of the bonded area. A clean, void-free edge is thus formed.

The method has been used to bond tantalum plates 0.064 in. (1.63 mm) thick. Three strands of solid lead solder wire were used as the filler. The plate was bent to make an angle of 2.5° with the baseplate on both sides of the vertex. The notch was cut by a hemispherical end mill 0.060 in. (1.52 mm) in diameter, to a depth of 0.040 in. (1.02 mm).

Other plate materials can be similarly

joined by optimizing the bonding parameters: location, shape, and depth of the notch; the filler material; bend angle and thickness of the flyer plate; and the amount and placement of explosive. For simplification, the flyer plate would not be bent, and masking tape would be applied to separate the plates outside of the notch. The explosive would be initiated as before, and the outer tab of the flyer plate would be bent as before to break it off at the notch. The method is not limited to flat surfaces.

This work was done by Laurence J. Bement of **Langley Research Center** *and Anne C. Kushnick of PRC. For further information, Circle 2 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-14096.

Making Ultrathin Solar Cells

Thin, efficient cells are fabricated without breakage or special handling.

NASA's Jet Propulsion Laboratory, Pasadena, California

A process produces extremely thin silicon solar cells — only 50 μm or less in thickness. Conventional solar cells are 300 μm or more in thickness. Because the new cells are so thin, electrons and holes have less opportunity to recombine before they are collected at the cell surfaces. Efficiency is therefore higher than in conventional solar cells. Moreover, because the volume of silicon is small, there is less chance of radiation damage in the new cells.

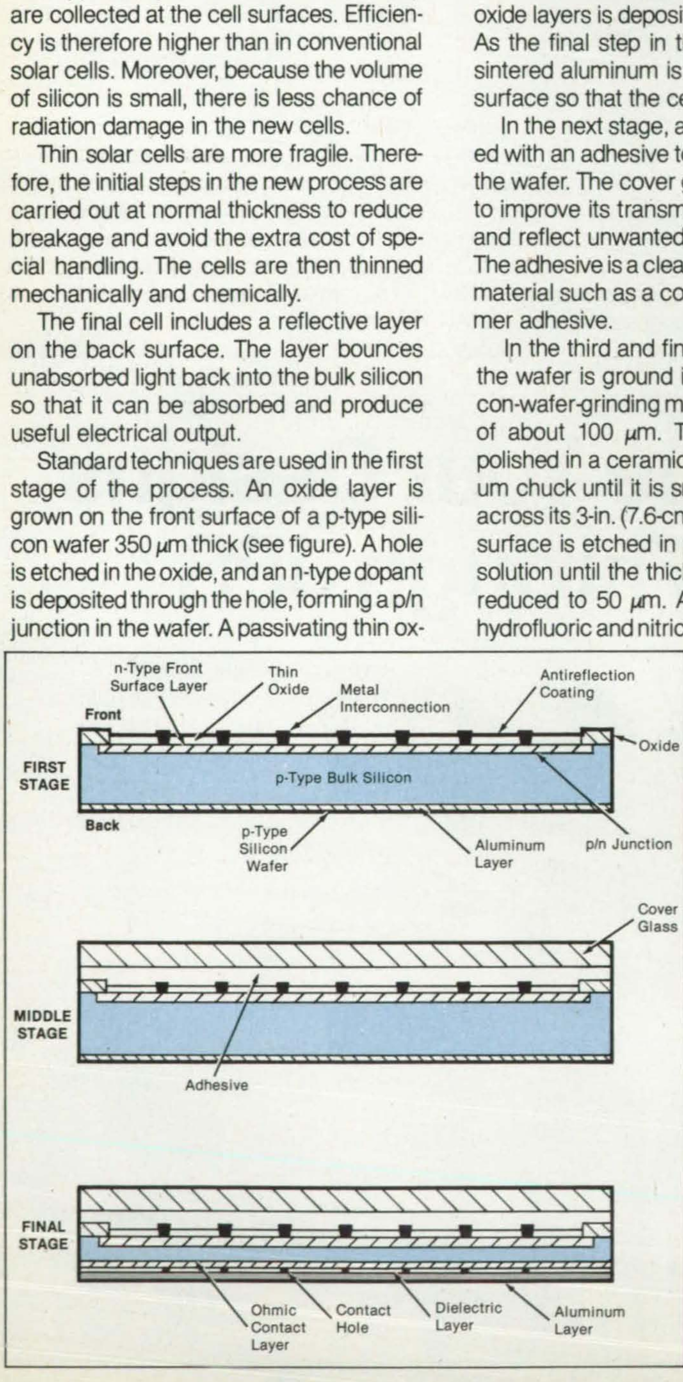
Thin solar cells are more fragile. Therefore, the initial steps in the new process are carried out at normal thickness to reduce breakage and avoid the extra cost of special handling. The cells are then thinned mechanically and chemically.

The final cell includes a reflective layer on the back surface. The layer bounces unabsorbed light back into the bulk silicon so that it can be absorbed and produce useful electrical output.

Standard techniques are used in the first stage of the process. An oxide layer is grown on the front surface of a p-type silicon wafer 350 μm thick (see figure). A hole is etched in the oxide, and an n-type dopant is deposited through the hole, forming a p/n junction in the wafer. A passivating thin oxide layer is grown over the n-type layer. Contact holes are etched in the thin oxide. Metal is deposited over the wafer, filling the holes. The metal is etched into a comb-shaped interconnection grid. An antireflection coat of tantalum oxide and aluminum oxide layers is deposited on the thin oxide. As the final step in this stage, a layer of sintered aluminum is formed on the back surface so that the cell can be tested.

In the next stage, a cover glass is bonded with an adhesive to the front surface of the wafer. The cover glass may be coated to improve its transmission of visible light and reflect unwanted ultraviolet radiation. The adhesive is a clear, ultraviolet-resistant material such as a commercial fluoropolymer adhesive.

In the third and final stage, the back of the wafer is ground in a conventional silicon-wafer-grinding machine to a thickness of about 100 μm. The back surface is polished in a ceramic distortion-free vacuum chuck until it is smooth within ±3 μm across its 3-in. (7.6-cm) diameter. The back surface is etched in potassium hydroxide solution until the thickness of the wafer is reduced to 50 μm. A final etch in mixed hydrofluoric and nitric acids removes 1,000 to 2,000 Å from the back, producing a clean surface.



A Thin Solar Cell is Prepared in three stages. The principal innovations—applying a cover glass and thinning the wafer on its cover-glass support—appear in the middle and final.

A highly doped ohmic-contact layer is formed on the back by the following steps: First, a layer of amorphous silicon containing 20 to 50 weight percent of boron dopant is deposited on the back to a thickness of 50 to 500 Å. Then the layer is melted with a pulsed laser beam so that it diffuses partially into the bulk silicon, forming a thin alloy layer. This second step is carried out by moving the wafer in a vacuum chuck, step by step after each laser pulse, until the entire back surface has been scanned.

A pulsed excimer or neodymium:yttrium aluminum garnet (YAG) laser is used. The energy density in the beam is kept low — 1 to 3 J/cm^2 — so that the beam penetrates the wafer only slightly. It therefore does not damage the crystal structure (and create recombination centers) as ion implantation or laser annealing would. In addition, the laser pulses are kept short — about 50 ns — so that they do not overheat the adhesive on the front. The temperature of the adhesive bond should not exceed 150 °C, even briefly.

A dielectric layer is deposited on the back ohmic layer. The layer is formed from the decomposition of silane and ammonia in a plasma, at a temperature of about 100 °C. Contact holes are etched in the dielectric layer. Finally, a layer of aluminum is deposited on the back surface and into the contact holes. The aluminum layer serves as both a reflector of light and an electrical contact to the back face.

This work was done by George W. Cogan, Lee A. Christel, J. Thomas Merchant, and James F. Gibbons of SERA Solar Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 126 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

George W. Cogan
General Manager
SERA Solar Corporation
3131 Jay Street
Santa Clara, CA 95054

Refer to NPO-17798, volume and number of this NASA Tech Briefs *issue, and the page number.*

Bonding Aramid Rope to Metal Fitting

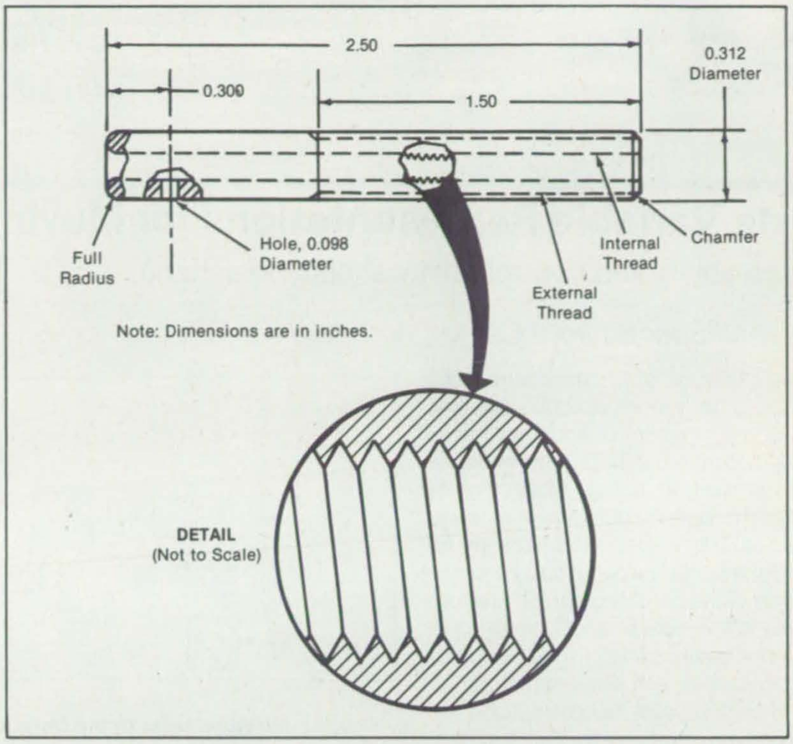
Strength is increased over that of eye splices and swages.

Lyndon B. Johnson Space Center, Houston, Texas

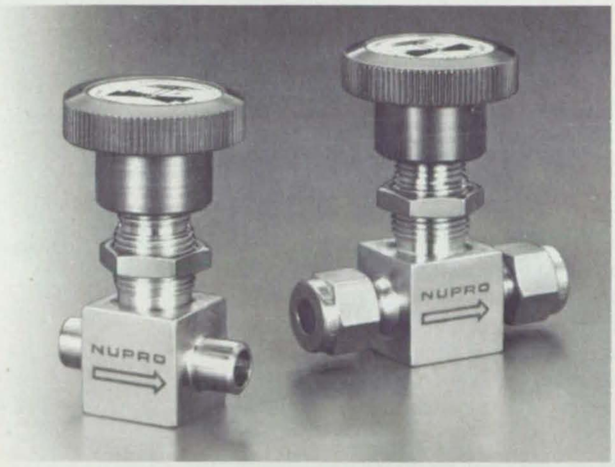
A method for joining Kevlar (or equivalent) aramid rope to a tubular corrosion-resistant steel end fitting increases the strength of the joint under tension to approximately three-fourths that of the rope itself. The previous methods of joining — eye splicing and swaging — could provide only 25 percent of the strength of the rope.

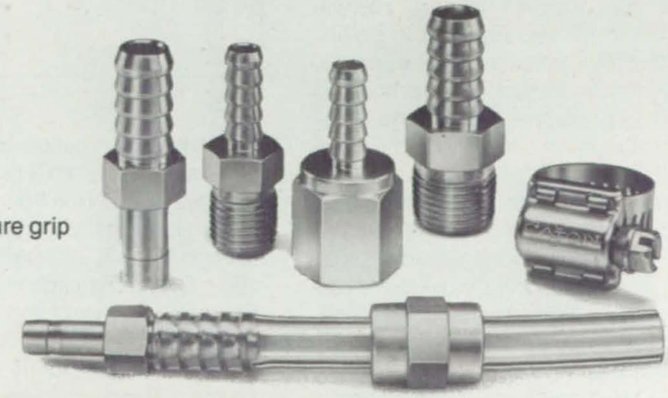
The end fitting (see figure) has an external thread for attachment to a structure. The tube also has an internal thread. In the fabrication process, the adhesive-impregnated rope end is inserted in the bore of the tube. The internal thread provides a more effective bonding area and better bearing and shear-loading capability, thereby increasing the tensile strength of the cured joint. So that the internal thread does not come to a sharp edge that might abrade the rope, a pilot hole is first drilled through the tube with a slightly larger tap drill diameter than is usual for the thread size; then, when the thread is tapped, the crest is flat rather than pointed.

This work was done by Dung T. To and Shigeru Oishi of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 65 on the TSP Request Card.* MSC-21618



The **End Fitting** contains an internal thread, which provides a good bonding surface. A small radial hole enables the injection of adhesive into the bore.





Mathematics and Information Sciences

State-Variable Representations for Moving-Average Sampling

Observability and controllability should be enhanced.

Marshall Space Flight Center, Alabama

Two state-variable representations have been derived for a continuous-time plant driven by a control algorithm that includes a zero-order hold and measurements sampled at multiple rates by multiple-input/multiple-output moving-average processes. The new representations are expected to enhance the observability and controllability of the plant. Applications are likely to include the mathematical modeling of navigation systems that include star trackers, gyroscopes, and accelerometers.

Two state-variable representations had been derived previously for such a system with measurements sampled at a single rate (see Figure 1). The system is represented at instants separated by periods of T. Samples of the output vector $\mathbf{z}(t)$ are taken at N consecutive intervals of T/N (where N is an integer) and multiplied by weighting matrices H_j (where $j = 0$ to $N-1$). In the first representation, the resulting products are summed and divided by N to obtain the moving-average measurement vector $\mathbf{y}_F$ at intervals of T. In the second representation, which is intended for use in exact state reconstruction in a deterministic control system, a modified moving-average measurement vector $\mathbf{y}'_F$ is generated by subtracting, from $\mathbf{y}_F$, a feedforward signal consisting of a delayed, filtered version of the control vector.

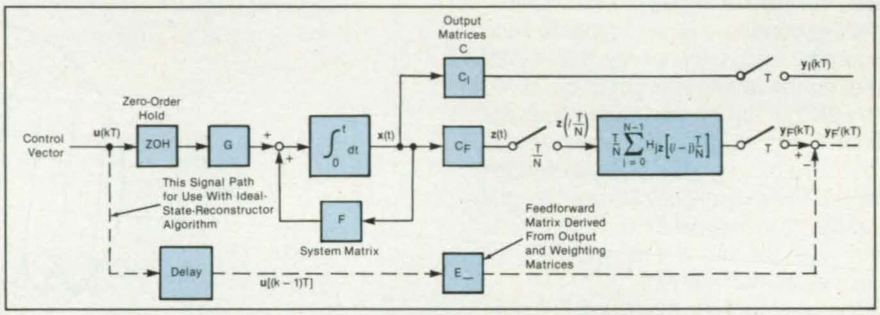


Figure 1. **Measurements of the Output** are N-term averages produced at intervals of T by summing sequences of N weighted samples taken at intervals of T/N.

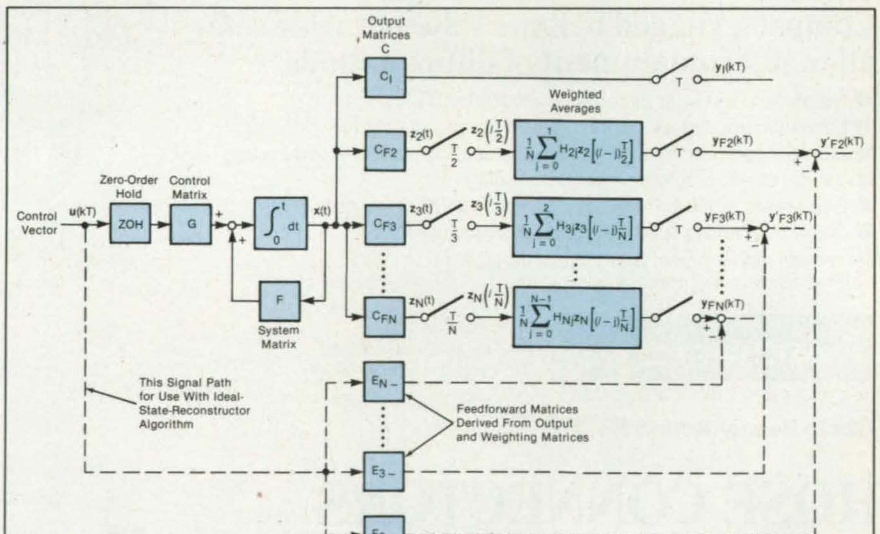


Figure 2. This **System is Similiar** to that of Figure 1, except that the output vectors are sampled at multiple rates.

The new state-variable representations are extensions of the foregoing and apply to a system that is similar except that multiple samples of $\mathbf{z}(t)$ are taken at intervals from T/N to $T/2$ (see Figure 2). In the first representation, the state vector $\mathbf{x}$ and auxiliary vectors η_2 through η_N at sampling instant $(k+1)T$ are specified in terms of the state and auxiliary vectors at sampling instant kT, of the control vector $\mathbf{u}$ at instant kT, and of various matrices derived from the control system output and weighting matrices. The instantaneous output-measurement vector $\mathbf{y}_I$ and the moving-average-sampled output measurement vectors $\mathbf{y}_{F2}$ through $\mathbf{y}_{FN}$ at sampling instant kT are specified in terms of the state and auxiliary vectors at kT and a matrix based on the instantaneous output matrix C_I. In the second representation, $\mathbf{x}[(k+1)T]$ is expressed in terms of $\mathbf{x}(kT)$, $\mathbf{u}(kT)$, and various matrices derived from the control and system matrices, while $\mathbf{y}_I(kT)$ and $\mathbf{y}'_{F2}(kT)$ through $\mathbf{y}'_{FN}(kT)$ are specified in terms of $\mathbf{x}(kT)$, C_I and matrices constructed from the output and weighting matrices of the various sampling rates.

This work was done by Michael E. Polites of **Marshall Space Flight Center**. *Further information may be found in NASA TP-2909 [N89-24507], "Further Developments in Modeling Digital Control Systems With MA-Prefiltered Measurements."*

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-28405

Recursive Inversion by Finite-Impulse-Response Filters

The recursive approximation gives a least-squares best fit to the exact response.

Ames Research Center, Moffett Field, California

A recursive algorithm yields a finite-impulse-response approximation of an unknown single-input/single-output, causal, time-invariant, linear, real system, the response of which is a sequence of impulses. The algorithm is applicable to such system-inversion problems as the suppression of echoes and the identification of a target from its scatter response to an incident impulse.

The response (that is, the output) of the system is the sequence $\{y_k\}$, which is related to the input sequence $\{u_k\}$ via the convolution

$$y_k = h_k * u_k = \sum_{i=0}^{k} h_i u_{k-i},\ k \geq 0$$

The impulse-response sequence $\{h_k\}$ can be deduced from the responses to white-noise or unit-impulse inputs. The problem is to find the inverse impulse-response sequence $\{h_k^-\}$, which would reverse the roles of the input and output according to the convolution

$$u_k = h_k^- * y_k$$

Because the order of a system can be so high as to make it impractical to compute the exact inverse, the problem is modified into the search for an inverse impulse-response sequence $\{f_k\}$ that approximates $\{h_k^-\}$. If $\{f_k\}$ were exactly equal to $\{h_k^-\}$, then $f_k * h_k$ would equal the unit impulse sequence

$$\delta_k = \begin{cases} 1 \text{ for } k = 0 \\ 0 \text{ for } k > 0 \end{cases}$$

Therefore, minimization of the sum of squares

$$\|f_k * h_k - \delta_k\|^2 = \sum_{k=0}^{\infty} (f_k * h_k - \delta_k)^2$$

is a suitable criterion for the approximation. The approximation is also subject to the restriction that it have a finite impulse response of length n.

It can be shown that the foregoing requirements lead to the recursion

$$f_{m+1} = f_m - [R_m h_m/(1 + h_m^T R_m h_m)] h_m^T f_m$$

where

$$h_k = \begin{cases} [h_k, h_{k-1} \ldots h_0, 0 \ldots 0]^T \text{ for } k \leq n-1 \\ [h_k, h_{k-1} \ldots h_{k-n+1}]^T \text{ for } k \geq n \end{cases}$$

T denotes the matrix transpose, and

$$R_{m+1} = R_m - [R_m h_m h_m^T R_m / (1 + h_m^T R_m h_m)]$$

The recursion for R_{m+1} is initialized at $R_n = T_n^{-1}(T_n^{-1})^T$, where

$$T_n^{-1} = \begin{bmatrix} h_0^- & & 0 \\ h_1^- h_0^- & \ddots & \\ \vdots & & \\ h_{n-1}^- h_{n-2}^- \cdots h_0^- \end{bmatrix},\quad h_0^- = 1/h_0$$

and

$$h_k^- = (-1/h_0) \sum_{i=1}^{k} h_{k-i}^- h_i \text{ for } k \geq 1$$

An approximate mathematical model of the system can be found by inverting the approximate inverse $\{f_k\}$. Expressed as a z transform, the model is of the all-pole type; namely,

$$\left(\sum_{k=0}^{n-1} f_k z^{-k} \right)^{-1}$$

This approach yields a solution to the problem of system identification from its impulse response.

The recursive least-squares procedure can be modified to compensate a system by cascading it with a relatively simple system to obtain an approximation of a desired impulse response $\{g_k\}$. In this case, the recursion is derived from minimization of the norm

$$\|f_k * h_k - g_k\|$$

This work was done by Ralph E. Bach, Jr., and Yoram Baram of **Ames Research Center**. *For further information, Circle 9 on the TSP Request Card.* ARC-12247

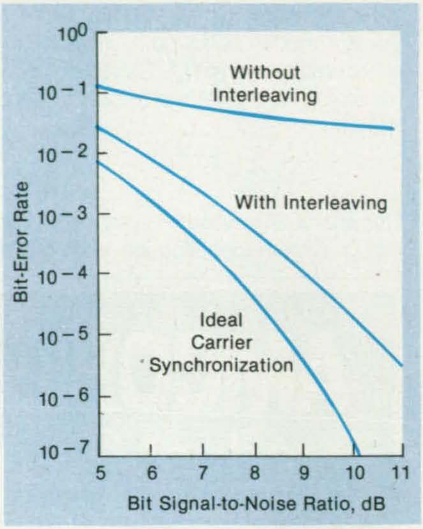
Interleaving Would Enhance Trellis-Coded Modulation

Errors caused by imperfect carrier demodulation references would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

Interleaving of symbols transmitted via trellis-coded modulation, together with deinterleaving at the receiver, is expected to reduce the "radio" or "noisy-reference" loss encountered in reception. This loss is an increase in the bit-error rate (or, equivalently, a decrease in the effective signal-to-noise ratio), caused by phase error between the received signal and the locally generated carrier reference signal used to demodulate the received signal.

In a practical receiver, the coherent demodulation reference is derived from a carrier-synchronization subsystem, e.g., a Costas loop in a suppressed-carrier system or a phase-locked loop in a discrete-carrier system. Because this subsystem derives its reference from a noisy version of the transmitted signal, the phase of the demodulation reference includes a random erroneous component. The manner in which the random error process degrades the error-probability performance of the receiver depends on the ratio of the data rate to the bandwidth of the loop or, equivalently, on the rate of variation of the phase error during a data-symbol period. In many applications, this rate of variation is large; that is, the data rate is much higher than the bandwidth of the loop. In such a case, the phase error can be considered to be constant during several consecutive symbol periods.



The Bit-Error Rate of a system based on rate-one-half, two-state-trellis-coded, quadrature-phase-shift keying and a loop signal-to-noise ratio of 13 dB was computed for transmission both with and without interleaving. Also shown for comparison is the plot for zero radio loss — that is, ideal carrier synchronization.

Representative cases of this type were analyzed theoretically, both without interleaving and with interleaving to a depth of ~ $1/B_LT_S$ symbols, where B_L = the bandwidth of the loop and T_S = the symbol period. The analysis showed that the radio loss can be reduced significantly (see figure). The amount of this reduction depends on the particular trellis code and the region of operation of the system as characterized by such parameters as the bit-error rate and the signal-to-noise ratio of the loop. If the radio loss is already small even without interleaving (as tends to be true in suppressed-carrier systems), interleaving does not help much. Nevertheless, if the system can tolerate the delay associated with the interleaving/deinterleaving process, it is useful to include this process in the system design because it also helps to reduce the degradation caused by such other impairments of a bursty nature as intersymbol interference and fading.

This work was done by Dariush Divsalar and Marvin K. Simon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 124 on the TSP Request Card.*
NPO-17899

Generalized Covariance Analysis for Remote Estimators

Applications include a variety of remote-control systems with and without delays.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique has been developed to predict the true covariance of a stochastic process at a remote location when control is applied to the process both by an autonomous (local-estimator) control subsystem and a remote (non-local-estimator) control subsystem. The technique was intended originally to be used in the design and evaluation of ground-based schemes for the estimation of the gyro parameters of the Magellan spacecraft. Potential terrestrial applications include navigation and the control of industrial processes.

Systems that involve combinations of autonomous and remote control — especially deep-space missions that depend on ground-based estimation and control — are characterized by communication and processing delay. To obtain a timely response to information available at the spacecraft (or process location), it is necessary to make the spacecraft (local) control subsystem at least partly autonomous in its estimation and control capabilities. On the other hand, the limitations of the onboard computational capacity, combined with other practical considerations, make it necessary to perform the most sophisticated computations at the ground station (remote) control subsystem.

Ground-based (remote) control provides improved estimation, but it is here that the inherent communication and processing delays and the other limitations on communication exert their deleterious effects. As a result, the ground-based (remote) estimates of parameters of the process are conditioned on only a subset of the data available to the spacecraft (local) control subsystem, and the ground-based-estimation problem has to be treated as a prediction problem rather than as the standard filtering problem of the local estimator.

The new technique for computation of the true covariance of the process has the following salient features:

- A generalized state vector is defined to characterize the overall system. This vector is a concatenation of the state vector of the system or process to be controlled, the state vector of the local estimator, the delayed state vector of the remote estimator, and a measurement vector of variable but unbounded dimension.
- A generalized covariance matrix is defined for the generalized state vector.
- Efficient, numerically stable matrix-factorization algorithms are provided for measurement, control, and time propagation (i.e., updating) of the factors of the generalized covariance matrix.

It is, of course, possible to specialize this general approach to the case in which the remote and local estimators operate synchronously. It is then also possible to generalize to the case of more than two estimators. Thus modified, the new method provides means for the evaluation of a distributed-estimation scheme that has negligible delays.

This work was done by Jack N. Boone of Martin Marietta Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 69 on the TSP Request Card.*
NPO-17824

Life Sciences

Hardware, Techniques, and Processes

Cloned Hemoglobin Genes Enhance Growth of Cells

Cells are "infected" with oxygen-binding capability.

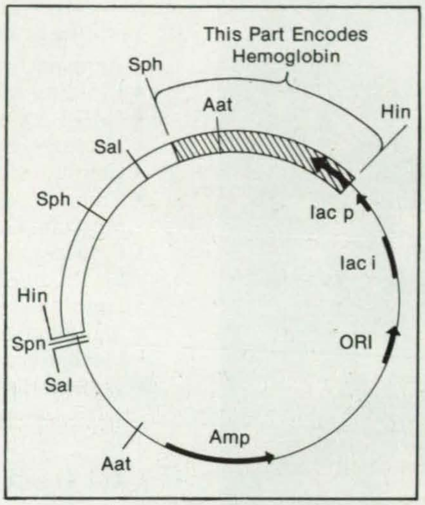
NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that portable deoxyribonucleic acid (DNA) sequences can be incorporated into host cells to make them produce hemoglobins — oxygen-binding proteins essential to the function of red blood cells. This biotechnological feat is accomplished by a recombinant-DNA method that includes the following essential steps:

- Preparation of part of a gene or other natural or artificial DNA sequence capable of directing the host cell to produce hemoglobin;
- Cloning the portable DNA sequence directly into the host cell or into a vector (e.g., a plasmid or virus) that can be transferred into, and be replicated in, the host cell;
- Transferring the vector (if used) into the host cell;
- Culturing the host cell under conditions that favor the replication and propagation of the vector and the production of the hemoglobin; and
- Harvesting the protein and activating it to bind oxygen.

The host cells used in the experiments were *Escherichia coli* bacteria. The portable DNA sequence chosen for the experiments was part of the genetic material of the bacterium Vitreoscilla, which produces a type of hemoglobin. The vectors were pUCl9/pRED2 and other plasmids of the *E. coli* cells (see figure).

The vectors were chosen on the basis of their ability to cause the host cells to express the portable DNA sequence. In particular, a vector should contain "operational elements" — DNA sequences that express promotion, regulation, and termination of the production of hemoglobin. Finally, DNA sequences for transcription and translation should be present.



This **Nucleotide Sequence** of the plasmid pUCl9/pRED2 of *E. coli* includes a part from Vitreoscilla that encodes the production of hemoglobin.

One set of experiments yielded recombinant *E. coli* cells that included significant amounts of hemoglobin, indicated by a reddish tint. In another set of experiments, the recombinant *E. coli* cells were found to grow faster and to a greater density than did unaltered cells of the same strain grown under identical conditions. In a third set of experiments, it was observed that the production of hemoglobin in the recombinant cells decreased with an increase in the oxygen content of the culture medium.

The method should be useful in several biotechnological applications. One is the enhancement of growth of cells at higher densities. Another is the production of hemoglobin to enhance supplies of oxygen in cells, for use in chemical reactions that require oxygen, as an additive to serum to increase the transport of oxygen, and for binding and separating oxygen from mixtures of gases.

This work was done by Chaitan Khosla and James E. Bailey of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 113 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-17517, volume and number of this NASA Tech Briefs *issue, and the page number.*

Environmental Control of a Genetic Process

The concentration of oxygen controls the production of hemoglobin.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that the environment can be manipulated to control such genetic processes as the transcription and translation of DNA sequences. In particular, *E. coli* bacteria altered to contain a DNA sequence that encodes the production of hemoglobin were made to produce hemoglobin at rates that decreased with increases in the concentration of oxygen in the culture media. This represents an amplification of part of the method described in the preceding article, "Cloned Hemoglobin Genes Enhance Growth of Cells" (NPO-17517).

Here, the emphasis is on some of the DNA sequences that usually precede the gene of interest in a DNA polymer. Among these are the "promoter" sequences, which provide sites for the initiation of transcription of the gene into messenger ribonucleic acid. Others, called "regulator" sequences, include attenuators, regulators, and enhancers, which determine the frequency or rate of initiation of transcription and/or translation. The combined effect of all of these, known collectively as "promoter/regulator" DNA sequences, is to determine the extent of eventual expression of the gene.

There is enormous variety in the structures and functions of promoter/regulator sequences. Functions can be activated or deactivated by various environmental factors, including changes in temperature and the presence or absence of various substances. In this case, the experimenters sought a promoter/regulator sequence that would switch from low to high expressive activity at constant temperature upon the reduction of the concentration of

oxygen dissolved in the culture medium. Such a promoter/regulator sequence would be advantageous in a laboratory setting because it is easy to reduce the level of dissolved oxygen at high cell densities, without having to add any chemicals to the growth medium to induce the expression of genes.

The recombinant-DNA concepts and techniques used to demonstrate the manipulation of promoter/regulator DNA sequences were similar to those described in the preceding article. As before, DNA sequences from Vitreoscilla (strictly aerobic bacteria that live in oxygen-poor environments) were implanted in the *E. coli* bacteria via plasmid vectors. The "upstream" (in a genetic sense) promoter/regulator sequence was fused with a "downstream" sequence that encodes hemoglobin.

The manipulation of promoter/regulator DNA sequences opens a promising new subfield of recombinant-DNA technology for the environmental control of the expression of selected DNA sequences. New recombinant-DNA fusion gene products, expression vectors, and nucleotide-base sequences will emerge. Likely applications for this new technology include such aerobic processes as the manufacture of cloned proteins and synthesis of metabolites, the production of chemicals by fermentation, enzymatic degradation, the treatment of wastes, brewing, and a variety of oxidative chemical reactions.

This work was done by Chaitan Khosla and James E. Bailey of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 110 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

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Refer to NPO-17576, volume and number of this NASA Tech Briefs *issue, and the page number.*

Membrane Bioreactor With Pressure Cycle

Inhibitory reaction products and gradients of concentration are removed.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved class of multilayer membrane bioreactors uses convection forced by differences in pressure to overcome some of the diffusional limitations of prior bioreactors. The problem is to provide nutrients to the biocatalyst in a bioreactor and to remove the products (including both the product and the undesired gaseous or other byproducts), which can inhibit the activity of the biocatalyst and thereby slow or stop production. Prior bioreactors have relied largely on diffusion to effect these transfers of materials to and from the biocatalyst. In a reactor of the new class, a flow of nutrient solution reduces adverse gradients of concentration, keeps cells supplied with fresh nutrient, and sweeps away the products faster than diffusion alone can. As a result, the overall yield and rate of reaction are increased.

The principle of operation is illustrated with the simple bioreactor shown schematically in the figure. As in some prior bioreactors, the biocatalyst can be a layer of immobilized cells, (e.g., *Saccharomyces cerevisiae*, which takes up glucose and produces ethanol and carbon dioxide). The biocatalyst is held below a hydrophobic membrane and above a hydrophilic membrane. The nutrient liquid is supplied through the hydrophilic membrane from below. The desired product (e.g., ethanol) is dissolved in the nutrient liquid and transferred to a solvent or extractant liquid through a lower hydrophobic membrane at the bottom of the nutrient layer. The undesired gaseous byproduct (e.g., carbon dioxide) is removed by a sweeping gas (e.g., air) that flows in the space above the upper hydrophobic membrane.

The pressures in the sweeping gas and nutrient liquid are controlled cyclically to obtain the desired cyclical convection of nutrient liquid into and out of the biocatalyst layer. During one phase of the cycle, the pressure in the nutrient layer is made higher than the pressure in the sweeping gas, so that the nutrient liquid is forced through the hydrophilic membrane into the biocatalyst layer and the sweeping and byproduct gases are forced out of the cell layer through the upper hydrophobic membrane. The difference between the pressures is not, however, made so great as to force the nutrient liquid through the upper hydrophobic membrane into the sweeping-gas layer.

During the opposite phase of the cycle, the pressure in the sweeping-gas layer is made greater than the pressure in the nutrient layer, so that the nutrient, containing the desired product (e.g., ethanol), is forced out of the biocatalyst layer into the nutrient layer. Thus, the product dissolved in the nutrient is brought more rapidly into contact with the extractant in the lowest layer. The cycle is then repeated.

This work was done by George S. Efthymiou and Michael L. Shuler of Cornell Research Foundation, Inc., for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 96 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

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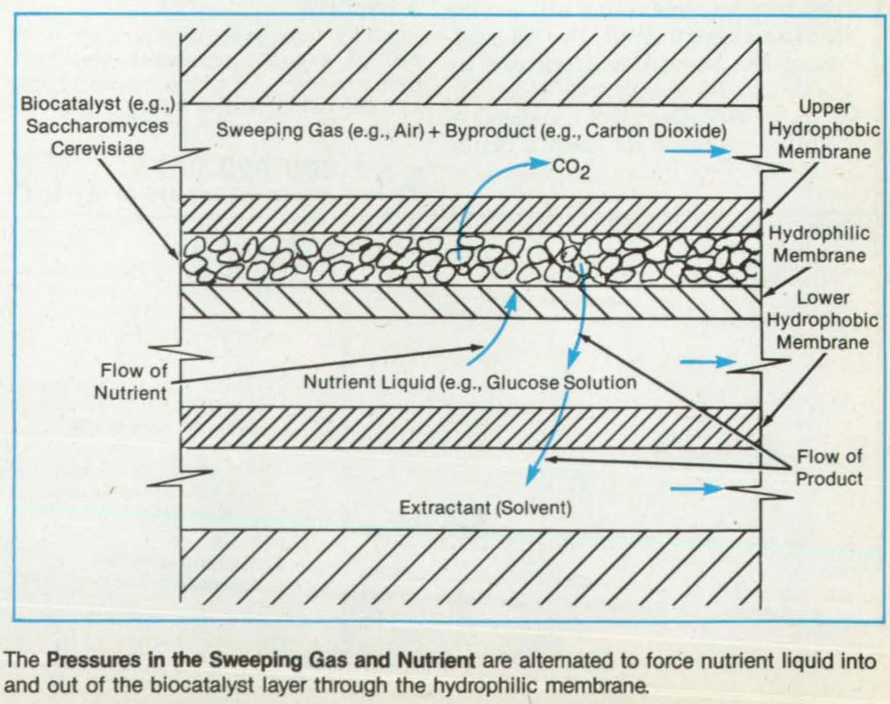
Refer to NPO-17974, volume and number of this NASA Tech Briefs *issue, and the page number.*



The **Pressures in the Sweeping Gas and Nutrient** are alternated to force nutrient liquid into and out of the biocatalyst layer through the hydrophilic membrane.

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Circle Reader Action No. 405

New on the Market

Global Specialties, New Haven, CT, has announced PROTOLAB™, a **computer-simulated electronics laboratory** to build and test actual circuits. It consists of a computer program designed to emulate a fully-stocked electronics lab and an instructional experiment workbook. Designed for IBM PC compatible or Macintosh computers, PROTOLAB comes with a set of virtual instruments including a voltmeter, ammeter, dual-trace oscilloscope, ohmmeter, wattmeter, and sweep generator.

Circle Reader Action Number 798.

GEC Plessey Semiconductors, Scotts Valley, CA, has introduced a fully-integrated **image processing subsystem** for use in real-time digital video systems. The PDSP16488 can remove noise and aliasing effects or enhance edges for pattern recognition purposes, and performs a two-dimensional convolution between the pixels within a video window and a set of stored coefficients. It supports pixel rates up to 40 MHz, and has up to eight internal line stores.

Circle Reader Action Number 794.

A new concept in **relay switching**, the Arcless Relay from Electronic Specialty Corp., Vancouver, WA, accomplishes switching without arc or bounce, which preserves relay contact. When relay contacts are made or broken, power semiconductors switch and carry the power load until the contacts have transferred. The Arcless Relay can switch current loads of up to 200 amps and voltages of up to 300 v DC and 200 v AC.

Circle Reader Action Number 800.

The Industrial Encoder Division of BEI Motion Systems Company, Goleta, CA, has announced a new **current source/sink output** on its optical shaft angle encoders. The Interface is designed for operation at 7.5 to 24V with 40ma source and 30ma sink capability. This option will provide compatibility with current source electronics popular in European drives and controls.

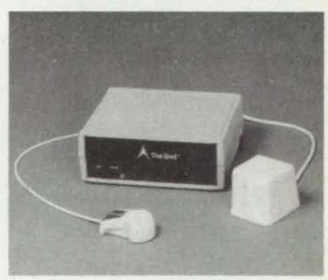
Circle Reader Action Number 788.

A high-velocity **electric gun system** that produces metal coatings harder and more dense than previously attainable is available from TAFA Inc., Concord, NH. Unlike other spray systems that splay out at a short distance from the nozzle, the Arc Jet™ stream maintains a more pencil-shaped contour. At a distance of 5", the Arc Jet has a coated deposit pattern 0.8" in diameter, while the standard arc spray gun has a pattern 1.2" in diameter. Further, the velocities of the spray particles are approximately 49 percent greater than with a standard gun, according to the manufacturer.

Circle Reader Action Number 792.

The Bird, a **six-degree-of-freedom input device** which allows movement and rotation of images through natural hand or body motions, has been introduced by Ascension Technology Corp., Colchester, VT. Using its onboard 16-bit CPU, the Bird computes the position and orientation in free space of its tiny receiver, which can be mounted in a cube, a mouse, or any other housing. Outputs consist of X, Y, and Z positional coordinates and their corresponding rotational matrix or orientation angles.

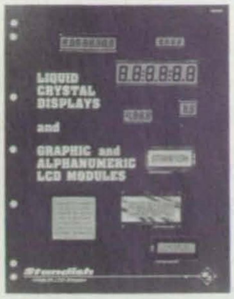
Circle Reader Action Number 790.



VIDEO MTF™, a **real-time optical measurement system** that allows instantaneous, sagittal, and tangential measurement of modulation transfer function (MTF) in lenses is offered by Optikos Corp., Cambridge, MA. MTF is a measure of the quality and performance of lenses used in applications-simulated environments. The modular system uses Microsoft Windows 3.0, which provides for interactive comparisons of data and vivid graphics.

Circle Reader Action Number 796.

New Literature



The HAMLIN LCD Division of Standish Industries Inc., Lake Mills, WI, has published a 12-page brochure detailing its line of **liquid crystal displays (LCDs) and graphic and alphanumeric LCD modules**. The brochure includes specifications, dimensions, wiring diagrams, pinout assignment, and operating characteristics.
Circle Reader Action Number 704.

The Quick Reference Guide to Power Sources, from Wall Industries, Exeter, NH, details **DC to DC converters and AC to DC power supplies** in the 1.5 to 150 watt range. Application notes cover measurement techniques, fusing, output ripple/noise measurement, ground connections, and recommended load connections.
Circle Reader Action Number 714.

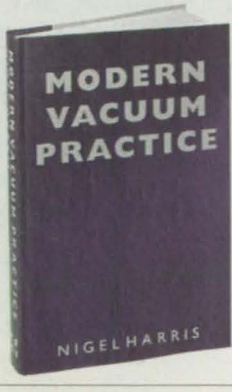
Industrial Computer Source, San Diego, CA, has issued the fall/winter edition of its catalog featuring **industrial computer systems and data acquisition, control, and communication products for the IBM PC/XT/AT**. New products are 20/15/10 slot chassis with built-in keyboard, 486/25 MHz and 386/25/33 MHz CPU cards, 19" rack accessories, A/D and communication cards, and LabTech Notebook with ICONview.
Circle Reader Action Number 712.

The Product Test System (PTS) Data Book from Thermotron Industries, Holland, MI, is a 20-page resource for **designing a turnkey environmental test system**. Eliminating the need to build custom test electronics for environmental chambers, the PTS can evaluate many products simultaneously. The data book provides specifics on system applications, integration specifications, function modules, and Thermotron's technical services.
Circle Reader Action Number 702.

A new development tools catalog from Intel Corp., Hillsboro, OR, features the ICE™-486 **in-circuit emulator**, which provides real-time emulation for the i486 microprocessor at speeds to 33 MHz. The publication also features an in-target software debugger for the 8096OCA, the ONCE™ -386 SX adapter, and a 2 Mb relocatable expansion memory board for the ICE -386 DX 25 and 33 MHz emulators
Circle Reader Action Number 710.

A 120-page catalog from Emulation Technology Inc., Santa Clara, CA, highlights **VLSI and surface mount test accessories**. It describes over 2500 products used to test, debug, and adapt plastic quad flat packages, socketed plastic-leaded chip carriers, and other new types of packages. The accessories are used mainly with development systems such as logic analyzers, and memory and logic programmers.
Circle Reader Action Number 706.

Modern Vacuum Practice, from Edwards High Vacuum International, Wilmington, MA, covers the **methods of producing and measuring pressure in the high vacuum range** as well as system construction and operation. The book illustrates the various equipment used in vacuum processes, such as dry pumps, turbomolecular pumps, cryopumps, and measurement and control instrumentation.
Circle Reader Action Number 708.



A View To The Future

(Continued from page 12)

would provide routine transit between the moon and Earth, and ultimately between Mars and the Earth.

Building A Lunar Base

If we're going back to the moon to stay, we're talking about major differences from the Apollo missions, much more than just planting a flag or chipping samples off rocks. We're talking about developing the capability to house and utilize large numbers of people, about creating the technologies for assembling bases. We're talking about using local resources to sustain humans for the longer term. This will require methods for extracting and processing minerals in an alien environment, to recover oxygen, or in the case of Mars, to manufacture fuel. Further, it will require new technologies in life support systems, and new power sources—perhaps compact nuclear reactors.

For a Mars mission, we're going to have to develop and send along maintenance vehicles, and we're going to have to enhance crew capabilities in diagnostics by using robotics. Robots will be needed for other jobs as well, such as identifying sites. We may want to send ahead a rover to survey the local terrain so we know where it's safe to land. We need to test new techniques on robotic missions, techniques such as aerobraking—using the friction between the spacecraft and the planet's atmosphere to slow the craft, rather than wasting fuel to accomplish this.

The surface of Mars is approximately the size of the Earth's land area, so we're not likely to get very far on our first excursion. To extend the human exploratory capability, we may send out robots remotely operated from orbit or the planet's surface using technologies such as virtual presence.

Spinoff Benefits

SEI can act as a focal point and a catalyst for technology development across a wide range of areas. One of the challenges we face in putting this program together is to maximize the technical and economic benefits to the nation. NASA has a long history of spinoffs, but in previous programs spinoffs have come after the fact. We want to build technology transfer into this program from the beginning, so we can maximize the interchange with the private sector and enhance the country's economic foundation.

We've created an outreach program to gather innovative ideas from the public, and we are talking about technologies with other agencies such as the departments of Defense and Energy. A synthesis group is going to take these ideas and come up with alternatives for implementing them, some comments on what our priorities in technology should be, and what near-term milestones we should establish to demonstrate real progress over coming years.

We also have a presidential directive to carry out exploratory dialog with potential international partners, including the Soviet Union. Over the next several months, we will be having discussions with the Canadians, Europeans, and Japanese to learn what their interests and capabilities are in cooperating with the U.S. on this initiative.

We're at the beginning of a long period of activity, and we have a lot of homework to do. Decisions on whether to proceed and how to proceed are still several years away. ❑

Subject Index

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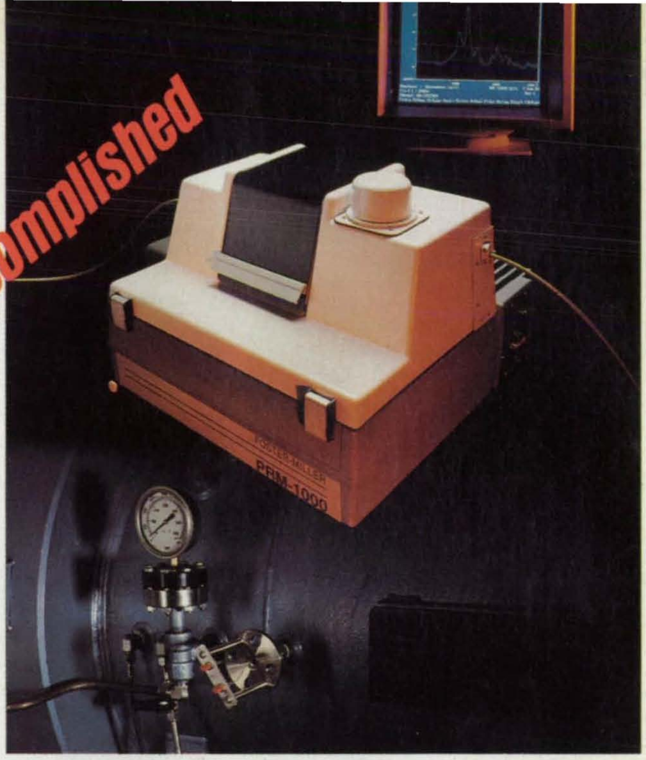
Mission Accomplished

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



A new analytical system directly measures the chemistry in advanced composite materials through the use of fiber optics.

A NASA-industry team has produced the first analytical system capable of directly measuring reaction chemistry in a variety of monomers and polymers. The patented invention, dubbed the In Situ Fiber Optic Polymer Reaction Monitor, could lead to significantly higher yields in the manufacture of complex composite parts, with consequent reductions in cost. NASA expects the technology to find numerous research and commercial applications in the aerospace, environmental, and industrial arenas.

The measurement technique may alleviate problems associated with the manufacture of carbon fiber composite materials by recognizing the need to redistribute temperature and pressure during the cure process. The monitoring of pure resin chemistry helps to yield optimum materials, since voids or imperfections can be compensated for during processing, according to Dr. Philip Young, a senior polymer scientist at NASA's Langley Research Center, which aided Foster-Miller Inc. of Waltham, MA in developing the monitor.

Current approaches to cure monitoring involve sensing of material properties such as dielectric behavior or ultrasound attenuation. While these methods have led to improvements in processing, they are limited in that they measure only secondary resin effects. The changes in resin chemistry and hence important mechanical properties must be inferred with consequent inaccuracies due to interpretation and relevance of the signals generated.

"The new technique provides first-hand information about chemical reactions as opposed to measuring secondary change," said Mark Druy, principal investigator of the system for Foster-Miller.

The Foster-Miller/NASA fiber optic method is unique because it tracks a fundamental aspect of a chemical reaction - the vibration of atoms and molecules associated with the dissociation and formation of chemical bonds. The vibrational characteristics are picked up by a novel infrared fiber optic sensor which is imbedded in the composite part. These infrared transmitting optical fibers are connected to a Fourier Transform Infrared (FTIR) spectrometer which can compute and display spectral changes in real time.

The monitoring system may be directly applied to materials and used in spacecraft and commercial transport structures, said Young. Many other uses exist for a sensor that is universal to all organic materials and most inorganic gases. These include monitoring the integrity of composites in the in-service environment, the remote sensing of hazardous materials such as in smokestacks, and the examination of industrial processes in reactors and furnaces. "With proper development and funding," said Young, "numerous unique applications are feasible." ❑

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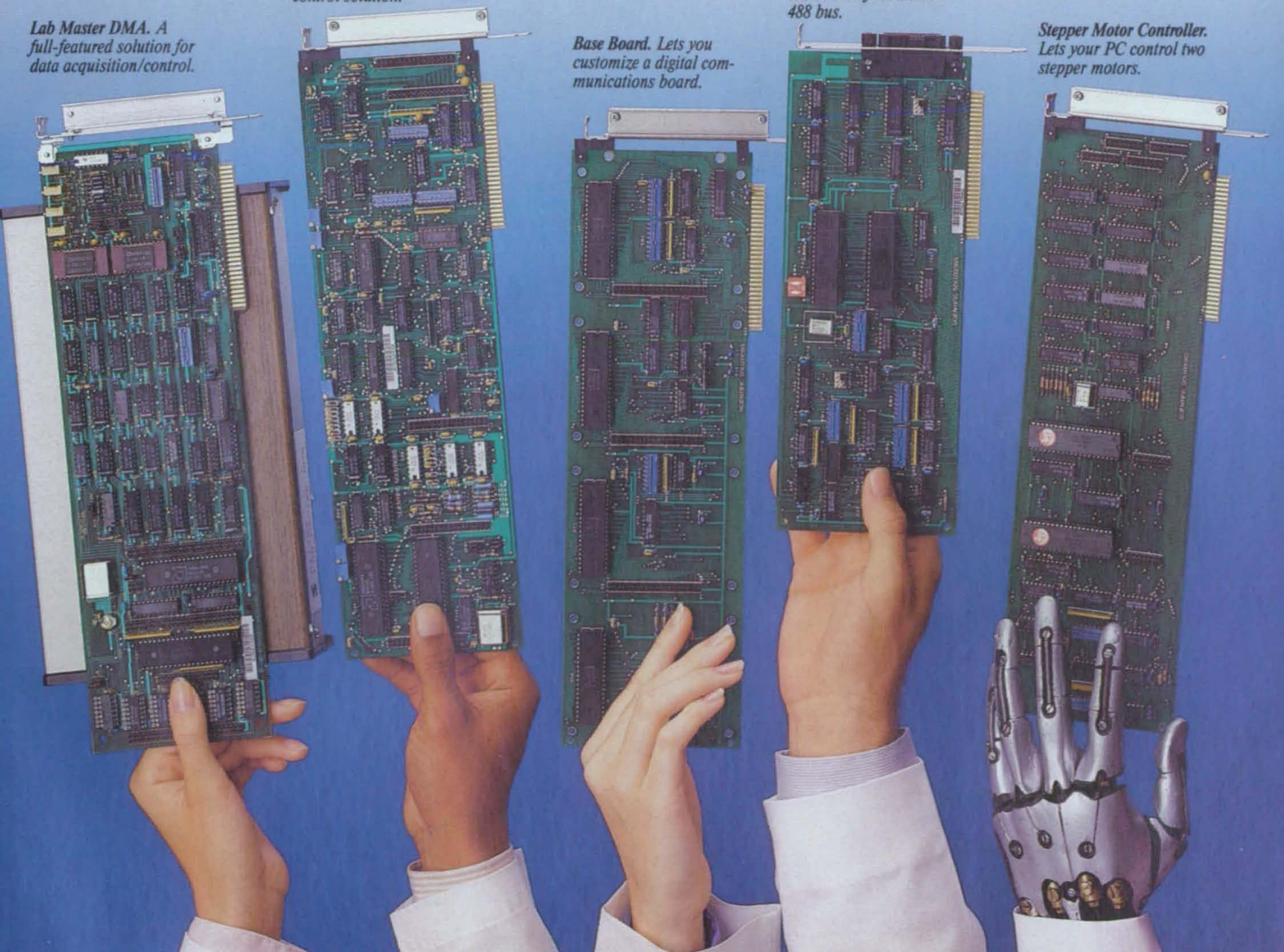

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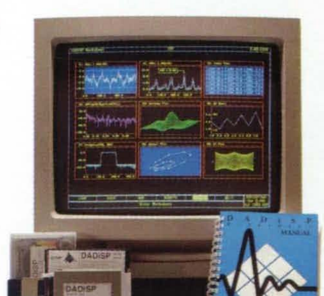

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