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Electrical Engineer

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Pratt & Whitney's 22" Advanced Ducted Propeller low-noise fan model is tested in the 9 x 15' wind tunnel at Lewis Research Center. Lewis' focus on aeropropulsion research includes efforts in advanced subsonic transport. For more information on facilities and opportunities at Lewis, see the Resource Report on page 24.

Photo courtesy of Lewis Research Center
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1b-16b Industry Focus: Motion Control/Positioning Equipment
Follows page 98 in selected editions only.

On the cover: Using a computer network that reached across California, XCORP of Beverly Hills designed the XCAR, a fuel-efficient, low-emission, composite, recyclable car. A consortium of suppliers, defense labs, and NASA developed the prototype. An XCAR model will be one of the cutting-edge transportation innovations on display in the Transportation Tomorrow pavilion at Technology 2005 (October 24-26). For more information on the XCAR, see NASA Innovations on page 20.

Photo manipulation and digital collage by Douglas Mcdonald
Photo courtesy of XCORP

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**C. Thanks to Xilinx FPGAs, the doctor really can see you now. MuTech developed a PCI board that works with today's Pentium and Power PC computers to deliver an affordable method of diagnosing problems in real time.**

**D. StrataCom uses Xilinx FPGAs to deliver the WAN systems their customers need today, while developing the broadband ATM solutions they'll definitely need tomorrow.**

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For those who have access to the Internet, general information can be accessed with Mosaic software on the NASA Commercial Technology Home Page at URL: http://nctn.oact.hq.nasa.gov. Instructions regarding how to acquire the free Mosaic software can be obtained by sending an e-mail request to innovation@oact.hq.nasa.gov.

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Image Data Compression
Having Minimum Perceptual Error
(U.S. Patent No. 5,426,512)
Inventor: Andrew B. Watson, Ames Research Center
Image data compression helps reduce the load on communication network computer infrastructure by reducing redundancy, the number of bits, and invisible image-components—but perceptual error is often the cost. Mr. Watson's invention provides a method for compressing visual information, based on luminance masking, contrast masking, and error pooling, that provides a visually optimized image with high resolution and low perceptual error, minimizing such error for a given bit rate.

For More Information Write In No. 753

Extended Linear Ion Trap
Frequency Standard Apparatus
(U.S. Patent No. 5,420,549)
Inventor: John D. Prestage, Jet Propulsion Laboratory
The low number of confined ions in a trapped ion-based frequency standard for atomic clocks leads to a low signal-to-noise ratio, limiting clock stability. The linear ion trap increases the number of trapped ions tenfold and gives a similar increase in clock stability. Dr. Prestage's new extended linear ion trap, with two ion-trap regions, requires magnetic shielding only in the second region and decreases by a hundredfold the volume of the region requiring shielding.

For More Information Write In No. 756

High-Energy-Density and High-Power-Density Ultracapacitors and Supercapacitors
(U.S. Patent No. 5,426,561)
Inventors: Shiao-Ping S. Yen and Carol R. Lewis, Jet Propulsion Laboratory
To increase efficiency sufficiently to make them practical, batteries for electric vehicle propulsion systems need low weight and volume, thus high energy and power densities in the capacitors. Ultracapacitors and supercapacitors have been devised to this end, but neither yet are sufficient for an electric vehicle propulsion system. Yen and Lewis's new ultracapacitor and supercapacitor designs replace the two discrete metal current collectors for anode and cathode with a single thin polymer film, reducing capacitor volume threefold and increasing energy density ninefold.

For More Information Write In No. 755

Mechanical Energy Absorber
(U.S. Patent No. 5,423,400)
Inventor: Clarence J. Wesselski, Johnson Space Center
Mechanical energy-absorbing systems often are sensitive to friction coefficient changes and extreme temperature changes, produce a sharp load spike at the beginning of a stroke, and require close manufacturing tolerances. The present invention employs diaphragm elements that frictionally engage the shaft and are opposed by a force-regulating set of disc springs that stabilize the load level even if the friction coefficient greatly increases. This force feedback counters the effects of manufacturing tolerances, sliding surface wear, temperature changes, dynamic effects, and lubricity.

For More Information Write In No. 751

Slow-Release Fertilizer
(U.S. Patent No. 5,433,766)
Inventors: Douglas W. Ming and Dadigamuwage C. Golden, Johnson Space Center
Mineral fertilizers such as apatite do not supply all nutrients, contain toxic elements, and often need micronutrient supplements. Also, multiple mineral phases diffuse in the soil at varying rates, offer little control over a plant's daily micronutrient needs, require large quantities because of soil impediments, and can be washed away. This slow-release fertilizer is a synthetic calcium phosphate apatite having agro-nutrients embedded in its crystalline structure, is free of toxins, and releases micronutrients as the apatite dissolves.

For More Information Write In No. 752

Extra-Corporeal Blood Access, Sensing, and Radiation Methods and Apparatuses
(U.S. Patent No. 5,429,594)
Inventor: Kent D. Castle, Johnson Space Center
The apparatuses have one or more access ports in tubing, through which blood flows, and with associated windows for either treating or analyzing the blood. Flow rate may be controlled for treatment radiation such as neutrons, ions, photons, or alpha particles; other possible treatments through the apparatus include heat, sound, electrical energy, or electrostatic force.

For More Information Write In No. 754

NASA Tech Briefs, October 1995
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For More Information Write In No. 524
Thin-Film Power Transformers

Microfabrication techniques would be used to produce these transformers. The proposed transformers could have geometric features finer than conventionally made models. (See page 44.)

Process-Information Display Panel for Welder’s Visor

A head-up display mounted on a welder’s visor would supply key process information in real time. Such a display would help the welders to follow process parameters more uniformly and to guide new welders away from problems previously encountered by others. (See page 48.)

Trioxane: a Fuel for Direct-Oxidation Fuel Cells

Trioxane can be used as a substitute for formaldehyde in these cells. The former has been identified as a high-energy, nontoxic, solid substitute for formaldehyde. (See page 63.)

Closed-Loop System Removes Contaminants From Inert Gas

A limited quantity of inert gas is sufficient for processing semiconducting materials. The recycled gas is purified by cartridges that remove water vapor and oxygen. Porous metal filters remove particles. (See page 64.)

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For More Information Write In No. 567
Camera On A Chip

The Active Pixel Sensor (APS), developed at NASA's Jet Propulsion Laboratory, stores on a single computer chip all of the components necessary to produce an image. The camera-on-a-chip technology makes possible an imaging system that is smaller, less expensive, and more efficient than current charge-coupled device (CCD) imaging sensors, according to Dr. Eric Fossum, who led the development team at JPL. CCDs cost about $1000 per million pixels when made for low-volume applications. APS devices are made in a conventional integrated circuit facility for one-third what a similar wafer using the CCD process costs. The complementary metal-oxide semiconductor (CMOS) technology used to manufacture the APS is used for almost all microprocessors and memory chips.

Developed by JPL's Center for Space Microelectronic Technology for space applications, the sensor enables the manufacture of low-cost, low-power, miniature cameras with on-chip timing, control, and drive electronics. It can communicate directly with a microprocessor or computer.

Commercial uses include personal computer visual communications, advanced television, electronic still cameras, laboratory-based cameras, medical and nuclear instruments, toys, automobiles, and space-based surveillance systems. JPL has signed an agreement with AT&T for videoconferencing applications, and with Kodak for electronic photography.

A Powerful Alternative

NASA's Lewis Research Center has developed a thermophotovoltaic (TPV) power system that converts heat energy into electrical energy by coupling the heat energy to an emitter to produce infrared light. A low-bandgap photovoltaic device or solar cell, sensitive to IR light, is placed in front of the emitter to produce electricity. The thermal energy can come from any source, from fuel combustion to nuclear decay to concentrated solar energy.

Lewis researchers have developed two methods of converting thermal to radiant energy. One involves the use of a black-body emitter, such as silicon carbide, to produce a broadband photon spectrum. A high-pass filter reflects the unusable photons back to the emitter, where they are adsorbed and aid in maintaining the emitter temperature.

The second method couples thermal energy to a selective emitter, which is composed of a rare earth oxide that has a characteristic emission band indicative of the rare earth element used in the emitter. Outside this band, the emitter produces little radiant energy. This method provides the highest system efficiency, but the blackbody/filter method supplies the highest power density. Both methods employ rare earth doped YAG crystals.

The small, lightweight, quiet TPV power systems have applications in remote/RV power, consumer and utility power generation, and in co-generation applications such as self-powered natural gas furnaces. The system also could provide electricity for an electric vehicle, resulting in reduced pollution since the fuel would burn more thoroughly at lower temperatures.

McDonnell-Douglas has teamed with Lewis to develop TPV power systems for utility scale power generation using concentrated sunlight.

Heart Helper

Developing a long-life implantable artificial heart is a goal of medical researchers worldwide. With no such product on the near horizon, NASA's Johnson Space Center has joined forces with Baylor College of Medicine to develop a Left Ventricle Assist Device (LVAD) that doesn't replace the heart, but supplements its pumping capacity in the left ventricle.

Tools and techniques used by NASA in spacecraft propulsion system component design were used in the design of the LVAD, which is a small, implantable, axial-flow pump that minimizes red blood cell trauma and thrombosis. The LVAD consists of three components: a flow straightener to direct the incoming flow axially and support the front bearing; an inducer/impeller (the only moving part) that rotates between 10,000 to 12,000 revolutions per minute; and a diffuser that redirects the tangential flow and supports the rear bearing. There are no seals or diaphragms which can fatigue, fail, or
Generating Ozone by Electrolysis

Lynntech, Inc. of College Station, TX, teamed with NASA’s Johnson Space Center to develop an electrochemical process of generating ozone for reclamation and repurification of wastewater in regenerative life support systems.

Ozone gas is a nonpolluting water treatment chemical with a growing number of commercial applications. When introduced into water, it breaks down into oxygen and water, leaving no harmful residual chemicals. It has become more widely used as a municipal drinking water disinfectant, replacing chlorine which produces more disinfection by-products.

Ozone cannot be stored as a compressed gas—it must be generated at the application site—and usually is made by the corona discharge process, which is expensive on a small scale due to high equipment costs. The new alternative process forms ozone electrochemically by the electrolysis of water, using ozone in combination with ultraviolet light.

Electrochemical ozonizers have a number of commercial applications, such as creating ozone for disinfecting ultra-high-purity water used in the manufacture of semiconductor devices. Hazardous wastewater containing organic pollutants can be treated using the new process, which eliminates the pollutants by oxidation, rather than transferring them from one place to another. The process creates a concentrated ozone source, generating a gas stream containing up to 20% ozone by weight. The higher concentrations generated by this process permit more effective transfer of ozone into a process stream.

Small-scale water recycling systems are becoming common, and alternative disinfectants to chlorine are being sought. Electrochemical ozonizers could serve this growing market in the U.S.

Green Machine

Renew, reuse, recycle. From paper bags to soup cans to soda bottles, virtually every type of packaging is recyclable. Now, NASA is helping to drive an innovation that could make your car totally recyclable.

The government's automobile standards for the future specify a low-emission, fuel-efficient, recyclable, affordable "Supercar." XCORP of Beverly Hills, CA—in cooperation with 36 aerospace and automotive engineers and NASA—has designed a concept car that could meet such requirements. The rear-wheel-drive, rear-engine XCAR features an all-composite monocoque chassis. It's expected to get up to 90 miles per gallon and reduce emissions by 80% compared to other vehicles. And if that's not enough, the car also would be wallet-friendly, sporting a sticker price between $10,000 and $13,000.

XCORP used a computer net across California to design the car, and a consortium of suppliers and defense labs has developed a prototype in conjunction with NASA’s Far West Regional Technology Transfer Center at the University of Southern California. NASA Langley Research Center's fluid dynamics computer department will conduct crash simulations using the Internet, and a new rapid prototyping plant at the Department of Energy in Kansas City will produce the car's parts.

A class of materials called Environmental Composites (ECs) is mixed with aluminum to produce an inexpensive, recyclable, one-piece car body. The lightweight, strong, noncorrosive, nonconducting, vibration-dampening composites are made using a low-emission, low-energy manufacturing system. They even can be formulated from agricultural waste or recycled materials.

The XCAR can be manufactured using one-third as many parts as a conventional car, eliminating spot welding, drilling, bolting, and most finishing operations commonly used in the manufacture of steel cars. And when the XCAR has reached the end of its environmentally friendly road, it can be stripped easily and its main components, advanced polymers and aluminum, can be recycled.

An XCAR model will be featured in Technology 2005's "Transportation Tomorrow" exhibit pavilion of automotive, aviation, marine, and mass transport advances.
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Seeing is Believing
Affecting nearly 50 million people each year worldwide, cataracts remain the major cause of blindness. There is no medical treatment to prevent, halt, or reverse the progression of cataracts—surgery is the only recourse. A new method of detecting the onset of cataracts noninvasively eventually may be used to develop and test new drugs or diet therapies that could slow the formation of cataracts, or dissolve them, before surgery is required.

A compact fiber-optic probe developed for microgravity science experiments on the space shuttle has been applied to eye diagnostics through NASA’s Lewis Research Center. The probe is based on dynamic light scattering principles and has no moving parts. It does not require optical alignment, and contains a miniature microscope for imaging the eye. The size of a pencil, the probe is positioned in front of the eye and delivers a low power cone of laser light into the eye. The light is back-scattered by the protein molecules of the lens through a receiving optical fiber to a photodetector. The system provides a means for studying physical properties of the anterior and posterior chambers of the eye.

The device detects not only cataracts but also diseases of the chambers and indicates patients affected by cholestrolosis. Complete eye diagnostic capabilities are provided to ophthalmologists in one small instrument package.

A Unique Plastic
A patented thermoplastic, developed by Robert Bryant at NASA’s Langley Research Center, shows promise as a useful tool in almost all manufacturing processes. LaRC SI (soluble imide) is a moldable, soluble, strong, crack-resistant polymer that can survive at high temperatures and pressures. While originally designed for high-speed civilian aircraft, it promises to be useful in almost all manufacturing processes.

The polyimide is the highest-performing class of plastics. It is superior to epoxies, polyesters, and other materials since it can withstand hostile environments and be molded into any shape. It bonds to itself and is soluble only once, making it ideal for such applications as multilayer flexible circuits.

The thermoplastic is based on readily available compounds. When melted, it can be painted or sprayed onto a surface, where it hardens when dry. LaRC SI is unlikely to burn, and is resistant to hydrocarbons, lubricants, antifreeze, hydraulic fluid, and detergents found in manufacturing environments. It also can be used as a base film or adhesive for use by manufacturers of mechanical parts, abrasive coatings and thin films.

For more information on these technologies, contact the NASA field center that sponsored the research (see page 14). For information on Technology 2005, call 1-800-633-0062, ext. 117.
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For More Information Write In No. 527
Lewis Research Center

In 1940, the US Congress authorized NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), to build a facility solely for aircraft engine research. Named for the NACA's former director of aeronautical research, George W. Lewis, the Cleveland, Ohio-based laboratory sponsored valve research for radial engines—the war's workhorses—a cooling system for the B-29, fuels, lubricants, and seals. The center went on to develop liquid hydrogen propellant and the Centaur upper-stage launch vehicle for the space program, enabling Apollo astronauts to reach the moon. Lewis' chemical propulsion, seal design, and engine bearings research contributed to the space shuttle's main engines.

As NASA's lead center and Center of Excellence in aeropropulsion, Lewis conducts research and technology development in subsonic, supersonic, hypersonic, and high-performance aircraft propulsion systems, supported by research in materials, structures, internal fluid mechanics, instrumentation and control, interdisciplinary technologies, and aircraft icing. For next-generation, high-speed civil transport—which must improve upon current supersonic jets for fuel-efficiency and environmental considerations—Lewis is collaborating with General Electric and Pratt & Whitney to devise new enabling propulsion materials. Ceramics matrix composites, a major thrust of Lewis' materials research, could operate uncooled in the engine's extremely high-temperature, low-emission combustors.

In satellite communications, another Lewis specialty, the center manages the Advanced Communications Technology Satellite (ACTS) project, essentially an orbiting technology laboratory, to meet increasing communications demands. ACTS is testing wide bandwidth channels and the Ka frequency band to compensate for the already congested C and Ku bands; spacecraft antennas that generate narrow spot beams; and a digital communications processor that routes traffic from the hopping spot-beams to the appropriate destination.

As with the ACTS program, Lewis focuses many of its projects to benefit the users in industry and academia who work with the center during development. Already, from ACTS, Motorola is adapting Ka-band and onboard switching technologies to its worldwide communications system, and Norris Communications is constructing a Ka-band spot-beam satellite.

Facilities

Over 4000 personnel at Lewis' 350-acre Cleveland site and 6400-acre Plum Brook site carry out its aeronautical and related programs in 24 major facilities and over 500 specialized research facilities. The Icing Research Tunnel, the world's largest, was established in 1944 and led to the development of ice protection technologies that largely have diminished icing problems for aircraft, although research in improvements continues at the tunnel. The Hypersonic Wind Tunnel, the only nonvitated hypersonic tunnel in the US, produces high mass-flow rates of high-temperature, uncontaminated air for simulating Mach 5 through Mach 7 velocities. Lewis also has 10 x 10-foot supersonic, 8 x 6-foot supersonic/transonic, and 9 x 15-foot subsonic wind tunnels; a propulsion systems laboratory; an engine component research laboratory; and a powered lift research laboratory.

Lewis' research in spacecraft power is carried out in facilities such as the Energy Conversion Laboratory, where new photovoltaic technologies are created.

Boeing's inlet concept for high-speed civil transport is tested at Lewis' 10 x 10 wind tunnel.
The Space Power Research Laboratory develops electrochemical power systems such as lightweight nickel-hydrogen batteries and hydrogen-oxygen fuel cells.

Lewis' Materials Division furthers innovations in ceramics, tribology, polymer matrix composites, and ceramic and metallic coatings. The new Microgravity Materials Science Laboratory offers access to academic, industry, and government researchers to conduct low-gravity materials processing experiments on the shuttle and in the future of the space station. To test the reliability and life of ceramic structures, researchers in Lewis' Structures Division wrote CARES, which won the 1994 NASA Software of the Year award (NASA Tech Briefs, December 1994, p. 12).

The Business Community as Customers

Although aeronautics and aerospace forms the primary thrust of Lewis research, the center also offers technology transfers and collaborative projects, employing the center's facilities and expertise in fluid mechanics; surface modification; energy storage systems and thermal transport; materials development and structural design; and electronics, communication, and instrumentation.

"We were interested in areas that might have a very strong coupling with the immediate community (Cleveland), which is known for its premier medical facilities and research," said Ann Heyward, chief of Lewis' Office of Commercial Development (OCD). "We already had many people in the lab transferring technologies from aerospace to health and medical applications and decided that it made sense to try and integrate this under one umbrella."

Lewis has collaborated with the bioengineering community to produce biologically compatible coatings for implants; structural-modeling computer codes for orthopedic implants; computer-assisted, minimally invasive surgery; acousto-ultrasonic detectors for bone and muscle deterioration; fiber-optic sensors; noninvasive, miniaturized sensors; and improved wheelchair-batteries.

"Our ultimate goal is to solve our customer's problem," said Heyward. "That may involve taking a Lewis technology and looking for an application for it—a 'technology push' approach. We are also looking at 'market pull' factors—what things are important to our customers and where they are looking for technologies, and trying to make those matches transfer.
where we can." Lewis is compiling a directory of expertise to be available in the next few months, she explained, "so if customers know they need some expertise in a particular area, they can turn to it in this directory."

The OCD has streamlined some of the processes by which industry can link up with Lewis. For example, it has standardized language in drawing up Space Act Agreements. "By doing so, and making it available electronically, we cut the time to prepare and approve an agreement from a year to about a month," Heyward said. "In one directorate alone, we've had a tenfold increase in the number of agreements in the last two years."

Lewis now has over 500 cooperative relationships of various kinds and leads the NASA field centers in the number of Small Business Innovation Research (SBIR) participants it manages.

Successful Transfers

This emphasis on partnering has resulted in a prolific amount of spinoffs and other applications of Lewis technology. In 1994, Lewis selected two companies, Hitec Products, Inc. and HITEC Corp., to commercialize its advanced high-temperature resistance strain gauges. Critical to advanced gas turbine engines and hypersonic aerospace vehicles, the gauges can accurately measure static strain to temperatures of 800° C, compared to 400° C by other instruments. Hitec sold 75 gauges in one month, and HITEC received several requests for gauge installation. Gauge sales are projected at $3-5 million in the next four years.

Lewis is a Center of Excellence in microgravity science, researching combustion science and fluid physics. This has led to at least one potentially important spinoff for the health care industry: a medical diagnostic tool that is a fiber-optic, laser light-scattering probe for early detection of cataracts, cholestrolisis, and other systemic and eye diseases. (For more on this technology, see "NASA Innovations" beginning on page 20.)

To increase the life of Allison Engine Co.'s Model 250 helicopter and rotary-wing aircraft turbine engine, Lewis and the company signed an Aerospace Industry Technology Program cooperative agreement with Howmet Corp., Cannon-Muskegon Corp., and Purdue University last January. By integrating new materials into the turbine wheel—dubbing to tripling wheel life—and other components, the effort aims to maintain Allison Engine's US market share against increasing foreign competition. On top of NASA's $1.9 million cost share to the project, its partners contributed $4.4 million.

Other commercialized Lewis technologies include thin-film diamond-like carbon (DLC) used in scratch-resistant coatings for eyeglasses, wear-resistant hip-joint balls, and coatings for surgical needles to minimize needle-puncture damage to the patient and reduce recovery time. Research in ion propulsion for spacecraft has filtered into the development of industrial ion-beam sources, used for etching electronic microcircuits and depositing thin films for solar cells or optical equipment—or depositing DLC. When the center was hunting for a way to feed fuel into a weightless orbiting spacecraft's engine, it devised a magnetized fluid with finely ground iron oxide particles. This gave birth to Ferrofluidics Corp. of Nashua, NH, which found that a ferrofluidic rotary shaft seal solved a contamination problem in a system for making semiconductor chips. Now the use of ferrofluids in rotary shaft seals of all kinds has increased, and most computer memory disk drives use magnetic fluids.

For further information, contact Ann Heyward, Office of Commercial Development, Lewis Research Center, Cleveland, OH 44135; Tel: 216-433-3494; Fax: 216-433-5266; E-mail: caannr@lims01.lerc.nasa.gov.
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Photo courtesy of Arnold Engineering Development Center

For More Information Write in No. 518
Magnetic or Optical Surface Layer Would Indicate Strain

The surface layer would be deformed along with the substrate.

Langley Research Center, Hampton, Virginia

In a proposed method of obtaining information on strain at a surface of a material specimen, a magnetic coat (like that on magnetic tape) or an optical coat (like that on a compact disk) would be applied to all or part of the surface to be monitored. The coat would contain a record of its initial geometrical condition and would be read to determine changes in its condition, which changes would correspond to changes in the monitored surface.

The coating layer and the associated measuring equipment, taken together, would constitute a system called a "material strain monitor" (MSM). The system (see figure) would include an electronic module connected to a reading/writing probe via a data cable. The reading/writing probe would include wheels or other means of determining displacement of the probe along the surface. The probe would also include a reading/writing head, which would read and write information in the coating layer. A technician would press a "start" button on the probe to initiate the strain-monitoring procedure. The probe would then move over the surface to be monitored, writing or reading information in the coating layer.

In coating the surface to be monitored, magnetic particles could be mixed with a bonding agent and the mixture could be applied to the surface as a paint or spray. The resulting thin surface film would resemble the coating layer on a magnetic recording tape. The reading/writing probe used with such a film would be a standard magnetic reading/writing head capable of aligning the random magnetic domains in the film.

Alternatively, the coating layer could be a photographic emulsion applied in the dark. In this case, the reading/writing head could be connected to the electronic module via a fiber-optic cable and would include a lens to focus light onto the photographically treated surface. The fiber-optic cable could be used to both write in (expose) the emulsion and read from (measure the reflectance of) the emulsion.

The electronic module would include a logic submodule, a data bus, and a displacement-voltage generator, which together would measure the motion of the reading/writing probe over the monitored surface by use of rate-of-change-of-voltage (dV/dt) processing: The output of the displacement-voltage generator would govern the rate of generation of pulses by a voltage-controlled oscillator. These pulses would drive an output amplifier that would be connected to the reading/writing probe during writing. During reading, an input amplifier would be connected to the reading/writing head and a phase detector would compare the phase of the input (reading) signal with the phase of the signal from the displacement-voltage generator. The output of the phase detector would be digitized and stored in memory along with the position calculated by the logic submodule, which would integrate the signal from the displacement-voltage generator.

A Pattern of Information would be stored magnetically or optically in the coating. Deformation of this pattern would provide data on the deformation of the underlying material. The electronic module would process the stored information.
The CY-9000 1/2" digital tape drive gives you fifty times the capacity and four times the speed of 3490 drives—with a much lower cost per megabyte. Writing data at 12 MB per second, it can store 42 GB in less than an hour. With a 32 MB data buffer, it's the perfect match for the fastest host computer systems running the most demanding storage and data collection applications.

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generator to calculate the distance (measured via rotation of the wheels) traveled along the surface.

Information would be written into the surface layer prior to deformation. The information pattern would remain embedded in the material and would suffer the same deformation as that of the material. Therefore, it would provide quantitative data on plastic deformation of the material. The data could be vectorized by writing the information in orthogonal tracks. Inasmuch as magnetic or optical lines can be read at densities of more than 10^6/in. (about 4 \times 10^7/cm), the MSM could measure plastic deformations at high data densities anywhere a surface could be suitably coated. In contrast, conventional strain gauges can measure at single locations only, are vulnerable to mechanical disturbances, and cannot achieve high densities of data. The MSM will likely be very important in research in materials and mechanics; in particular, it is expected to compete strongly with systems based on image-analysis and laser techniques now being developed to obtain information on strain fields.

This work was done by Joseph S. Heyman of Langley Research Center. No further documentation is available.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center; (804) 864-9260. Refer to LAR-14510.

Media Controller for Receiving Data From a TAXI™ Link

This circuit buffers data signals and detects some abnormalities in the signals.

Lyndon B. Johnson Space Center, Houston, Texas

The TAXI™ media controller (TMC) is an interface circuit that supports the operation of test equipment in diagnosis of a telemetry system in which data are communicated via TAXI™ links. The TMC is designed specifically for use with a TAXI™ test adapter for monitoring and testing telemetry data signals generated by payloads and other subsystems of the Space Station Freedom. The TMC can also be used with other data-communication test equipment for testing TAXI™ links or other links that generate signals according to the same protocols.

"TAXI" as used here means "transparent asynchronous xmitter/receiver interface" (using "xmitter" for "transmitter" as is occasionally done in the electronics industry). A unidirectional high-speed serial data link can be constructed with TAXI™ transmitting and receiving integrated-circuit chips: At the source of data, a TAXI™ transmitting chip implements a 4-bit/5-bit coding scheme for serial transmission in which extra bits (beyond those needed to communicate data) are added for command symbols. At the receiving end of the link, a TAXI™ receiving chip decodes the signal and deserializes the data stream.

The test equipment in the original application is required to receive the data output of the TAXI™ receiver, verify the applicable data-packet protocol, and verify that the data rate does not exceed the data-buffering capabilities of the high-rate frame multiplexer which is used to receive the telemetry in the real system. The TMC helps the test adapter to perform these functions. Overall, the TMC can be characterized as providing an interface between the output port of a TAXI™ receiving chip and the input port of a memory system in the test adapter (see figure).

The output of the TAXI™ receiving chip consists of decoded parallel data and command symbols, which could, in principle, be clocked into compatible test-adapter logic circuits by use of a receiving clock signal derived from the serial data signal. However, because the phase and frequency of this clock signal vary with the data stream, this clock signal is not suitable for clocking logic circuits in the test adapter that...
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For More Information Write In No. 535
Data-Logger Interface and Test Controller

Marshall Space Flight Center, Alabama

A data-logger interface and test controller (hereafter "the controller" for short) has been developed to enable the automation of tests in conjunction with data-acquisition functions performed by data loggers that have output-switching capabilities. The controller includes relay logic circuits that remain deenergized until an out-of-tolerance condition on any data channel is discovered. The controller is designed to be connected to a Fluke model 2286A (or equivalent) data-logger system, which features 3 control channels with 8 data inputs per channel. The controller includes an elapsed-time counter that keeps track of power outages.

This work was done by Donnie R. Burch for Marshall Space Flight Center. For further information, write in 84 on the TSP Request Card. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-22978.

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**Wireless Infrared Data Link**

The rate of repetition of infrared pulses indicates a measured physical quantity.

*Lyndon B. Johnson Space Center, Houston, Texas*

An infrared transmitter and receiver have been designed for wireless transmission of information on a measured physical quantity (for example, temperature) from a transducer device to a remote-acquisition system. In the transmitter, the output of a transducer (in this example, a thermocouple) is amplified and shifted with respect to a bias or reference level, then fed to a voltage-to-frequency converter to control the frequency of repetition of current pulses applied to an infrared-light-emitting diode. In the receiver, the frequency of repetition of the pulses is converted back into a voltage indicative of the temperature or other measured quantity. This voltage is fed to the data-acquisition system.

In the original temperature-measurement application, the transducer is a type-T thermocouple. In the transmitter, the voltage output of the thermocouple is amplified, shifted with respect to a bias or reference level, and fed to a voltage-to-frequency converter to control the frequency of repetition of pulses applied to an infrared-light-emitting diode that radiates at a wavelength of 880 nm. The frequency is 3.6 kHz at a temperature of 20°C and changes with temperature at a rate of 5.1 Hz/°C. The temperature resolution of the transmitter is about 0.1 °C.

An infrared-sensitive phototransistor in the receiver detects the modulated infrared signal. The electrical output of the phototransistor is processed by a waveform-conditioning amplifier, then by a frequency-to-voltage converter, then by an adjustable-gain, adjustable-offset amplifier. The final output voltage of the receiver varies with the thermocouple reading at a rate of 26 mV/°C; at this rate, the increment of voltage that corresponds to the temperature resolution of the transmitter (2.6 mV per 0.1 °C) matches the voltage resolution of most commercial data-acquisition systems.

The transmitter and receiver are small and light in weight, and they consume little power. Modified versions with suitable coding of signals could be used to transmit multiple measurements. Potential applications include logging data while drilling for oil, transmitting measurements from rotors in machines without using slip rings, remote monitoring of temperatures and pressures in hazardous locations, and remote continuous monitoring of temperatures and blood pressures in medical patients, who could thus remain mobile.

This work was done by Timothy E. Roth of Allied Signal Technical Services Corp. for Johnson Space Center. For further information, write in 87 on the TSP Request Card. MSC-22567

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**Neural Networks Analyze Data in Particle-Impact-Noise Tests**

Interpretation of test data is more objective and accurate.

*Lewis Research Center, Cleveland, Ohio*

Electronic neural networks and computers have been put to use in analyzing data acquired in particle-impact-noise-detection (PIND) tests of packaged electronic components. PIND tests are performed to detect loose particles in the packages that could cause failures during subsequent operation of the packages in the presence of accelerations or other effects — for example, loose electrically conductive particles that could bounce into positions in which they would cause short circuits.

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while a microphone picks up the noise emitted by the shaken part. The output of the microphone is recorded, yielding a history of noise that is subsequently analyzed.

Previously, data from PIND tests were analyzed in a labor-intensive and error-prone process of subjective human interpretation. The average accuracy of such interpretation has been found to be about 44 percent. Accordingly, the neural-network computerized method was introduced to automate the analysis and to increase its accuracy by reducing human subjectivity and error.

In this method, the recorded noise signal is first processed by a computer-controlled analog-to-digital converter. The digitized noise-signal data (see figure) are then processed into voltage data bins, the contents of which serve as inputs to a neural network. The neural network then analyzes the data, deciding whether or not the tested package contained loose particles.

Neural networks of both the backpropagation and the self-organizing-map types have been successfully trained and tested on PIND data. Preliminary results suggest that the use of neural networks will result in significant improvement in the quality and reliability and decrease in the cost of PIND testing.

This work was done by Lois J. Scaglione of Lewis Research Center. For further information, write in 65 on the TSP Request Card, LEW-16077.

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CCD/CID Processors Would Offer Greater Precision

Each cell would contain 1 bit of the binary representation of a matrix element.

NASA’s Jet Propulsion Laboratory, Pasadena, California

Charge-coupled-device/charge-injection-device (CCD/CID) data processors of a proposed type would offer the advantages of massively parallel computational architecture and high computational speed typical of older CCD/CID data processors, but with increased precision. Typically, the precision of an older CCD/CID processor is limited to about 8 bits. The proposed devices could be made precise to an arbitrarily large number of bits. CCD/CID processors are especially useful in performing matrix-vector multiplications in a variety of applications, including solving partial differential equations, processing signal and image data, control computations, and neural-network simulations. The greater precision of the proposed devices could help to ensure accuracy in CCD/CID implementations of pseudospectral neural networks — a particular class of artificial neural networks that are especially well suited to solving nonlinear differential equations.

Figure 1 is a simplified schematic diagram of a typical older CCD/CID array. Each cell in the array is connected to an input column line and an output row line via a column gate and a row gate, respectively. These gates acting together hold, in a silicon substrate underneath them, a charge that represents an analog matrix element. In a default mode of operation, the matrix charges sit under the column gates.

In the basic matrix-vector multiplication mode of operation, with a binary input vector, the column gates serve as binary-analog multipliers by transferring the matrix charges toward the row gates only where the input bits of the columns indicate binary “ones.” The charge transferred under the row gates is summed capacitively on the output line of each row, yielding an analog output vector that is the product of the binary input vector with the analog charge matrix. By virtue of the principle of operation of the CCD, the charges are sensed nondestructively, and the charge matrix is restored to its original state simply by pushing the charges back under the column gates.

A bit-serial digital-analog matrix-vector multiplication can be obtained from a sequence of binary-analog matrix-vector multiplications, by feeding in vector input bits sequentially, and adding the corresponding output contributions after scaling them with the appropriate powers of 2. A simple parallel array of divide-by-2 circuits at the output accomplishes this task. Further extensions of the basic matrix-vector multiplication scheme support full digit-
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Thus, the price of increased precision would be increased size (each matrix element being spread over b rows). One added benefit would be a reduction in refresh time, inasmuch as each packet of charge would represent only a binary quantity.

Computation would proceed as follows: At clock cycle one, the matrix A, in its binary representation, would be multiplied by the binary vector

$$\begin{bmatrix} u_1^0 & \ldots & u_N^0 \end{bmatrix}$$

which would contain the least significant bits of vector \( (u_1, \ldots, u_N) \). By virtue of the charge-transfer mechanism, analog voltage

$$\begin{bmatrix} \omega \cdot \frac{\delta}{0} \ldots \omega \cdot \frac{\delta}{p-1} \end{bmatrix}$$

would be sensed at the output end of each row. At clock cycle two, these voltages would be fed into a pipelined analog-to-digital converter having \( d \) bits of precision (where \( d = \log N \), and \( N \) denotes the number of columns of A), while simultaneously A would be multiplied by

$$\begin{bmatrix} u_1^1 & \ldots & u_N^1 \end{bmatrix}$$

[which would contain the next more significant bits of \( (u_1, \ldots, u_N) \)], yielding \( \omega \cdot v \).

At clock cycle three, the digital representations of

$$\begin{bmatrix} \omega \cdot \frac{\delta}{0} \ldots \omega \cdot \frac{\delta}{p-1} \end{bmatrix}$$

would be bit-mapped into a register with an appropriate offset (in general, \( k \) bits of offset at clock cycle \( k \) for element \( y_i^b \)), each offset pointer would be incremented by one, the voltages \( \omega \cdot v \) would be fed into the analog-to-digital converter, and A would be multiplied by vector

$$\begin{bmatrix} u_1^2 & \ldots & u_N^2 \end{bmatrix}$$

to obtain \( \omega \cdot v \). Elements

$$\begin{bmatrix} k \omega \cdot y_i^b \end{bmatrix}$$

with same row index \( i \) would then be fed into cascaded sum circuits, in parallel for all \( i \), pipelined over \( k \). Thus, the components \( v_i \) of the product \( v = Au \) would be obtained after \( \log^2 b \) cycles, and the overall latency would be \( b + \log^2 b + 3 \). If one needed to multiply a set of vectors \( u \) by the same matrix A, this pipelined architecture would result in an output vector every clock cycle.

This work was done by Jacob Barhen, Nikzad Toomarian, and Amir Fijany of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 130 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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Multi-Band Frequency-Selective Microwave Reflectors

Double-loop patch and slot elements are used in two different frequency-multiplexing designs.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1. This Array of Double-Round-Loop Conductive Patches is highly reflective at frequencies around 33 GHz (in the K'_u band).

Two different frequency-selective reflectors have been studied for use in multiplexing signals at selected frequencies in the S, X, K', and K'_u frequency bands in a microwave communication system. One reflector is designed to be highly transmissive at frequencies of 2.3 GHz (in the S band) and 13.8 GHz (in the K', band); at the same time, it is highly reflective at frequencies of 7.2 and 8.4 GHz (in the X band) and 32 and 34.5 GHz (in the K'_u band). The other reflector is designed to be highly transmissive in the K'_u band and highly reflective in the S, X, and K, bands.

These frequency-selective reflectors are closely related to the ones described in several previous articles in NASA Tech Briefs, including "Frequency-Selective Microwave Reflectors" (NPO-18701), Vol. 18, No. 1, (January, 1994), page 32; "Improved Dichroic Microwave Reflector" (NPO-18664), Vol. 19, No. 8, (August, 1995), page 34; "Double-Square-Loop Microwave Reflectors" (NPO-18676), Vol. 18, No. 3, (March, 1994), page 38; "Tri Band Circular-Loop Dichroic Microwave Reflector" (NPO-18714), Vol. 18, No. 3, (March, 1994), page 41; "Making Curved Frequency-Selective Microwave Reflectors" (NPO-18755), Vol. 19, No. 8, (August, 1995), page 38; and "More Circular-Loop Dichroic Microwave Reflectors" (NPO-18940), Vol. 19, No. 1, (January, 1995), page 42.

The first-mentioned reflector is designed according to a double screen approach. The double screens were bonded to the front and back surfaces of a foam- or honeycomb-core dielectric...
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Thin-Film Power Transformers

Layers of ferromagnetic, conductive, and insulating materials would be used.

**NASA's Jet Propulsion Laboratory, Pasadena, California**

Miniature power transformers would be made by thin-film microfabrication techniques, according to a proposal. The microstructures of these transformers would be built in multiple thin layers, which would typically consist, variously, of ferromagnetic, electrically conductive nonferromagnetic, and electrically insulating materials (see figure).

The proposed transformers could have geometric features finer than those of transformers made in the customary way by machining and mechanical pressing. In addition, some thin-film materials exhibit magnetic-flux-carrying capabilities superior to those of the customary bulk transformer materials. Taking advantage of the flexibility of design afforded by thin-film microfabrication techniques, one could choose the materials, shapes, thicknesses, and lateral dimensions of the thin layers to shape magnetic-flux paths, suppress eddy currents, obtain specified reluctances, and otherwise generally optimize designs and performance characteristics. Thin-film transformers might be suitable for low-cost, high-yield mass production.

This work was done by Romney R. Katti of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 94 on the TSP Request Card. NPO-19092

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A Transformer Core would be made of thin layers of an insulating material interspersed with thin layers of a ferromagnetic material. Flux-linking conductors made of thinner nonferromagnetic-conductor/insulator multilayers could be wrapped around the core.
**Miniature X-Ray Tubes**

Micromachined field emitters would be used instead of thermionic emitters.  
*NASA's Jet Propulsion Laboratory, Pasadena, California*

Miniature x-ray tubes have been proposed for use in portable instruments used to analyze minerals. Instead of the thermionic emitters (hot filaments or cathodes heated by hot filaments) of conventional x-ray tubes, micromachined field emitters (see figure) would serve as the sources of electrons in the proposed x-ray tubes. Filaments are subject to breakage, their lifetimes are limited, and they are sensitive to operation in vacuum and near-vacuum environments. Fabricated from silicon wafers, the micromachined field emitters (MFEs) would not be subject to breakage or restrictions on lifetimes, and can tolerate vacuums that filaments cannot. MFEs use low voltage (+100V) to obtain field emission across a micron-size gap. Thus, they are small and use little power.

The miniature x-ray tubes would be very robust, immune to shock and vibration, and could be permanently sealed with a getter for continued pumping. They could be combined with solid-state x-ray detectors for analysis of x-ray fluorescence. For protective redundancy, a single tube could contain an array of field emitters. Because of the smallness of the field emitters (~1μm), the x-ray tubes could be made quite small. Very little power would be needed to cause emission of electrons, and the tubes could be operated in a flash mode, so that the overall power demand of such a tube would be so low that it could be satisfied by a trickle-charged battery.

This work was done by Gregory H. Bearman of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 11 on the TSP Request Card. NPO-19364

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**Sinterless Formation of Contacts on Indium Phosphide**

Heat is unnecessary to achieve low contact resistance.  
*Lewis Research Center, Cleveland, Ohio*

An improved technique makes it possible to form low-resistivity (≈10⁻⁶ Ω·cm²) electrical contacts on indium phosphide semiconductor devices without damaging the devices. Previously, metal contacts were deposited on n-doped InP and sintered to reduce the contact resistance. The sintering process caused intermixing of the metal and semiconductor, destroying all but the deepest junctions under the contacts. In the improved technique, a layer of AgP₂, 40 Å thick is deposited on the InP before depositing a metal contact. The AgP₂ interlayer sharply reduces the contact resistance, without need for sintering.

This work was done by Victor G. Waizer and Navid S. Fatemi of Sverdrup Technology Corp. for Lewis Research Center. For further information, write in 4 on the TSP Request Card. LEW-15814
Multilayer Active Control for Structural Damping and Optical-Path Regulation

Two control concepts are combined.
NASA's Jet Propulsion Laboratory, Pasadena, California

Two active-control concepts have been incorporated into a system for suppression of vibrations in a truss structure and regulation of the length of an optical path on the structure to the nanometer level. In the original intended application, the structure would be a lightweight truss structure supporting a stellar interferometer in zero gravitation. However, the control concepts should also be applicable wherever there is a need to maintain high precision and make a lightweight structure behave as though it had the stiffness of a much heavier structure.

One of the active-control concepts involves direct control of the length of the optical path, one end of which lies within a retroreflective optical assembly. In an experimental version, the optical assembly is mounted on a trolley, attached via flexures and a low-frequency large-amplitude voice coil actuator to the free upper end of a tower-like cantilevered flexible structure. A lightweight mirror within the assembly is mounted on a high-frequency, small-amplitude piezoelectric actuator. The two actuators respond to measurements from optical-path-length sensors: the outputs of the sensors are processed into actuator commands by a feedback control subsystem (see Figure 1). This concept has been described in more detail in a number of previous articles, including "Stabilizing Optical-Path Length on a Vibrating Structure" (NPO-19040), NASA Tech Briefs, Vol. 19, No. 8 (August, 1995), page 48; "Controllable Optical Delay Line for Stellar Interferometry" (NPO-18686), Laser Tech Briefs, Vol. 1, No. 1 (September, 1993), page 44; and "Test Bed for Control of Optical-Path Lengths" (NPO-18487), Laser Tech Briefs, Vol. 2, No. 1 (Winter, 1994), page 61.

The other active-control concept, called "dial-a-strut", has also been discussed in previous articles, though not under its present name. In dial-a-strut control, one uses active structural members (struts that contain both sensors and actuators) in conjunction with active feedback control subsystems to achieve a form of active damping in which each active member acts like a passive damper in a frequency range of interest. Ideally, one would optimize damping by making the effective mechanical impedance of an actively controlled member equal to the complex conjugate of the mechanical impedance of the rest of the structure. In practice, this is not feasible, and instead one adjusts dials on the front panel of the control electronics (hence the name, "dial-a-strut") to adjust the effective stiffness and damping parameters of the controlled strut to match

Figure 1. The Optical-Path-Length-Control Subsystem contains two feedback control loops to obtain active damping in a wide amplitude-and-frequency range.

Figure 2. The Impedance-vs.-Frequency response of an experimental actively controlled structural member was adjusted to a smooth approximation of the impedance of the rest of the structure.

This work was done by Zahidul H. Rahman, John T. Spanos, and James L. Fanson of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 57 on the TSP Request Card. NPO-19041

NASA Tech Briefs, October 1995
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Systolic Processor Array for Recognition of Spectra

Spectral signatures of materials would be detected and identified quickly. NASA’s Jet Propulsion Laboratory, Pasadena, California

A proposed systolic array of digital data processors would quickly detect and identify spectral signatures of materials of interest that appear in images produced by advanced imaging spectrometers of high spectral resolution. Called the Spectral Analysis Systolic Processor Array (SPA^2), this array would be relatively inexpensive and would satisfy the need to analyze the large, complex volume of multispectral data generated by imaging spectrometers to extract the desired information: the computational performance needed to do this in real time exceeds that of current supercomputers.

The SPA^2 would be able to locate highly similar segments or contiguous subsegments in two different spectra at a time. Exploiting this capability, the SPA^2 could compare sampled spectra from instruments with a data base of spectral signatures of known materials. The SPA^2 would compute and report scores that would express the degrees of similarity between the sampled and data-base spectra. Higher scores would be deemed to indicate that the material(s) of interest had been detected at the sampling locations in the spectral images.

The building block of the SPA^2 would be a 400,000-transistor complementary metal oxide/semiconductor very-large-scale integrated circuit chip called the “Biological Information Signal Processor” (BISP). This chip (see figure) contains 16 processing elements that operate at a clock frequency of 12.5 MHz. It can compare spectral images as long as 4,194,304 elements. The SPA^2 composed of BISPs could operate orders of magnitude faster than does a CRAY-2 computer, yet it would fit in a package smaller than 20 cm^3.

This work was done by Edward T. Chow and John C. Peterson of Caltech for NASA’s Jet Propulsion Laboratory. For further information, write in 22 on the TSP Request Card.

NPO-18880
Computer-Aided Air-Traffic Control in the Terminal Area

Ames Research Center, Moffett Field, California

A developmental computer-aided system for the automated management and control of arrival traffic at a large airport would include three integrated subsystems. One subsystem, called the Traffic Management Advisor, establishes optimized landing sequences and landing times for aircraft arriving in designated airspace several hundred miles from the airport. Another subsystem, called the Descent Advisor, generates advisory data for fuel-efficient and conflict-free de-scents of aircraft assigned to available terminal gates. The third subsystem, called the Final Approach Spacing Tool, provides heading and speed clearances that produce an accurately spaced flow of aircraft on their final approaches. A data base that includes current wind measurements and mathematical models of performances of types of aircraft contributes to effective operation of the system.

This work was done by Heinz Erzberger of Ames Research Center. For further information, write in 58 on the TSP Request Card. ARC-13332

Process-Information Display Panel for Welder’s Visor

Information would be presented adjacent to the welder’s usual field of view.

Marshall Space Flight Center, Alabama

A head-up display (HUD) unit would be mounted in a welder’s visor or helmet (see Figure 1) to provide process information in real time, according to a proposal. Until now, success in manual welding has depended on the welder’s training and intuition in judging the progress of a weld by interpreting sights and sounds. The proposed display would enable the welder to gain greater awareness of the effects of welding while controlling the welding process in the usual way(s) by use of a foot pedal, voice command, and/or manipulation of the welding torch. Data obtained during the welding process could be used to compare welding performance with a guideline or model performance established through laboratory tests or through a data base compiled from experience, making it possible to avoid the need for every new welder on the job to solve the same problems that were previously solved by other welders.

One candidate design concept calls for a fully packaged HUD that would present computer-generated graphics adjacent to the normal viewing window of the welder’s visor or helmet (see Figure 2). The virtual-reality industry has created a new generation of such devices, with color and with resolutions of as much as 640 x 480 pixels and with higher-resolution units expected to come to market. Some modifications may be necessary to mount the display unit in the visor or helmet.

The HUD could be used, for example, to inform the welder of binary parameters like the states of solenoid-actuated switches and valves. Such continuously varying parameters as the rate of travel of the torch along the workpiece could be depicted by use of arrows, the lengths of which would be proportional to the deviations of the parameters from desired values or ranges of values. Colors could also play a key role; for example, the color of an arrow could be made to change from yellow to red as the error increased to an intolerable level. Such symbolic representation of the data would favor quick, intuitive interpretation.

In many cases, manual arc welding (as contrasted with automated arc welding) still offers the best balance of setup time, production volume, capital investment, and quality. Display devices of the proposed type could be especially beneficial in supporting and enhancing the continued practice of manual arc welding in such cases; even NASA and its contractors continue to use manual arc welding for fabrication and repair of much flight hardware and ground support equipment. The proposed display devices could also be of value in industries that invest millions of technician-hours each year in manual arc welding for a variety of products.

This work was done by Carolyn Russell of Marshall Space Flight Center and Ken Gangl of Advanced Welding Concepts, Inc. No further documentation is available.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26322.
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Five-Channel Polychromator Head
This device is part of a Raman-scattering temperature-measuring system.

Marshall Space Flight Center, Alabama

Figure 1 illustrates the five-channel polychromator head of a laser Raman polychromator that is being developed for use in measuring the rotational temperatures of \( \text{H}_2 \) molecules in subscale combustors. Each channel consists of a 1-mm fiber-optic cable that is individually translatable along the dispersion axis of a spectrometer to provide both flexibility and fine-tuning capability.

The basic idea is to measure the temperature in terms of the temperature dependence of Raman scattering of a laser beam from hydrogen molecules in the Q branch of the vibrational ground state. The Raman-scattered light can be resolved into a small number of spectral lines, the relative intensities of which indicate the population distribution of the hydrogen molecules in various rotational states. These spectral lines are denoted by their rotational quantum numbers, \( J \), and the ratio between the intensities of any two of these spectral lines is related in a known way to the temperature at the point of measurement.

Figure 1. The Five-Channel Polychromator Head samples the Raman-scattering spectrum simultaneously at five wavelengths.

Figure 2. The Laser Raman Thermometer is not a thermometer in the usual sense of the word, but a noncontact spectrometer that measures temperature indirectly in terms of the relative intensities of selected Raman-scattering spectral lines.
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The five-channel polychromator is used in conjunction with five photomultipliers (one photomultiplier for each channel) for simultaneous measurement of the $J = 0$ through $J = 4$ transitions of the $v = 0 \rightarrow v = 1$ Q branch. The photomultipliers offer high sensitivity and dynamic range, and the multiple channels eliminate the need for time-consuming scanning.

Figure 2 illustrates the laboratory configuration of the Raman thermometer in which the five-channel polychromator head is installed. The head is mounted on the exit plane of a double monochromator (spectrometer) with plane holographic gratings of 2,400 grooves/mm. The reciprocal linear dispersion at the middle of the spectrum (wavelength of 538 nm) is 0.14 nm/mm. The output signal of each individual fiber-optic cable is sent to a separate photomultiplier, the output of which is sent to a signal-conditioning amplifier. The outputs of the amplifiers are gated and boxcar-averaged. A computer digitizes, stores, and analyzes the boxcar-averaged data via real-time algorithms.

This work was done by Richard Eskridge, Chris Dobson, Mike Lee, and Tony Robertson of Marshall Space Flight Center. For further information, write in 46 on the TSP Request Card. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-28846.

Improved Bakeout Chambers Within Vacuum Chambers
Heated enclaves reduce contamination further.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates schematically one of several vacuum-bakeout chambers that have been redesigned to reduce contamination. When operated according to a revised bakeout procedure, they yield measurements of contamination on vacuum-bake test articles more accurate than were available previously, and the potential for post-bake recontamination of the vacuum-baked articles is reduced.

These chambers are improved versions of the one described in "Bakeout Chamber Within Vacuum Chamber" (NPO-18959), NASA Tech Briefs, Vol. 19, No. 5 (May, 1995), page 52. As before, each of the present vacuum-bakeout chambers includes an inner heated chamber surrounded by an insulating blanket that is, in turn, surrounded by a cold shroud, all mounted within a conventional vacuum chamber. The heated inner chamber is called a "bakeout chamber," and is now called an "enclave." The cold shroud is cooled by flowing liquid nitrogen; the cold shroud is used to reduce background pressure in the vacuum chamber and thereby reduce the deposition of background contamination on contamination detectors located near the bakeout chamber.

The improvements in design and bakeout procedure were made to satisfy the following three criteria: (1) A test article must not become contaminated by outgassed volatile materials at any time during bakeout, contamination-level testing, or post-test warmup of the cold shroud; (2) The background rate of outgassing by the chamber hardware must be negligibly small in comparison with that of the test article; and (3) the method used to measure contamination must positively verify that the required degree of cleanliness has been achieved.

The enclave consists mostly of a can and cover made of stainless steel and electropolished to remove contamination embedded in their surfaces. Contamination detectors of several different types (residual-gas analyzer, thermoelectric quartz-crystal microbalance, and cryogenic quartz-crystal microbalance) are mounted facing orifices in the cover, so that their directional sensitivity patterns cause them to measure predominantly the outgassed contaminants that stream from the enclave through the orifices. The measurement of contamination involves a multistep procedure in which the various detec-

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tions are operated at various temperatures and pressures.

By enclosing the test article in the enclave and keeping the walls of the enclave hotter than the test article during bakeout, one prevents condensation of contaminants on the inner walls of the enclave. In preparation for measurement of contamination of the test article, the background rate of outgassing by the chamber hardware is minimized by baking the enclave at a temperature greater than the maximum expected operating temperature of the test article. During bakeout, contaminants leave the enclave through the orifices and are removed from the vacuum chamber — some by the vacuum-chamber pump, others by condensing onto the cold shroud.

After bakeout is complete and before a post-bakeout test of cleanliness of the test article, the enclave is cooled slowly enough to prevent the condensation of volatile contaminants that are still being emitted from the test article (contaminants are still being emitted because the temperature of the test article lags behind the temperature of the enclave; that is, the test article is still hot at this phase of operation). After the post-bakeout test, the shroud is warmed slowly enough to limit the flux of desorption from the shroud to an acceptably low level, while the enclave is purged with high-purity gaseous nitrogen to minimize backstreaming of contaminants into the enclave.

This Improved Bakeout Chamber incorporates hardware features that, in conjunction with an improved bakeout procedure, reduce spurious contamination and increase the accuracy of contamination measurements.

This work was done by Kenneth R. Johnson, Daniel M. Taylor, Robert W. Lane, Maximo G. Cortez, and Mark R. Anderson of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 96 on the TSP Request Card. NPO-19015

Techniques for Topographical Mapping via Interferometric SAR

Data-processing techniques combined with advanced navigational capabilities yield terrain-height maps.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two techniques for processing data acquired by an airborne interferometric synthetic-aperture-radar (SAR) system yield terrain-height maps. The techniques are predicated on the availability of an accurate navigational system that yields data on the motion and orientation of the airplane that carries the SAR system and, thus, also effectively gives the orientation of the baseline between the two radar antennas of the system.

The figure presents a simplified view of the broadside-looking interferometric-SAR geometry. For an SAR system operating at a wavelength \( \lambda = c/f \) (where \( c \) = the speed of light and \( f \) = the radar carrier frequency), the phase shift, \( \phi \), between the radar returns received at the two antennas is given by

\[
\frac{\phi \lambda}{2\pi} = |r_{21}| \cos(\theta - \theta_{21})
\]

where \( r_{21} \) is the baseline vector between the two antennas and \( \theta_{21} \) is the angle of this baseline above the nadir direction. This angle can be computed from the navigational data. The other quantities indicated in the figure are given by

\[
\theta = \theta_{21} + \arccos \left( \frac{\phi \lambda}{2\pi |r_{21}|} \right)
\]

\[
h = H - r \cos \theta, \text{ and } y = r \sin \theta.
\]

Thus, in principle, the three-dimensional coordinates of a target point on the terrain can be determined from (1) the position and orientation of the airplane as given by the navigational system and (2) the slant range \( r \) and phase shift \( \phi \) as measured by the SAR system.

One of the two techniques resolves the \( 2\pi N \) ambiguity (where \( N \) is an integer) in the measured value of \( \phi \), enabling an absolute determination of the terrain height \( h \). In an older technique, this ambiguity was resolved by use of a reference terrain point of known elevation. In the present technique, no a priori elevational information is needed: Instead, this technique involves the construction of a differential SAR interfero-
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Verifying Dissolution of Wax From Hardware Surfaces

Wax removed by cleaning solvent is revealed by cooling the solution with liquid nitrogen.

Marshall Space Flight Center, Alabama

An improved solvent cleaning procedure and associated cleanliness test have been devised for removing wax that previously coated a piece of hardware and for verifying that the wax has been removed. Such a procedure and test are needed in the case of hardware that must be protected by wax during machining or plating but is required to be free of wax during subsequent use. In a previous solvent cleaning procedure and cleanliness test, carbon tetrachloride (which is highly toxic) was used as the solvent, and infrared spectroscopy was used to detect wax in the solvent flushings. A typical infrared analysis took as long as 2 hours.

The improved cleaning procedure and test take less than 5 minutes. Unlike the previous infrared-analysis cleanliness test, the improved test does not require special skill or equipment and can be performed at the cleaning site. In addition, the improved procedure and test enable recovery of all the cleaning solvent.

In the improved cleaning procedure, one uses 1,1,1-trichloroethane or perchloroethylene as the solvent. In the improved cleanliness test, liquid nitrogen, in a proportion of up to 40 volume percent, is mixed into the solvent flushings to cool them. The same proportion of liquid nitrogen is mixed into an equal amount of solvent known to be pure. If the solvent flushings contain a significant quantity of wax, a separate waxy phase collects on top of the flushing solution and can be identified by visual comparison with the clean solution.

This work was done by Benjamina G. Montoya of Rockwell International Corp. for Marshall Space Flight Center. For further information, write in 51 on the TSP Request Card. MFS-29978
Simple Magnetic Device Indicates Thickness of Alloy 903

Relative strength of attraction shows whether an alloy overlay is thinner than allowable.

Marshall Space Flight Center, Alabama

The figure illustrates a simple, handheld, magnetic device that can be used to determine whether an overlay of alloy 903 on a body of alloy 718 is thinner than allowable in a specific application. The device is called a "ferrite indicator" and was originally designed to be used in determining the ferrite content of a specimen of steel. It is placed in contact with the specimen and functions by indicating whether a magnet that it contains is attracted more strongly to the specimen or to a calibrated reference sample.

An experiment showed that the magnetic characteristics of alloy 903 make it suitable for inspection of overlays of this material by the ferrite-indicator technique. In the application that motivated the experiment, there was a need to ensure that the overlay of alloy 903 was at least 0.020 in. (about 0.5 mm) thick. In the experiment, one of the available reference samples gave an indication of 0.025 in. (about 0.6 mm). [The extra 0.005 in. (about 0.1 mm) can be used to advantage as a margin of safety.]

This work was done by Pin Jeng Long, Sergio Rodriguez, and Mark L. Bright of Rockwell International Corp. for Marshall Space Flight Center. For further information, write in 100 on the TSP Request Card. MFS-29980

The Ferrite Indicator is shown here with several reference samples.

Slide Rule for Calculating Curing Schedules

Marshall Space Flight Center, Alabama

A special-purpose slide rule has been devised for calculating schedules for storing and curing adhesives, sealants, and other materials that are characterized by known curing times and shelf lives. The use of the slide rule can prevent mistakes that are commonly made in determining storage and curing schedules. The slide rule is calibrated in days and hours. In using the slide rule, one simply selects the curing time and the starting calendar day and time; the slide rule indicates the number of days of curing and the hour when cure will be completed on the final day. It is, however, necessary to account separately for the number of days when the cure extends into the following month.

This work was done by Don Heater of Thiokol Corp. for Marshall Space Flight Center. For further information, write in 93 on the TSP Request Card. MFS-28938

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For More Information Write In No. 434
Trimethoxymethane (TMM) has been identified as a high-energy fuel for direct-oxidation fuel cells. TMM can be synthesized from natural gas (methane) and can be handled easily because it is a non-toxic, low-vapor-pressure liquid. Data obtained from both half-cell and full-cell tests indicate that TMM can be oxidized at very high rates. Thus, TMM is considered to be an excellent candidate for use in direct-oxidation fuel cells in vehicles and portable power supplies.

The electrochemical oxidation of TMM, represented by

\[ (\text{CH}_3\text{O})_3\text{CH} + 5\text{H}_2\text{O} \rightarrow 4\text{CO}_2 + 20\text{H}^+ + 20\text{e}^- \]

has been studied in experiments in half cells in which the electrolyte was 0.5 M sulfuric acid and the electrocatalysts were Pt/Sn and Pt/Ru electrodes. It was found that TMM can be oxidized at potentials considerably more negative than those of methanol. As shown by the data plotted in Figure 1, increasing the concentration of TMM increases the kinetics of its oxidation. The kinetics are also increased by increasing the temperature: at temperatures as high as 60 °C, the rate of oxidation is twice that at 25 °C.

Experiments on the direct oxidation of TMM were carried out in a liquid-feed-type fuel cell developed previously for direct oxidation of methanol. In this cell, Nafion 117, a commercial proton-conducting solid-polymer membrane, was used as the electrolyte. The membrane electrode assembly included a specially constructed fuel-oxidation electrode made of an unsupported Pt/Ru catalyst layer (4 mg/cm²) and a gas-diffusion-type unsupported platinum electrode (4 mg/cm²) for the reduction of oxygen. A fuel solution of 2 M TMM was circulated past the anode of the cell, while oxygen at a pressure of 20 psi (=140 kPa) was applied to the cathode. The CO₂ produced by the oxidation of TMM was easily separated from the fuel solution in a tall glass column.

Analysis revealed no oxidation products other than methanol, which may be an intermediate product in the process of oxidation of TMM to carbon dioxide and water. Inasmuch as the particular fuel cell was designed to handle methanol in the first place, the presence of methanol is no cause for concern. Figure 2 shows current-vs.-voltage characteristics of the cell in an experiment using TMM and in another experiment using methanol as the fuel.

This work was done by George A. Olah, Surya G. Prakash, Sekharipuram R. Narayanan, Eugene Vamos, and Subbarao Surampudi of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 63 on the TSP Request Card.

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

William T. Callaghan, Manager Technology Commercialization JPL-301-350 4800 Oak Grove Drive Pasadena, CA 91109

Refer to NPO-19228, volume and number of this NASA Tech Briefs issue, and the page number.
GE Plastics' New Material Selection Database, GE Select™, Is The Most Comprehensive Ever

GE Plastics has unveiled a new disk-based material selection database designed to make the specification of its engineering thermoplastics easier than ever before. This comprehensive database, named GE Select, covers the diverse family of GE polymers and provides complete properties and engineering data on over 500 commercially available resin grades.

The data is presented in an easy-to-use format designed to help engineers maximize material potential, optimize material usage, and eliminate costly over-design. GE Select was developed by GE Plastics' Advanced Design Engineering group and drew heavily on results from a comprehensive survey of design engineers from across the U.S. Many of the engineers surveyed said they would prefer a disk-based system as opposed to accessing an engineering database via an on-line service. GE Select is the answer to this and many other customer needs.

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Once a user has determined some or all of the performance criteria required for an application, he or she accesses the GE Select program. The database opens automatically with material and grade names displayed in a Grade Table Window. By using a Material Selection dialog box, users can conduct a search of product grade property profiles to match specific application requirements.

GE Select searches the database and displays property information and engineering data for those resin grades that meet the criteria established by the user.

Special functions on the menu bar permit the plotting of engineering data, such as Tensile Stress vs. Strain, for product/grade comparisons. GE Select also allows users to overlay combinations of materials and test parameters—a key feature for design engineers. Engineering data available on GE Select include: Tensile Creep Data, Tensile Fatigue Data, Dynamic Mechanical Analysis Data, and Rheology Data.

User-Friendly Format

With GE Select, users can customize query windows, browse through material data sheets and display engineering data from the GE Engineering Design Database (EDD).

Easy Access

The two-disk program is available in both Microsoft® Windows and Macintosh® formats. It also can be downloaded directly from the Internet by accessing GE Plastics' www.ge.com on-line address.

For more information on GE Select, call 800-845-0600.

For More Information Write In No. 533
Dimethoxymethane: A Fuel for Direct-Oxidation Fuel Cells

This fuel can be electro-oxidized at sustained high rates without poisoning electrodes.

NASA's Jet Propulsion Laboratory, Pasadena, California

Dimethoxymethane (also called methyldiol), is a nontoxic liquid that has been identified as one of several high-energy fuels for direct-oxidation fuel cells. DMM has been found to undergo facile electro-oxidation to carbon dioxide and water, with methanol as a possible intermediate product. The electro-oxidation is catalyzed at Pt/Sn and Pt/Ru electrodes. The high rates of oxidation sustained by DMM make it possible to operate liquid-feed cells at significant power densities at temperatures close to ambient. The performance of DMM is superior to that of methanol at the same temperature. DMM can be synthesized from natural gas (methane) and is thus a viable alternative to methanol in direct-oxidation fuel cells.

The electro-oxidation of DMM involves a series of dissociative adsorption steps followed by a surface reaction to form carbon dioxide and water. The electro-oxidation reaction is represented by

\[(\text{CH}_3\text{O})_2\text{CH}_2 + 4 \text{H}_2\text{O} \rightarrow 3 \text{CO}_2 + 16 \text{H}^+ + 16 \text{e}^-\]

Experiments on the electro-oxidation of DMM were carried out in half cells in which the electrolyte was 0.5 M sulfuric acid and the electrocatalysts were gas-diffusion-type Pt/Sn and Pt/Ru electrodes. It was found that DMM can be oxidized at potentials considerably more negative than those of methanol.

Although increasing the temperature was found to increase the rate of oxidation significantly, the low boiling temperature of DMM (41 °C) made it impractical to use temperatures greater than 37 °C in the half-cell experiments. As shown in Figure 1, increasing the concentration of DMM increases the rate of its oxidation.

Experiments on the direct oxidation of DMM were carried out in a liquid-feed-type fuel cell developed previously for direct oxidation of methanol. In this cell, the electrolyte was a membrane of Nafion 117, which is a commercial proton-conducting solid polymer. The membrane electrode assembly included a specially constructed fuel-oxidizing electrode made of an unsupported Pt/Ru catalyst layer (4 mg/cm²) and a gas-diffusion-type unsupported platinum electrode (4 mg/cm²) for the reduction of oxygen. A fuel solution of 1 M DMM was circulated past the fuel-oxidizing (anode) side of the cell, while oxygen was supplied to the cathode at a pressure of 20 psi (=140 kPa). The carbon dioxide produced by the oxidation of DMM was easily separated from the fuel solution in a tall glass column.

Analysis revealed no oxidation products other than methanol, which may be an intermediate product of the process of oxidation of DMM to CO₂ and H₂O. The presence of methanol is not a cause for concern because the fuel cell was designed for use with methanol and the methanol is ultimately oxidized to carbon dioxide and water.

Figure 2 shows the current-vs.-voltage characteristic of the cell at 37 °C. The cell potential was 0.20 V at a current density of 50 mA/cm²; this performance was comparable to that obtained using methanol as the fuel. Better performance is expected at higher temperature and by use of Pt/Sn catalyst. Alternatively, the low boiling temperature of DMM also makes it a candidate for a gas-feed operation.

This work was done by George A. Olah, Surya G. Prakash, Sekharipuram R. Narayanan, Eugene Vamos, and Gerald Halpert of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 81 on the TSP Request Card.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to: William T. Callaghan, Manager Technology Commercialization JPL-301-350 4800 Oak Grove Drive Pasadena, CA 91109

Refer to NPO-19229, volume and number of this NASA Tech Briefs issue, and the page number.
Trioxane: A Fuel for Direct-Oxidation Fuel Cells

Trioxane can be used as a substitute for formaldehyde.

Trioxane has been identified as a high-energy, nontoxic, solid substitute for formaldehyde as a water-soluble fuel for use in direct-oxidation fuel cells. Trioxane has been found to undergo facile electrochemical oxidation to water and carbon dioxide at platinum and platinum-alloy electrodes in liquid-feed-type fuel cells that contain acid electrolytes or solid proton-exchange membrane electrolytes. Trioxane exhibits less crossover than do such conventional fuels as methanol and formaldehyde. Being a solid at ambient temperature, trioxane offers significant advantages in handling and transportation. Trioxane can be synthesized from natural gas with relative ease. The electro-oxidation of trioxane to carbon dioxide and water is believed to occur according to the reaction

\[
(\text{CH}_2\text{O}_2 + 6\text{H}_2\text{O} \rightarrow 3\text{CO}_2 + 12\text{H}^+ + 12\text{e}^-)
\]

Experiments on the electro-oxidation characteristics of trioxane were performed in half cells with temperature control. The electrolyte was sulfuric acid at various concentrations between 0.5 and 2.0 M. The cells contained gas-diffusion-type electrodes consisting of platinum/tin at an areal density of 0.5 mg/cm² on a high-surface-area carbon. The data in Figure 1 indicate that increasing the concentration of trioxane results in an increased rate of oxidation. Current densities as high as 100 mA/cm² were realized at potentials of 0.4 V — comparable to the performance realized with formaldehyde.

Cyclic voltammetry showed that the mechanism of oxidation of trioxane does not involve a breakdown to formaldehyde before electro-oxidation. Increasing the concentration of acid was also found to result in increased rates of electro-oxidation. Therefore, it was projected that very high rates of electro-oxidation would occur when using a solid electrolyte of Nafion™ (a commercial perfluorinated, hydrophilic, proton-exchange polymer), which exhibits an acidity equivalent to that of 10 M sulfuric acid.

Experiments on the direct oxidation of trioxane were carried out in a liquid-feed-type fuel cell developed previously for direct oxidation of methanol. In this cell, a Nafion proton-conducting solid-polymer membrane was used as the electrolyte. The membrane electrode assembly included a specially constructed fuel-oxidation electrode made of an unsupported Pt/Ru catalyst layer and a gas-diffusion-type unsupported platinum catalyst for the reduction of oxygen. A fuel solution of trioxane at a concentration of 1 M was circulated past the anode of the cell, while oxygen at a pressure of 20 psi (140 kPa) was applied to the cathode. The CO₂ produced by the oxidation of trioxane was separated from the fuel solution in a tall glass column.

Figure 2 shows the current-vs.-voltage characteristics of trioxane in this fuel cell. This performance can be improved considerably by use of platinum/tin electrodes. The measured rate of crossover was found to be no more than 1/5 that in a comparable methanol fuel cell. Decreased rates of crossover are extremely desirable, inasmuch as crossover reduces the efficiency and performance.
Closed-Loop System Removes Contaminants From Inert Gas

The system can be used in place of a supply of purge gas.

NASA's Jet Propulsion Laboratory, Pasadena, California

A closed-loop system for the purification of an atmosphere of inert gas includes a bellows pump, a cartridge for removal of oxygen, a cartridge for removal of water vapor, and porous metal filters at the ends of the cartridges for removal of particles. These components are connected in series with each other and with a chamber in which the gas is to be used (see figure). In the specific application for which the system was devised, the chamber is one in which semiconducting materials are processed. By virtue of the closed-loop operation, a limited supply of inert gas is adequate to provide an atmosphere for industrial processing of semiconductors.

The rate of leakage of the bellows pump is less than $10^{-6}$ cm$^3$/s. All tubes in the system are electropolished and connected together by VCR fittings. Because the gas comes in contact with only metallic parts, the pump does not add new impurities to the gas.

The oxygen-removing cartridge contains a packed oxygen-sorbent material. The cartridge can be heated to a temperature as high as 300 °C for operation in the scrubbing mode or for regeneration of the spent sorbent. Four classes of oxygen sorbents have been developed at NASA's Jet Propulsion Laboratory, each class being best suited for operation in a specific temperature range. These classes of sorbents are (a) copper-exchanged zeolites (200 to 400 °C), (b) copper-modified carbon molecular sieves (room temperature to 250 °C), (c) copper-containing platinum zeolites (100 to 400 °C), and (d) cobalt-containing platinum-modified zeolites (400 to 800 °C).

All of these sorbents take in oxygen by catalytic oxidation of copper. The equilibrium level of oxygen after removal is well below 1 part per trillion at temperature.

The Concentration of Oxygen in this closed-loop system is kept low by use of a heated catalytic sorbent bed in a cartridge. It is also proposed to keep the concentration of water vapor low by use of a predried zeolite sorbent bed in another cartridge, and to remove particles smaller than 0.1 μm by use of porous metal filters.
Electrochemical Deposition of Thiolate Monolayers on Metals

The degree of coverage can be controlled with relative ease.

NASA's Jet Propulsion Laboratory, Pasadena, California

An electrochemical method has been devised for coating metal (usually, gold) surfaces with adherent thiolate monolayers. In comparison with older, nonelectrical chemical solution methods, the present electrochemical method affords greater control over the location and amount of material deposited and makes it easier to control the chemical composition of the deposits. One important potential use for this method lies in the fabrication of chemically selective thin-film resonators for microwave oscillators used to detect pollutants: a monolayer can be formulated to bind selectively the pollutant chemical species of interest, causing an increase in mass of the monolayer and a corresponding decrease in the frequency of resonance. Another important potential use lies in selective chemical derivatization for purposes of improving adhesion, lubrication, protection against corrosion, electrocatalysis, and electroanalysis.

A compound used in this method is denoted by the general chemical formula XRSY. "S" is used here in the standard sense to denote sulfur, which is the component that bonds to the metal substrate. Y denotes a group that is lost during deposition, partly because it bonds to S less strongly than does the metal substrate; Y can represent hydrogen (in which case XRSY is a thiol), a
metal (in which case XRSY is a thiolate salt), or another organic group.

R is a molecular group that forms somewhat of an isolation layer in that it lies between S moiety attached to the metal and the X moiety at the outer end. R is chosen to obtain a desired packing density, stability, thickness, and/or other characteristics of the monolayer to suit a specific application. R can be any of a variety of organic groups; for example, a linear alkane chain [(CH₃)ₙ, where n is an integer].

R and X together determine the characteristics of the deposit. The outer end group, X, is chosen to provide the end functionality required in a specific application. X end groups that have proven useful include CH₃, CF₃(CF₂)ₙ, COOH, and OH; other potentially useful end groups include inorganic complexes with thiol ligands, organometallic compounds, cyclodextrins, and crown ethers.

In preparation for the deposition process, XRSY is dissolved in any of a number of compatible electrolytes; typically, the electrolyte is an aqueous solution of KOH. The process can be carried out in any suitable electrochemical system that includes a voltammetric analyzer and cell assembly. The XRSY/electrolyte solution and the working, reference, and counter electrodes of the system are placed in the cell. (The working electrode is the metal substrate to be coated.) The cell is purged with a chemically inert gas to remove dissolved oxygen. The electrodes are connected to the voltammetric analyzer. For the first 10 to 30 s, the applied voltage is set at a level at which any adsorbed compounds are desorbed so as to clean completely the working electrode, with stirring of the solution to facilitate transport of any desorbed impurities away from the substrate to prevent redesorption. The voltage is then stepped to the deposition voltage, which has been preselected from the anodic deposition wave, to establish a redox equilibrium, thus providing for the desired level of coverage. Typical deposition times range upward from about 1 min.

The figure shows a cyclic voltammogram that contains peaks showing the oxidative adsorption and reductive desorption of a layer of the thiolate HOCH₂CH₂S₋ on Au on a mica substrate. This plot shows that the adsorption and desorption processes are well-defined and reproducible.

This work was done by Marc D. Porter and Duane E. Weissharr of Iowa State University for NASA's Jet Propulsion Laboratory. For further information, write in 88 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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45 Spedding Hall
Iowa State University
Ames, IA 50014

Refer to NPO-19469, volume and number of this NASA Tech Briefs issue, and the page number.
VISION

Twenty years ago when our SITe team was developing the first thinned CCD imagers for some of the world's most powerful telescopes, we were already thinking ahead. We were visualizing all the ways our research, design experience, and manufacturing capability could be applied to creating imagers for a broad range of applications that need analytical or diagnostic imaging precision. We called those first such imagers "Scientific CCD's".

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Call us today for more information about our complete line of digital electronic imaging products.
On the cover:
A three-dimensional isometric plot of the atomic velocity distribution in a "Bose-Einstein condensate" achieved by a group of scientists from NIST, the University of Colorado, and JILA. Using laser trapping, followed by magnetic trapping, the group got the rubidium-87 atoms in a dilute gas down to 170 nanokelvins. There the peak indicated a cluster of atoms "frozen" into a stationary quantum state, and acting like a single atom, as predicted independently in 1924 by Albert Einstein and Indian physicist Satyendra Nath Bose. Photo by Mike Matthews/University of Chicago, courtesy of Science News.

LASER DIODE OPTICS

When your application demands high quality laser diode optics, think of Optima. Our 336 Series collimating lenses have been used in space systems and in more down-to-earth applications like bar code readers, laser pointers, and smoke detectors. Whether you need a custom assembly or just an off-the-shelf component, we'd like you to consider Optima. Please ask for our catalog covering the following items:

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- COLLIMATING AND OBJECTIVE LENSES -- GLASS OR PLASTIC
- SINGLETS, DOUBLES AND ACHROMATS
- ANAMORPHIC PRISMS
- OPTICAL FLATS -- MIRRORS, BEAMSPLITTERS, FILTERS
- DIFFRACTION GRATINGS
- ASPHERIC LINE GENERATOR LENSES
Formally announced in July, OptoSigma Corp. (Santa Ana, CA), a new company, brings together a group of US optical-industry veterans led by Paul Kenrick, formerly of Melles Griot, US, and Sigma Koki Co., a Japanese manufacturer of electro-optical and laser components. "We will offer a broad-based catalog of laser-quality optical components and optomechanical products," Kenrick says, "backed by the best technical support." Sigma Koki plans to invest in a modern production facility in the US. OptoSigma will offer "items selected from around the world" to complement its own product range. The company is located at 2001 Deere Ave., Santa Ana 92705; (714) 851-5881; (714) 851-5058.

Newport Corp. (Irvine, CA) has announced it will be the exclusive distributor of LightPath Technologies Inc.'s (Tucson, AZ) standard catalog and custom products using its patented GRADIUM lens system for all laser/electro-optic and semiconductor applications. GRADIUM lenses are the first commercially available components that use the material, which has a refractive-index gradient along the optical axis, eliminating spherical aberration. Made up of glass layers diffused into a single piece, the lenses can be produced in much larger sizes than standard GRIN rod lenses or molded aspheres, LightPath says. Twelve-mm and 25-mm positive and negative lenses are now available from Newport.

The Richardson Grating Laboratory (Rochester, NY) has been sold to Life Sciences International plc (LSI) of London, England, and is now an operating unit of Spectronic Instruments. The Laboratory, which designs and manufactures ruled and holographic diffraction gratings for the research and commercial optics markets, became part of Milton Roy Co. in 1985; Milton Roy later became a subsidiary of Sundstrand Corp. The analytical instrumentation businesses of Milton Roy are included in the LSI purchase. With 1994 sales of $273 million, LSI is an international supplier and manufacturer of scientific equipment for laboratories. Among its other operating units in the United States is NESLAB, the Portsmouth, NH, manufacturer of recirculating chillers.

MicroE Inc. (Needham Heights, MA) has purchased the diffractive-optics-based microencoder business of BEI Electronics Inc. (San Francisco, CA). MicroE was formed by CEO Don Mitchell, with funding from Massachusetts and Pennsylvania venture capital firms and private investment, to develop the patented scale-based interferometric linear and rotary position sensor technology formerly owned by BEI. Mitchell invented the MicroEncoder, a device based on physical optics for measuring linear or rotary motion. According to Mitchell, the MicroEncoder offers accuracy comparable to conventional laser interferometers at much lower cost and in a much smaller size. MicroE is located at 130 A St., Needham Heights 02194; (617) 455-1414; FAX (617) 455-6514.

Coherent Inc. (Santa Clara, CA) and Uniphase Corp. (San Jose, CA) entered into a patent license agreement and an asset purchase agreement. Uniphase obtained a limited nonexclusive sublicense on the Sipes patent, assigned to Coherent by Amoco, the original corporate holder, and covering the technique of focusing the output of a diode pump laser into the solid-state laser medium. In exchange for this, Coherent acquired the assets of Uniphase's Torrance, CA, diode laser operation. Kevin Kalkhoven, president of Uniphase, said the patent technology will materially aid the company's development of green and blue solid-state microlasers. For Coherent, said Bernard Couillard, general manager of the Laser Group, the addition of diode laser technology to its diode-pumped solid-state business, recently buttressed by the acquisitions of Atlas GmbH and Amoco's non-telecommunications assets, would strengthen its position in the medical and OEM markets.

Digital Instruments (Santa Barbara, CA) has established an Internet "mailing list" for scanning probe microscopy (SPM) users. It calls the list "an open and unedited forum for discussing and exchanging technical information, views, issues, and applications of SPM...." Those who wish to subscribe should send a line similar to the following to major-domo@di.com: "subscribe spm <your E-mail address>.

Edmund Scientific Co. (Barrington, NJ) dedicated the new $1.2-million 19,000-sq.-ft. "Pauline Edmund Wing" at a ceremony July 31. President Robert M. Edmund said the two-story structure was named to recognize the great contribution made to the company by his mother, who served for some 30 years as vice president of operations. He noted that "based on our sales growth for the past five years, the new addition will take care of the present expansion needs while satisfying a projected growth five years from now." Edmund's work force has increased by 60% to 160 in the past decade, as its product offerings and its familiar 236-page catalog expanded to encompass a wide selection of optical components and instruments, scientific instruments, and educational aids. New Jersey Congressman Robert E. Andrews was the keynote speaker at the ceremony.

A hole 35 microns in diameter drilled by a pulsed Ti:sapphire laser in a stainless steel plate at the University of Michigan's Center for Ultrafast Optical Sciences. Photo courtesy Xinbin Liu, Univ. of Michigan.

FCI Environmental Inc. and EG&G Energy Measurements, both of Las Vegas, NV, will collaborate to develop rugged miniature fiber optic sensors to monitor the environment for petrochemicals and other pollutants. The cooperative agreement involves EG&G technology originally created to support the Department of Energy's nuclear weapons testing program. With it, said Geoff Hewitt, FCI's president, the company will be able to build sensors that can be placed in remote locations for long periods of time to detect a variety of chemicals and hazardous toxins. FCI, a wholly owned subsidiary of FiberChem Inc., developed the first commercial fiber optic chemical sensor to detect and quantify petroleum hydrocarbons in air or water in real time.

Notes from Industry and the Federal Laboratories
A Field Medical System Using a Laser Diode

The portable unit makes incisions, stops bleeding, and closes wounds.

USAF Phillips Laboratory, Kirtland Air Force Base, New Mexico

A medical laser system developed at USAF Phillips Laboratory is a very compact device that provides the field paramedic or physician with a unique portable battery-operated medical capability. The laser system is able to cut like a scalpel, coagulate bleeding, and close wounds.

Emergency medical system physicians and battlefield medics have a similar need to improve emergency wound procedures to reduce treatment time and trauma to the victim. Phillips Laboratory's MedPac consists of a completely self-contained system based on a laser diode and operated by a rechargeable battery. The laser energy is delivered by a fiber optic cable that provides the very high power density necessary at the tip to cut and cauterize tissues.

The system dimensions are 3" X 7" X 9" and its weight is eight pounds; it will easily fit into a small belt pack. It is powered by one rechargeable sealed lead-acid battery. A recharging port is also provided, as is a key lock for safety and security. If the system is used in a belt-pack, only the optical fiber will extend from the pack. The laser light at the tip of the fiber is very intense: one kilowatt per square centimeter. Several standard disposable sterile medical tips are available that can be directly applied to the wound and are being evaluated for cutting and coagulation.

The most important electronic element in the MedPac is the high efficiency constant-current laser driver. This driver uses the latest DC-to-DC converter technology combined with extremely low-resistance power MOSFETs to provide a compact, efficient package that is ideally suited for battery-powered field devices. Typical efficiency is greater than 82% for load currents up to 30 A. This helps reduce energy losses due to heat generation in the laser driver, and also extend battery life.

An important requirement for driver circuits is that they accurately regulate the current flowing through the laser. The current variation for this device is typically less than 1% as the input is varied between 9 and 15 V. Current overshoot at turn-on is less than 0.5%.

DC-to-DC converter technology helps to reduce the current drain on the battery power source. The supply current is reduced by approximately the ratio of \( V_i/V_{out} \). In the present application, which uses a 12-V battery, the battery supplies 3.5 A for a laser drawing 20 A at 2.0 V. This improves efficiency by a factor of 6 over a circuit using a voltage regulator to reduce the input voltage to the level required by the laser. A 12-V 4.6-A/hour battery provides approximately 60 minutes of maximum power from the laser.

The laser driver also has a unique feature that allows it to utilize nearly 100% of the available battery energy. The internal low-dropout current regulator will keep the laser current constant until the battery voltage drops below 3.8 V. This provides a longer useful run time per battery charge.

The MedPac control unit is made up of three functional parts. These are the thermal-electric (TE) cooler controller, a signal-conditioning circuit for the display, and a temperature watchdog circuit.

The TE cooler circuit is made from a thermistor circuit and a switching current supply. The thermistor has a constant current flowing through it that is used to set the idle temperature of the laser. The voltage across the thermistor is fed into the switching current supply, which drives the cooler. The current supply has three modes of operation: on (not switching), on (switching), and off. When the laser temperature is above 17 °C the cooler circuit is turned completely on (non-switching). It supplies 2.5 A to the cooler and draws 2.5 A. When the laser temperature reaches 15 °C the circuit starts to switch, supplying 2.0 A and...
The temperature watchdog circuit will turn off the laser's power supply when the temperature falls below a set temperature. It is read from a current-sensing resistor on the laser current supply board. Both the temperature and power signals are fed into the digital panel meter.

The front-panel display has the ability to show either the laser's temperature or output power. The power is derived from the laser's current. This is only a rough estimate, because the power varies over temperature and the laser is set up to have a running temperature between 15-30 °C. It is read from a current-sensing resistor on the laser current supply board. Both the temperature and power signals are fed into the digital panel meter.

Two different procedures, cutting and welding, have a running temperature between 15-30 °C. It is estimated that the MedPac can function in various ground and air environments ranging from Arctic, tropics, and pressurized flight environments.

In conjunction with the Medical School, environmental and altitude chamber tests followed a matrix that included standard day, Arctic (18 °C, 20% humidity), tropical (100 °C, 100% humidity), and flight (60 °C, 7000 ft., pressurized). Both lasers, CO2 and diode, can be varied up to 9 W of output power, but were set to operate at 5 W. The results were as follows:

- Standard day: scalpel cut (1 cm) 2 seconds; CO2 3 seconds; MedPac 3 seconds;
- Arctic environment: scalpel cut 2 seconds; CO2 4 seconds; MedPac 3 seconds;
- Tropical environment: scalpel cut 2 seconds; CO2 3 seconds; MedPac 2 seconds;
- Flight environment: scalpel cut 2 seconds; CO2 3 seconds; MedPac 3 seconds.

The resulting times for the incisions were not as important as the conditions of the cuts. However, the important outcome of these particular tests is that the MedPac laser provided a clean, bloodless incision.

MedPac, the Field Medical Laser System, provides the physician with a lightweight, portable surgical laser tool that can produce immediate coagulation and closure of wounds. This results in less loss of blood, an improved view of the wound site, and better control of patient care, thereby sustaining homeostasis. Furthermore, with the advent of diode laser technology, other applications are surfacing that allow for advanced battlefield trauma care, as well as patient stabilization in civilian care. These include wound sterilization, bacteriology, and tissue welding.

This work was done by Michael Allen, Mark Gaddis, Dan Garber, Doug Webb, John Kelly, and Michael Colvard for US Air Force Phillips Laboratory. A patent is pending. The group wishes to acknowledge one of the inventors, Capt. Andy Keipert, for his dedication to the Field Medical Laser System Program.

Inquiries concerning rights for commercial use of this invention should be addressed to Michael S. Allen, USAF Phillips Laboratory, Phillips Laboratory, PL/LIDA, 3550 Aberdeen Ave, SE, Kirtland AFB, NM 87117-5776; (505) 846-7034; FAX (505) 846-4313. Alternatively, inquiries may be directed to the Alliance for Photonic Technology, Inc., 851 University Blvd. SE, Bldg. 1, Suite 200, Albuquerque, NM 87106-4339; (505) 272-7001.

InxGa1-xAs/GaAs Quantum-Well Infrared Photodetectors

Detectivities of experimental devices were found to be comparable to those of AlxGa1-xAs/GaAs devices.

NASA’s Jet Propulsion Laboratory, Pasadena, California

The first infrared photodetectors that operate at wavelengths as long as 18 μm have been made with multiple-quantum-well structures that consist of quantum-well layers of InxGa1-xAs alternating with non-lattice-matched quantum-barrier layers of GaAs. Heretofore, quantum-well infrared photodetectors (QWIPs) have been made with quantum-well layers of...
GaAs alternating and lattice-matched, variously, with quantum-barrier layers of Al$_{0.2}$Ga$_{0.8}$As, Ga$_{0.4}$In$_{0.6}$As, or Al$_{0.6}$In$_{0.4}$P. Note that GaAs is the well material in the older devices and the barrier material in the present devices.

The choice of materials for the present QWIPs was affected principally by two considerations. One was that in comparison with GaAs, In$_{0.2}$Ga$_{0.8}$As is potentially a superior quantum-well material because of its stronger absorption of infrared radiation. The other consideration was that in comparison with Al$_{0.2}$Ga$_{0.8}$As, which is the usual barrier material in the older devices, GaAs is potentially a superior barrier material because it exhibits superior transport properties (lower scattering and higher mobility of charge carriers).

The figure illustrates the quantum-well layer configurations of two experimental QWIPs made of In$_{0.15}$Ga$_{0.85}$As/GaAs. The first device contains five 80-Å-thick In$_{0.15}$Ga$_{0.85}$As quantum-well layers doped to $5 \times 10^{17}$ cm$^{-3}$, separated by 500-Å-thick quantum-barrier layers of undoped GaAs. The outer contact layers are made of GaAs doped to $10^{19}$ cm$^{-3}$: unlike in older QWIPs, the heavily doped contacts are made of the higher-band-gap GaAs semiconductor — in this case, GaAs. This is quite different from the Al$_{0.2}$Ga$_{0.8}$As/GaAs heterostructure, in which the GaAs is the low-band-gap quantum-well and contact material.

This reversal of roles is necessary because a thick contact layer of the strained, non-lattice-matched In$_{0.15}$Ga$_{0.85}$As would contain too many defects and threading dislocations. The design of the first device makes use of the strong bending of the energy band in the region between the heavily doped GaAs contact layers and the first and last In$_{0.15}$Ga$_{0.85}$As quantum wells. This results in a large quantum-mechanical-tunneling current, which essentially short-circuits the first and last wells, thus effectively making contact with the low-band-gap material. The active quantum-well structure therefore consists of the middle three quantum wells.

The second device contains three 85-Å-thick In$_{0.15}$Ga$_{0.85}$As quantum-well layers doped to $1 \times 10^{17}$ cm$^{-3}$, interspersed with four 500-Å-thick quantum-barrier layers of undoped GaAs. The outer contact layers are made of GaAs doped to $1 \times 10^{17}$ cm$^{-3}$. It is worth noting that unlike the first device, this device contains undoped GaAs spacer layers between the outermost quantum well and the outer contact layers: as a result, the tunneling injection current from the contacts to the quantum wells should be significantly smaller than it is in the first device. Therefore, the dark current of the second device should be smaller, resulting in higher detectivity.

Experiments have confirmed that the dark current of the second device is much smaller than that of the first device at temperatures below 60 K. The spectral responsivities of the devices were measured at 40 K with a bias of 100 mV: For the first and second devices, the responsivities peak at wavelengths of 15.3 and 18 μm, respectively, while both devices reach their long-wavelength (half-peak) cutoffs at 18.3 μm. The detectivities of both devices increase with decreasing temperature: at 10 K, the detectivities of the first and second devices were found to be $8.0 \times 10^{7}$ cm$^{-2}$Hz$^{1/2}$/W and $9.7 \times 10^{10}$ cm$^{-2}$Hz$^{1/2}$/W, respectively — comparable to the detectivities of Al$_{0.2}$Ga$_{0.8}$As/GaAs QWIPs.

This work was done by Sarath D. Gunapala, Jin S. Park, True-Lon Lin, and John K. Liu of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 69 on the TSP Request Card. NPO-19323
New Laser Treatment for Enlarged Prostate

A diode laser device could result in a cost-effective, safer, and less painful treatment.

*Inhalation Toxicology Research Institute (ITRI), Albuquerque, New Mexico*

Enlarged prostate (benign prostatic hypertrophy) is a common disease affecting up to half of all men over the age of sixty. As the part of the prostate gland around the urethra increases in size with advancing age, the urethral opening decreases, resulting in difficult urination and urine retention in the bladder. Symptoms include frequent urination, discomfort, urinary-tract infections, and in severe cases, urinary tract obstruction. Treatment is directed at reducing the prostatic tissue surrounding the urethra. Hormone treatment sometimes succeeds, but most treatments involve destroying the prostatic urethra and tissues by surgical excision or laser coagulation necrosis via the urethra. Both require several days of hospitalization; in addition, laser treatment uses fairly expensive equipment.

ITRI is collaborating with Índigo™ Medical, Inc., of Palo Alto, CA, to demonstrate a new treatment procedure in which development and testing of the Índigo™ 830 portable diode laser may lead to effective interstitial thermotherapy for chronic enlarged prostate.

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For More Information Write In No. 462

October 1995
which a small fiber attached to a diode laser is placed directly into the prostate to necrotize tissue. The laser costs much less and is safer to operate than the Nd:YAG lasers typically used in laser coagulation necrosis. Because it delivers its energy more slowly, it is easier to control. Moreover, unlike current approaches, interstitial thermotherapy does not destroy the urethra, which can lead to significant pain, increased risk of bleeding, and need for transfusions.

This work began as a collaboration between Air Force Phillips Laboratory, Los Alamos National Laboratory, and Indigo™ Medical, Inc., to design a prototype laser and fiber that could be used in tissue. The collaboration continued, under the direction of Dr. Bruce Muggenburg at the Inhalation Toxicology Research Institute, as the system was evaluated. The treatment is now being further evaluated in clinical trials. Patents are pending.

Inquiries regarding use of the treatment can be directed to Dr. Horst Adam, Indigo™ Medical, Inc., 1049 Elwell Court, Palo Alto, CA 94303, or Dr. Charles H. Hobbs, Inhalation Toxicology Research Institute, PO Box 5890, Albuquerque, NM 87185; (505) 845 1037; FAX (505) 845-1198.

Measuring Pixel-Position Errors on CCD Imagers

Interference fringes are used as a reference pattern.

NASA’s Jet Propulsion Laboratory, Pasadena, California

Deviations of the positions of pixels on a charge-coupled-device (CCD) image detector from a nominal rectangular grid pattern can be measured by a method in which coherent-light interference fringes are used as a reference pattern. These deviations are attributed, at least in part, to imperfections in step-and-repeat machinery used to generate the grid patterns in manufacturing. The method was conceived for use in determining pixel-position errors in astrometric cameras to be flown aboard space-craft. The method can also be applied to the determination of similar errors in (and calibration of) terrestrial CCD cameras used as position sensors; for example, position-measuring cameras that are parts of robotic systems.

Figure 1 illustrates schematically how the interference fringes are formed on the CCD and measured. Light from a helium/neon laser is coupled into a single-mode optical fiber that is split into two single-mode optical fibers at a directional coupler. The ends of the two fibers are held a few millimeters apart in an aluminum block. The ends of the fibers lie on the surface of the block that faces the CCD, with their optical axes perpendicular to this surface. This surface is polished to make it reflective so that the optical axes can be aligned perpendicular to the face of the CCD by use of an ancillary technique that involves observation of multiple reflections of a laser beam.

The ends of the fibers are held at a distance of about 1 m from the CCD, so
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Figure 1. **Interference of Laser Beams** emerging from the two optical fibers forms a fringe pattern that is used as a reference grid.

that in the case of a CCD of typical dimensions, the spatial interval between successive interference fringes is about 20 pixels. The fringe spacing, the polarization of the laser light, and the orientation of the fringes in the CCD plane are not critical; it is not even necessary to suppress jitter because the effects of fluctuations on the readouts of the pixels are suppressed by integrating the readouts over exposure times of a few seconds. In addition to the exposure taken with interfering light from both fibers, an exposure is taken with light from each fiber alone; these single-fiber exposures provide calibration data that are used to correct for spatial variations of the intensities of the beams from the fibers when analyzing the readouts from the two-fiber exposure by the technique described next.

The time-integrated CCD readouts from the two-fiber exposure are digitized, corrected for beam spatial variations, and compared with the corresponding computer-generated data on ideal interference fringes. The global fringe spacing, orientation, phase,
amplitude, and modulation of the actual interference pattern are deemed to be those of whichever computer-generated pattern best fits the measurement data according to the method of least squares.

The residual (error) quantities of the least-squares best fit are due to (1) poor quantum-efficiency calibration, (2) subpixel gradients in illumination and/or sensitivity, and/or (3) the pixel-position errors that one seeks to determine. The effects of quantum-efficiency calibration errors can be suppressed by making many single-fiber exposures. The effects of intrapixel gradients can be suppressed by making the fringe spacing much larger than a pixel, and preferably at least 10 pixels; this is the reason for the choice of the 20-pixel fringe spacing mentioned above.

The remaining residual quantities can thus be attributed to pixel-position errors; the position error, Δx, for each pixel is estimated from Δx = e/M, where e is the residual quantity for that pixel and M is the gradient (change per unit pixel width) of the idealized interference pattern at the nominal position of the pixel (see Figure 2). The position errors are thus estimated only in the neighborhoods that contain the maximum gradients of the idealized interference pattern; a map of position errors across the entire CCD is obtained by piecing together maps made from fringe patterns with different phases.

This work was done by Stuart B. Shaklan, Mike Shao, Yekta Gursel, and Jeffrey Yu of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 44 on the TSP Request Card. NPO-19419
The intensity of light emitted by these excited species correlates directly with the type and quantity of metal present.

Because the monitor relies on the measurement of optical output resulting directly from laser input, measurements can be performed in situ, with both input and output transmitted through windows in the exhaust duct transporting the effluent. A major advantage of the LASS technique is that it can measure metals embedded in particles or in liquid aerosols, which account for most of the metals emitted from hazardous waste treatment processes.

Sandia's transportable continuous emissions monitor (CEM) is suitable for in-plant application. The prototype consists of three basic components: (1) an optical probe, shown schematically in the figure; (2) rugged instrumentation racks that contain a spectrometer, detector, and control instrumentation; and (3) a personal computer for data acquisition and control.

The optical probe unit contains a pulsed Nd:YAG laser plus focusing and collection optics. Frequency-doubled (532-nm) Q-switched laser output is expanded and collimated by a pair of lenses and then is focused in the effluent stream by a third lens. The final laser-focusing lens also serves to collect and collimate a portion of the optical emission from the laser-induced breakdown. This emission is focused on the tip of a fiber-optic bundle, which transmits the plasma emission to the instrumentation-rack-mounted spectrometer and detector. The prototype monitor is controlled remotely by a personal computer, which also analyzes measured optical-emission spectra to determine metal concentrations in real time.

The prototype CEM was successfully demonstrated at DOE funded pilot-scale waste-treatment facilities in South Carolina and Idaho. These tests showed that hazardous metals can be measured in the effluent from thermal-treatment facilities that are processing metal-containing wastes. This was the first demonstration of the ability of a laser-spark CEM to determine metal concentrations through analysis of individual spectral lines in a complex "real" effluent, where numerous spectral features from nonregulated species were also present. Well-isolated spectral lines of regulated metals were identified and analyzed, even in the presence of large abundances of interfering species. The measurements also provide the first real-time insight into how emissions change as system operating parameters are changed. An advanced prototype will be demonstrated at a full-scale thermal treatment facility in 1996.

In addition to the application to hazardous waste treatment facilities, the LASS metals monitor has potential commercial application to a wide variety of other sources, including fossil-fuel power plants, industrial furnaces and boilers, electroplating facilities and semiconductor manufacturing processes.

This work was done at Sandia National Laboratories under the sponsorship of the Dept. of Energy Office of Technology Development's Characterization, Monitoring, and Sensors Technology Crosscutting Program. For further information, contact Bill Flower, Principal Investigator, MS 9103, Sandia National Laboratories, Livermore, CA 94551-0969.

Inquiries regarding rights for the commercial use of this device should be directed to C.V. Subramanian, Manager, Licensing, Sandia National Laboratories, Livermore, CA 94551-0969.

**Micromachined, Electrostatically Deformable Reflectors**

Beam-control reflectors could be integrated with electronic control circuits.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Micromachined, closed-loop, electrostatically actuated reflectors (µCLEARs) are being developed to provide relatively simple and inexpensive alternatives to the large, complex, expensive adaptive optics used to control wavefronts of beams of light in astronomy and in experimental laser weapons. The development of µCLEARs may not only overcome some of the disadvantages and limitations of older adaptive optics but may also satisfy demands of a potential market for small, inexpensive deformable mirrors in electronically controlled film cameras, video cameras, and other commercial optoelectronic instruments.

Micromachining can be used to make a deformable mirror, its supporting...
structure, and actuation circuitry. The actuation circuitry can include electrostatic-actuator electrodes, sensing electronics, drive circuits that apply electrostatic-deflection voltages to the actuator electrodes, and control circuits. The actuation circuitry can be fabricated on the same silicon wafer that contains the supporting structure; this integration minimizes electrical noise and results in a compact, lightweight, inexpensive, electrically and optically sensitive adaptive optic that is relatively insensitive to environmental effects. Typically, the deformable mirror is made from a separate piece of silicon or other material and attached to the supporting integrated circuit structure.

The figure illustrates the configuration of a basic prototype μCLEAR without integrated actuation circuitry. This μCLEAR includes a micromachined mirror mounted on a micromachined silicon frame. The mirror can be a thin film as shown here or it can be thicker — even as thick as the frame, depending on the required stiffness of the mirror. The mirror is electrically grounded and aligned above a planar array of actuator electrodes, forming an array of parallel-plate capacitors. A window that holds a transparent electrode is mounted in the front of the mirror surface.

A bias voltage applied to the transparent electrode moves the mirror into a preload deformation position away from the array of actuator electrodes. Application of a voltage to an actuator electrode results in electrostatic attraction between that electrode and the mirror, resulting in a deformation, concentrated in the vicinity of that electrode, of the mirror toward that electrode. The capacitances between actuator electrodes and a mirror can be exploited to obtain capacitive feedback indicative of the distances between the electrodes and the mirror and thus indicative of the state of displacement or deformation of the mirror. The capacitive displacement feedback from each actuator electrode eliminates the need for costly and complex optical deformation feedback, and enables more accurate position control than can be obtained from conventional open-loop systems.

Electrostatic actuation can be achieved at powers and voltages smaller than those of piezoelectrically actuated adaptive optics. The thicknesses of mirrors and structural boundary conditions can be widely varied among μCLEAR designs to obtain deformations in various preferred modes. Actuator electrodes can be laid out in specified patterns to achieve the desired deformations with minimum numbers of electrodes and simplified control algorithms and electronics. Closed-loop electrostatic actuation can be combined with advanced control algorithms that take into account the nonlinear structural behaviors.
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**Scene Generation Test Capability**

Lasers can test focal plane arrays against realistic mission scenarios.

**Engineering Development Center, Arnold Air Force Base, Tennessee**

A scene generation test capability (SGTC) has been developed that can test visible and IR sensor subsystems. This capability will enable sensor developers to reduce development risks by testing focal plane arrays (FPAs) and data subsystems against realistic mission scenarios in a space environment. The SGTC can simulate the sensor’s mission by projecting complex scenes directly onto the sensor’s array in real time. Such scenes will test a sensor’s capacity to detect, track, and discriminate targets against realistic backgrounds. The SGTC was implemented in two phases, the transportable direct-write scene generator and the focal plane array test chamber.

The SGTC uses laser beams to paint scenes directly onto the sensor’s FPA much as an electron gun paints pictures directly onto a television screen. Like a movie, a mission scenario is broken down into a sequence of individual scenes or frames. SGTC scenes are created in the visible and infrared at discrete wavelengths and projected onto the FPA in real time. The SGTC design is versatile enough to accept scene data from a variety of sources such as the Strategic Scene Generation Model (SSGM) and SDIO’s Phenomenology Data Centers. The scenes projected by the SGTC are virtually unlimited in content.

The key to the success of the SGTC is the direct-write scene generator (DWSG) technique (see figure), which uses acousto-optic devices to position and control the intensity of the laser beam that paints the scene. Scene information is fed into a complex electronic system that controls the acousto-optic devices. The DWSG is synchronized to the FPA integration time to ensure proper registration of each frame or image. The image processing system is capable of controlling this synchronization, as well as creating, editing, and displaying the contents of the scene.

The advantage of an electronically controlled, computer-programmable system is that each pixel is addressed directly during each frame of operation. The ease of storage and playback facilitates comparison testing between various FPAs. The main strengths of the DWSG system are: (1) relatively unlimited scene content (blooming targets, complex backgrounds, plumes, gamma events); (2) compatibility with staring or scanning FPAs; (3) no moving parts in the cryovacuum environment; and (4) lower initial and operating costs.

The system can also simulate the effects of degraded sensor components such as optics, focal planes, and stray light control baffles. Algorithm robustness can be evaluated by the controlled addition of noise to the scenario.

The use of a laser as an external radiation source in conjunction with narrow spectral bandpass filters means that the test of mirrors. For example, layouts of actuator electrodes, control algorithms, and actuation circuits can be designed to provide control of individual deformation modes (e.g., finite numbers of Zernike modes), with minimal interactions among modes.

This work was done by Randall K. Bartman, Paul K. C. Wang, Linda M. Miller, Thomas W. Kenny, William J. Kaiser, Fred Y. Hadaegh, and Michael L. Agronin of Caltech for NASA’s Jet Propulsion Laboratory. For further information, write in 79 on the TSP Request Card. NPO-19154
article can be placed in a small cryovacuum dewar rather than a large test chamber. The DWSG hardware can reside outside this dewar as well, so that physical changes do not have to be made with the test chamber at ambient conditions whenever scene content is changed. Time to change scenes and/or mission scenarios is reduced to a matter of hours. Time to reconfigure the test capability from one sensor type to another (stare to scanner or vice-versa) is estimated at two to four weeks.

A traceable blackbody reference source, also located outside the chamber, is used to perform blackbody characterizations of the test article, thus providing a critical traceability path from DWSG scenes to real-world phenomena.

The transportable direct-write scene generator (TDWSG) was developed to validate the DWSG concept and meet near-term test needs. A single TDWSG module, using a 1.06-micrometer laser, can paint a scene area as large as 128X128 pixels. There are twelve such modules currently available.

A validation test was conducted using an 80-frame scenario developed using the strategic scene generation model. The scenario consisted of several targets over a mountain-sea background. The first test used an FPA (128 by 128) with 20-micrometer pixels and a cutoff wavelength of 2 micrometers. The scenario was projected at a frame rate of 0.5 kHz. The second validation test was successfully performed using an FPA (6 by 64) with 100-micrometer pixels and a cutoff wavelength of 25 micrometers. The same scenario was projected at a frame rate of 3 kHz. The 1.06-micrometer laser source successfully addressed both FPAs despite the wide difference in cutoff wavelength (visible vs. LWIR).

System stability tests have been performed as well. Single DWSG modules can be grouped together to address a variety of test requirements such as large rectangular or offset test areas.

Development of a more capable yet transportable focal plane array test chamber was completed last year. The scene generation hardware is located outside the chamber (one of three types is available) at ambient conditions. A traceable blackbody reference source is used to perform characterizations of the test article. As with the TDWSG, this establishes a critical traceability path from the scene generated with the DWSG to real-world phenomena. Hardware and software tests have been completed for this program; scene projection demonstrations have been performed at 0.514, 1.06, and 5.4 micrometers, and the system is ready for use. A 10.6-micrometer diagnostic capability also exists.

This work was done by Microcraft Technology, Inc., the aero-dynamic ground-test contractor for the Arnold Engineering Development Center. Inquiries concerning rights for the commercial use of this invention should be addressed to Heard Lowery, Arnold Engineering Development Center, Arnold AFB, TN 37389-6400; (615) 454-3709.
Correcting for Capacitance in Tests of Solar Cells

Modifications of the test procedure and software yield corrected $I-V$ characteristics.

NASA's Jet Propulsion Laboratory, Pasadena, California

A modified procedure for testing solar photovoltaic cells and modified software for processing the test data provide corrections for the effects of cell capacitance. The modified test procedure and software are needed because (a) some photovoltaic devices (for example, silicon solar cells with a back-surface field region) store minority charge carriers in the cell junction and thus exhibit significant capacitance, (b) capacitance affects current-vs.-voltage ($I-V$) measurements made when a transient load is connected to a cell, and (c) a transient load is used in the unmodified version of the test procedure.

In the modified testing procedure as in the unmodified one, $I$ and $V$ are measured under various loads when the solar cells are illuminated by a pulsed source of artificial sunlight. The first part of the modified procedure consists of the unmodified procedure, in which $I-V$ measurements are taken as the load is swept from short to open circuit during a pulse of artificial sunlight. This procedure yields a complete $I-V$ curve, but in the case of high cell capacitance this procedure yields measured values of $V$ that are below the true cell voltages for the corresponding measured values of $I$.

In the modified procedure, $I-V$ measurements are also taken under four fixed-load conditions: (1) at a current a few percent below the short-circuit current, (2) at a current near the maximum-power point, (3) at half the short-circuit current, and (4) near the open-circuit voltage, where the current is only a few percent of the short-circuit current.

The modified software uses the fixed-load $I-V$ data, which lie on the true $I-V$ curve, to produce an interpolated $I-V$ curve that closely represents true $I-V$ data. This approximation of the true $I-V$ curve resembles the transient-load $I-V$ curve but is shifted to slightly higher voltage at a given current (see figure).

This work was done by Robert L. Mueller of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 2 on the TSP Request Card. NPO-19516

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October 1995
Laser-Based Metal Surface Decontamination System

A new system reduces secondary wastes and provides more protection for personnel. Ames Laboratory, Iowa State University, Ames, Iowa

Developed at Ames Laboratory of the US Department of Energy (DOE), a new system uses lasers to remove contaminants from metal surfaces. Unlike other surface cleaning tools, lasers can be used to remove both tenacious surface coatings and portions of the metal substrate without creating copious secondary wastes. With the proper laser parameters, it is possible to simultaneously ablate and efficiently collect materials from a metal surface. This is particularly useful when samples contain hazardous (i.e., radioactive) or valuable materials.

Laser energy can be transmitted over long distances by either mirrors or fiber optics. Thus, exposure of workers and equipment to hazardous materials can be significantly reduced.

Research in laser surface decontamination at Ames began in 1990 to support the recycling of metal wastes generated during the decommissioning of former DOE facilities. Many millions of tons of stainless steel and high-value metals such as nickel are expected to result from the decommissioning program. Without efficient surface decontamination technologies, these metals could be consigned to landfill burial—a waste of resources and a potential source of pollution.

The technique should find applications in the commercial nuclear industry. Also, it can replace the use of hazardous organic solvents and corrosive acid baths needed for surface cleaning and plating removal, respectively.

During the surface cleaning process, a plasma forms close to the sample’s surface. It is possible to control the cleaning process in real time by monitoring a spectral line emitted by the plasma associated with a species of interest.

The technology has been demonstrated on planar and cylindrical surfaces as well as on internal cylindrical surfaces. Cleaning rates vary with the metal treated and the tenacity of the surface coating. For aluminum, an easily ablated material, a radioactive thorium oxide coating deposited during decades of service was removed at rates exceeding two square meters per hour using an excimer laser.

Because the cleaning rate varies sublinearly with the laser’s irradiance and linearly with its repetition rate, a high-repetition-rate laser is optimal for surface cleaning. Such a laser was part of a sys-

Decontamination of stainless steel with excimer laser irradiation (248 nm)

- Power density = 1.5E06 W/cm²
- Power density = 3E08 W/cm²
- Power density = 6E08 W/cm²

Decontamination of stainless steel with excimer laser irradiation (248 nm).
term used to remove fission product contamination from Haynes 25, an extremely hard alloy. Much slower cleaning rates (about 0.1 m² per hour) were required than was the case for aluminum. In another application, the surfaces of lead bricks were efficiently decontaminated at high cleaning rates. In each case, an optical fiber delivered energy from the high-repetition-rate laser to the material.

A proprietary system designed to optimize laser removal rates and provide flexible beam-delivery options was developed co-operatively by Ames and Lockheed Martin Idaho Technologies Company (LMIT).

This work was done by Ho-ming Pang and M.C. Edelson for the Dept. of Energy's Ames Laboratory, Russell L. Ferguson at LMIT, and M.C. Edelson for the Dept. of Energy's Ames Laboratory.

Inquiries concerning rights for the commercial use of this invention should be sent to Lida Clarksean, LMIT, Technology Transfer Office, Idaho National Engineering Laboratory, 2525 Fremont Ave., Idaho Falls, ID 83415 3805; (208) 526-0012.

**MQW Optical Feedback Modulators and Phase Shifters**

Modulators would consume less drive power and would be compatible with integrated circuits.

**NASA's Jet Propulsion Laboratory, Pasadena, California**

Multiple-quantum-well (MQW) devices would be used as optical feedback modulators in conjunction with laser diodes, according to a proposal. Laser diodes equipped with the proposed MQW optical feedback modulators may prove useful in a variety of analog and digital optical-communication applications, including fiber-optic signal-distribution networks and high-speed, low-crossstalk interconnections among supercomputers or very-high-speed integrated circuits.

Whereas most of the previous effort to develop MQW modulators focused on exploitation of the electro-absorption aspect of the quantum confined Stark effect (QCSE), the proposed development would exploit the accompanying electro-optical aspect of the QCSE — a variation in the index of refraction with the applied electric field. The proposed development would also exploit the sensitivity of laser diodes to optical feedback. This approach is the reverse of the prior approach, in which optical feedback was regarded as a nuisance because it could cause unstable operation and laser diodes were therefore packaged with optical isolators to suppress optical feedback.

The upper part of the figure illustrates the use of an external modulator, according to the prior approach, to achieve well-behaved modulation of the laser output. Typical radio-frequency and optical insertion losses in this arrangement are about 40 dB. Moreover, because of the low damage-threshold power of the modulator (typically, 10 mW) and optical insertion loss as high as 10 dB in the external modulator, it is often difficult to achieve an acceptably high signal-to-noise ratio at the receiver.

The lower part of the figure illustrates the use of a proposed MQW optical feedback modulator. Because the sizes and capacitances of the proposed MQW optical feedback modulators would be smaller than those of typical external modulators used previously, the proposed modulators would require lower drive voltages. Other expected advantages of the proposed modulators include smaller optical insertion losses and compatibility of MQW structures with control electronic circuits of the monolithic microwave integrated-circuit and very-high-speed integrated-circuit types.

To reduce insertion losses and required radio-frequency drive voltages, an MQW modulator according to the proposal would be designed expressly for the purpose, with a novel MQW and electrode structure to achieve feedback modulation through the back side of the laser. Calculations of the electro-optical aspect of the QCSE indicate that optical phase shifts of the order of π radians are potentially achievable with some MQW structures.

An MQW device of the proposed type would include a patterned metal electrode on the surface facing the laser diode. This electrode would be used to bias the device to reflect part of the light incident upon it, shifting the phase of that part of the light by π radians. The part of the light not reflected by this electrode would enter the device, travel back (leftward in the figure) through the...
MQW layers, be reflected from the rear (leftmost in the figure) mirror, pass through the MQW layers again, then leave the device through the electrode gaps and return to the laser. The phase of this part of the light would depend on the voltage applied to the MQW device. Thus, one could vary the phase of light returned to the diode laser in a spatially complex manner, thereby influencing the spatial pattern of the output laser beam. Because changing the spatial pattern of the laser beam would change the efficiency of coupling of the beam into an optical fiber, the part of the beam that entered the fiber would become correspondingly amplitude-modulated.

This work was done by Deborah J. Jackson of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 13 on the TSP Request Card. NPO-19310

The Proposed Modulation Scheme would differ from the prior external-modulation scheme in that it would exploit feedback, taking advantage of the electro-optical effect in an MQW device.

Databases for Laser Effects on Aerospace Materials

A database resource covers laser effects on many materials.

High Temperature Materials Information Analysis Center, Purdue University, West Lafayette, Indiana

Laser effects data and technical information on aerospace materials are being collected and analyzed from a variety of sources, and will be made available to qualified users. The objective is to bring together analyzed data in the form of a computer searchable database for convenient access by user communities. An analyzed database is offered as a means of providing informational support to

October 1995
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**FOR MORE INFORMATION WRITE IN NO. 395**

Laser use is increasing, especially for industrial applications. Accessing an information repository should prove a much less expensive way of satisfying data requirements compared to regenerating new test data.

The point of contact for this activity is Dr. R.H. Bogaard of the High Temperature Materials Information Analysis Center (HTMIAC), which is operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University, is sponsored by the Defense Technical Information Center. HTMIAC's mission is to promote timely dissemination of information and provide unbiased data-analytical and evaluative support on topics within its scope. Laser effects coverage by HTMIAC concerns laser-induced damage, damage threshold, and property degradation following exposure. Definition of damage, test methods, and laser-beam parameters are of course also important. Materials of interest include aerospace structural materials, infrared detector materials, optical system components, insulations, coatings, and filters, etc.

Data and information are collected from government reports and, depending upon the data restriction levels for each project, from public access literature available in the form of journal articles and conference proceedings. For one project currently under way, HTMIAC staff have been visiting government document repositories to assemble a laser-effects database covering various wavelengths on many different materials. Another current topic of interest is laser-induced damage-threshold data that have been published in the open literature for optical system components. The databases will be distributed in diskette form for use on a personal computer. One version will be a public-access diskette, and another a classified version containing all available information.
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For More Information Write In No. 815

Narrow-Linewidth Ti:Sapphire Laser
A specification sheet for the SenTinel, the newest addition to its solid-state laser line from MPB Technologies, Dorval, PQ, Canada, says the tunable flashlamp-pumped Ti:sapphire laser has the narrowest linewidth of its kind available. It is grating-tunable from 690-980 nm with a single set of mirrors, with a linewidth throughout this range of 0.005 nm. Additional line narrowing to 0.0005 nm can be achieved with an optional intracavity etalon.

For More Information Write In No. 816

CW Wavelength Measurement
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For More Information Write In No. 818

Analog Convection Transducer
The HPS Division of MKS Instruments Inc., Boulder, CO, releases a single-sheet full-color brochure on its SensaVac® Series 907 Analog Convection Transducer, a convection-enhanced Pirani sensor integrated with an electronic control circuit. Capable of measuring vacuum pressure from 10^{-3} to 1000 Torr, the 907 can be used as a system control element, relay, gauge, alarm, and remote sensor. The brochure describes the 907's operating principle, specifications, and pricing.

For More Information Write In No. 819

980-nm Pump Laser Reference
Lasertron, Burlington, MA, makes available a specification sheet called the "980-nm Pump Laser Reference Guide." The pumps are used to energize erbium-doped fiber amplifiers for long-distance fiber optic telecommunications. The sheet describes the company's 14 980-nm pump products, offered in four basic packages: longhorn, butterfly, double pump and "super-cooled" single pump.

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For More Information Write In No. 801

Diode-Pumped Nd:YAG for FT-Raman Spectroscopy

Spectra-Physics Lasers, Mountain View, CA, calls its Model T10-106c an advanced diode-pumped CW laser optimized for high-performance FT-Raman spectroscopy. The Nd:YAG head is pumped by a 10-W diode bar coupled into a bundle of multimode optical fibers. Pump source is field-replaceable without realignment, the company says. Output power is 2.5 W. All diode-pumped products carry a 12-mo. 5000-hr. warranty.

For More Information Write In No. 802

Laser Diode Control Instrumentation

Three new product lines from Newport Corp., Irvine, CA, include temperature controllers, laser diode drivers, and temperature-controlled mounts. The Model 300 series thermolectric temperature controllers provide control of ±0.005 °C over a range of -50 to +150 °C. The Model 500 series drivers span power levels of -50 mA to 6 A. The series 700 mounts have two 12.5-W TE coolers to control diodes with outputs up to 3 W. The Model 740 telecom mounts allow easy mounting of diodes with dual in-line and butterfly packaging.

For More Information Write In No. 805

Gradient Index Capability for Software

Focus Software Inc., Tucson, AZ, announces that Light-Path Technologies' LPPTBD lead silicate glass, an axial gradient index (AGRIN) optical material, is to be included in the materials database of XE and EE editions of Focus's ZEMAX optical design program. Because this material's dispersion also varies along the optical axis, the data files contain coefficients describing the variation of Buchdahl coefficients throughout the material, enabling the ZEMAX program to compute the index at any wavelength. Focus's software models lenses, mirrors, tilted and decentered systems, holograms, diffractive optics, and more.

For More Information Write In No. 804

TE Coolers for Thermal Viewer Systems

Marlow Industries, Dallas, TX, makes available a broad line of thermoelectric coolers for thermal viewer systems. They provide temperature stabilization down to 175 K in cooled and uncooled FLIR systems. Marlow says the coolers provide no vibration in the focal plane, high mean time between failures, and low life-cycle costs.

For More Information Write In No. 803

Pulse Generators for Noisy Environments

The isolated outputs of the models PG-9310, PG-9410, and PG-9510, making up the new line of power generators from Quantum Composers Inc., Bozeman, MT, were designed specifically for electrically noisy environments. Functions include precise control of pulsewidths and recall of up to 12 saved configurations. All channels have independently programmable pulsewidth, delay, and output polarity. System operating modes include continuous, single-shot, external trigger/gate, and other special control modes.

For More Information Write In No. 806
**Optical Construction Plates**
AF Optical Co., Trabuco Canyon, CA, offers optical construction plates for component linking and mounting. The system permits the user to detach his setup and use it as a standalone unit. Plates feature built-in post-mount capability and precise three-point mounting and adjustment. Tilts and shifts are possible. Researchers can create setups in the Z direction to expand table capacity, and R&D setups can be converted to portable show-ready systems.

*For More Information Write In No. 807*

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**Visible Laser Sensors for Distance Measuring**
The visible red laser sensors from Aromat Corp., New Providence, NJ, join the company's broad line of IR devices for measuring and profiling distances. Both are triangulation systems, and thus are less costly than interferometric systems by a factor of 10. Available as the LM100 and LM200 series, the sensors offer measurable ranges from 30-400 mm, small spot size (0.07 x 0.03 mm), and ease of target positioning because of the visible beam.

*For More Information Write In No. 808*

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**Frequency-Doubled Nd:YAG for Industrial Use**
Lee Laser, Orlando, FL, introduces the Model 818TQ/40G, a high-power frequency-doubled Nd:YAG laser for industrial micromachining. Rated at 25 W average at a pulse rate of 10 kHz, the laser is intended for applications where the 530-nm wavelength makes possible greater power absorption or smaller beam focus diameter. Lee's wavelength transfer module enables rapid change between the fundamental 1064-nm wavelength and the 530-nm harmonic.

*For More Information Write In No. 809*

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**Photoelectric Sensor with Laser Light Source**
Keyence Corp. of America, Woodcliff Lake, NJ, calls its Model FS-L the first fiber optic photoelectric sensor to use a laser light source. The small FS-L amplifier (2.5 in. long x 1.6 in. high x 1.1 in. wide) couples a visible-spot semiconductor laser to a specially designed optical system to produce a parallel beam that can detect a 10-mm object at a distance of 10 m. Response time is 0.25 ms.

*For More Information Write In No. 810*

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**Image Processing with 1000s of MFLOPs**
The SPIRIT-Image PC image processing system from Sonitech, Wellesley, MA, is designed for both digital signal processing (DSP) and non-DSP programmers whose tasks need 100s to 1000s of MFLOPs of computation. Standard functions and several example software routines are included for immediate out-of-the-box setup and processing.

*For More Information Write In No. 812*

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**Laser Eye Protection Filters**

*For More Information Write In No. 813*

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**Compact Nd:YAG with Wavelength Options**
Big Sky Laser, Bozeman, MT, calls its new Model CFR 200/MINICE the smallest, lightest Nd:YAG available. According to the manufacturer, the rugged, environmentally sealed system, designed for maximum flexibility, versatility, and simplicity, is more than 70% smaller than other commercial systems. The laser delivers 200 mJ of Q-switched 1.06-µm energy at up to 30 Hz. Other wavelengths available are 532 nm, 355 nm, 266 nm, and 1.57 µm.

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For More Information Write In No. 452
CLIPS provides extensive features to support the rule-based programming paradigm, including seven conflict-resolution strategies, dynamic rule priorities, and truth maintenance. CLIPS 6.0 supports more complex nesting of conditional elements in the "if" portion of a rule ("and", "or", and "not" conditional elements can be placed within a "not" conditional element). In addition, there is no longer a limitation on the number of multifeature slots that a deftemplate can contain.

The CLIPS Object-Oriented Language (COOL) provides capabilities for object-oriented programming. Features supported by COOL include classes with multiple inheritance, abstraction, encapsulation, polymorphism, dynamic binding, and message passing. CLIPS 6.0 supports tight integration of the rule-based programming features of CLIPS with COOL (that is, a rule can pattern match on objects created by COOL).

CLIPS 6.0 provides the capability to define functions, overloaded functions, and global variables interactively. In addition, CLIPS can be embedded within procedural code, called as a subroutine, and integrated with such languages as C, FORTRAN, and Ada. CLIPS can be easily extended by use of several well-defined protocols. CLIPS provides several options for delivery of programs, including the ability to generate stand-alone executables or to load programs from text or binary files.

CLIPS 6.0 provides support for the modular development and execution of knowledge bases with the "defmodule" construct. CLIPS modules enable the grouping together of a set of constructs, such that explicit control can be maintained by restricting access to the constructs by other modules. This type of control is similar to global and local scoping used in such languages as C or Ada. By restricting access to deftemplate and defclass constructs, modules can function as blackboards, permitting only certain facts and instances to be seen by other modules. Modules are also used by rules to provide control over execution.

The CRSV (cross-reference, style, and verification) utility software included in previous versions of CLIPS is no longer included. The capabilities formerly provided by CRSV are now available directly within CLIPS 6.0 to aid in the development, debugging, and verification of large rule bases.

COSMIC offers four distribution versions of CLIPS 6.0: UNIX (MSC-22433), VMS (MSC-22434), Macintosh (MSC-22429), and IBM PC (MSC-22430). Executable files, source code, utility software, documentation, and examples are included on the program media. All distribution versions include identical source code for the command-line version of CLIPS 6.0. This source code should be compilable on any computer equipped with an ANSI C compiler. Each distribution version of CLIPS 6.0, except that for the Macintosh computer, includes an executable for the command-line version. For the UNIX version of CLIPS 6.0, the command-line interface has been successfully compiled on a Sun4 computer running SunOS, a DECstation computer running DEC RISC ULTRIX, an SGI Indigo Elan computer running IRIX, a DEC Alpha AXP computer running OSF/1, and an IBM RS/6000 computer running AIX. Command-line interface executables are included for Sun4 computers running SunOS 4.1.1 or later and for the DECstation computer running DEC RISC ULTRIX. The makefiles may have to be modified slightly to be used on other computers running UNIX.

The UNIX, Macintosh, and IBM PC versions of CLIPS 6.0 each include a platform-specific interface. Source code, a makefile, and an executable for the Windows 3.1 interface version of CLIPS 6.0 are provided only on the IBM PC distribution diskettes. Source code, a makefile, and an executable for the Macintosh interface version of CLIPS 6.0 are provided only on the Macintosh distribution.
diskettes. Likewise, for the UNIX version of CLIPS 6.0, only source code and a makefile for an X-Windows interface are provided. The X-Windows interface requires MIT's X Window System, Version 11, Release 4 (XIIR4) or later, the Athena Widget Set, and the Xmu library. The source code for the Athena Widget Set is provided on the distribution medium. The X-Windows interface has been successfully compiled on a Sun4 computer running SunOS 4.1.2 with the MIT distribution of XIIR4 (not OpenWindows), an SGI Indigo Elan computer running IRIX 4.0.5, and a DEC Alpha AXP computer running OSF/1 1.2.

The VAX version of CLIPS 6.0 comes only with the generic command line interface. ASCII makefiles for the command-line version of CLIPS are provided on all the distribution media for UNIX, VMS, Macintosh, and DOS.

Four executables are provided with the IBM PC version: a windowed interface executable for Windows 3.1 built by use of Borland C++ v3.1, an editor for use with the windowed interface, a command-line version of CLIPS for Windows 3.1, and a 386 command-line executable for DOS built by use of Zortech C++ v3.1. All four executables are capable of utilizing extended memory and require an 80386 or better central processing unit (CPU). Users who need executables on 8086/8088 or 80286 CPUs must recompile the CLIPS source code themselves. Users who wish to recompile the DOS executables by use of Borland C++ or Microsoft C must use a DOS extender program to produce an executable capable of using extended memory.

The version of CLIPS 6.0 for IBM PC-compatible computers requires DOS v3.3 or later and/or Windows 3.1 or later. It is distributed on a set of three 1.4-MB, 3.5-in. (8.89-cm) diskettes. A hard disk is necessary. The Macintosh version is distributed in compressed form on two 3.5-in. (8.89-cm), 1.4-MB Macintosh-formatted diskettes, and requires System 6.0.5 or higher, plus 1 MB of random-access memory. The version for DEC VAX/VMS is available in VAX BACKUP tar format on a 1,600-bit/in. (630-bit/cm), 9-track magnetic tape (standard distribution medium) or a TK50 tape cartridge. The UNIX version is distributed in UNIX tar format on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (Sun QIC-24). For the UNIX version, alternate distribution media and formats are available upon request.

The CLIPS 6.0 documentation includes a user's guide and a three-volume reference manual that consists of basic and advanced programming guides and an interfaces guide. An electronic version of the documentation is provided on the distribution medium for each version: in Microsoft Word format for the Macintosh and PC versions of CLIPS, and in both PostScript format and Microsoft Word for Macintosh format for the UNIX and DEC VAX versions of CLIPS. CLIPS was developed in 1986 and version 6.0 was released in 1993.

This program was written by Gary Riley, Brian Donnell, Huyen-Anh Bebe Ly, and Chris Ortiz of Johnson Space Center.

For further information on CLIPS 6.0, write in 226 on the TSP Request Card.

For further information on MSC-22430, write in 227 on the TSP Request Card.

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Pairwise-Comparison Software

This program collects similarity data for psychometric scaling and cognitive research.

PWC (which stands for “pairwise comparison”) is a computer program that collects data for psychometric scaling techniques now used in cognitive research. The cognitive tasks and processes of human operators of automated systems are considerations that now figure prominently in the process of defining requirements for such systems. Recent developments in cognitive research have emphasized the potential utility of such psychometric scaling techniques as multidimensional scaling for representing human knowledge and cognitive processing structures. Such techniques involve collecting measurements of stimulus-relatedness from human observers. When data are analyzed according to these scaling approaches, an n-dimensional representation of the stimuli is produced. This representation is said to describe the subject’s cognitive or perceptual view of the stimuli.

PWC applies the technique of pairwise comparisons, which is one of the many techniques commonly used to acquire the data necessary for these types of analyses. PWC administers the task, collects the data from the test subject, and formats the data for analysis. It thereby addresses many of the limitations of the traditional “pen-and-paper” methods. By automating the data-collection process, PWC prevents subjects from going back to check previous responses, eliminates the possibility of erroneous transfer of data, and eases the burden of administering and taking the test in which the data are acquired. By use of randomization, PWC ensures that subjects see the stimuli pairs in random order, and that each subject sees pairs in a different random order.

PWC is written in Turbo Pascal v6.0 for IBM PC-compatible computers running MS-DOS. The program has also been successfully compiled with Turbo Pascal v7.0. A sample executable code is provided. PWC requires 30K of random-access memory for execution. The standard medium for distribution of this program is a 5.25-in. (13.335-cm), 360K MS-DOS-format diskette. Two electronic versions of the documentation are included on the diskette: one in ASCII format and one in MS Word for Windows format. PWC was developed in 1993.

This program was written by Wendell R. Ricks of Langley Research Center. For further information, write in 160 on the TSP Request Card. LAR-15143

Software for Computing Reliability of Other Software

Nonspecialists will likely prefer this program to others developed for the same purpose.

The Computer Aided Software Reliability Estimation (CASRE) computer program is a software tool developed for use in measuring the reliability of other software. CASRE is easier for nonspecialists in reliability to use than are many other currently available programs developed for the same purpose.

During the past 20 years, mathematical models of the reliability of software have been developed; these models can be used to predict the rates of failure of software systems. These models can be useful management tools during testing periods, enabling developers to (1) determine when the required
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reliabilities of software systems have been achieved, (2) estimate the times and efforts necessary to achieve required levels of reliability, and (3) quantitatively assess the effects of shortages of resources during testing periods.

CASRE incorporates the mathematical modeling capabilities of the public-domain Statistical Modeling and Estimation of Reliability Functions for Software (SMERFS) computer program and runs in a Windows software environment. CASRE provides a menu-driven command interface; the enabling and disabling of menu options guides the user through the (1) selection of a set of failure data, (2) execution of a mathematical model, and (3) analysis of the results from the model.

Input to the models is simultaneously displayed as text and in a high-resolution form that can be controlled to enable the user to view the data in several different ways; for example, times between successive failures or cumulative numbers of failures. Predictions made by a model and statistical evaluations of the applicability of a model can be superimposed on a plot of data used as input to the model.

CASRE also incorporates earlier findings that the accuracy of prediction can be increased by combining the results of several models in a linear fashion. Users can define their own combinations of models, store them as part of the software configuration, and execute them in the same way as that of any other model.

This program would be particularly useful to software-development organizations searching for ways to manage their development resources more effectively. Inasmuch as CASRE was developed with the nonspecialist in mind, it should gain wider acceptance than do those software tools that require detailed knowledge of the models.

CASRE is written in C language for IBM PC-series and compatible computers running MS-DOS v5.0 or higher. This program requires 1MB of disk space for installation and up to 64KB of disk space for every failure-history file. The minimum required hardware and software required for running CASRE is the following: an 80386 processor with an 80387 coprocessor; Windows 3.1; 4MB of random-access memory (RAM); a mouse, trackball, or equivalent pointing device; a 16-in. (41-cm) or larger VGA monitor; and a video circuit card supported by Windows 3.1. Although CASRE can be executed on this minimum required hardware and software, the minimum combination of hardware and software recommended for execution of CASRE is the following: a 66-MHz 80486 DX/2 hardware system; Windows 3.1; at least 8MB of RAM; a mouse, trackball, or equivalent pointing device; a 19-in. (48-cm) VGA monitor; and a laser printer with a resolution of at least 300 dots per inch (12 dots per millimeter). CASRE may not function correctly on hardware based on the local bus architecture. The standard medium for distribution of CASRE is a 3.5-in. (8.89-cm), 1.44MB MS-DOS-format diskette. CASRE was developed in 1993 and is a copyrighted work with all copyright vested in NASA.

This program was written by Allen Nikora, Thomas M. Antczak, and Michael Lyu of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 3 on the TSP Request Card. NPO-19307

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Ceramic Replaces Metal in High Performance Optomechanical Structures

Ceramic components feature dimensional stability, low cost, and ease of fabrication.

Langley Research Center, Hampton, Virginia

Recently developed ceramic materials and fabrication techniques have been integrated by Langley Research Center workers to produce superior optomechanical structures for spacecraft and aircraft instrumentation. The basic features of these novel supports, such as dimensional stability, low cost, and ease of fabrication, also make them ideal for many commercial optical systems as well.

Ceramic supports for optical components and benches offer important advantages over the usual metal parts. Ceramic materials expand and contract only slightly with changes in temperature. Moreover, they are relatively inexpensive and lightweight.

Nearly all optical components are mounted on supports and benches made of aluminum, stainless steel, or Invar (or equivalent) nickel/iron low-expansion alloy. Aluminum is lightweight, but expands and contracts significantly; its coefficient of thermal expansion at room temperature is $2.5 \times 10^{-6} / ^\circ C$. In optics, where precise alignments are essential, temperature-related dimensional changes can make a system inoperable. Stainless steel and Super Invar (or equivalent) have low coefficients of thermal expansion, about one-third and one-fifth, respectively, of that of aluminum; but they are heavy, expensive, and difficult to machine. In fact, much of the weight of optical systems is attributable to metal mounts.

Certain ceramics, on the other hand, have coefficients of thermal expansion lower than those of stainless steel and Invar, with density like that of aluminum, and they cost far less — about $10/\text{lb}$ (about $22/\text{kg}$) versus $1,000/\text{lb}$ ($2,200/\text{kg}$) for Invar and $50/\text{lb}$ ($110/\text{kg}$) for aluminum (1992 prices). Ceramics expand and contract only negligibly with changes in temperature and can thus be slip cast at Langley Research Center without temperature control.

Dimensionally stable optical mounts (far left of Fig. 1) and benches (Fig. 2), have been fabricated using a slip-casting technique. Slip casting is defined here as a process that consists of a slip (ceramic powders dispersed in an aqueous media) being poured into a porous mold, which extracts a large percent of the liquid from the slip leaving a semisolid part.

Developing a porous mold requires that a master pattern of required dimension be machined from aluminum, which is inexpensive, lightweight and easy to machine (far right of Fig. 1). Extreme importance was placed on design and preparation of the master, since it is the most important item in producing the mold.

The first step in producing a slip cast ceramic part is to fabricate a silicone rubber mold (middle of Fig. 1). Silicone rubber was used as the mold material because the silicon acted as a release agent for the molded parts. Hot wax was poured into the mold to produce a wax master. A quality inspection (dimensional and visually) is performed on the wax master upon its removal from the mold.

The wax master is encapsulated in a moisture-absorbing compound. The wax is burned out, leaving a dimension-al cavity equal to that of the master. A ceramic slip is poured into the cavity and allowed to jell (1 to 2 h) before removing the mold. Because the mold becomes more plastic with increasing water absorption, it can be peeled off of the green ceramic body, regardless of the ceramic body shape.

A note of caution: If the ceramic part is placed in the furnace before final drying, the remaining moisture will turn to steam, and its volume will increase several hundred times. This steam will generate tremendous pressure within the ceramic part and explode or crack. To avoid explosions or cracks, the air around the piece must be totally saturated with water vapor as the temperature is raised to remove remaining moisture. No sur-

Figure 1. A Dimensionally Stable Optical Mount (left) is shown with a master pattern (right) and a silicone rubber mold (center).

Figure 2. This Ceramic Optical Bench was fabricated via slip-casting technique.

NASA Tech Briefs, October 1995
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face evaporation can then occur. After the piece has reached uniform temperature (below 100 °C), the relative humidity of the air around the piece can be slowly lowered to allow drying to occur. Careful control of the temperature and humidity in the dryer is important. The dried piece is fired in a furnace, which can increase temperature at less than 1 °F/min (0.6 °C/min).

This work was done by Peter Vasquez, Robert L. Fox, and Stephen P. Sandford of Langley Research Center. No further documentation is available. LAR-14948/LAR-14981

**Optoelectronic Inclinometer**

Tilt would be measured with respect to a vertical mirror.

*Langley Research Center, Hampton, Virginia*

A proposed optoelectronic instrument would measure the tilt of an object about a single horizontal axis by measuring the change of position and orientation of a laser beam reflected from a hanging mirror. The mirror would remain vertical while the rest of the instrument rotated with the object.

The instrument (see figure) would include a rectangular open frame mounted in the object, the tilt of which was to be measured. The mirror, made of heavy material or weighted, would be mounted in high-quality bearings in a gimbal that would, in turn, be held by a rod pivoted at its upper end. Thus, the rod, gimbal, and mirror taken together would constitute a pendulum. The frame or enclosure would be oriented so that the gimbal axis would be nominally parallel to the axis about which the tilt was to be measured, while the pivot axis of the pendulum would be nominally horizontal and perpendicular to the gimbal axis.

Acting via the combination of the pendulum and gimbal, gravitation would keep the mirror vertical when the frame tilted about either or both horizontal axes. A source of light (e.g., a laser diode or a light-emitting diode equipped with a collimating or focusing lens) would emit a beam that would be reflected from the mirror onto a linear array of photodetectors. The source of light would be oriented so that at zero tilt, both the beam of light from the source and the beam reflected by the mirror would lie in a horizontal plane.

The Optoelectronic Inclinometer would measure tilt about the gimbal axis by measuring the change in position and orientation of the beam of light reflected from the mirror hanging in the gimbal.
and the reflected beam would land at or near the midlength of the linear array of photodetectors. As the object and the instrument frame tilted about an axis parallel to the gimbal axis (pitch), the spot of light cast by the reflected beam would be translated along the array. Tilt of the object and instrument frame (about the pivot axis of the pendulum (roll)) would produce a small (second-order) change in the position of the spot with respect to the array, but this effect may be tolerable at small tilt angles. The maximum amount of tilt about the pivot axis of the pendulum that the instrument could tolerate would depend on the size of the mirror and the physical size of the linear array and the spacing of the components. A compensating lens could be included to correct for nonlinearity and to ensure that the beam continued to fall on the array throughout the desired angular range of the instrument.

This work was done by Timothy D. Schott of Langley Research Center. No further documentation is available.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center; (804) 864-9260. Refer to LAR-14728.

More About Pressure Probes for Turbulent Flows

An array of probes yields data on static and total pressures and cross-stream turbulence.

Ames Research Center, Moffett Field, California

The figure illustrates an array of pressure probes for use in a turbulent stream of inviscid, incompressible fluid. The measurements of the probes in this array can be processed into time-averaged values of the static pressure, the total pressure based on the entire velocity, the stagnation pressure based on the time-averaged streamwise component of velocity (along which the probe tubes are required to be aligned), and cross-stream turbulence.

The array is a combination of the separate pressure-probe arrays described in "Measuring Streamwise Momentum and Cross-Stream Turbulence" (ARC-11934), NASA Tech Briefs, Vol. 16, No. 8, (August 1992), page 53, and "Probe Rakes To Measure Static Pressure and Turbulence" (ARC-12973), NASA Tech
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For recapitulate: Each probe is designed by applying potential-flow theory to the flow field on and near its surface. An upstream-facing probe orifice can be shaped to sense the stagnation pressure based on the entire velocity or on one or more components of velocity—in this case, the streamwise component. An orifice on the side of the probe tube downstream from the tip can be positioned to sense a combination of static pressure and pressure attributable to cross-stream turbulence. The cross-sectional shape of a probe tube can be made elliptical, and the probe orifices positioned around the circumference in such a way as to increase or decrease, by a known factor, its response to one of the components of cross-stream turbulence.

The equations that express the directional responses of the various probes in the array can be solved together to eliminate unknown quantities; this makes it possible to process the digitized time-averaged probe readings together to obtain the time-averaged static, stagnation, and cross-stream-turbulence pressures. In the case of the five-probe array shown in the figure, one obtains the time averages of the two stagnation pressures, plus redundant values of the time-averaged static pressure and the time-averaged cross-stream-turbulence pressures.

This work was done by Vernon J. Rossow of Ames Research Center. For further information, write in 80 on the TSP Request Card.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-11935.

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These Five Pressure Probes yield readings from which one can compute time averages of the entire and streamwise stagnation pressures, the static pressure, and the pressures associated with the two components of cross-stream turbulence. The three lower probes yield data that are redundant (in principle) and that could, therefore, be used to reduce errors.
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Quick-Release Pin With Lever Action

The mechanism can be operated with a gloved hand.
Lyndon B. Johnson Space Center, Houston, Texas

The figure illustrates original and modified versions of a quick-release ball-detent pin with a T-handle. The original version is a commercially available mechanism called a "pip pin," and is released by pressing the button on the handle. The original version is advantageous in that it resists inadvertent actuation. However, it is disadvantageous in that the operator must exert a force on the button, usually by pressing on the button with a thumb while simultaneously grasping the T-handle with at least two other fingers; this can be difficult to do, especially when wearing a heavy glove.

In the modified version, a lever has been added to the handle to facilitate actuation. The lever action reduces the actuation force. In addition, one is no longer limited to use of a thumb and at least two fingers to exert the reduced actuation force; the lever-action pin can also be operated by squeezing on any point of the moveable ends of the lever and handle together between a thumb and forefinger or by simply grasping and squeezing the handle and lever with the entire hand in a more natural grasp. Tests showed that the modified release pin can be operated easily with a gloved hand.

This work was done by Robert C. Trevino of Johnson Space Center. For further information, write in 29 on the TSP Request Card. MSC-22398

Calibration Valve With Built-In Test Port

Lyndon B. Johnson Space Center, Houston, Texas

A calibration valve includes a built-in test port for calibrating control-panel gauges in place, without having to remove them for calibration. The use of this valve reduces the number of plumbing parts and thus the number of potential leakage points. In addition, the application of the calibration valve saves time when calibrating the control-panel gauges or transducers and prevents damage or loss of the instruments by not having to remove them from the control panel for calibration.

This work was done by Carmine A. Pilichi of Rockwell International Corp. for Johnson Space Center. For further information, write in 85 on the TSP Request Card. MSC-22410

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For More Information Write In No. 538
Inflatable Pole

This portable device extends reach up to 20 ft (6 m).

Lyndon B. Johnson Space Center, Houston, Texas

An inflatable pole is a lightweight, portable tool for reaching an object at a height or across a gap. When not in use, the tool collapses to 3 to 5 percent of its inflated length. The pole was developed for use as a self-rescue device by an astronaut who becomes untethered outside a spacecraft: the astronaut would use the pole to reach a grapple on the spacecraft and pull to it. The pole might also be useful on Earth as a rescue device or in performing routine tasks like

Before Deployment, the inflatable tube is neatly pleated in the space between the shaper tube and the fabric sheath. After deployment, it extends stiffly from the barrel of the gun.
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For More Information Write In No. 610
changing a high light bulb without a ladder.

The pole includes a 2-in.-diameter (10-
cm-diameter) tube of urethane-coated
Kevlar (or equivalent polyester) fabric. Before use, the tube is bunched on a
shaper rod in a gas gun (see figure). To
deploy it, a user presses the trigger of the
gun releasing a regulated
30-psi (0.21-
MPa) blast of nitrogen from a separate
bottle. The gas inflates the tube. A fabric
cover prevents snagging and ensures
that the tube emerges straight.

The operator can stop deployment of
the tube at any point up to its maximum
20-ft (6.1m) extension by releasing the
trigger; this action applies the brakes on
the gun barrel. The operator thus con-
trols the length of the pole. Once
deployed, the tube remains inflated and
stiff while the operator uses it. The tube
weighs only about 7 oz. (0.2 kg); thus, it
has low inertia when extended, so that it
can be maneuvered easily.

When the task with the inflatable pole
has been completed, the operator opens
a vent valve to deflate the tube. The oper-
ator then opens the gun, removes the
fabric cover, and repacks the tube.

This work was done by Scott A. Swan
of Johnson Space Center. For further
information, write in 76 on the TSP
Request Card.

This invention is owned by NASA, and
a patent application has been filed.
Inquiries concerning nonexclusive or
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Patent Counsel, Johnson Space Center;
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Estimating Vibrational Powers of Parts
in Fluid Machinery

Vibrations of components are taken to be governed by local physics of flow.

Lewis Research Center, Cleveland, Ohio

In a new method of estimating the
vibrational power associated with a
component of a fluid-machinery sys-
tem, the physics of flow through (or in
the vicinity of) the component is regard-
ed as governing the vibrations. The
method was devised to generate scal-
ing estimates for the design of new
parts of rocket engines (e.g., pumps,
combustors, nozzles) but is also appli-
cable to terrestrial pumps, turbines, and
other machinery in which turbulent
flows and vibrations caused by such
flows are significant.

The new method stands in contrast to
several prior methods in which the vibra-
tional powers associated with the com-
ponents were estimated by scaling from
global variables (e.g., engine thrust or
exhaust velocity). In the new method, it
is assumed that the scaling law is

\[
\frac{G_{\text{new}}^2}{P_{\text{new}}} = \frac{G_{\text{ref}}^2}{P_{\text{ref}}}
\]

where \( G \) denotes the mean-square
local vibrational power, \( P \) denotes the
specific power (that is, the power per
unit mass) of the pump or other com-
ponent, the subscript "new" denotes
the new component for which the esti-
mate is sought, and the subscript "ref"
denotes a similar preexisting reference
component (e.g., a pump of similar, but
not identical design), the vibrations of
which have been measured.

The specific power of a pump or other
component for use in equation is given by

\[
P = \frac{KQ^3}{M}
\]

where \( K \) is a lumped parameter that
summarizes the effects of the flow
geometry in or about the component, \( Q \)
is the volumetric flow rate, and \( M \) is the
mass of the component. The lumped
parameter is given by

\[
K = \frac{1}{\int_{x=0}^{x_f} \left( \frac{1}{A(x)} \right)^3 \frac{1}{L(x)} \, dx}
\]

where \( A(x) \) is the local cross-sectional
area presented to the flow at position \( x \),
\( L(x) = \) the local characteristic length in
the plane of \( A(x) \) (e.g., separation be-

tween a pump impeller and pump
housing) perpendicular to the flow, and \( x_f \)
= the length of the flow path through the
component.

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NASA Tech Briefs, October 1995
Of course, this method of scaling is only approximate: strictly speaking, the use of $K$ is valid only if the fluid has constant density (is incompressible). The validity of the method also depends on the assumption that the fluid flows quasi-steadily and that the flow gives rise to uncorrelated acoustic powers in different parts of the pump. Despite these limitations, when the method was applied to data from five different rocket-engine turbopumps, the processed data all lay near one straight line on a logarithmic plot (see figure).

This work was done by S. A. Harvey and L. C. Kwok of Rockwell International Corp. for Lewis Research Center. For further information, write in 10 on the TSP Request Card.

LEW-15194

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**Testing and Analysis of Rubbing of Turbine-Blade Tips**

A combination of established techniques has been applied to a modern design problem.

**Marshall Space Flight Center, Alabama**

A unique combination of established techniques of experimentation and theoretical analysis has been devised to study the stresses induced in turbine blades by intermittent or periodic rubbing of the tips of the blades in turbine housings. Rubbing is an inevitable consequence of modern high-speed, high-efficiency turbine designs, which call for blade-tip clearances to be as small as possible: this is because thermal and centrifugal growth of blade-tip radii during operation sometimes reduces the already small blade-tip clearances to zero. It is necessary to quantify the stresses caused by rubbing in order to predict the fatigue lives of the blades.

In the initial application, the theoretical analysis involved time-domain numerical simulation of the responses of the blade to various rubbing excitations. For this purpose, the blade was represented by a conventional, linearly responding finite-element mathematical model. The simulated rubbing excitation was a once-per-revolution half sine pulse of tangential force at the blade-tip/housing seal interface, with a duration equal to

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Figure 1. Stress at the Root of the Blade Shank was computed as a function of speed and contact arc in a parametric numerical-simulation study of the dynamic response.

the tip/housing contact time. Between excitatory pulses the simulated tangential force on the tip was zero.

In a parametric study, these computations were performed to map the response of the blade as a function of the length of the rubbing-contact arc and the speed of rotation of the turbine shaft. For each pair of values of these parameters, the simulation of dynamic response was continued until a steady-state dynamic motion was reached — typically in 30 to 40 revolutions. Figure 1 shows some of the results of this parametric study.

The experimental part of the effort involved the construction of a unique testing apparatus (see Figure 2). A turbine rotor was instrumented with strain gauges on its blades, and slip rings were used to pass the outputs of the gauges to external tape recorders. A simulated tip-seal segment of a housing was connected to a hydraulic actuator coupled with a control system and a displacement transducer. The motion of the tip-seal segment could thus be controlled precisely. In the tests, the turbine was driven at speeds up to 32,700 r/min. and the tip-seal segment was moved in to effect rubbing contact for short periods of time. The results of tests verified analytical predictions that the dynamic behavior consists of once-per-revolution rubs alternating with periods of free vibrations.

Figure 2. This Testing Apparatus simulates blade-tip rubbing and measures the dynamic responses of the blades.
Wet/Dry Vacuum Cleaner

A hydrophobic bag with an absorbent pad retains water and dust.

Lyndon B. Johnson Space Center, Houston, Texas

The vacuum cleaner collects and retains dust, wet debris, and liquids. Designed for housekeeping on Space Station Freedom, it functions equally well in normal Earth gravity or in microgravity. It generates acoustic noise at comfortably low levels and includes circuitry that reduces electromagnetic interference to other electronic equipment.

The vacuum cleaner (see figure) draws materials into a bag made of a hydrophobic sheet with layers of hydrophilic superabsorbing pads at the downstream end material. The hydrophobic sheet lets air, but not liquid, leave the bag, while the hydrophilic material gels the liquid to retain it after the vacuum cleaner has been turned off. The hydrophilic material can gel many times, forming a gel that can be mixed with other substances as needed.

The Molded Polycarbonate Case Houses the other components of the vacuum cleaner. The hose is made of silicone rubber covered with Nomex fabric.

NASA Tech Briefs, October 1995
times its own weight of liquid. The bag holds dust particles larger than 40 mm and absorbs up to 48 oz (1.42 L) of liquid. Suction is developed by a two-stage blower driven by a modified commercial 120-Vdc motor. The two stages help to keep noise low. The blower also provides a secondary airflow to cool its electronic components.

This work was done by Harold Reimers of Johnson Space Center and Jay Andampour, Craig Kunitser, and Ike Thomas of Lockheed Engineering & Sciences Co. No further documentation is available. MSC-22044

**Shielded, Automated Umbilical Mechanism**

Fluid and/or electrical connectors are protected against debris.

*Lyndon B. Johnson Space Center, Houston, Texas*

An umbilical mechanism automatically connects and disconnects various fluid couplings and/or electrical contacts while shielding the mating parts from debris. The mechanism reacts mating and demating loads internally, without additional supporting structures.

The mechanism is designed for service in outer space, where its shields would protect against micrometeoroids, debris, ultraviolet radiation, and atomic oxygen. It could be used on Earth to

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**ACTIVE SUBASSEMBLY**

**PASSIVE SUBASSEMBLY**

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The **Active Subassembly Mates** with the passive subassembly of the umbilical mechanism.

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NASA Tech Briefs, October 1995
connect or disconnect fluid or electrical utilities in harsh environments like those of nuclear powerplants or undersea construction sites, or in the presence of radioactive, chemical, or biological hazards, for example.

The mechanism consists of an active and a passive subassembly. It can accommodate an initial linear misalignment of 0.250 in. (6.35 mm) and angular misalignment of 2° between the subassemblies.

The mating sequence consists of the following steps (see figure):

1. The active subassembly with its connector retracted is coarsely aligned relative to the passive subassembly.
2. A carrier in the active subassembly begins to move a plug down as a cam action opens the debris shields in this subassembly.
3. The active and passive subassemblies are precisely aligned and locked together by a pin-and-drogue device.
4. Acting via a cam and linkage, the carrier in the active subassembly begins to open the debris shield of the passive subassembly.
5. When the debris shield in the passive subassembly is completely open, the plug attached to the active subassembly is 50-percent mated with a receptacle in the passive subassembly.
6. The carrier continues to extend the plug until it is completely mated with the receptacle.

All functions — extension of the plug, mating, and movement of the debris shields — are actuated by a single motor. If the mechanism jams or fails at any point in the sequence, an override feature in the drive train allows manual operation. The plug and receptacle in the mechanism can readily be changed between fluid-transfer and electrical applications.

This work was done by Daniel R. Barron, Bron F. Morrill, and Vytas Jasulaitis of McDonnell Douglas Corp. for Johnson Space Center. For further information, write in 99 on the TSP Request Card.

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

John Scholl, Counsel
McDonnell Douglas Corp.
5301 Bolsa Avenue
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(714) 896-5999

Refer to MSC-22053, volume and number of this NASA Tech Briefs issue, and the page number.
Sinterless Fabrication of Contact Pads on InP Devices

Carefully chosen contact materials are used.

Lewis Research Center, Cleveland, Ohio

Manufacturing/Fabrication

Research has shown that with a proper choice of material, low-resistance contact pads can be deposited on solar cells and other devices by an improved technique that does not involve sintering. Until now, sintering has been used and has often proven destructive to the devices being fabricated.

To make low-resistance electrical contact to an InP semiconductor device according to the prior technique, contact metal is deposited on the semiconductor, then the contact metal must be sintered at high temperature. Although the sintering step desirably reduces the contact resistance, it also undesirably induces substantial interdiffusion between the metal and the InP substrate. Unless carefully controlled by imposition of diffusion barriers or by use of such techniques as rapid thermal processing, this interdiffusion can quickly degrade or destroy the device. Such shallow-junction devices as junction field-effect transistors and solar cells are particularly susceptible to damage during formation of contacts.

Research directed at understanding the mechanisms involved in the contact-sintering process has resulted in the identification of a special group of materials that includes the phosphides of gold, silver, and nickel; specifically, Au$_2$P$_3$, Ag$_2$P, and Ni$_3$P. The introduction of one of these materials between an underlying n-doped InP semiconductor and an overlying current-carrying metal layer results in low contact resistance. Further research has indicated that only a very thin interlayer of any of these compounds is needed to obtain low contact resistance, without having to subject the contact to the destructive sintering process.

Phosphide layers with thicknesses of the order of 20 to 30 Å on moderately doped InP are sufficient to make contact resistivities range downward to as little as $10^{-6}$ Ω-cm$^2$ (see figure). These values are only slightly greater than those obtained by use of the destructive sintering process.

This work was done by Victor G. Weizer of Lewis Research Center, Navid S. Fatemi of Sverdrup Technology, Inc., and Andras L. Korenyi-Both of Calspan Corp. Further information may be found in NASA TM-105670 [N92-24802/TB], "Sinterless Contacts to Shallow Junction InP Solar Cells."

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. LEW-15863

Wax Reinforces Honeycomb During Machining

Wax-filled honeycomb can be cut to a precise contour on a lathe.

Langley Research Center, Hampton, Virginia

A method of machining on a conventional metal lathe has been devised for precise cutting of axisymmetric contours on honeycomb cores made of composite (matrix/fiber) materials. The method was devised because, heretofore, the fragility of these materials in their as-manufactured, unrestrained condition has made contouring difficult.

Composite honeycomb core materials exhibit high stiffnesses at low densities. Their composition and properties often make them the materials of choice for sandwich constructions in which composite face sheets are used. Some applications of these materials involve rigorous geometric tolerances. An example of such an application is as a core mater-
Machining of honeycomb materials on multiaxis milling machines is possible, but achievable surface accuracies are limited by the lower positioning accuracies generally associated with milling machines as compared with those of metal lathes. Also, corrections for tool geometries must be made as functions of cutting angles. Lathe turning generally provides accuracies higher than those obtained with milling machines, because of the smaller number of axes on which the cutting tool of a lathe must move. Also, the simple point geometry of the lathe cutting tool eliminates the need for geometric correction for the cutting angle.

The innovative method of machining on a lathe involves a preparation in which the honeycomb is placed in an appropriate fixture and the fixture is then filled with a molten water-soluble wax. A number of different waxes have been tried. Saunders Yellow™ water-soluble wax was found to work well; others may also work. (The identity of this particular wax is given for completeness only and does not constitute an endorsement, expressed or implied, by the NASA Langley Research Center.)

During filling of the fixture, the upper surface of the wax should be kept fluid and allowed to solidify last to reduce the formation of voids: this can be done by occasional application of heat to the surface with a hot-air gun. Shrinkage associated with the solidification of the wax causes additional molten wax from the top to be drawn down into the cells of the honeycomb. The wax serves both to fasten the honeycomb to the fixture and to support the individual honeycomb cells during the machining process.

The figure shows a wax-filled low-density graphite/phenolic honeycomb in a fixture positioned on a numerically controlled lathe for machining of a paraboloidal contour. A computer program was written to generate coordinates along the desired parabolic contour based on the focal length of the paraboloid.
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plate is not removed during the machining process. The metal lathe shown in the figure has a specified machining accuracy of ±0.0005 in. (about ±0.01 mm).

After machining, the wax-filled honeycomb is sawn from the aluminum fixture, then placed in hot water to remove the wax, then rinsed for 10 min in dilute (0.5 weight percent) hydrochloric acid at room temperature. The honeycomb is then washed with deionized water and dried.

This work was done by Timothy W. Towell, David T. Fahringer, Peter Vasquez, and Alan P. Scheidegger of Langley Research Center. No further documentation is available. LAR-14927

Improved Hermetic Feedthrough Seals for Optical Fibers

Inorganic sealing materials withstand widely ranging temperatures.

Lewis Research Center, Cleveland, Ohio

Improved hermetic feedthrough seals for optical fibers can withstand temperatures from as low as −325 °F (about −198 °C) to as high as 392 °F (about 200 °C) while maintaining a helium leak rate of below 10⁻¹¹ cm³/s. This feedthrough material was used in an optical connector design targeted to meet the specifications of the space shuttle main engine environment as well as the expected environment of space-based rocket engines. The seal was demonstrated to perform exceptionally through salt spray, sinusoidal and random vibrations (20 to 2000 Hz), mechanical shock (40 g's) thermal shock at the extreme temperatures, humidity, and radiation (neutron fluence, gamma, and ion) testing.

The figure depicts a simplification of a feedthrough of the improved type, for illustrative purposes. Polyimide buffered glass/glass fibers are hermetically sealed to the feedthrough unit with the polycrystalline ceramic material. The sealing technology was demonstrated in two feedthrough types: a continuous fiber type as shown in the figure and a type where one end of the fiber is terminated with an SMA connector mate. The latter type may be constructed with a standard MIL-C-38999 Series 3 or 4 bulkhead-mound, hermetically sealed receptacle.

Throughout the environmental testing, the optical signal passing through the units was monitored. The prototype feedthroughs passed the required tests with negligible insertion losses.

This work was done by Robert Jul-Lin Fan of LiteCom, Inc., for Lewis Research Center. For further information, write in 120 on the TSP Request Card. LEW-15417

This Feedthrough Seal on an Optical Fiber can be made primarily or entirely of inorganic materials that withstand widely ranging temperatures.
Level Indicator on a Tubular Inside Micrometer

Leveling helps to ensure accurate measurements.

Marshall Space Flight Center, Alabama

A bubble-type level-indicating attachment on a tubular inside micrometer (see figure) helps a novice user obtain accurate measurements. The attachment can be helpful because in some situations that involve measurement of large, tight-tolerance inside dimensions, inside micrometers that are not held level between the contact point can give inaccurate readings.

A bubble-type level indicator is modified for use in this application by grinding it to a known length. The modified level indicator is then attached to the tubular inside micrometer by threading it into micrometer extensions that are attached to the graduated thimble of the micrometer.

The user adjusts the position and orientation of the micrometer and verifies that it is level by observing the bubble in the level indicator. Upon feeling the correct drag between the micrometer tips and the workpiece, the user can be confident that the tool is being used correctly and an accurate measurement has been obtained.

This work was done by R. Michael Malinzak and Gary N. Booth of Rockwell International Corp. for Marshall Space Flight Center. No further documentation is available. MFS-30026

Pressurized Bladder To Secure a Tile During Bonding

John F. Kennedy Space Center, Florida

An apparatus for use in installing tiles with adhesive includes an inflatable bladder that holds a tile in place while the adhesive cures. Once the tile is placed in the desired position, the pressurized bladder is pressed against the tile with increasing force until the pressure in the bladder equals the desired tile bond pressure. A pressure gauge that can be monitored easily from a distance is used to ensure that the tile is being held with the proper force during curing.

This work was done by John M. Hutchinson of Lockheed Space Operations Co. for Kennedy Space Center. For further information, write in No. 436 on the TSP Request Card. KSC-11662

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Discrete Gabor Filters for Binocular Disparity Measurement

Binocular disparities would be determined from phases of discretized Gabor transforms.

Lyndon B. Johnson Space Center, Houston, Texas

Discrete Gabor filters have been proposed for use in determining the binocular disparity — the difference between the positions of the same feature or object depicted in stereoscopic images produced by two side-by-side cameras aimed in parallel. The magnitude of the binocular disparity can be used to estimate the distance from the cameras to the feature or object. In one potential application, the cameras would be charge-coupled-device video cameras in a robotic vision system, and binocular disparities and the distance estimates would be used as control inputs — for example, to control approaches to objects to be manipulated or to maintain safe distances from obstacles.

The major problem in determining the binocular disparity is to match corresponding features in the two images. Typical prior solutions have been computationally intensive and have often included explicit (and sometimes error-prone) feature-matching processes. In the proposed solution, no attempt is made to identify or match features explicitly. Instead, one matches features implicitly and obtains the binocular disparity by computing complex Gabor transforms (see Figure 1) of corresponding neighborhoods in the two images, then taking advantage of the fact that the phase shift between the Gabor transforms is proportional to the local binocular disparity in approximately the same way in which a phase shift in a Fourier transform of the entire image is proportional to a uniform lateral shift in the entire image. Characterizing this approach from another perspective, the local binocular disparity is computed directly from a locally computed parameter of the pair of images, and no formal matching process is needed.

In practice, it is necessary to compute the Gabor transforms by use of relatively coarse-grained two-dimensional filters or masks, each pixel of which approximates the value of the even or odd Gabor function at its position (see Figure 2). The size of

Figure 1. The Even and Odd Gabor Functions are used to compute complex Gabor transforms. The location of a feature (in this case, a step edge) can be determined from the phase of its complex Gabor transform.
The numbers and dots on the trajectory denote horizontal transform of a step edge, except that here it is computed approximately.

The filters are applied as follows. The two images are divided into corresponding windows of 8 x 8 pixels each. The even Gabor filter is overlaid on each window. The brightness at each pixel is multiplied by the filter value at that pixel. The sum of the brightness*filter products of the window is a single number and constitutes the filter output for that window. The odd Gabor filter is then overlaid on each window, and the process is repeated. The phase of the approximate Gabor transform of each window can then be obtained easily from the relative values of the even- and odd-filter outputs, and the phases of the transforms of the corresponding windows in the two images can be compared to obtain the phase shift and, hence, the local binocular disparity.

This approach involves less computation than do prior approaches based on convolution. In this approach, each 8 x 8 filter is applied only once to each 4 x 4 pixel neighborhood; in a convolution-based approach with a filter of equal size, it would be necessary to apply that filter to each 4 x 4 pixel neighborhood 16 times. This makes possible a considerable reduction in computation time and/or a reduction in the complexity of image-processing circuitry—important considerations in robotic systems.

This work was done by Carl F. W. Weiman of Transitions Research Corp. for Johnson Space Center. For further information, write in 111 on the TSP Request Card. MSC-22094.
Automated Diagnosis of Conditions in a Plant-Growth Chamber

Expert-system software advises nonexpert technicians about how to respond to malfunctions.

John F. Kennedy Space Center, Florida

The Biomass Production Chamber Operations Assistant software and hardware constitute an expert system that diagnoses mechanical failures in a controlled-environment hydroponic plant-growth chamber and recommends corrective actions to be taken by technicians. The plant-growth chamber and the expert system are subjects of continuing research directed toward the development of highly automated closed life-support systems aboard spacecraft to process animal (including human) and plant wastes into food and oxygen. The development of larger terrestrial biomass-production and recycling systems might also benefit from this research.

The chamber and associated equipment (see figure) provide 200 ft² (18.6 m²) of plant-growth area with controlled light levels, temperature, humidity, airflow, air composition, nutrient solution, temperature, pH, electrical conductivity, and chemical composition. Wheat, soybeans, lettuce, potatoes, and strawberries have been grown in the chamber. For purposes of this research, the knowledge base of the expert system concentrates on wheat crops. The knowledge base incorporates expertise from multiple expertise domains, including biology, electrical engineering, mechanical engineering, and chemistry. The knowledge base was developed by a group of experts in these fields and in information systems, using the techniques of knowledge engineering.

The system uses a Microsoft Windows interface to give technicians intuitive, efficient access to critical data. By selecting an icon on the Windows display, a technician can analyze a set of data, view operating equipment through closed-circuit television, cause the expert system to begin a diagnostic procedure, examine technicians' work schedules, or command the system to perform a computational simulation.

In the diagnostic mode, the system prompts a technician for information. For example, if a malfunction occurs in the nutrient-delivery system, the expert system asks for the time, location, and type of malfunction.

The Nutrient-Delivery System is one of several complex equipment systems that provide conditions favorable to the growth of plants. The expert system recommends responses to malfunctions in the nutrient-delivery system. Plans for the future call for extension of the expert system to respond to malfunctions in all the equipment systems.
of malfunction; the status of backup nutrient-delivery pumps; the type and the stage of growth of the crop; the visible amount of water in the plant trays; the ability to reduce the temperature; and the ability to turn lights on or off. When the expert system has enough information, it generates a recovery plan.

The recovery plan not only gives instructions for how to correct the malfunction, but also indicates steps to minimize damage to the crop in the interim; this is an important feature because a malfunction can usually be diagnosed in a few minutes, but a few hours may be needed for repairs. For a nutrient-delivery failure, the expert system might advise such emergency measures as turning off lights, reducing the temperature of the air, and closing drains on plant trays to reduce the metabolic rate of the plants and conserve the remaining nutrient solution. For each measure, and for combined measures, the expert system estimates the time available before serious damage occurs. For a prolonged failure, the system may even advise that the crop be replanted.

This work was done by Barry R. Clinger and Alfred L. Damiano of McDonnell Douglas Corp. for Kennedy Space Center. For further information, write in 9 on the TSP Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-3017. Refer to KSC-11761.

Predatory Microorganisms Would Help Reclaim Water

Pathogenic microorganisms would be removed from water without use of harsh chemicals, intense heat, or ionizing radiation. Marshall Space Flight Center, Alabama

Wastewater-reclamation systems of a proposed type would use predatory, nonpathogenic microorganisms to consume pathogenic microorganisms. The predators in question are Dictyostelium amoebae, which consume bacteria (and presumably, could also be induced to eat microalgae, viruses, and protozoa). The Dictyostelium amoebae convert their prey into their own cell substance, which is largely cellulose. Dictyostelium is not harmful to humans, other macroscopic animals, or macroscopic plants. The cellulosic product could be subjected to further biodegradation or other treatment. Unlike some other wastewater-reclamation systems, these systems would not require the use of toxic chemicals, intense heat, or ionizing radiation (γ rays or ultraviolet) to destroy microorganisms.

Two apparatuses have been constructed to test the concept. One of them includes a growth chamber that contains an 18-in. (45.7-cm)-diameter rotating plate, on which petri dishes are placed. Each dish contains Dictyostelium growing on agar and a porous stainless-steel disk inoculated with bacteria and amoebae. The dishes are illuminated by two lamps, which provide constant simulated sunlight to induce growth of cellulosic Dictyostelium stalks. The plate is slowly rotated so that all samples are exposed equally to the light. The air in the growth chamber is kept at high humidity by circulating it between the growth chamber and an auxiliary chamber in which water is sprayed. No special equipment is needed to keep the temperature in the growth chamber within an acceptable range.

The other apparatus includes two connected 5-gal (19-L) plastic tanks, one of which serves as a reactor vessel, while the other serves as a holding tank. The reactor vessel contains a
A multiple-chamber dialysis apparatus (see figure) grows protein crystals on Earth or in microgravity with a minimum of intervention by a technician. The apparatus includes a reservoir and a series of sample chambers attached to one end of the reservoir. A dialysis membrane that passes low-molecular-weight solutes, but not high-molecular-weight solutes, is placed between the reservoir and the first chamber. Another such membrane is placed between each chamber and the succeeding or preceding chamber. Access to each chamber can be gained through a screw-in plug in its side. Sliding gate valves between the precipitant and growth chambers could be used to start the growth process. The use of multiple chambers provides a gradation of nucleation and growth rates.

This work was done by Marc Lee Pusey for Marshall Space Flight Center. To obtain a copy of the report, "Multiple Chamber Dialysis System for Protein Crystal Growth," write in 72 on the TSP Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-28967.
**Coordinated Control of Mobile Robotic Manipulators**

A computationally efficient scheme is suitable for real-time implementation.

**NASA's Jet Propulsion Laboratory, Pasadena, California**

A computationally efficient scheme has been developed for on-line coordinated control of both manipulation and mobility of robots that include manipulator arms mounted on mobile bases. The scheme is applicable to a variety of mobile robotic manipulators, including robots that move along tracks (typically, painting and welding robots), robots mounted on gantries and capable of moving in all three dimensions, wheeled robots (see figure), and compound robots (consisting of robots mounted on other robots).

In the past, robots were typically mounted on stationary bases bolted to floors so that they could withstand the forces and torques applied to the bases when the robot arms carried payloads. However, there are significant advantages to placing robot arms on mobile bases. The mobility of a base extends the reach of the manipulator arm and increases the size of the robot workspace substantially at minimal cost. The additional movement of the base complicates the robot-control problem, but the availability of low-cost, high-performance computers makes it possible to achieve real-time control with computationally efficient algorithms like those of the present control scheme.

In some prior approaches taken in the development of control schemes, the additional degrees of freedom in the mobility of the base would have been regarded unfavorably because of the additional complexity that they introduce. In the present approach, the additional degrees of freedom are turned to advantage by using them to accomplish additional tasks specified by the user. Furthermore, the on-line nature of the present method is enhanced by the ability of the user to change the specifications of tasks during operation, as described below.

The theoretical basis of the present method is the configuration-control formalism, which was discussed in several prior articles in *NASA Tech Briefs*, including "Increasing the Dexterity of Redundant Robots" (NPO-17801), Vol. 14, No. 10 (October, 1990), page 88; "Redundant Robot Can Avoid Obstacles" (NPO-17852), Vol. 15, No. 10 (October, 1991), page 86; "Configuration-Control Scheme Copes With Singularities" (NPO-18556), Vol. 17, No. 2 (February, 1993), page 81; and "More Uses for Configuration Control of Robots" (NPO-18607/NPO-18608), Vol. 17, No. 10, (October, 1993), page 120. To recapitulate: A robot has \( n \) degrees of freedom. The basic task is to make the end effector (the hand at the tip of the manipulator arm) follow a prescribed trajectory in \( m \)-dimensional coordinates (where \( m < n \)). The \( r = n-m \) redundant degrees of freedom are used simultaneously to perform an additional task.

Additional tasks could include (but are not limited to) reaching around obstacles, avoiding collisions with objects in the workspace, maintaining one or more links of the manipulator arm in a desired pose, and/or optimizing the overall kinematics in both the redundant and nonredundant degrees of freedom to enhance overall manipulability. The additional task is mathematically modeled by a set of kinematic functions that, in effect, define the trajectory in the redundant degrees of freedom. These functions are specified by the user.

In the present method, the degrees of mobility are simply combined with the degrees of manipulation into one set that contains both the redundant and nonredundant degrees of freedom, and all degrees of freedom are treated on an equal footing according to the computationally efficient configuration-control formalism. The user can assign weighting factors to individual degrees of mobility or manipulation as well as to each task specification. The user can also change task specifications and weighting factors during operation. Thus, overall, the present method is characterized by conceptual simplicity, computational efficiency, and flexibility — all advantageous for online, real-time control.

This work was done by Homayoun Seraji of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 36 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; (818) 354-5179. Refer to NPO-19109.
Tuneable Auxiliary Control Mechanisms for RUM Actuators

Scan amplitudes could be maximized and/or power consumption minimized under changing conditions.

Marshall Space Flight Center, Alabama

Tuneable auxiliary control mechanisms for rotating unbalanced-mass (RUM) actuators are used to maximize scan amplitudes and/or minimize power consumption during changing conditions. This type of mechanism is a more sophisticated version of the type of mechanism described in "Auxiliary Control Mechanisms for RUM Actuators" (MFS-28817), NASA Tech Briefs, Vol. 19, No.8 (August, 1995), page 62.

To give meaning to an explanation of the tuneable version, it is necessary to repeat most of the description of the simpler version from the noted prior article. Figure 1 illustrates schematically a scientific instrument equipped with a pair of RUM actuators for oscillation about a single axis to produce a line scan, plus an auxiliary control mechanism that would establish and maintain a constant center-of-scan position and/or vary the center-of-scan at a rate much less than that of the scan itself. The basic components of this mechanism would be a stepping motor, a speed-reducing (torque-increasing) gear train, and an angular-position encoder. The stator of the stepping motor would be mounted on a stationary supporting structure, while the rotor would be connected to the low-torque input shaft of the gear train.

The high-torque output shaft of the gear train would lie on the axis about which the instrument was to be oscillated and would be connected to the instrument via a torsionally flexible coupling. The encoder would monitor the angular position of the high-torque shaft. Driven by a pair of RUM actuators, the instrument would oscillate torsionally, via the flexible coupling, about the angular position of the high-torque shaft. The holding torque of the stepping motor, amplified by the gear train, would suffice to prevent the slippage of the high-torque shaft out of the commanded center-of-scan position.

In many if not most cases, it would be preferable to choose the torsional stiffness of the flexible coupling so that the resonant frequency of torsional oscillation would equal the frequency of the scan produced by the RUM actuators. Adjustable trim masses could be added to provide for some limited tuning to resonance, and dampers could be added for stability. The resonance would amplify the effect of the RUM actuators (the dampers would reduce the amplification somewhat) so that the same scanning motion could be achieved with smaller unbalanced masses. With smaller unbalanced masses, the RUM actuators would consume less power: numerical examples from representative design cases suggest that RUM actuators equipped with auxiliary control mechanisms of this type would consume as little as 1/100 the power of scanning mechanisms based on gimbal torque actuators. This completes the explanation of the simpler previous version.

In the more sophisticated tuneable version, the torsional stiffness of the torsionally flexible coupling would be made adjustable on command. As shown in Figure 2, the torsional flexibility would be provided by a nominally radially oriented flexible blade. A rigid collar would attach the blade to the shaft connected to the scanned instrument and its RUM actuators. Movable rubber rollers would establish the off-axis contact point for transmission of torsion between the instrument shaft and the high-torque output shaft. The torsional stiffness would be increased or decreased by moving the rollers in or out, respectively. The rollers would be mounted on sleeves that could slide in radial grooves in a rigid frame attached to the high-torque output shaft. Each sleeve would be internally threaded to engage a radially oriented worm gear driven via a bevel gear by a stepping motor. Thus, the radial position of the collars and, with it, the torsional stiffness of the coupling, would be varied by use of the stepping motor.

Figure 1. An Auxiliary Control Mechanism like this one would make it possible to design a relatively small, cheap, energy-efficient rotating unbalanced-mass actuator, but it could be adjusted to only a limited extent, if at all.
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The adjustability would provide enhanced tuning at any time; the mechanism could be tuned to a resonant or nonresonant condition as needed, even in real time during a scan. Thus, the same mechanism could be adjusted as needed to accommodate various instruments with widely different moments of inertia, adjusted to change the amplitudes of scans in real time, and/or adjusted in real time to respond to changes in the inertial properties of the scanned instrument.

A combination of a pair of RUM actuators and an auxiliary control mechanism more complicated than that shown in the figure could be used to produce a two-dimensional (e.g., elliptical or raster) scan. By making its torsional stiffnesses adjustable, one could adjust the amplitudes and other parameters of the scans in real time. For example, in the case of an elliptical scan, one could change the major and/or minor axis of the ellipse, compensate for the effect of gravitation on the major and/or minor axis to obtain a circular scan, or compensate for differences between moments of inertia about the two scan axes to obtain a circular scan.

This work was done by Michael E. Polites and Dean C. Alhorn of Marshall Space Flight Center. For further information, write in 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, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-28930.

Modular Track System for Positioning Mobile Robots

A manipulator could reach desired positions more quickly and easily.

NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptual system for positioning mobile robotic manipulators on a large main structure would include modular tracks and ancillary structures that could be assembled easily along with the main structure. The system, called the "tracked robotic location system" (TROLS), was originally intended for application to platforms in outer space, but the TROLS concept might also prove useful on Earth; for example, to position robots in factories and warehouses.

The design of the TROLS would inherently solve some of the problems commonly encountered in positioning and orienting mobile robots. The surfaces of the main structure would be covered with the tracks, enabling the robots to reach all areas of interest. The contact between a robot and its tracks would automatically enforce the correct orientation. The main structure or the ancillary structures adjacent to the

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tracks would be marked with bar codes. Each robot would be equipped with bar-code-recognizing circuitry so that it could quickly find its way to its assigned location.

The tracks of the TROLS could be in the form of rails (see figure), grooves, or channels. The tracks would be built with standard dimensions and spacing so any module could be aligned with any adjacent module. The tracks would be located to enable robots to reach any object with which robots were required to interact.

**Mechanism for Adjustment of Commutation of Brushless Motor**

The adjustment can be performed while the motor is running.

*Marshall Space Flight Center, Alabama*

A mechanism enables the adjustment of the angular position of a set of Hall-effect devices that sense the instantaneous shaft angle of a brushless dc motor. The outputs of the sensors are fed to commutation circuitry. Measurement of the shaft angle is essential for commutation; that is, the application of voltage to the stator windings must be synchronized with the shaft angle. To obtain the correct angle measurement for commutation, the Hall-effect angle sensors must be positioned at the proper reference angle.

The Hall-effect angle sensors are mounted on an annular board called, appropriately, the "commutation board." The commutation board is mounted on one end of the motor housing. Part of the rotor and shaft pass through the central hole of the commutation board. Therefore, the angular position of the sensors was adjusted by turning off the motor, removing the end cap (which covers the commutation board), loosening the mounting screws that hold the commutation board, and manually rotating the commutation board by a small amount. The cap was then reinstalled and the motor was turned on, and the current drawn by the motor was measured. This procedure was repeated until an approximately minimum current reading was obtained. (A minimum current reading signifies maximum operating efficiency.)

The present mechanism (see figure) accelerates the adjustment procedure and makes it possible to obtain a more accurate indication of the minimum-current position because it provides for adjustment while the motor is running. The commutation board is held on the end of the housing by three mounting screws that are fitted with close tolerance to short circumferential slots in the...

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board. Preload springs under the heads of the mounting screws prevent inadvertent rotation of the commutation board when the screws are loosened for an adjustment. A gear sector is mounted at a location on the periphery of the commutation board; this gear sector engages a pinion sector that turns on a pin attached to the housing. The pinion and gear sectors feature a zero-backlash design.

A socket on the pinion receives an adjusting tool. To perform an adjustment, one inserts the tool in the socket via an access hole in the end cap. The tool is turned to rotate the pinion. By virtue of the gear ratio, this effects a fine angular adjustment of the commutation board. Once the adjustment yields a minimum current reading, the preload springs hold the board until the mounting screws are retightened.

This work was done by Richard E. Schaefer of United Technologies Hamilton Standard for Marshall Space Flight Center. For further information, write in 38 on the TSP Request Card.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-28958.

Unified Approach to Control of Motions of Mobile Robots

An updated configuration-control scheme incorporates a distinction between holonomic and nonholonomic constraints.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved computationally efficient scheme has been developed for on-line coordinated control of both manipulation and mobility of robots that include manipulator arms mounted on mobile bases. The present scheme is similar to the one described above in "Coordinated Control of Mobile Robotic Manipulators" (page 1b). Both schemes are based on the configuration-control formalism. The major difference between the two schemes is that unlike the previous one, the present one incorporates an explicit distinction between holonomic and nonholonomic constraints (see figure). Both schemes are characterized by computational efficiency and flexibility, which are advantageous for on-line, real-time control.

In addition to the article cited above, several other prior articles in NASA Tech Briefs have discussed aspects of the configuration-control formalism. These include "Increasing the Dexterity of Redundant Robots" (NPO-17801), Vol. 14, No. 10 (October, 1990), page 88; "Redundant Robot Can Avoid Obstacles" (NPO-17852, Vol. 15, No. 10 (October, 1991), page 86; "Configuration-Control Scheme Copes with Singularities" (NPO-18556), Vol 17, No. 2 (February, 1993), page 81; and "More Uses for Configuration Control of Robots" (NPO-18607/NPO-18608), Vol. 17, No. 10 (October, 1993), page 120. To recapitulate: A robot has n degrees of freedom. The basic task is to make the end effector (the hand at the tip of the manipulator arm) follow a prescribed trajectory in m-dimensional coordinates (where m<n). The r=n-m redundant degrees of freedom are used simultaneously to perform an additional task.

The additional task can be specified by the user and can include (but is not limited to) reaching around obstacles, avoiding collisions with objects in the workspace, maintaining one or more links of the manipulator arm in a desired pose, and/or optimizing the overall kinematics in both the redundant and nonredundant degrees of freedom to enhance overall manipulability. The additional task is mathematically modeled by a set of kinematic functions that, in effect, define the trajectory in the redundant degrees of freedom. The user can assign weighting factors to individual degrees of mobility or manipulation as well as to each task specification. The user can also change task specifications and weighting factors during operation.

In the present scheme, the degrees of mobility and the degrees of manipulation are treated within a common theoretically framework; to put it in slightly different terms, the mobile base and the manipulator are treated as closely
The Constraints Upon the Motion of a Mobile Base that supports a robot arm can be either holonomic (e.g., the kinematic constraints upon a mobile base that moves along a track) or nonholonomic (e.g., the kinematic constraints upon a mobile base with wheels like that of an ordinary highway vehicle).

This work was done by Homayoun Seraji of Caltech for NASA's Jet Propulsion Laboratory. For further information, write in 61 on the TSP Request Card. NPO-19508
Inversion of Dynamical Equations for Control of Attitude

Quat er nion and direction-cosine formulations lead to direct inversion for linear feedback control. Ames Research Center, Moffett Field, California

A method of inverting the nonlinear equations of the rotational dynamics of a rigid body could be used to design feedback control of the orientation of the body. The method is applicable to both direction-cosine and quaternion formulations, which are suitable for large-angle maneuvers. (These formulations are preferable to a Euler-angle formulation, which lends itself readily to inversion, but is not suitable for large-angle maneuvers.) Exploiting some apparently little-known properties of the direction cosine and quaternion formulations, the method leads to equations for a model-follower control system that exhibits exactly linear attitude-error dynamics.

Taking parallel approaches in both the direction-cosine and quaternion formulations, the method involves the simplification of the inversion of the equations for the angular accelerations as functions of the applied torques. The simplification is effected by transformations of coordinates that make it possible to express the angular velocity and angular acceleration in terms of the direction-cosine or quaternion elements and their derivatives with respect to time, the transformations being such that the resulting equations of state are linear.

Figure 1 depicts schematically the linearized attitude-control systems based on the two formulations. The direction-cosine system is limited to following roll-
Adaptive Force Control for Compliant Motion of a Robot

Performance is expected to be stable and uniform despite gross variations in environmental stiffnesses.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two adaptive control schemes offer robust solutions to the problem of stable control of the forces of contact between a robotic manipulator and objects in its environment. These schemes were developed within the compliant-motion control framework, as were a number of other robot-control schemes reported previously in NASA Tech Briefs.

A control scheme that ensures stable and robust operation of a robotic manipulator in contact with objects in its environment is a basic requirement for the successful execution of many robotic tasks. The control problem is especially challenging in an environment in which the stiffnesses of objects with which the end effector of the robot can make contact (*environmental stiffnesses* for short) are unknown and/or subject to change. The present control schemes provide for automatic tuning of the force controller of the robot to compensate for unknown and/or changing environmental stiffnesses in order to yield stable, uniform, and acceptable performance.

The two control schemes (see figure) are called "adaptive admittance control" and "adaptive compliance control." Both schemes involve the use of force-and-torque sensors that indicate contact forces, \( F \). The force-and-torque sensors can be replaced with proximity sensors, the outputs of which can be processed into virtual-contact-force signals, as though the end effector made contact with a nearby object via a spring. These virtual-contact-force signals are useful in preventing collisions with objects, following contours, and maintaining desired standoff distances.

Admittance control is an explicit force-control scheme in which a force set point, \( F_s \), is specified by the user and is tracked by a force compensator. This scheme is based partly on the concept of mechanical admittance, which relates the contact force to the resulting velocity perturbation. The end effector of the robot is commanded to deviate from its commanded position \( X \), by the amount \( X \), and to track the modified commanded trajectory \( X_{\text{c}} \). Two adaptive proportional-plus-integral-plus-derivative (PID) and proportional-plus-integral (PI) force compensators have been developed thus far and found to ensure robust tracking.

Compliance control is an implicit force-control scheme: this scheme establishes robot/environment interaction dynamics specified by the user in terms of a contact force as function of the difference between the actual position \( X \) and the desired position, \( X_{\text{c}} \), of the end effector. Two adaptive lag-plus-feedforward compliance compensators have been developed. The compliance compensators and the PI force compensator do not require information on the rate of change of force. Both the admittance and compliance control schemes included adaptation laws that constantly adjust the compensator gains to drive tracking errors toward zero; this is the feature that helps to ensure stable and uniform performance despite large variations in environmental stiffnesses.

These schemes performed well when tested in computational simulations in which they were used to control a seven-degree-of-freedom robot arm in executing contact tasks. The admittance scheme offers (1) the advantage of robust tracking of force set points and rejection of constant disturbances and (2) the disadvantage of requiring switching between reference motion command trajectories for unconstrained tasks and force-set-point command trajectories for constrained tasks and possible poor responses during transitions between them. The compliance scheme involves the use of reference motion commands in tasks of both types, so that it does not require switching of commands and therefore affords generally good responses during transitions. However, the compliance scheme offers the disadvantage of possibly less robust tracking of force commands and rejection of force disturbances. Therefore, the choice between admittance or compliance control is dictated by the requirements of the application at hand.

This work was done by Homayoun Seraji of Caltech for NASA's Jet Propulsion Laboratory. For more information, write in 59 on the TSP Request Card. NPO-19507
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For More Information Write In No. 641
For over 25 years, Nook Industries, Cleveland, OH, has been a major source of linear motion power transmission components. Nook Industries designs, manufactures and distributes a broad range of competitively-priced, energy-efficient linear motion components, accessories and systems serving the commercial and military markets and industrial equipment manufacturers to provide low-cost linear power transmission and guidance.

ActionJac™ Electric Cylinder Actuators were developed to fill the need for an enclosed, electric-powered, telescoping cylinder actuator. PowerTrac™ Precision Ball Screws are used to boost mechanical efficiency and increase positioning accuracy. Improved mechanical efficiency reduces drive motor torque requirements and hence, required motor size, by as much as one-third when compared to a similar actuator built around a screw with conventional threads. The electric cylinder is a clean, compact alternative to hydraulic systems and is capable of precise positioning.

Three model series of ActionJac Electric Cylinder Actuators are currently available from Nook Industries with dynamic load capacities from 500 to 40,000 lbs. and a broad range of travel rates: the DD Series (single reduction), the DDL Series (single reduction with torque limiters), and the RAD Series (double reduction). All electric cylinders are supplied with the following options: standard male clevis mounts; cylinder bearing supports; integral motors; hard, chrome-plated inner tubes; and PowerAc™ Acme Screws or PowerTrac Ball Screws for long, predictable life. Accessories include rod-type or rotary limit switches. An In-Line Encoder may be factory-installed for some electric cylinders in the DD Series.

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Electric cylinder actuators are widely used in industrial and manufacturing applications and in steel and paper mills when roll-type processing equipment needs periodic adjustment. Electric cylinder actuators also raise and position aircraft maintenance platforms and stages. Commercial and military satellite antenna manufacturers are using electric cylinder actuators for precise positioning of large, dish-type antennas.

When compared to air and hydraulic units, in addition to providing higher accuracy, they offer improved energy efficiency and longer life, frequently at a lower cost. Electric cylinder actuators also allow cleaner operation and easier synchronization in multiple actuator systems.

To receive a free design guide for ActionJac Electric Cylinder Actuators, call our Engineering "Hotline" at 800-321-7800 or Fax: 216-464-4669. (ActionJac™, PowerAc™ and PowerTrac™ are registered trademarks of Nook Industries, Inc., 23200 Commerce Park Road, Cleveland, OH 44122-5869.)

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**OILDYNE INTRODUCES TWO NEW INNOVATIVE PRODUCTS**

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Oildyne EMC Group has designed one of the smallest Smart Cylinders ever available. The cylinder is a remarkably small 1/4" bore, complete with an internal position feedback transducer that provides for infinite positioning capability. This is a perfect package for those applications where space is a premium but positioning and hydraulic forces are required. The cylinder features a maximum 9" stroke length and pressures up to 2500 psi. There is a miniature 3-pin quick disconnect electrical connector for connection to a PLC or other electronic motion controller.

Miniature Valve Pad Smart Cylinder

Oildyne has also developed a miniature Smart Cylinder featuring an integral hydraulic proportional valve pad and valve. Now, for the first time, it is possible to have a 1" bore hydraulic smart cylinder and mini hydraulic proportional valve as one complete integrated package. This provides a totally unique product for those applications where space is at a premium but hydraulic forces and positioning are a requirement.

These products are a part of a uniquely designed linear resistor position transducer family that allows for internal installation in cylinders as small as 1/4" bore. They feature a right angle exit for an electrical connection that provides an advantage not found in most position transducers. The design also has the advantage of being manufactured in any length desired rather than only in 1", 2", or 6" increments. For hydraulic or pneumatic applications the LRT/MLRT family provides the designer the opportunity for the smallest profile, infinite resolution, and linearity from 1% to 1% of stroke, depending on the model.

For More Information Write In No. 646
Precision MicroControl revolutionized the motion control industry with the DCX Modular Motion and I/O Control System. The DCX system is based on the concept of Distributed Process Control, where the intelligence functions are distributed among components. The DCX system uses a Plug-and-Play building-block approach to motion control. The result is a flexible, open architecture platform, allowing each controller to be individually configured to match the application. The distributed processing design allows motion and I/O functions to be added without performance degradation.

The DCX system includes five Motion Control motherboard models to choose from supporting PC/ISA bus, VME bus, and standalone applications. With more than 13 intelligent function modules, the DCX modular architecture offers the most flexible, plug-and-play motion control environment available today.

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For more information, contact PMC Corp., 2075-N Corte del Nogal, Carlsbad, CA 92009; Tel: 619-930-0101; Fax: 619-930-0222; E-mail: (for product information) pmcinfo@pmccorp.com; (for technical support) motion@pmccorp.com.

For More Information Write In No. 647
Automated Management of Documents

A report presents the main technical issues involved in computer-integrated documentation. The problems associated with the automation of management and maintenance of documents are analyzed from perspectives of artificial intelligence and human factors. Technologies that may prove useful in computer-integrated documentation are reviewed: these include conventional approaches to indexing and retrieval of information, the use of hypertext, and knowledge-based artificial-intelligence systems. A particular effort was made to provide an appropriate representation for contextual knowledge, including generation of contexts on hypertext links. Thus, it was found that indexing of documents in computer-integrated documentation is sensitive to contexts. Theoretical considerations of navigation in hyperspace, acquisition of indexing knowledge, and maintenance of large bodies of documentation are discussed.

This work was done by Guy Boy of Sterling Software for Ames Research Center. To obtain a copy of the report, "Computer Integrated Documentation," write in 54 on the TSP Request Card. ARC-13241

Spurious Numerical Solutions of Differential Equations

A paper presents a detailed study of spurious steady-state numerical solutions of differential equations that contain nonlinear source terms. Such model equations, along with applicable boundary conditions, are used to represent a baseline study for phenomena such as chemically reacting flows (e.g., in combustion). The equations are often solved numerically by time-marching methods, and the numerical solutions can sometimes diverge, oscillate, or converge to erroneous solutions, depending on the spatial and temporal discretizations, initial conditions, and the numerical boundary conditions used in the numerical (e.g., finite-difference) schemes: the recognition of this fact has given rise to an interdisciplinary field of study that has been called "the dynamics of numerics and the numerics of dynamics."

The main objectives of this study are (1) to investigate how well numerical steady-state solutions of a model nonlinear reaction/convection boundary-value problem mimic the true steady-state solutions and (2) to relate the findings of this investigation to implications for the interpretation of numerical results from computational-fluid-dynamics algorithms and computer codes that have been used to simulate reacting flows.

This work was done by A. Lafon and H. C. Yee of Ames Research Center. To obtain a copy of the report "Dynamical Approach Study of Spurious Steady-State Numerical Solutions of Nonlinear Differential Equations — III. The Effects of Nonlinear Source Terms and Boundary Conditions in Reaction-Convection Equations," write in 56 on the TSP Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-13209.

More About Spurious Numerical Solutions of DEs

A paper discusses the reliability of the time-dependent approach to numerical solution of nonlinear differential equations (DEs) that describe steady-state behaviors of physical systems. The time-dependent approach was followed in the related study described in the preceding article, "Spurious Numerical Solutions of Differential Equations" (ARC-13209). In the time-dependent approach, an approximate numerical solution for the steady state is obtained by numerically solving a time- or pseudotime-dependent version of the discretized counterpart(s) of the applicable ordinary or partial differential equation(s) and approaching the steady state asymptotically. The asymptotic results can sometimes converge or fail to converge to the true solutions, or converge to erroneous solutions that satisfy the discretized counterparts but not the underlying differential equations.

The paper notes that nonlinear dynamics and local and global bifurcation theory can be used to analyze and explain much of the asymptotic behavior of the discretized counterparts.

One of the conclusions drawn from the results of this study and the study described in the preceding article is that the use of a time step smaller than the linearized stability limit does not necessarily result in a true approximation to the exact solution, even though the initial data might be physically relevant.

The paper presents a comparison of the guidelines, assumptions, usage, and applicability of nonlinear, and of three methods of linear, stability analysis. It concludes, from the comparison, that nonlinear analysis uncovers many of the nonlinear phenomena that cannot be predicted by linearized analysis.

This work was done by H. C. Yee of Ames Research Center and P. K. Sweby of the University of Reading. To obtain a copy of the report, "On Reliability of the Time-Dependent Approach to Obtaining Steady-State Numerical Solutions," write in 50 on the TSP Request Card.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-13208.

Scattering of Nonplanar Acoustic Waves

A report presents a theoretical study of scattering of nonplanar acoustic waves by rigid bodies. The study was performed as part of an effort to develop means of predicting scattering, from aircraft fuselages, of noise made by rotating blades. The basic approach taken in the study was to model acoustic scattering by use of a boundary integral equation.
to solve the equation by the Galerkin method. This approach was followed in solving example problems that involved point acoustic sources. The computations by the present approach were found to converge on the exact solutions much faster than would computations performed with infinite series according to the method of separation of variables.

This work was done by Judith M. Gillman of Ames Research Center, F. Farassat of Langley Research Center, and M. K. Myers of George Washington University. To obtain a copy of the report, "A Boundary Integral Approach to the Scattering of Nonplanar Acoustic Waves by Rigid Bodies," write in 7 on the TSP Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center; (415) 604-5104. Refer to ARC-12837.

Electronic Components and Circuits

Fundamental Limitations of Passive Power Dividers

A report presents a novel theoretical analysis of the performance of passive, multiphase power dividers like those used to distribute power to the radiating elements of array antennas. Typically, a unit cell of a power-divider network is a three- or four-port subnetwork with one port terminated, and the subnetworks of a network are cascaded in multiple layers, so that insertion losses are of major concern. Starting with general equations for a passive power divider, the report derives a Hermitian dissipation matrix, $Q$, that can be expressed in terms of the traditional scattering matrix, $S$. Each eigenvalue of $Q$ represents the fraction of power dissipated in the network when the network is excited by an incident wave represented by the corresponding eigenvector. The general properties of Hermitian matrices and the more specific mathematical properties that represent passivity are used to draw conclusions about these eigenvalues and eigenvectors and the corresponding implications for power-division performance. The effects of geometrical factors in conductors with dimensions that are appreciable fractions of wavelengths, and thus cannot be accurately modeled as lumped circuit elements, are also considered. It is shown that passivity and geometrical factors impose fun-
damental limits on performance, beyond the limits imposed by losses in dielectrics and in the resistances of conductors. This work was done by Dimitrios Antsos of Caltech for NASA's Jet Propulsion Laboratory. To obtain a copy of the report, "Implications of Passivity on Power Division," write in 25 on the TSP Request Card. NPO-19600

Study of Corrosion of Lead-Sheathed Cables

A report presents a statistical analysis of corrosion failures of the lead-sheathed cables that serve as the primary communication links at Kennedy Space Center. Most of these cables were installed during the years 1962 through 1964, and cathodic protection was added to some parts of the cable network in 1971 and to other parts of the network in 1980. However, corrosion failures continued to occur. In the study, corrosion-failure data were analyzed by use of the Weibull distribution in the effort to assess the effectiveness of cathodic protection and to predict future failures.

This work was done by Rupert U. Lee of Kennedy Space Center. To obtain a copy of the report, "Statistical Analysis of Corrosion Failures of Lead-Sheathed Cables," write in 20 on the TSP Request Card. KSC-11627

Alternative Habitats for First Lunar Outpost

A report describes an investigation of alternative design concepts for habitable structures at an outpost to be established on the Moon. Beginning with a baseline habitat concept derived from a habitat module of the Space Station Freedom, the investigation was directed toward modification of the baseline design to achieve five design goals. The first goal was better access by personnel to the surface of the Moon. For example, the airlock could be relocated under the habitat for easier access. Alternatively, the landing spacecraft could be modified to lower the habitat closer to the lunar surface so that the height for lifting objects would be reduced. The second goal was to provide for future expansion of the outpost by disconnecting the habitat module from the landing spacecraft and moving and connecting it to other modules at the outpost. Provisions for achieving these goals could include ramps, suspension cables, hoists, and equipping modules with limited capabilities as wheeled land vehicles. The third goal was increasing habitable volume. This could be done by redesign and by use of spent fuel tanks as enclosures for additional habitable space. The fourth goal was protection against radiation; no specific action toward this goal was proposed. The fifth goal was reduction of the overall mass. This could be accomplished by redesign, using lightweight materials like aluminum/lithium and metal-matrix composites.

This work was done by Charles R. Fowler, Kauser S. Imtiaz, Irwin E. Vas, and Gordon R. Woodcock of the Boeing Co. for Marshall Space Flight Center. To obtain a copy of the report, "Alternative Habitats for First Lunar Outpost," write in 34 on the TSP Request Card. MFS-28953

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NASA Tech Briefs, October 1995
For More Information Write In No. 492
Apec high-strength polycarbonate, known for its unique combination of high heat resistance, toughness, transparency, color stability and fluidity, is described in a new 16-page color brochure issued by the Polymers Division of Bayer Corporation, Pittsburgh, PA. The brochure shows typical applications for this material, and provides information on flame retardance, chemical and stress crack resistance, solubility and processing methods. Bayer Corp., Polymers Division, 100 Bayer Road, Pittsburgh, PA 15205-9741; Tel: 412-777-2000.

Bayer Corp., Polymers Division
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A 28-page brochure is a design guide for piezoelectric ceramics in a variety of shapes and sizes. Piezoelectric and electromechanical properties for various PZT materials (lead zirconate titanate) are included, and various types of piezoelectric configurations, including stacks and bimorphs® are described. Tel: 216-252-8600; Fax: 216-232-8731.

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This 24-page HEIDENHAHN catalog features Metro and Cerro digital height gages for a variety of applications, including part, position and motion measurement. These gages can be used in the manufacturing environment, both in-process and post-process inspection gages. Also ideal for inspecting parts, monitoring, and calibration of measuring standards. HEIDENHAHN Corporation, 115 Commerce Drive, Schaumburg, IL 60173; Tel: 708-490-1191.

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The company, founded in 1945, is a specialist in prototype and production castings for the aerospace, automotive and commercial industries. Specialized quality and production control systems comply with ISO-9000 International Aerospace and all leading government, commercial, military and automotive specifications. Mechaized green sand, dry sand and permanent mold processes. On-site heat treating, In-house testing and laboratory facilities. Tel: 216-581-9200; Fax blueprints: 216-475-6611 for prompt quotes.

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NEW 1995-96 COLE-PARMER® INSTRUMENTS CATALOG
The new, free 1995-96 Cole-Parmar instruments catalog contains over 1700 full-color pages and features more than 40,000 products covering scientific instruments, equipment, and supplies. The catalog includes a detailed 40-page index and table of contents, informative introductory pages for many of the catalog sections, "Hot Tips," and an 8-page section of late-breaking products. Contact Cole-Parmar Instrument Company—in the USA or Canada, call toll-free 1-800-323-4340.

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MONITOR, RECORD & ANALYZE
Astro-Med's 32-channel recorder with built-in monitor, 170 Mbyte internal hard drive and front-panel floppy drive is described in this illustrated 20-page brochure. The unit, called the MT932K2, features extraordinary capabilities including three on-board analysis programs, Windows host control, Windows data analysis, and a wide variety of sophisticated data capture options. Tel: 800-343-4099; Fax: 410-822-2430.

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Electromagnetic field simulation software for electromechanical designers. Visualize field patterns and flux paths. Solve for force, torque, inductance and other electrical parameters on your desktop computer. Call for information on Maxwell EM. Ansoft Corporation; Tel: 412-261-3200; Fax: 412-471-9427.

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Puts eight thermo couple channels on monitor, printer, or disk for $279 complete. Specifically for laboratory and industrial temperature monitoring. Avoids complex set-up or installation and is functioning within minutes. RS-232 interface powers converter and eliminates sensor wires at computer. Quick-Basic® source code and compiled program provided. 16-channel and linear sensor options. Tel: 609-662-7272.

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WAVE/COMPRESSION SPRINGS
Just updated, Catalog #WS-93 contains NEW stock sizes of wave/compression springs available from stock, including spring design formulas, materials guide and typical applications. The manual describes the many advantages of Smalley's exclusive edgewinding manufacturing process. Smalley springs, available from 3/6" to 84" in diameter, are produced by circle-coiling flat wire to exact specifications involving no dies or special tooling charges. Tel: 708-537-7600; Fax: 708-537-7698.
Smalley Steel Ring Co.
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SEALED THREADED CONNECTORS
Brochure provides information on finishes and diagrams of pin contact arrangements of the DS series glass-to-metal hermetically sealed miniature connectors used where Vacuum, Gas or constant Pressure is required for Sensors, Valves, Instruments or Refrigeration.
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Edmund Scientific's free 228-page, color technical reference catalog features one of the largest selections of precision off-the-shelf optics and optical instruments, plus a complete line of components and accessories for both large volume OEM users as well as smaller research facilities and optical laboratories. Contains over 8,000 hard-to-find items, including a large selection of magnifiers, microscopes, telescopes, and "machine vision" products. Tel: 609-573-6259; Fax: 609-573-6233.
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MCM is the industry leader in the distribution of components, electronic repair parts and equipment. Catalog #36 includes test equipment from Tenma, Fluke and B&K, semiconductors, and much more. Over 21,000 items are in stock and ready to ship from distribution centers near Reno, NV and Dayton, OH, providing two day shipping to most of the continental US. A "must have" for all service technicians and electronics enthusiasts. Tel: 800-543-4350. TB02
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Catalog 565-959 describes SLO-SYN® SS2000 Servo Systems consisting of motors, amplifiers, controls and power supplies. Brushless motors employ resolver feedback and are precisely matched to amplifiers. Torque ratings from 7.4 to 780 in-lb continuous. Three-phase, sine wave, brushless amplifiers have peak power rating of 6 to 110 RPM. Control-amplifier 1 or 2 axes. Windows-based, icon-driven programming utility and BASIC-like commands. Superior Electric, 383 Middle Street, Bristol, CT 06010; Tel: 800-787-3532 or 600-585-4500.
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MICRO-TRACK DIGITAL CASSETTE RECORDING
This new 60-page handbook is a guide for engineers in the defense, aerospace, remote sensing and related sectors involved with capturing, processing and archiving large volumes of instrumentation data. Covers latest technologies, interfacing and applications. Available free to qualified applicants. Penny & Giles Data Systems, 3100 Medlock Bridge Road, Norcross, GA 30071; Tel: 770-448-9737 or +44 (0)1749 675454; Fax: 770-448-4719 or +44 (0)1749 676678.
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This catalog features replacement lamps at discount prices for all types of equipment. Lamps for audio-visual, photographic, micrographic, and graphic arts equipment. 100% guaranteed brand names—tool free ordering—no minimum order. All deliveries via Second-Day Air at NO extra cost. Also, lamps for medical and electronic instruments, microscopes and video use.
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Mercury-wetted contacts are covered in brochure. They are superior to conventional slip rings and feature sealed, ball bearing construction. Due to compact, low-cost connectors offer reliability, extremely low electrical noise, and less than 1 millihertz of noise. Ideal for computers, instrumentation, thermocouples, cable rears, strain gauges, packaging equipment, robotics, turntables, testing, and control devices. Mercotac Inc., 6195 Coro del Cedro #100, Carlsbad, CA 92021
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New 128-pg. catalog of ELECTROD's electro-magnetic products for rotary motion control. Pictures, drawings, specs and technical data on clutches, brakes, failsafe brakes, clutch/brake modules, AC motor brakes, permanent magnet brakes, reversing drives, magnetic particle devices, power supplies, etc.
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Full line of flat-faced, O-ring sealed tube fittings offering slip-in/slip-out ease and leakproof connections from vacuum to 6000 psi or more described in CPV Catalog 74. Choice of steel or stainless steel in OD tube sizes from 1/8" to 2". CPV Mfg. Inc., 851 Preston St., Philadelphia, PA 19104; Tel: 215-886-6258; Fax: 215-387-9043.

For More Information Write In No. 357

CPV Mfg. Inc.

THERMAL SPRAY PRODUCTS & SYSTEMS

Free brochure describes the thermal spray process as used to apply metal, ceramic, and cermet coatings. Process has applications in the aerospace, automotive, biomedical, turbomachinery, petrochemical, power generation, and general manufacturing industries. Miller Thermal, Inc. is a full-line producer of thermal spray products and integrated thermal spray systems. Tel: 414-734-9292; Toll-free in USA and Canada: 800-637-8307; Fax: 414-734-2166.

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Science Accessories

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NEW KIND OF VIDEO TEACHES FEA LESSONS

Finite Element Analysis In Action is a new kind of instructional video for engineers. Live lab and computer demonstrations show how to better use any FEA software. A case study of brittle fracture—which can happen to almost any material, even steel—provides real-world examples. Two lab experiments and two FEA analyses are conducted and the results compared. Demonstrates specific modeling and analysis techniques for predicting lab results with FEA. Tel: 800-482-5467; URL: http://www.algor.com/apd.htm.

APD

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BOOK DELIVERS REAL-WORLD FEA INSTRUCTION

FEA reference/textbook offers a blend of theory & real-world engineering examples. Dr. Constantine Spyrakos—well-known finite element specialist & textbook author—has created a reference for all mechanical engineers from designers to "gurus." Richly illustrated hardcover book includes a disk with every example problem. Subjects include: FEA basics, element types, modeling, types of analysis & the interpretation of results. Tel: 800-482-5467; URL: http://www.algor.com/apd.htm.

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THERMOFOIL™ HEATERS

Bulletin HS-201 lists over 200 sizes and resistances of etched-foil heating elements. Included are Kapton, silicone rubber, and mica insulated models for aerospace, medical, and industrial devices. The 32-page catalog offers complete technical specifications, custom design information and application ideas to help the reader solve unique heating problems using Thermofoil technology.

Minco Products Inc.

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NASA Tech Briefs’ Literature Spotlight section offers a low-cost way to reach over 205,000 industry and government LEADERS with your advertising message. These are technology managers, design engineers and scientists with tremendous buying power. The December 1995 issue is your next opportunity to use this high-impact sales tool. For more information or to reserve space in Literature Spotlight, contact your NASA Tech Briefs sales representative, or call Joseph Pramberger at (800) 944-NASA.
New on Disk

Mathcad 6.0 for Windows mathematical software from MathSoft Inc., Cambridge, MA, integrates World Wide Web and Lotus Notes connectivity, messaging and authoring features, and math, science, and engineering calculation tools in a single environment. The 32-bit program features new statistics and data analysis functions, visualization tools, and text formatting. The PLUS Professional Edition costs $349.95; the Standard Edition is $129.95.

For More Information Write In No. 720

HEM Data Corp., Southfield, MI, has released Snap-Master General Analysis 3.0 data analysis software. An Equation Builder guides users through statistical analysis, digital filtering, integration, differentiation, arithmetic, and comparing functions. The Windows-based program is priced at $495.

For More Information Write In No. 721

Working Model® version 3.0 motion simulation software from Knowledge Revolution, San Mateo, CA, features new parametric design capabilities, a scripting language for user customization, a faster dynamics engine, and more file export choices. Product engineers can test mechanical systems in early stages. The cost: $2495.

For More Information Write In No. 722

National Instruments, Austin, TX, has introduced Measure™ data acquisition and serial control software, a Windows-based spreadsheet add-on that combines Microsoft Excel with interactive menus for direct data acquisition, analysis, and report generation. The program costs $495.

For More Information Write In No. 723

WorldUp™ virtual reality and simulation software from SenseO Corp., Mill Valley, CA, allows modification of real-time object behavior and scene characteristics while the simulation is running. Based on the WorldToolKit™ program, it does not require C programming, but rather, uses an interpreted language similar to Visual Basic and a graphic user interface based on Windows and Motif components. It includes tools for modeling, building, and animating objects and environments, and accepts 3D models created in other CAD packages. Prices start at $3500.

For More Information Write In No. 725

Visio Corp., Seattle, WA, has introduced version 4.0 of Visio® and Visio Technical drawing and diagramming software. Optimized for Windows 95 and other Windows-based programs, Visio is designed for creating a range of diagrams; Visio Technical is for creating and sharing 2D drawings and technical schematics. Both versions create flowcharts, time lines, management diagrams, and geographic maps. Visio is priced at $249; Visio Technical is $399.

For More Information Write In No. 724

FEA PowerSystem 95 V6.4 finite element analysis software from Aegis Software Corp., Pittsburgh, PA, allows finite element analysis of CAD solid model designs on a Windows-based PC system. Solid models from most CAD programs can be translated, and surfaces and solids can be meshed automatically with an optional module. Static, dynamic, and thermal analysis input files are translated directly and launched automatically from a pre-processor. Prices start at $2995.

For More Information Write In No. 726

Numera Software, Seattle, WA, has introduced a Windows 95-based version of Visual CADD 2D drafting software. Mechanical engineers can use any Windows programming language or the built-in scripting language to customize the program. The new version is 300% faster, and features enhanced output capabilities and compatibility with other CAD programs, including AutoCAD. The software costs $595.

For More Information Write In No. 727

Merlin ME-961/991 systems use low-cost video tape recorders to capture over 2 hours of continuous data at rates up to 2.2 Mbits/sec. Open design permits use of interchangeable interface modules for a flexible data recording system. The ME-981 is qualified to MIL-STD 810E and is available in both ruggedized and rack-mount configurations.

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For More Information Write In No. 448

NASA Tech Briefs, October 1995
Product of the Month

Parker Hannifin Corp., ComputorMotor Division, Rohrert Park, CA, has introduced the ZETA Drive microstepping motor/drive system incorporating three patent-pending features: electronic damping, built-in stall verification, and electronic viscosity for greater usable torque and reduced settling time. According to the company, it is the fastest and smallest microstepping drive of its type, and is an alternative to open loop motion control systems. The drive measures 6.8" x 2" x 6.1", handles torques from 65 to 400 oz.-in., and operates at continuous speeds to 3000 RPM. ASCII-controlled microstepping is provided in 16 standard, selectable resolutions to 50,800 steps per revolution.

For More Information Write In No. 700

The Metricor 2000 modular, multi-parameter fiber-optic sensor system from Photoneics Inc., Wakefield, MA, measures over 20 physical parameters such as temperature, pressure, and void fraction for which over 50 application-specific probes are available. Any combination of probes can be mixed in a four-channel unit; single-channel and multiplexed units also are available.

For More Information Write In No. 701

The 1200DX digital engineering copier/ploter from JRL Systems Inc., Austin, TX, can be attached to a high-speed scanner for wide-format copying. It features enlargement, reduction, contrast adjustment, and copy count. The unit accepts input from an aperture card scanner, and enables scanned files to be saved and uploaded using optional software and a PC.

For More Information Write In No. 702

The VideoTherm 915 infrared camera from I.S.I. Group Inc., Albuquerque, NM, weighs only 4.5 pounds with the viewfinder and measures 4" x 4-3/8" x 7-3/8". The camera requires no coolants and features a built-in microphone. Images collected on videotape can be analyzed and enhanced with Infrasoft software that converts data from radiometric to temperature values.

For More Information Write In No. 703

The DataSYS 765 four-channel direct recording oscilloscope from Gould Instrument Systems Inc., Valley View, OH, is a waveform recording and transient capture instrument combining a traditional recorder and digital storage oscilloscope in one package. Users can record data directly to disks or memory cards at up to 250 k samples/second, or capture random events with durations of 10 ns.

For More Information Write In No. 704

The TP Series air temperature monitoring switches from Cambridge AccuSense Inc., Shirley, MA, can be installed anywhere in the cooling airflow to monitor ambient air temperature upstream or downstream of cardcages, power supplies, or filters. The solid-state, hysteresis-free switches operate from 0° C to 70° C and are compatible with most logic, relays, and indicators. They can trip at either one or two specified temperature setpoints with +1°C accuracy.

For More Information Write In No. 705

Precision Navigation Inc., Mountain View, CA, has announced the AX100 DHS and AX100 EGI navigation devices. The DHS is an attitude heading reference system that provides compass, tilt, and rotation information, and is designed to replace mechanical or fiber-optic gyroscopic systems. The EGI is an inertial navigation unit with an embedded GPS receiver that provides position, direction, and orientation.

For More Information Write In No. 706

The Sensorpad™ position sensing element from New England Instrument, Woonsocket, RI, integrates either internally or externally a military-grade position sensor into any device requiring position feedback. The sensing element is thin, frameless, and can be rigid or flexible with physical characteristics that may be modified for specific applications. It can be used in servo control systems, robotics, medical instrumentation, gimbal/actuators, and transducers.

For More Information Write In No. 707

Tektronix Inc., Beaverton, OR, has announced the THS 710 and THS 720 TekScope handheld oscilloscope/digital multimeter for troubleshooting electronic equipment. The device has an integrated 3-3/4-digit, 4000-count DMM with RMS for basic voltage, current measurement, and data logging. It is available with a portable printer, external fast charger, and additional voltage and current probes.

For More Information Write In No. 708

The Summa Expert™ computer digitizer tablets from Summagraphics Corp., Austin, TX, are 12" x 12" and 12" x 18" tablets with an intuitive interface for 3D rendering, CAD, graphic design, animation, and multimedia development. They provide 256 levels of pressure and are available with three pointing options: a cordless, three-button, pressure-sensitive pen; a cordless, four-button, articulating cursor; or a cordless, 16-button cursor. Accompanying software provides compatibility with PC and Mac platforms.

For More Information Write In No. 712

Elmo Mfg. Corp., New Hyde Park, NY, has introduced the Model 1322N color monitor that measures 13" diagonally and features a front-panel A/B switch. Other features are switchable B and C camera inputs with loop-through for both, and automatic V-hold circuitry. Front-panel picture controls include contrast, brightness, and color rendition. The monitor can be used for most color applications with over 300TV (H) line resolution.

For More Information Write In No. 713

The MVS modular machine vision system from Imaging Technology Inc., Bedford, MA, is available in two pre-packaged, expandable configurations for systems integrators and OEMs in machine guidance, industrial inspection, biomedical image analysis, and defense applications. The Windows-based system consists of image vision processing hardware and software, including a SVGA graphics board, two color monitors, a keyboard, and a mouse.

For More Information Write In No. 714

The VMC 186/40-TQ four-axis motion controller from Delta Computer Systems Inc., Vancouver, WA, provides coordinated position control and equipment or material movement for automation systems that use any VMC Design® or VMC-11® architecture and employ both quadrature encoders and magnetoresistive displacement transducers. It is designed for steel, plastic, rubber, automotive parts, and other manufacturing production line automation applications.

For More Information Write In No. 708
Paroscientific Inc., Redmond, WA, offers a six-page brochure of Digiquartz® pressure instrumentation products. Included are transducers, transmitters, depth sensors, pressure computers, fiber-optic systems, barometers, and portable standards.

For More Information Write In No. 740

3D Systems, Valencia, CA, has released a six-page brochure on QuickCast™ metal parts manufacturing technology for rapid prototyping before the hard-tooling process. The technology replaces wax patterns with resin patterns, and cuts production time of metal parts.

For More Information Write In No. 741

Edmund Scientific Co., Barrington, NJ, describes optical and science products such as lenses, achromats, and prisms. Video microscopy systems, microscopes, magnifiers, lab equipment, and accessories also are included.

For More Information Write In No. 742

Pragmatic Instruments, San Diego, CA, has released a four-page selection guide for waveform synthesizers used in automotive, communications, medical, scientific, and semiconductor applications. Included are product configurations and waveform creation software.

For More Information Write In No. 743

Bayer Corp. Polymers Division, Pittsburgh, PA, offers a 16-page brochure describing Apec high-heat polycarbonate that combines heat resistance, transparency, color stability, and flowability. Melt viscosity/flow and electrical properties are included.

For More Information Write In No. 744

CMX Systems Inc., Wallingford, CT, describes servo positioning systems. A description of the fringe counting interferometry technology on which the systems are based also is included.

For More Information Write In No. 746

An eight-page brochure from CMX Systems Inc., Wallingford, CT, describes servo positioning systems. A description of the fringe counting interferometry technology on which the systems are based also is included.

For More Information Write In No. 746

A technical reference catalog from Edmund Scientific Co., Barrington, NJ, describes optical and science products such as lenses, achromats, and prisms. Video microscopy systems, microscopes, magnifiers, lab equipment, and accessories also are included.

For More Information Write In No. 744

Bayer Corp. Polymers Division, Pittsburgh, PA, offers a 16-page brochure describing Apec high-heat polycarbonate that combines heat resistance, transparency, color stability, and flowability. Melt viscosity/flow and electrical properties are included.

For More Information Write In No. 744

A 76-page catalog of compressed air products from EXAIR Corp., Cincinnati, OH, features vortex tubes, cabinet coolers, air knives and amplifiers, and static eliminators. Solutions to common industrial cooling, cleaning, drying, conveying, and static control problems are offered.

For More Information Write In No. 747

For more information, call (201) 338-6500, FAX (201) 338-1625 or write CM Furnaces at: CM Furnaces Inc. 103 Dewey Street, Bloomfield, NJ 07003
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