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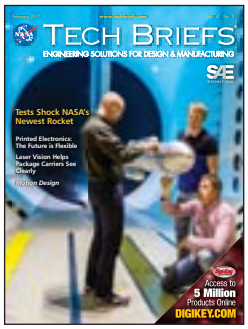
NASA Tech Briefs



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Motion Design

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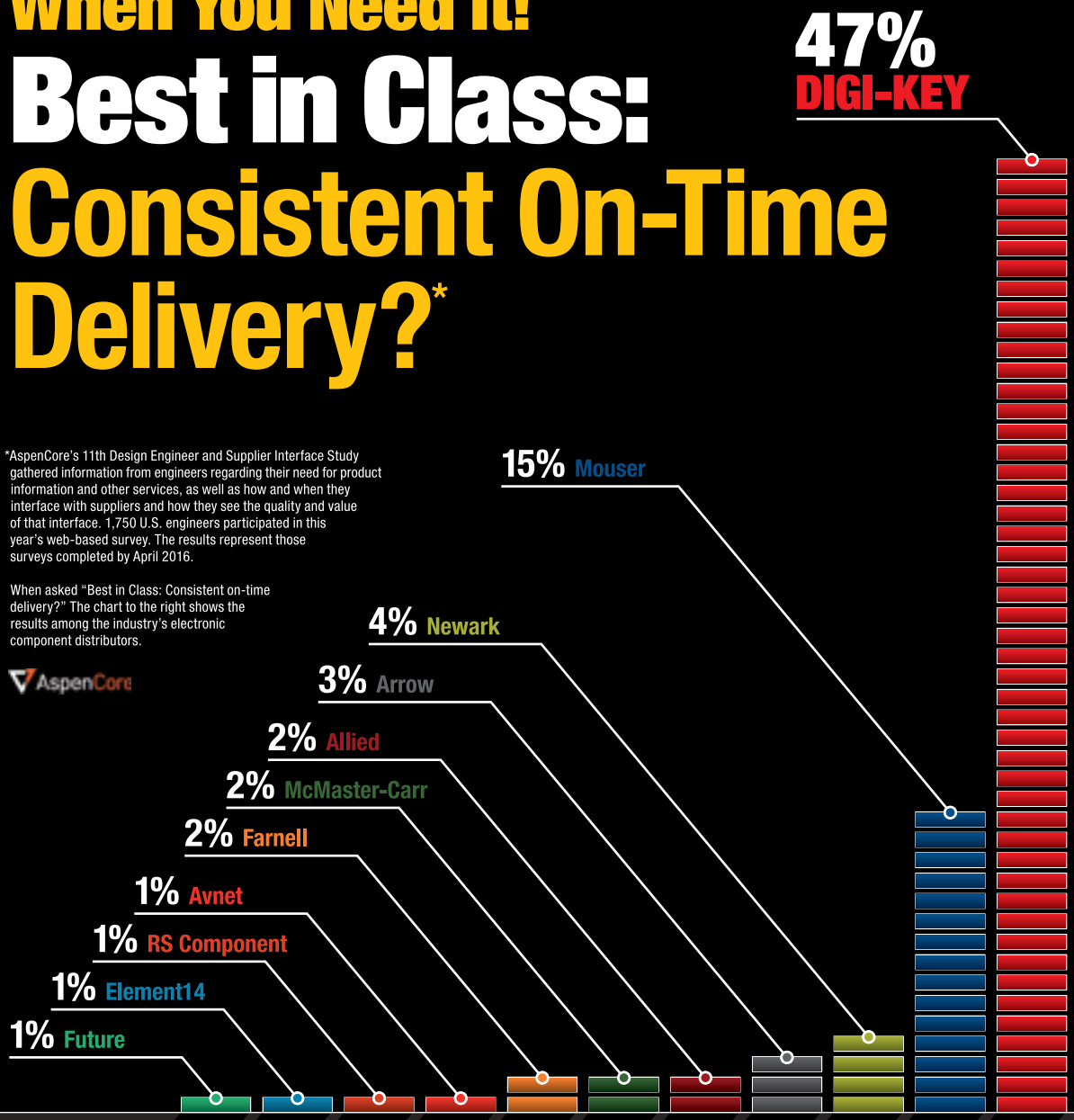

*AspenCore's 11th Design Engineer and Supplier Interface Study gathered information from engineers regarding their need for product information and other services, as well as how and when they interface with suppliers and how they see the quality and value of that interface. 1,750 U.S. engineers participated in this year's web-based survey. The results represent those surveys completed by April 2016.

When asked "Best in Class: Consistent on-time delivery?" The chart to the right shows the results among the industry's electronic component distributors.

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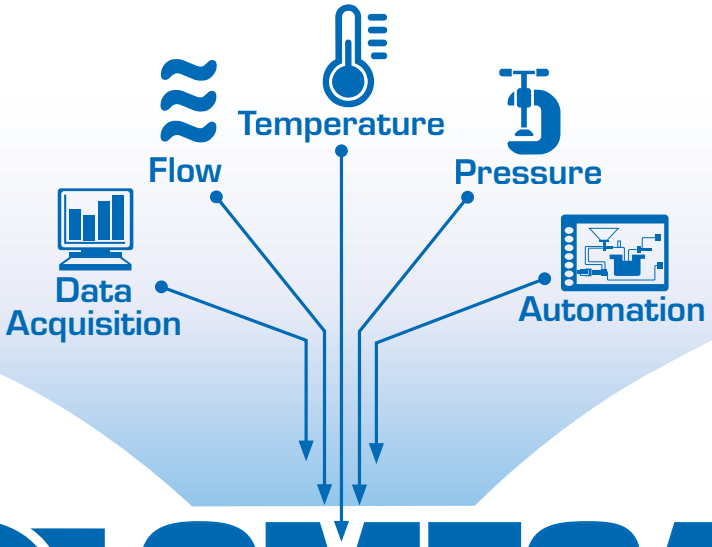

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NASA TECH BRIEFS

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Motion Design

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Product of the Month

OriginLab (Northampton, MA) released Origin and OriginPro 2017 data analysis and graphing software.

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On the cover

Final touches are made on a 10-foot model of the world's most powerful rocket, the Space Launch System (SLS), just before testing it in the Transonic Dynamics Tunnel at NASA's Langley Research Center (Hampton, VA). SLS will send an Orion spacecraft to an asteroid and other deep space destinations on the Journey to Mars, and may also open new possibilities for robotic science missions to places like Saturn and Jupiter. Find out more on page 8.

(NASA photo by David C. Bowman)

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UP FRONT

Linda Bell
Editorial Director

Editor's Choice

A filtration device eliminates contaminants from water supplies, especially where there is a need to collect potable, medical-grade water from a contaminated supply. The device uses acoustics, rather than pressure, to drive water through small-diameter carbon nantoubes. It requires less power than conventional systems, and can be used in municipal water facilities, distilleries, desalination plants, wastewater treatment facilities, and consumer markets. Find out more on page 50.

NASA Mars Cardboard Experience

The NASA Mars Cardboard Experience gives you an immersive view of several different technologies that may be used by astronauts exploring the Martian landscape. Learn about how humans will utilize technology to pioneer the Red Planet. The app includes both cardboard and non-cardboard options for view. Visit **www.nasa.gov/directorates/spacetech/apps** to download the app for iPhone, iPad, or Android.

Next Month in NTB

The March issue will feature the winners of the 2016 *NASA Tech Briefs* Readers' Choice Product of the Year Awards. Find out which products you voted the best of 2016.

SLS Undergoes Critical Wind Tunnel Testing

Final touches are made on a 10-foot model of the SLS before testing in the Transonic Dynamics Tunnel. (NASA/David C. Bowman)

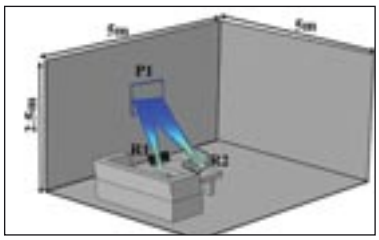
The Transonic Dynamics Tunnel at NASA's Langley Research Center has hosted hundreds of NASA projects — most recently, a 10-foot model of the world's most powerful rocket, the Space Launch System (SLS). Engineers are testing the model to understand how the rocket may perform during deep-space missions. SLS will send an Orion spacecraft to an asteroid and other deep space destinations on the Journey to Mars, and may also open new possibilities for robotic science missions to places like Saturn and Jupiter.

This test is particularly focused on understanding how the cargo version of the heavy-lift SLS rocket — capable of lifting 105 metric tons — will behave at speeds just below supersonic, where shock waves begin to form on the vehicle and can oscillate on the rocket.

Langley wind tunnel experts installed 446 miniature microphones on the SLS model to understand the rocket's behavior in Earth's thick lower atmosphere. The data was recorded using high-speed data acquisition computers, and ultimately was used as input to a structural computer model of SLS to determine how aerodynamic unsteadiness shakes the rocket during flight.

Visit www.nasa.gov/exploration/systems/sls

Technology Turns Your Living Room into a Wireless Charging Station



A simple representation of the in-home wireless power transfer scheme. (David Smith, Duke University)

A device similar in size and shape to a flat-screen TV could soon be remotely charging any device within its line of sight. A system developed by Duke University engineers would be able to automatically and continuously charge any device anywhere within a room, making dead batteries a thing of the past.

Wireless charging systems exist, but they rely on platforms that require their own wires, and the devices must be placed in the immediate vicinity of the charging station. The new solution relies on metamaterials — a synthetic material composed of many engineered cells that together produce properties not found in nature. Liquid crystals integrated with the metamaterial elements enable the reconfigurable satellite antennas.

A flat metamaterial device no bigger than a typical flat-screen television could focus beams of microwave energy down to a spot about the size of a cellphone within 10 meters. It should also be capable of powering more than one device at the same time. The system could be embedded in the ceiling and wirelessly charge everything in a room.

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Products of Tomorrow

This column presents technologies that have applications in commercial areas, possibly creating the products of tomorrow. To learn more about each technology, see the contact information provided for that innovation.

▶ HIV Test on a USB Stick

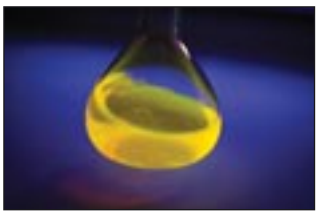
Scientists at the Imperial College London have developed an HIV test on a USB stick. It uses a drop of blood to detect HIV, and then creates an electrical signal that can be read by a computer, laptop, or handheld device. The disposable test could be used for HIV patients to monitor their own treatment, or to enable patients with HIV to be managed more effectively in remote locations. It monitors the amount of virus in the bloodstream, and can produce a result in less than 30 minutes. Current tests take at least three days, and often longer, and involve sending a blood sample to a lab. A drop of blood is placed onto a spot on the USB stick. If any HIV virus is present in the sample, a change in acidity is triggered, transforming a mobile phone chip into an electrical signal. This is sent to the USB stick, which produces the result in a program on a computer or electronic device.

Contact: Dr. Graham Cooke, Department of Medicine, Imperial College London
Phone: +44 (0)20 7594 3903
E-mail: g.cooke@imperial.ac.uk
www3.imperial.ac.uk

▶ Gear Bearings

NASA's Goddard Space Flight Center has developed gear bearings that combine gear and bearing functions into a single unit that significantly improves gear drives for electrical, internal combustion, and turbine motors. The gear bearing design incorporates anti-backlash, improved thrust bearing performance, and phase-tuning techniques for low-speed reduction. Because it combines gear and bearing functions, it reduces weight, number of parts, size, and cost, while also increasing load capacity and performance. The gear bearings form rolling friction systems that are compatible with most gear types, including spur, helical, elliptical, and bevel gears. These self-synchronized components can be in the form of planets, sun, rings, racks, and segments thereof.

Contact: Goddard Space Flight Center
Phone: 301-286-5810
E-mail: techtransfer@gsfc.nasa.gov
https://technology.nasa.gov/patent/GSC-TOPS-12



▶ Glow-in-the-Dark Dye Fuels Liquid-Based Batteries

University at Buffalo scientists identified a fluorescent dye called BODIPY as an ideal material for stockpiling energy in rechargeable, liquid-based batteries that could one day power cars and homes. BODIPY (boron-dipyrromethene) shines brightly in the dark under a black light, but the traits that facilitate energy storage are less visible. The dye has unusual chemical properties that enable it to excel at two key tasks: storing electrons and participating in electron transfer. Batteries must perform these functions to save and deliver energy, and BODIPY is very good at them. In experiments, a BODIPY-based test battery operated efficiently and with longevity, running well after researchers drained and recharged it 100 times. Based on these experiments, the scientists predict that BODIPY batteries would be powerful enough to generate an estimated 2.3 volts of electricity.

Contact: Charlotte Hsu, University at Buffalo
Phone: 716-645-4655
E-mail: chsu22@buffalo.edu
www.buffalo.edu

Who's Who at NASA

Farzin Amzajerdian, Principal Investigator, Langley Research Center, Hampton, VA

Since 2003, Farzin Amzajerdian has worked on the Navigation Doppler Lidar (NDL), a sensor designed to support safe and precise vehicle landings on Mars and other destinations. The breadbox-sized NDL contains three lasers, a small electronics box, and lenses connected by fiber-optic cables. Amzajerdian will soon oversee the testing of the technology in California's Mojave Desert.

NASA Tech Briefs: How is the NDL similar to the sensor used on Mars missions?

Farzin Amzajerdian: The Mars Science Laboratory (MSL) had a radar with multiple antennas to provide altitude and velocity information during the critical "Seven Minutes of Terror." [The "Seven Minutes of Terror" was the time required for the Mars-bound spacecraft to travel from the top of the atmosphere to the surface of the planet.] A lot of those complicated landing events occurred based on the information that the radar was providing. The NDL is very similar to the MSL radar. The NDL offers altitude and velocity — the speed coming down and the direction of the vehicle.

NTB: How does the NDL work?

Amzajerdian: NDL has multiple antennas. In our case, there are three laser beams propagating in slightly different directions from each other toward the ground. Using the Doppler effect, we measure the velocity range to the ground, along the laser beam. We need at least three beams to calculate the velocity vector — the x-y-z component.

NTB: How does the use of radar compare to NDL's use of lasers?

Amzajerdian: Laser radiation has a much higher frequency compared to radar, which makes the measurement more precise. Radars are still bulky and expensive, and require a lot of signal processing to make sense of the signals. The NDL is much smaller. Because the NDL relies on a lot of components that are used by the telecom industry, it can be relatively low-cost.

NTB: NASA's Lander Vision System (LVS) takes pictures of terrain and compares them to existing land maps. How will the NDL and the LVS work together?

Amzajerdian: The NDL is a standalone sensor, very much like the inertial measurement unit (IMU) that all landing vehicles have. The LVS provides a very precise position of the vehicle. The NDL gives the data required for the lander to navigate to a specific location.

NTB: Are there applications beyond landing of spacecraft?

Amzajerdian: There are situations where aircraft cannot rely on a GPS signal. That is especially true for some military applications. The NDL can help aircraft navigate without the GPS signal, because it provides altitude and velocity information. When helicopters land in the field, they pick up a lot of dust, degrading the pilot's visibility. In those types of situations, having good information about velocity and altitude relative to the local ground allows the pilot to land in degraded visual environments.

To learn more, read a full transcript, or listen to a downloadable podcast, visit ***www.techbriefs.com/podcast****.*

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PRINTED ELECTRONICS:
THE FUTURE IS FLEXIBLE

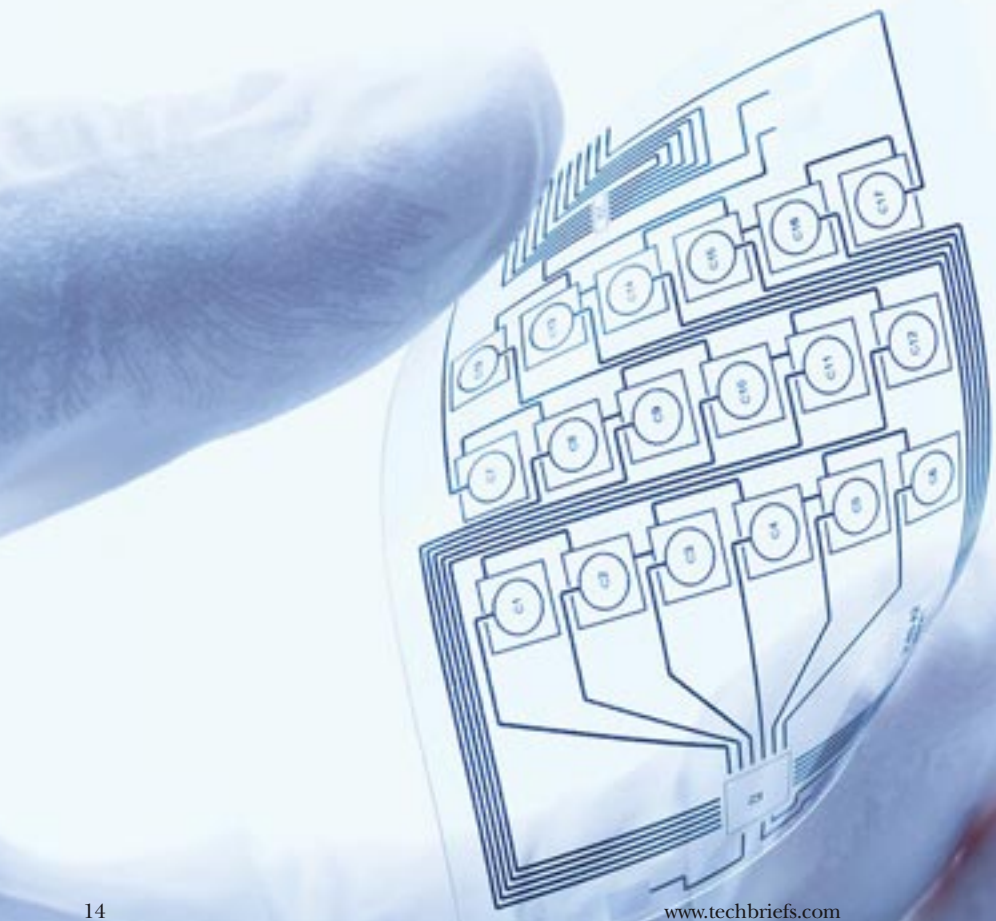
Chances are that most of us have used a printed electronic device, whether it's a security tag on a piece of clothing, or a plastic badge used to open the door of our workplace. Printable electronics have diverse potential applications in flexible solar cells, batteries, sensors, lighting products, medical diagnostic devices, drug delivery devices, smart packaging and clothing, and displays. Following are several innovative applications incorporating printable electronics.

Low-Cost Printable Electronics Fabrication

The need for low-cost and environmentally friendly processes for fabricating printable electronics and biosensor chips is rapidly growing. NASA has developed a unique approach for an atmospheric pressure plasma-based process for fabricating printable electronics and functional coatings. This system involves aerosol-assisted, room-temperature printing in which an aerosol carrying the desired material for deposition is introduced into a cold plasma jet operated at atmospheric pressure.

The deposition is the result of the interaction of the aerosol containing the precursor material with the atmospheric pressure plasma containing a primary gas. Aerosol-assisted plasma deposition is a high throughput and facile process for printing and patterning that is easily scalable for industrial production. Multiple jets can be used for depositing different materials, and the approach can be adapted to a variety of platforms.

Commercial applications for the system include biomedical technology, consumer electronics, e-paper, security, and communications.



"Stamping" Electronics Using Nanotubes

Imagine food packaging that displays a digital warning that the food is about to spoil, or a window in your house that displays the weather forecast based on measurements of the temperature and humidity levels outside.

Engineers at MIT invented a fast, precise printing process that could enable these electronic surfaces. The team developed a stamp made of carbon nanotubes that can print electronic inks onto rigid and flexible surfaces. The process should be able to print transistors small enough to control individual pixels in high-resolution displays and touchscreens. The process also may provide a relatively inexpensive, quick way to manufacture other electronic surfaces.

Because techniques such as inkjet printing are difficult to control at very small scales, they tend to produce "coffee ring" patterns where ink spills over the borders, or uneven prints that can lead to incomplete circuits. The new technique uses a nanoporous stamp that allows a solution of nanoparticles, or "ink," to flow uniformly through the stamp and onto whatever surface is to be printed.

The carbon nanotubes are grown on a surface of silicon in various patterns, including honeycomb-like hexagons and flower-shaped designs. The nanotubes are coated with a thin polymer layer to ensure the ink would penetrate throughout the nanotubes, and the nanotubes would not shrink after

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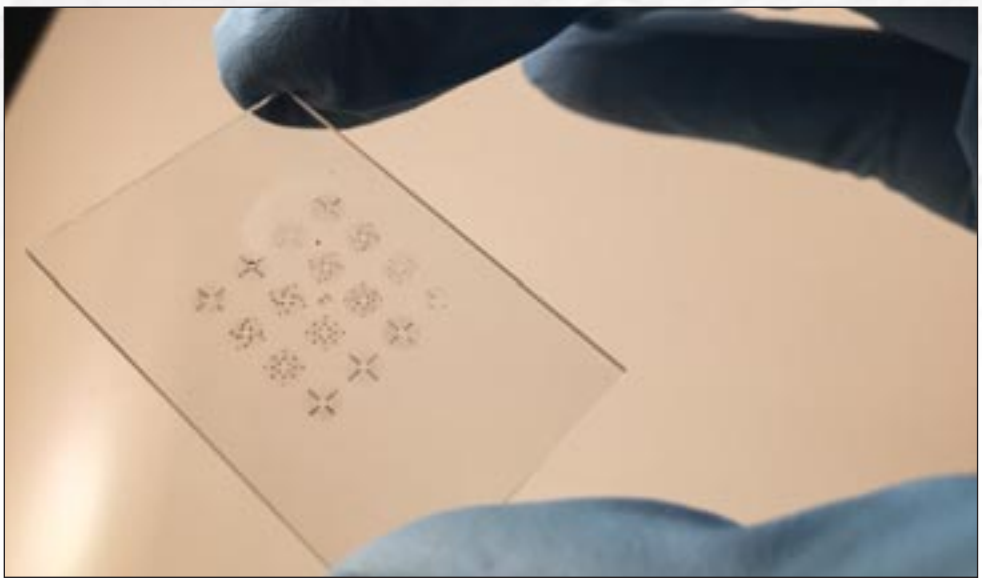
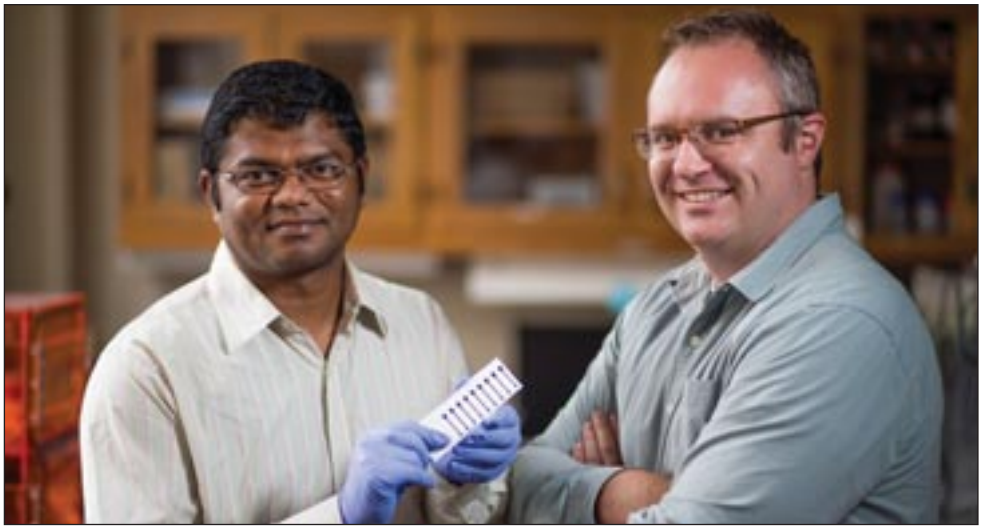


MIT researchers fabricated a stamp made from carbon nanotubes that prints electronic inks onto rigid and flexible surfaces. (Sanha Kim and Dhanushkodi Mariappan)



Iowa State researchers Suprem Das (left) and Jonathan Claussen are using lasers to treat printed graphene electronics such as those printed on a sheet of paper. (Christopher Gannon)

the ink was stamped. The stamp is then infused with a small volume of electronic ink containing nanoparticles such as silver, zinc oxide, or semiconductor quantum dots.

The key to printing precise, high-resolution patterns is in the amount of pressure applied to stamp the ink. A model was developed to predict the amount of force necessary to stamp an even layer of ink onto a substrate, and the concentration of nanoparticles in the ink. After stamping ink patterns of various designs, the team tested the printed patterns' electrical conductivity. After heating the designs after stamping, the printed patterns were highly conductive, and could serve as high-performance transparent electrodes. Going forward, the team plans to pursue the possibility of fully printed electronics.

Printed Graphene Treated with Lasers Enables Paper Electronics

The graphene carbon honeycomb is just an atom thick, conducts electricity and heat, and is strong and stable. Recent projects that used inkjet printers to print multi-layer graphene circuits and electrodes have led to graphene's use for flexible, wearable, low-cost electronics. But once printed, the graphene has to be treated to improve electrical conductivity and device performance, which usually means high temperatures or chemicals that could degrade flexible or disposable printing surfaces such as plastic films or even paper.

Iowa State University researchers developed a method that uses lasers to treat the graphene. By treating inkjet-printed, multi-layer graphene electric circuits and electrodes with a pulsed-laser process, electrical conductivity was improved without damaging paper, polymers, or other fragile printing surfaces.

The inkjet-printed graphene is transformed into a conductive material capable of being used in new applications such as sensors with biological uses, energy storage systems, electrical conducting components, and paper-based electronics.

The engineers developed computer-controlled laser technology that selectively irradiates inkjet-printed graphene oxide. The treatment removes ink binders and reduces graphene oxide to graphene, physically stitching together millions of tiny graphene flakes. The process makes electrical conductivity more than a thousand times better. The localized laser processing also changes the shape and structure of the printed graphene from a flat surface to one with raised, 3D nanostructures that resemble tiny petals rising from the surface. The rough and ridged structure increases the electrochemical reactivity of the graphene, making it useful for chemical and biological sensors.

The work paves the way for the creation of low-cost and disposable graphene-based electrochemical electrodes for applications including sensors, biosensors, fuel cells, and medical devices.

Electronic Devices "Printed" with Magnetic Ink

University of California San Diego (UCSD) engineers developed a magnetic ink that can be used to make self-healing batteries, electrochemical sensors, and wearable, textile-based elec-

A self-healing circuit printed on the sleeve of a T-shirt was connected with an LED light and a coin battery. The circuit and the fabric it was printed on were both cut, at which point the LED turned off. Within a few seconds, the LED turned back on as the two sides of the circuit came together again and healed themselves.

trical circuits. The ink is made of microparticles oriented in a certain configuration by a magnetic field that enables particles on both sides of a tear to be magnetically attracted to one another, causing a device printed with the ink to heal itself. The devices repair tears as wide as 3 millimeters.

Existing self-healing materials require an external trigger to kickstart the healing process. They also take anywhere between a few minutes to several days to work. The new system requires no outside catalyst to work, and damage is repaired within about 0.05 second.

The ink was used to print batteries, electrochemical sensors, and wearable, textile-based electrical circuits. Then the devices were damaged by cutting them and pulling them apart to create increasingly wide gaps. The devices still healed themselves and recovered their function while losing a minimum amount of conductivity.

A self-healing circuit was printed on the sleeve of a T-shirt and connected with an LED light and a coin battery. The circuit and the fabric it was printed on were both cut. At that point, the LED turned off. Within a few seconds, the LED started turning back on as the two sides of the circuit came together again and healed themselves, restoring conductivity. In the future, engineers envision making different inks with different ingredients for a wide range of applications.

RESOURCES

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Use of Beam Deflection to Control an Electron Beam Wire Deposition Process

Langley Research Center, Hampton, Virginia

NASA Langley Research Center researchers have a strong technology foundation in the use of electron-beam (e-beam) deposition for freeform fabrication of complex shaped metal parts. While e-beam wire deposition is of interest for rapid prototyping of metal parts, cost-effective near-net shape manufacturing, and potential use in space, it is also of intense interest for industrial welding and fabrication in a range of applications, from small components to large aerospace structures. Through significant advancements in techniques to improve control of the process, NASA greatly expands upon the capabilities of the e-beam fabrication and welding process.

The technology employs rastering of the e-beam in the region of the wire and substrate melt zone. By controlling the raster pattern, the e-beam selectively heats the outer edges of the wire as it strays from the melt zone. With such selective heating, the wire automatically curls back away from the high-heat outer edge and back into the region of the molten pool. Thus, with a fixed raster pattern, the process becomes self-correcting without any sensing or external control of process parameters.

This innovation provides a continuous and predictable deposition pattern, and simplifies deposition of complex geometries. It also optimizes microstructural control of the solidified molten metal. It provides efficient use of power and feedstock, and improves automated operation.

Potential applications include welding of metal structures for automotive, aerospace, and other industrial and commercial manufacturing; freeform fabrication of complex metal components in remote locations; near-net shape manufacturing and rapid prototyping; and use in a variety of metal fabrication markets, from automotive and aerospace to sporting goods and medical devices.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-64.

Thermal Stir Welding Process

Marshall Space Flight Center, Alabama

NASA's Marshall Space Flight Center is developing an improved joining technology called thermal stir welding that improves upon fusion welding and friction stir welding. This new technology enables a superior joining method by allowing manufacturers to join dissimilar materials and to weld at high rates. NASA's technology offers users an exciting alternative to state-of-the-art fusion and friction stir welding technologies.

The new thermal stir technology addresses shortcomings in fusion welding and friction stir welding. Fusion welding compromises the microstructure of the material and thus lessens its physical properties. Friction stir welding is limited by the dependent heating and stirring functions when using a rotating shoulder/pin configuration. The shoulder produces frictional heat to bring the material into the plastic state, and forges the welded material with extremely large forces. This forging effect requires a very robust backing anvil for support. The welding pin, inside the workpiece, spins at the same rate as the shoulder, further restricting the process. This dependent motion of the welding pin and shoulder restricts the speed of the welding process.

The thermal stir process separates the characteristic heating and matrix transformation processes of the friction stir welding process. It can use a fusion welding apparatus (laser, plasma torch, etc.) to initially melt the material. It may also use a solid-state heating process such as induction resistance heating. If a fusion heating apparatus is employed to heat the material, a separate grinding/extrusion feature recrystallizes the resulting dentritic matrix structure as it transforms from the melted temperature state through the plastic temperature state.

The heat sources that melt each material of the weld joint can be independently controlled. For example, a copper/aluminum weld joint can have independent temperature control as each alloy is brought into its respective plastic and melting states. This independent melting feature is advantageous because it provides a thermal environment conducive to the joining of dissimilar metals, such as copper and aluminum or stainless steel and titanium. Because these independent heat sources are kept separate from the weld matrix transformation feature (the grinding/extrusion teeth), higher weld travel rates are possible as compared to fusion and friction stir welding processes.

Unlike friction stir welding, this technology requires no backing anvil. The apparatus used for the weld process is enclosed in a main housing, which allows for the possibility of an inert environment in the melting compartment if needed.

This technology has potential applications in the following industries, especially where fusion or friction stir welding is already used: aerospace, automotive, shipbuilding, storage tank or cylinder manufacturing, construction, and railway cars.

NASA is actively seeking licensees to commercialize this technology. Please contact Sammy A. Nabors at sammy.nabors@nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/MFS-TOPS-7.

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Systems, Apparatuses, and Methods for Using Durable Adhesively Bonded Joints for Sandwich Structures

A preform insert enables redundant bond lines and mass efficient load transfer across the joint.

Langley Research Center, Hampton, Virginia

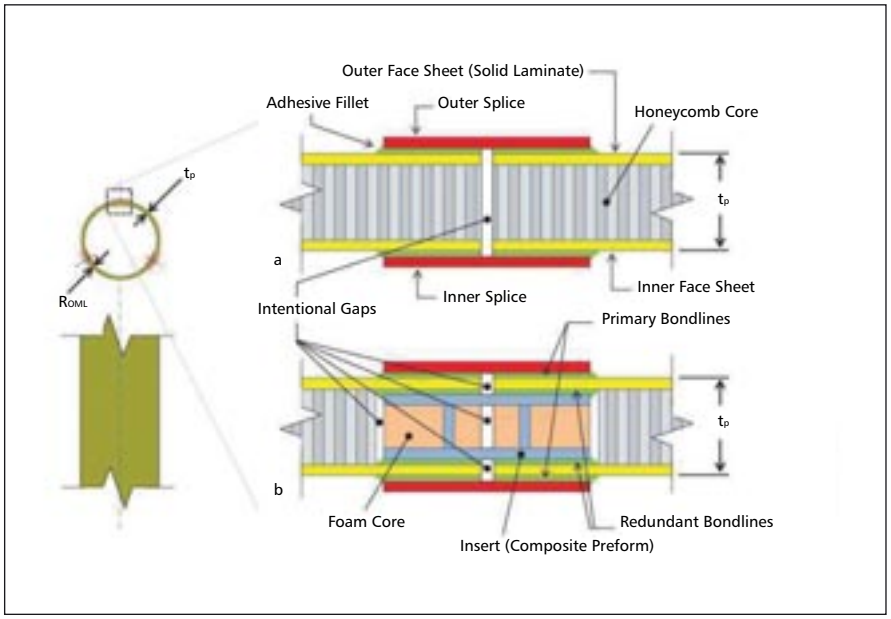
NASA's Langley Research Center has developed a new adhesively bonded joint concept for curved and flat panel sandwich architectures. A woven preform, inserted into the seam between sandwich panels, provides a larger total bonding area and multiple load paths for an improved distribution of load through the joint. NASA is able to create structures by joining sections of sandwich panels or curved shells. The new joint provides more durable load transfer and redundant load paths compared to current state-of-the-art adhesively bonded strap joints.

NASA is developing next-generation launch vehicles that will be based on high-performance composite materials and innovative manufacturing methods. As such, NASA uses adhesively bonded joints where possible, instead of mechanically fastened (bolted) joints, to design and manufacture structures. The adhesive joints are typically lighter and distribute loads more efficiently across an interface, while mechanically fastened joints are prone to stress concentrations around the bolts. The new durable redundant joint (DRJ) offers improved safety and load carrying capability for sandwich structures when compared to conventional H-type joints. The DRJ uses a composite preform to connect two ends of a curved, composite sandwich panel to form, for example, a cylindrical vehicle segment.

NASA has performed detailed finite element modeling of the new joint architecture to obtain initial indications for the structural response to a simplified hoop loading. Results indicate that the DRJ provides an improved stress-strain response without a severe mass penalty, peak stresses are independent of the joint overlap length, and the DRJ will redistribute a load to accommodate joint damage or manufacturing defects.

This technology can be used in aerospace applications, joining composites for heavy lift vehicle segments and wing sections or wing boxes. It can also be used in wind power systems for turbine propeller construction.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-93.



A detailed description of single (a) and DRJ (b) adhesively bonded joint architectures. All face sheets and splice plates are solid laminates composed of unidirectional laminas.

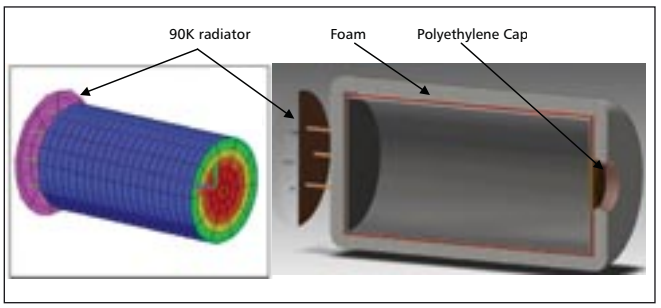
Preliminary Design of a Cryogenic Hydrogen Radiation Shield for Human Spaceflight

Liquid hydrogen is the most mass-efficient radiation shielding material.

Goddard Space Flight Center, Greenbelt, Maryland

Human susceptibility to the harsh space radiation environment has been identified as a major hurdle for exploration beyond low-Earth orbit (LEO). High-energy protons and nuclei ions from Solar Energetic Particles (SEPs) and Galactic Cosmic Rays (GCRs) can result in radiation doses that are dangerous to astronaut health and even survivability if the astronauts are not adequately shielded. These high-energy particles also cause significant amounts of secondary radiation when they impinge on the spacecraft structure. Hydrogen or hydrogen-rich materials are ideal materials for radiation shielding because hydrogen does not easily break down to form a secondary radiation source.

A concept study of a Cryogenic Hydrogen Radiation Shield (CHRS) was conducted in 2008 and results showed that liquid hydrogen is the most mass-effective



In this potential CHRS geometry, the crew module (green) is surrounded by an annular hydrogen tank (blue) with a bore in the middle. The ends of the capsule are protected by toroidal tanks that allow for axial access. The centers can be plugged with polyethylene caps. (Left represents the thermal model for this design.)

material for protecting a spacecraft if proper design is implemented. A secondary benefit may be that the hydrogen can also be used as fuel for a final burn that could help capture a spacecraft into low-Earth orbit or allow reentry into Earth's atmosphere while on a return trajectory from other planetary bodies such as Mars or asteroids, or the liquid hydrogen can be used for a burn on a lunar or Martian ascent vehicle. The required areal density of the cryogenic hydrogen depends on the duration and the trajectory of a mission and the intensity of the space radiation. The previous study also showed that in order to protect the astronauts from space radiation with an annual allowable radiation dose less than 500 mSv, 140 kg/m^2 of polyethylene is necessary. For a typical crew module that is 4 meters in diameter and 8 meters in length, the mass of polyethylene radiation shielding required would be more than 17,500 kg. The same study found that the requirement for hydrogen shielding is 40 kg/m^2 surface area.

Liquid and solid hydrogen at cryogenic temperature have higher densities and require smaller storage tanks. However, the CHRS needs a delicate thermal system that can protect cryogenic hydrogen from evaporation during the mission. This study includes a trade study to compare liquid and solid hydrogen, and a preliminary thermal design for the CHRS cryogenic thermal system. The trade study showed that subcooled solid hydrogen is a better choice than liquid hydrogen. The reasons are as follows. First, solid hydrogen absorbs more heat than liquid hydrogen before it evaporates. Second, solid hydrogen needs a smaller tank than liquid since solid is denser than liquid. Finally, it is easier to manage solid than liquid in space. The design temperature of solid hydrogen is around 10K, which allows solid hydrogen to absorb more heat before changing phase to liquid. The design also includes a ground cooling system that can freeze and subcool liquid hydrogen.

The CHRS crew module is surrounded by an annular hydrogen tank with a bore in the middle. The ends of the capsule are protected by toroidal tanks that allow for axial access. The centers of the toroid can be plugged with polyethylene caps. Thermal and fluid design requirements can be met by using proper cryogenic thermal management techniques such as freezing and subcooling the cryogen, selecting appropriate tank materials and thickness, adding MLI, using aluminum foam inside of the tank to enhance thermal conduction, using a 90K radiator to remove heat at higher temperature, and employing a 10K cryocooler. This study performed parametric thermal analyses for different combinations of passive and active thermal systems. The design was optimized to minimize the system mass and meet the thermal requirements. Load-responsive MLI can be used to reduce para-

sitic heating at the launch pad. The preliminary thermal design showed that the areal density of CHRS with a cryogenic thermal system is around 70 kg/m^2, which is 50% of the density of polyethylene shielding. With CHRS, the mass of the crew module with radiation shielding decreases from more than 26,500 kg to less than 17,800 kg. CHRS saves nearly 8,800 kg from a 4-meter-diameter and 8-meter-long cylindrical crew module, and halves the required shielding mass when compared with polyethylene shields. It saves close to $44 million in launch cost based on $5,000 per kg estimated by SpaceX. With a 10K cryocooler, the system can support missions of any length. A 50-watt heater can maintain the crew module at room temperature.

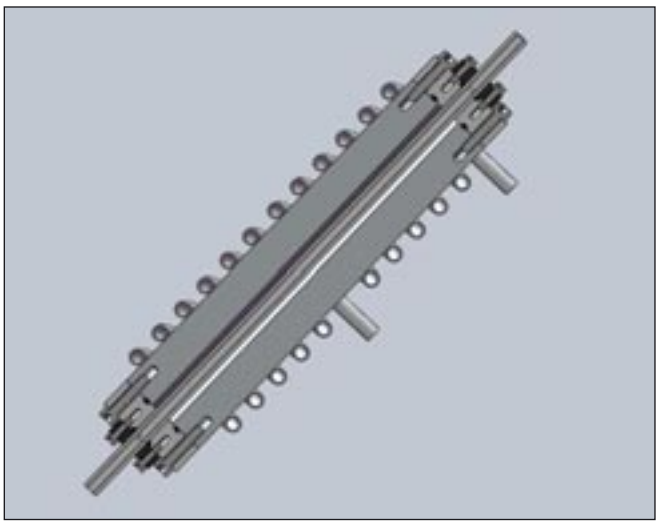
This work was done by Xiaoyi Li, Shuvo Mustafi, and Alvin Boutte of Goddard Space Flight Center. ***NASA is actively seeking licensees to commercialize this technology. Please contact Scott Leonardi at Robert.S.Leonardi@nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/GSC-17262-1.*** *GSC-17262-1*

Methods of Making and Using Tubular Solid Oxide Fuel Cells (SOFCs)

SOFCs have applications in vehicle auxiliary power units, and emergency backup power for telecom and cable repeaters.

John H. Glenn Research Center, Cleveland, Ohio

Human-occupied vehicles and autonomous vehicles such as rovers and landers may benefit from the fuel flexibility and high energy density of solid oxide fuel cells (SOFCs), compared to batteries and polymer electrolyte membrane (PEM) systems. Fuel systems greater than 1 kW are traditionally planar and exhibit high volumetric power density; however, due to large sealing areas, they have poor cycling characteristics. Recently, 250 cycles on a Tubular SOFC (T-SOFC) system (Protonex Technology Corp.) was demonstrated. Hot zones designed around T-SOFCs have a lower packing



The first casting mold, fabricated from aluminum, was a single-part mold with a straight bore.

density, but significantly better cycle life and start times, making them an ideal solution. By increasing the power density of T-SOFCs, overall hot zone and system volumetric power densities can be greatly improved. Extending the methodology of freeze-casting to T-SOFCs will provide a system with the micro-structural advantages of their planar counterpart, but with the rapid thermal cycling capacity of traditional extruded SOFCs.

Another key advantage to the use of the SOFC generators as a power system for space applications is the use of logistical fuels and oxidants. This is because a SOFC can directly take syngas (a mixture of carbon monoxide and hydrogen), a product from catalytically reformed hydrocarbon fuels, in comparison to PEM fuel cells that have to run on pure hydrogen.

A new method for the fabrication of freeze-cast T-SOFCs was developed. The use of ice as a sublime able mold barrier allows for easy casting and removal of tubes from the mold. The uniform thermal environment created radial freezing, and the use of a zirconia (8YSZ), ethanol xylene-based electrolyte coating showed good sintering to the support. This process generated the desired unique finger-like microstructure that allows better fuel gas diffusion and enhances the anode triple-phase boundaries. An electrolyte layer was fully sintered. The electrolyte and the outside of the freeze-cast anode had strong binding interface. Previous experience on T-SOFCs (at both single cell level and stack level) reveals that the tubular geometry does have great capacity for fast start-up and cool-down.

This work was done by Yanhai Du and Joshua Persky of Yanhai Power, LLC for Glenn Research Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact http://technology.grc.nasa.gov.*** *LEW-19308-1*

Tool Designs for Friction Stir Welding

This repeatable, environmentally friendly, cost-effective weld method is able to weld traditionally "unweldable" alloys.

Lyndon B. Johnson Space Center, Houston, Texas

Friction stir welding (FSW) is a solid-state welding process that shows promise in the aerospace industry. A new system of experimentation has been used to quickly make and screen new tool designs. After conducting a literature review, friction stir tools were designed to optimize material flow around the tool. Plastic prototypes of these tools were produced. FSW has been simulated by running these tools through clay with a milling machine. Surface appearance,

nugget appearance, void size and location, and the effects of plunge depth and shoulders on mixing in FSW clay were all similar to metallic FSW, and show promise for using this technique as an inexpensive way to test the effectiveness of tool design.

A rotating FSW tool is slowly plunged into two adjacent pieces of metal and traverses along the seam between them. Friction and plastic deformation of material by the pin creates heat that lowers the yield strength of the material. The deformed material flows behind the pin, and is forged by the downward force on the shoulder resulting in the recrystallization of the material. The two pieces are "stirred" together and a weld is created between them.

Aluminum alloys of 2xxx and 7xxx-series previously considered "unweldable" by traditional methods can be welded with FSW. Aluminum alloys, titanium alloys, copper alloys, lead, zinc, magnesium, ferrous alloys (including stainless steel), and nickel alloys can all be welded using FSW. This process is highly repeatable, and can weld most joint configurations and structural shapes. FSW is also environmentally friendly, producing no harmful emissions, and requiring no solvents for degreasing.

This process is more cost-effective than other forms of welding because few consumables are required, and surface cleaning is minimal. FSW has lower residual stresses than other welding methods, and does not encounter solidification cracking. FSW components can result in lightweight aerospace machines that require less fuel. For example, the space shuttle external tank was originally made with 2219, but later was composed of 2195, lowering its weight, but increasing its weld complexity. Using FSW, this process becomes simpler and more cost-effective because of its repeatability and reduced weight. FSW also shows promise for use to quickly combine aluminum with carbon nanotubes to produce advanced composites.

Thirty-one new pin and shoulder prototypes were tested, and some were found to be superior to conventional friction stir tools based on preliminary testing.

This work was done by Lucie Johannes of Johnson Space Center, Daniel Tanner of Brigham Young University, and Daniel J. Rybicki of Jacobs Technology. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact jsc-techtran@mail.nasa.gov.***
MSC-24550-1

Novel Electrochemical Cell Designs for Simultaneous Production of Methane and Oxygen via the Electrolysis of Carbon Dioxide and Water

The two-chamber cell design allows electrolysis of water and carbon dioxide in separate chambers to minimize production of unwanted products.

John F. Kennedy Space Center, Florida

NASA has investigated and demonstrated the simultaneous production of methane (CH_4) and oxygen (O_2) via the electrolysis of carbon dioxide (CO_2) and water (H_2O) in one or more ionic liquids (ILs). In order to improve the likelihood of methane and oxygen production, and to reduce the likelihood of unwanted side-product formation, several innovative approaches were investigated. Research has shown thousands of options for ionic liquids that can be used in the electrochemical process; however, care must be taken to choose an ionic liquid that has high carbon dioxide solubility, limited change in viscosity due to carbon dioxide absorption, and chemical stability during the electrochemical process.

Research was focused on using the commercially available EMIM and BMIM ionic liquids with either tetrafluoroborate or hexafluorophosphate anions. A copper cathode and a platinum anode were chosen for the initial electrochemical cell design. One of the limitations described in the research was the production of unwanted side-products during the electrochemical process. In many cases, it was hypothesized that the electrochemical cell design could be a contributing factor in the production of unwanted side-products, and that a different cell design could minimize the number of unwanted side-products and increase the conversion of carbon dioxide and water into methane and oxygen.

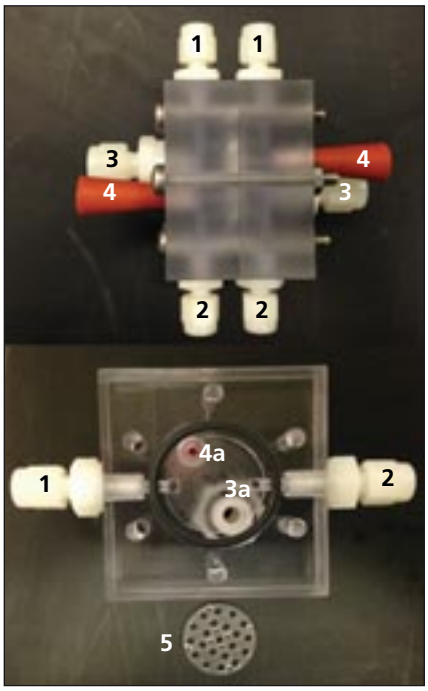
Multiple custom electrochemical cells were designed and fabricated for use in studying the feasibility of producing methane and oxygen from the simultaneous electrolysis of carbon dioxide and water. Initially, two cell designs (one small-volume, one larger volume) were fabricated for the project. These first two cells were two-chamber cells fabricated from polycarbonate. The small-volume, two-chamber cell was designed to provide a very short working distance between the working and counter electrodes (approximately 0.11") and was designed to hold a total volume of 8 ml of each electrolyte (ionic liquid and water). The larger-volume, two-chamber cell was fabricated by modification of a commercially available Gamry Paracell. The larger cell was designed to hold a total volume of approximately 35 ml of each electrolyte for larger-scale methane production.

In both cells, a proton-exchange membrane (typically a Nafion membrane) was used to separate the two chambers of each cell. During early testing, the small-volume cell was damaged, and a new cell was designed and fabricated that was similar to the large-volume, two-chamber cell but with a smaller electrolyte capacity (approximately 10 ml of each electrolyte). Test results obtained from electrolysis experiments performed using the new small-volume cell were unexpected; the copper working electrode was poisoned, and the presence of calcium and carbonate were detected on the surface of the electrode. Further investigation led to the conclusion that the source of the

calcium and carbonate was the polycarbonate used for cell fabrication. To eliminate the presence of calcium and carbonate, an exact replica of the 10-ml cell was fabricated from high-density polyethylene (HDPE). An electrochemical experiment conducted using the HDPE cell did not show the production of any methane, but did show the production of carbon monoxide and hydrogen. Additionally, no calcium carbonate was detected.

Another cell that was evaluated was a commercially available, two-chamber glass cell with a glass frit separating the two halves of the cell. Several experiments were conducted using this cell, but several issues were identified, including gas leakage. Novel caps were fabricated for the cell to eliminate this issue, but the cell was damaged while preparing for an experiment, and no methane production data was collected for this cell design.

The two-chamber cell design provides the opportunity to minimize the production of unwanted side-products by minimizing the interaction between the aqueous electrolyte and the ionic liquid electrolyte. Additionally, the two-chamber cell design provides the opportunity to circulate each electrolyte independently, which allows the purification and removal of unwanted products in each electrolyte by whatever means is necessary for each individual electrolyte (without worrying about the other electrolyte). This is a huge advantage when dealing with long-term use, especially from an ISRU perspective where consumables are limited.



The small-scale electrolysis system consists of (1) gas inlet ports, (2) gas outlet and sampling ports, (3) ports for reference electrodes for each half-cell, (3a) feedthrough port for reference electrode, (4) sealing plugs for electrode wire feed, (4a) feedthrough port for wire feed to working and counter electrode, and (5) perforated polycarbonate support for proton exchange membrane (PEM) and electrode spacer.

This work was done by Tracy Gibson, Jan Surma, James Captain, Steven Parks, Anthony Muscatello, and Paul Hintze of Kennedy Space Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact KSC-DLTechnologyTransfer@mail.nasa.gov.***
KSC-13986

Reliability Testing of High-Power Devices

Before a new high-power semiconductor device can be used for industrial applications, it must be thoroughly tested to determine if it will survive environmental stresses and continue to meet specifications. This is especially true for the latest wide-bandgap semiconductor materials such as silicon carbide (SiC) and gallium nitride (GaN) to ensure they can withstand high voltage and temperatures.

New application areas often mean that devices must be able to withstand severe ambient conditions. For example, in automotive traction control systems, the cooling liquid for the combustion engine may reach temperatures as high as 120 °C. To provide sufficient margin, the maximum junction temperature (TJMAX) must be increased to around 150 to 175 °C. And in safety-critical applications such as aircraft, the concept of zero-defects is being adopted to help meet stricter reliability requirements.

The V_{DS} ramp and the High Temperature Reverse Bias (HTRB) tests are among the most common tests for evaluating the reliability of these power devices under a range of conditions.

In a V_{DS} ramp test, drain-source voltage is stepped or ramped up from a low voltage to a voltage that's higher than the rated maximum drain-source voltage, and specified device parameters are evaluated. This test is useful for tuning design and process conditions, as well as verifying that the device delivers the expected performance. For example, dynamic $R_{DS(ON)}$, monitored using a V_{DS} ramp test, provides a measurement of how much a device's ON-resistance increases after being subjected to a drain bias, while Vb or max V rating is performed when the device is OFF and drain voltage is ramped up. The V_{DS} ramp test is generally used as a quick form of parametric verification.

An HTRB test, on the other hand, evaluates long-term stability under high drain-source bias. During an HTRB test, device samples are stressed at or slightly less than the maximum rated reverse breakdown voltage at an ambient temperature close to their maximum TJMAX over a long time — typically 1,000 hours. In HTRB testing, the leakage current is continuously monitored throughout the test and a fairly constant leakage current is generally required to pass the test. Because it combines electrical and thermal stress, this test can be used to check junction integrity, crystal defects, and ionic contamination level, which can reveal weaknesses or degradation effects in the field depletion structures at the device edges and in the passivation.

Power device characterization and reliability testing require test instrumentation with both high-voltage-sensitive current measurement capabilities. During operation, devices undergo both electrical and thermal stress. When in the ON state, they must pass tens or hundreds of amps with minimal loss (low voltage, high current). When they are OFF, they must block thousands of volts with minimal leakage currents (high voltage, low current). Additionally, during the switching transient, they are subjected to a brief period of both high voltage and high current. The high current experienced during the ON state generates a large amount of heat, which may degrade device reliability if it is not dissipated efficiently.

Factors for Successful Testing

Reliability tests typically involve high voltages, long test times, and often multiple devices under test such as for wafer level testing. This means that well-designed test systems and measurement plans are essential to avoid breaking devices, damaging equipment, and losing test data. Here are some factors to consider for successful V_{DS} ramp and HTRB reliability testing.

Device connections — When testing vertical devices with a common drain, proper connections between the device and the test instrumentation — typically one or more source measure units (SMU) with central software control — are required to prevent stress termination in case of a single device breakdown test. As show in Figure 1a, when testing a single device, voltage can be applied at the drain only for V_{DS} stress and measure, which requires only one SMU per device. Alternatively, as shown in Figure 1b, each gate and source can be connected to a SMU for more control for measuring current at all terminals, extending the range of V_{DS} stress, and setting voltage on the gate to simulate a practical circuit situation. Note that final or functional testing of packaged parts is simpler compared to testing on the wafer.

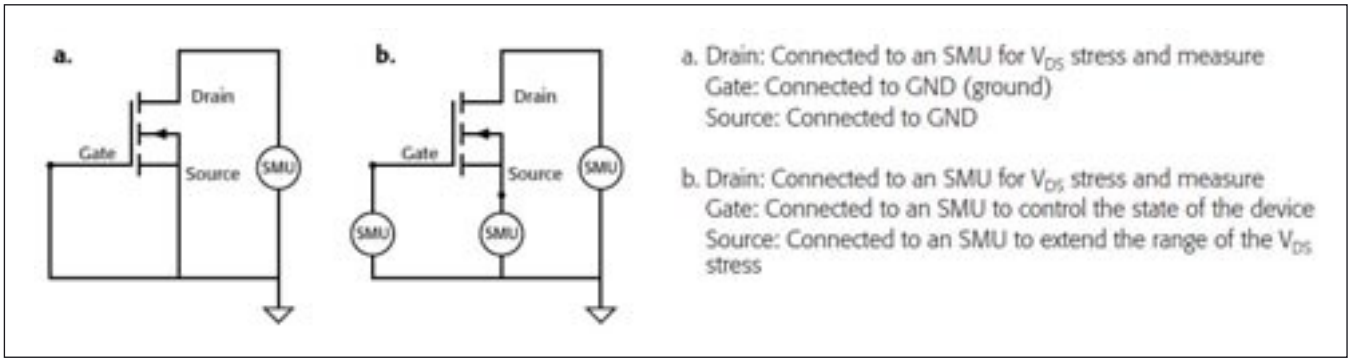


Figure 1. Single device connections for V_{DS} ramp testing.

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Current limit control — Current limits are needed to allow for adjustment at breakdown to avoid damage to the probe card and device. When a breakdown occurs, it's advisable to keep a high-level limit current from running to that particular device because, over an extended time, the high-level current can actually melt the probe card tips and damage the devices. Therefore, reliability test solutions should include dynamic limit change functionality that allows the current limit to vary by pre-determined settings. The limit value is often set as a multiple of the measured current, and in some cases, the current should be reduced by three orders of magnitude, which corresponds to 106 times lower in terms of power.

Stress control — High-voltage stress must be well controlled to avoid overstressing the device, which can potentially lead to unexpected device breakdown. In addition, it should be possible for the user to terminate the test early without the risk of losing already acquired data. A soft bias/abort function allows forced voltage or current to reach the desired value by ramping gradually at the start or the end of the stress, or when aborting the test, instead of changing suddenly.

Data management — Effective data collection is essential to accommodate the large datasets due to the long times involved and multi-device testing. One way to keep data volumes under control is to only log data that is important to the task at hand. For instance, data points may only be logged when a current shift exceeds a specified percentage as compared to previously logged data, or when the current is higher than a specified noise level.

The V_{DS} ramp and HTRB tests are important power device reliability tools for parametric verification and long-term stability evaluation of the latest high-voltage power semiconductors. Software with support for the considerations outlined here, combined with precision instrumentation, can be used for a wide variety of applications at the device, wafer, or cassette level, and in settings from a simple benchtop test setup to an automated, integrated rack of instruments.

This article was written by Jennifer Cheney, Product Marketing Engineer at Tektronix, Beaverton, OR. For more information, visit ***http://info.hotims.com/65848-122****.* ■

Electronic Device **Monitors the Heart** *and* **Recognizes Speech**

Researchers from the University of Colorado Boulder and Northwestern University have developed a tiny, soft, and wearable acoustic sensor that measures vibrations in the human body, allowing them to monitor human heart health and recognize spoken words. The stretchable device captures physiological sound signals from the body, has physical properties matched with human skin, and can be mounted on nearly any surface of the body. The sensor resembles a small Band-Aid®, weighs less than one-hundredth of an ounce, and can gather continuous physiological data.

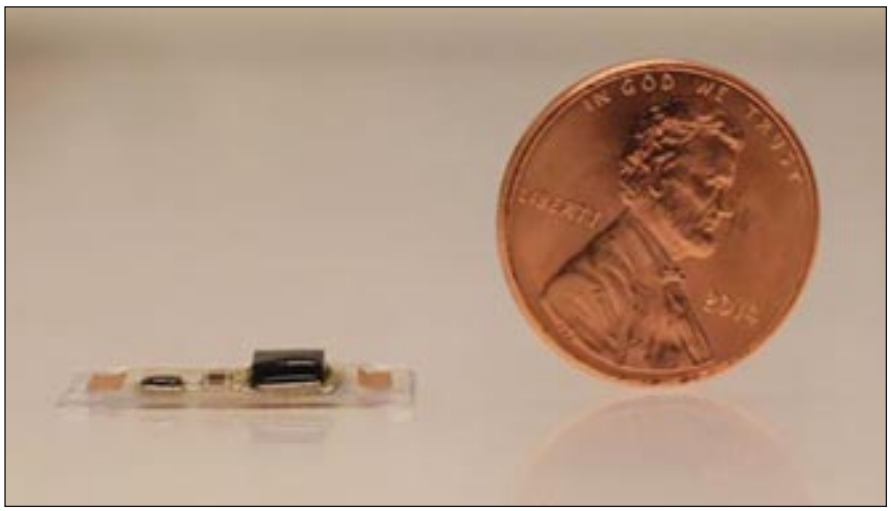
The device picks up mechanical waves that propagate through tissues and fluids in the human body due to natural physiological activity, revealing characteristic acoustical signatures of individual events that include the opening and closing of heart valves, vibrations of the vocal cords, and movements in gastrointestinal tracts. The sensor can also integrate electrodes to record electrocardiogram (ECG) signals that measure the electrical activity of the heart, as well as electromyogram (EMG) signals that measure the electrical activity of muscles at rest and during contraction.

While the sensor was wired to an external data acquisition system for the tests, it can easily be converted into a wireless device for use in remote, noisy places such as battlefields, or to produce quiet, high-quality cardiology or speech signals that can be read in real time at distant medical facilities.

Vocal cord vibration signals also could be used by military personnel or civilians to control robots, vehicles, or drones. The speech recognition capabilities have implications for improving communication for people suffering from speech impairments.

The sticky, flexible polymer encapsulating the device is stretchable enough to follow skin deformation. The device contains a tiny commercial accelerometer to measure the vibration of body acoustics, and allows for the evaporation of human sweat. Vocal cord vibrations can be gathered when the device is on one's throat to control video games and other machines.

For more information, visit ***www.colorado.edu/today/****.* ■



The tiny, wearable acoustic sensor can be used to monitor heart health and recognize spoken words. (Northwestern University, University of Colorado Boulder)

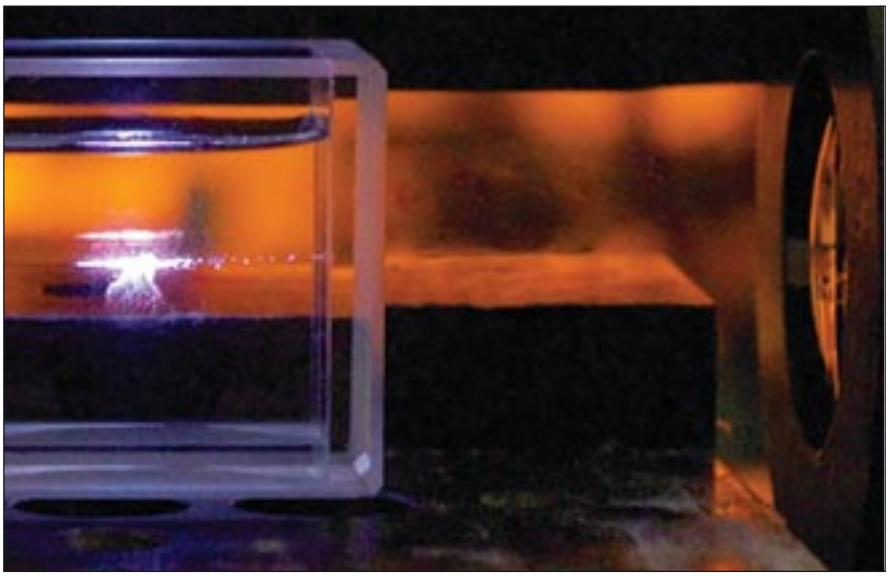
Split Laser System for Environmental Monitoring

Environmental monitoring — the assessment of air, water, and soil quality — is highly important to oil and gas exploration companies, landowners, regulatory agencies, municipalities, and any organization measuring emissions and pollutants. The majority of monitoring technologies, however, are expensive and labor intensive, often requiring sample collection and preparation (i.e., external lab analysis) that can dramatically alter the sample and its inherent components. Of those technologies that do allow for in-situ analysis, few are amenable to measurements under harsh conditions, such as high temperature and/or pressure.

Researchers at the U.S. Department of Energy's National Energy Technology Laboratory (NETL) have developed a novel split laser system for in-situ environmental monitoring via Laser Induced Breakdown Spectroscopy (LIBS) or Raman analysis. The design features fiber-coupled, optically pumped, passively Q-switched lasers that are small, portable, low-cost, and robust enough for even downhole applications. The technology can be used in a wide array of applications including carbon dioxide (CO_2) monitoring for CO_2 sequestration, oil and gas monitoring, and water analysis (groundwater and municipal systems).

Laser Induced Breakdown Spectroscopy, an atomic emission spectroscopy, offers solutions to the drawbacks of conventional environmental monitoring technologies. It provides rapid and relatively simple qualitative and quantitative elemental analysis. Significantly, this analysis can be accomplished without the need for sample collection or preparation. Moreover, LIBS can be applied to in-situ measurements of gases, liquids, and solids, making it amenable to the monitoring of air, water, and soil. The majority of available LIBS systems, however, are large and complex, employing above-ground, laboratory-scale lasers.

A LIBS system was designed that is fully adaptable to field use and capable of measurements in harsh environments. The system has been designed to be portable, with a minimal number of optical components, no moving parts, and no electrical connections, which should translate into far lower production costs than competitive devices. In addition, unlike competing LIBS systems that employ actively Q-switched lasers, this system utilizes a passively switched laser, providing the same degree of precision timing as the actively switched output, with fewer components and a lower-cost laser system.



The split laser system has been designed to be portable, with a minimal number of optical components, no moving parts, and no electrical connections.

The NETL system also employs a unique split laser design. Conventional LIBS analysis requires complete laser systems to deliver a high peak pulse to the sample, incompatible with the use of optical fibers that are ideal for at-a-distance monitoring. To avoid fiber optic damage, this system employs a remotely positioned laser diode pump capable of generating a peak power of only a few hundred watts as compared to the megawatts produced by conventional systems. The low peak pulse is delivered via a fiber optic cable to a remotely located solid-state laser where the high peak pulse necessary for analysis is produced. Significantly, this unique dual laser arrangement, coupled with solid-state optics, permits monitoring of even severe downhole environments while avoiding system damage.

The split laser design also provides for multipoint analysis, allowing multiple lasers to be distributed over a broad area, ideal for applications such as the detection of CO_2 leakage from an injection basin. Adding to the system's flexibility, with few modifications, the same system can also be used to provide output for Raman analysis, permitting the identification of organic compounds such as methane. Thus, one system can be designed to be used for both LIBS and Raman investigations. For example, the system can be used above ground or downhole to directly monitor CH_4 via Raman analysis, and detect changes in groundwater ions via LIBS.

For more information, visit ***https://www.netl.doe.gov/.*** ■

Measuring Tiny Forces **with Light**

Photons have no mass, but they have momentum. This allows researchers to use light to push matter around. Scientists at the Physical Measurement Laboratory (PML) at the National Institute of Standards and Technology (NIST) have taken advantage of this property to develop devices that can create and measure minute forces, an area traditionally underserved by the metrology community.

The official SI unit of force is the newton. One newton is equivalent to about the weight of an average-sized apple. The experiments the group is working on can measure forces that are tiny fractions of a newton — from micronewtons (10^{-6}, millionths of a newton) all the way down to 15 femtonewtons (10^{-15}, a million billionth of a newton) at the level of atomic interactions.

The PML team is currently developing two types of force-measurement devices that use laser light to reliably create small forces. The first is a chip-sized sensor that can use micro- to milliwatt-power light. The second is a tabletop device designed for laser light of about 1 watt, but which could potentially be developed for light of tens of kilowatts of power.

Eventual commercial applications could include sensors that use laser light as a built-in reference, allowing scientists to ensure their devices really are measuring force correctly. But the potential applications go beyond force into inexpensive field-portable balances for near-instant measurement of masses of a milligram or less, and into compact laser power meters that make their measurements in real time.

A Chip-Sized Balance

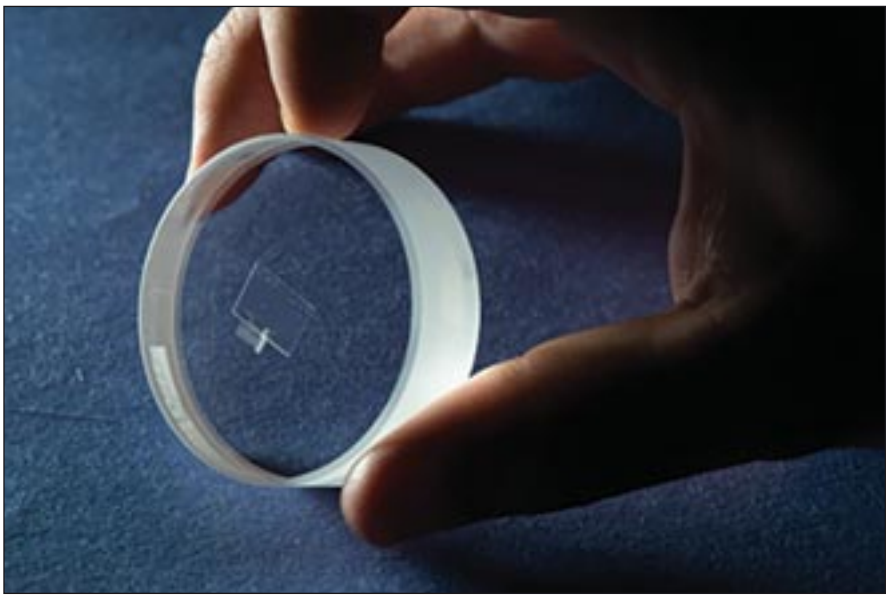
The smaller of the two types of force meter being developed is a chip-sized sensor made of fused quartz. It consists of a small cantilever less than 1 cm in length. The bigger the force, the more the cantilever moves. A built-in interferometer acts as a motion sensor. Physically pushing the cantilever is one way to apply a force for measurement. But researchers also need to gauge the sensitivity of their sensor. The best way to measure sensitivity is to apply a well-known force to the cantilever and see how it is interpreted by the interferometer.

To manipulate the cantilever with light, it was fitted with a highly reflective, gold-coated surface that can reflect light shining on it from an optical fiber. When this light hits the gold surface, it transfers its momentum to the cantilever, which begins to vibrate.

They found that if laser light is reflected off the surface, there's a relatively straightforward way to calculate what the force should be based on the laser power. The higher the power, the more photons there are, and the larger the force that's generated. Furthermore, since the cantilever's resonant frequency changes almost instantly if a mass is placed on it, the mechanism could also be used as a very sensitive balance; particularly for objects that are extremely valuable or dangerous. For example, it

could be used as a field-portable disposable tool for measuring samples of hazardous materials.

Unlike the current "gold standard" method of measuring laser power — a cryogenic radiometer — a chip-based laser power meter like this can be used at room temperature and in real time.



A prototype for the chip-sized small-force meter. The cantilever is near the intersection of the two rectangles in the center of the glass cylinder.

The Force of a Single Photon

But even at the lowest laser powers used so far — just millionths of a watt — the light still contains an enormous number of photons. A force measurement device capable of single-photon detection could be developed. The reason is that integers don't have uncertainty; if you count individual photons, and you know how much force each photon produces, then you can calculate the force.

The proposed scheme would require measuring mere zeptonewtons of force (10^{-21}), which translates to 100 million photons per second. Before that's possible, the team has to determine how to cool the single-photon force sensors down to just fractions of a degree above absolute zero, which requires a cryostat. But a typical cryostat creates too many vibrations for such precise measurements — a factor of 10,000 more than they could accept.

While they prepare to test their prototype in a new, less shaky cryostat design, they've turned the vibration issue into a potential solution for a different problem. The force sensors could be used as accelerometers, which enable measurement of how much vibration the cryostats are creating.

For more information, visit ***https://www.nist.gov/news.*** ■

Test & Measurement

Laser Scanning Technique for Testing Fire-Damaged Concrete

Fire is one of the most serious potential risks to concrete structures such as bridges, tunnels, and buildings. A significant loss in strength occurs when concrete is heated above 300 °C.

Research at The University of Nottingham (UK) and the University at Ningbo (China) has found that laser scanning is a viable structural safety technique to detect the damaging effects of fire on concrete. Concrete is the most extensively used construction material worldwide with an average global yearly consumption of 1 cubic meter per person. Fire is one of the most serious potential risks to concrete structures such as bridges, tunnels, and buildings.

While concrete is known to have high fire resistance and retain much of its load-bearing capacity, its physical, chemical, and mechanical properties do undergo severe modifications when subjected to high temperatures. A significant loss in strength occurs when concrete is heated above 300 °C. A structural safety assessment provides information needed to evaluate the residual bearing capacity and durability of fire-damaged concrete structures. These assessments are also used to propose the appropriate repair methods or to decide if demolition is needed.

There are several conventional on-site and off-site techniques for assessing fire-damaged concrete. Some on-site methods include visual inspections of color change and physical features, whereas off-site methods involve invasive tests such as core drilling or lab-based techniques.

The engineering teams studied the use of terrestrial laser scanning (TSL) as a non-destructive way to assess and detect fire-damaged concrete in a structural safety appraisal. The method allows scanning to be done at a distance, which improves site safety. Scanning is also quick, with millions of points measured in a few seconds, and spatial resolution acquired in a short time. This is advantageous for engineering structures, considering their scale or magnitude.

Baseline Assessments of Concrete

The study investigated the influences of scanning incidence angle and distance on the laser intensity returns. Concrete color change was also studied. Data was collected and interpreted on unheated and heated concrete to establish the baseline condition of the material.

Study experiments were carried out in a controlled laboratory and used two phase shift terrestrial laser scanners to scan the concrete specimens before heating, and then after they were cooled again. The concrete specimens were heated in a furnace to elevated temperatures of up to 1,000 °C; the temperature attained is an important factor in assessing fire-damaged concrete.

To assess color change in the heated concrete, specimen images were captured using a camera attached to the laser scanner. A flatbed scanner was also used to scan heated concrete surfaces and capture images. It is these images that were used for analysis due to their resolution.

During the experiments, the measurement of the incidence angles for the concrete blocks was found to vary with distance. As the scanning distance increased, the incidence angle decreased, and both scanners showed the same trend. A comparative analysis of the laser intensity for heated and unheated concrete showed that the recorded intensity values for heated concrete are higher than those for unheated concrete. The laser intensity values of heated concrete showed a remarkable increase in the concrete exposure temperatures from 250 °C to 1,000 °C.

Such a correlation between the intensity and the exposure temperature is of importance in assessing the condition and extent of damage to concrete. This finding implies it could be possible to use laser intensity to detect the state of concrete, whether it has been heated or not. The study has also shown that RGB data improves the visual identification of features, and provides a rough idea of the concrete condition after a fire. Laser scanners have an advantage in that most of them have either an internal or external camera that can be used to capture concrete images if good resolution can be achieved.

Although the laser scanners had different wavelengths, the results demonstrated the feasibility of using TLS as an approach to assessing levels of fire-damaged concrete, and provided an understanding of the condition of concrete in relation to the strength changes of concrete when it is heated to elevated temperatures. A structural safety assessment provides information needed to evaluate the residual bearing capacity and durability of fire-damaged concrete structures. They are also used to propose the appropriate repair methods or to decide if demolition is needed.

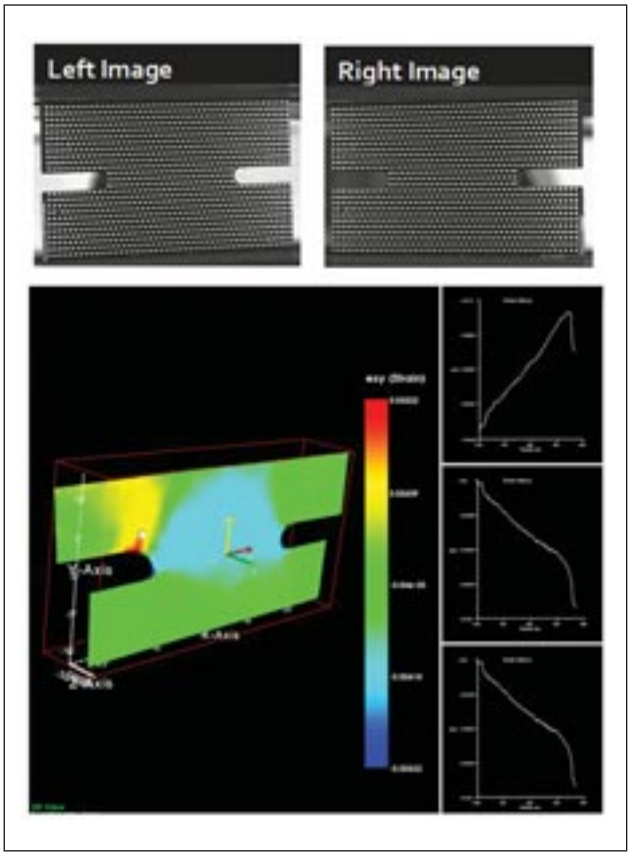
For more information, visit ***www.nottingham.ac.uk/news/.*** ■

Test & Measurement

3D Measurement and Visualization of **Displacement and Strain Fields**

The Naval Research Laboratory (NRL) has developed a metrology workbench for the measurement and visualization of displacement and strain fields in three dimensions. The workbench uses two or more cameras to image a specimen, and includes custom software that implements the 3D Meshless Random Grid method.

A random pattern of optically distinct dots is applied on the specimen surface. This procedure greatly reduces specimen preparation time compared to other optical methods. With the help of the software, the dots are identified and tracked, and their displacement is computed as the specimen deforms under various loads. Additionally, optically distinct intrinsic features of the specimen surface can be tracked, allowing for remote measurement of deforming objects in various length scales including the nanoscale.



The workbench uses two or more cameras to image a specimen, and includes custom software that implements the 3D Meshless Random Grid methods.

In contrast to the Pure Grid Method (PGM), a uniform grid on the surface of the sample is not required, simplifying setup and allowing the test and measurement of irregularly shaped objects. The NRL method is both faster and more accurate when compared to Digital Image Correlation (DIC) techniques.

Other features of the software include a choice of any number of gauge points, optional calculation of advanced deformation measures, automated detection of convex and non-convex domain geometries, time-domain filtering, import/export capabilities, scripting interface, and multi-operating system capability.

Applications include experimental mechanics applications, material characterization, remote sensing, reverse engineering, quality control, nanoscale engineering, non-contact metrology, and finite element analysis validation.

For more information, visit ***https://www.nrl.navy.mil/techtransfer/***. ■

Eddy Current System and Method for Crack Detection

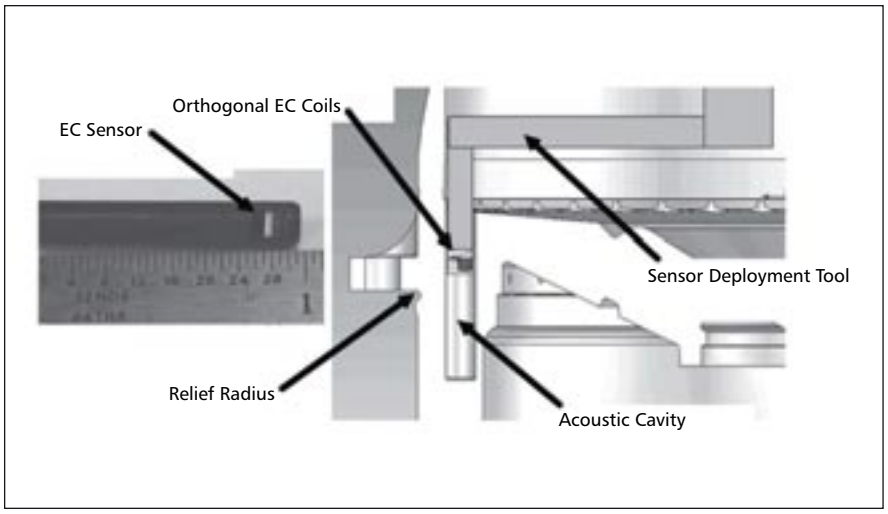
This probe can identify outer surface damage from within the interior of installed hardware.

Langley Research Center, Hampton, Virginia

NASA's Langley Research Center has developed a new eddy current inspection device that probes for cracks in parts of metal structures that are often inaccessible without extensive disassembly. The probe is specially designed for insertion into the cavity of a part to inspect the surrounding structure in an outward direction. For example, the probe may be held inside a large, thick tube and pointed outward to inspect the outer diameter of the tube. NASA used the probe to test for stress corrosion cracking in the relief radius of Space Shuttle thrusters without having to dismantle the hardware, reducing inspection time while ensuring the health of the structure. NASA Langley is seeking organizations that would like to license the probe to test for cracks in rocket thrusters and other metallic structures with hard-to-reach inspection areas.

Test results have shown that the system is a robust, operator-independent, and reliable inspection method for granular crack detection in the relief radius of thruster components. It is designed to inspect for outer surface damage by accessing the structure from the interior of the thruster cavity and probing in an outward direction. The technique incorporates a dual-frequency, orthogonally wound eddy current probe mounted on a stepper-motor-controlled scanning system.

A photograph of the prototype eddy current sensor and a schematic diagram



A photograph of the prototype eddy current sensor (left) and a schematic diagram of an eddy current thruster inspection tool (right).

of the technique are shown in the figure. Matched eddy current coils are arranged orthogonally to each other and scanned into the acoustic cavity of the thruster. In the conceptual diagram, the inspection coil on the left is arranged with its axis along the circumferential direction. This orientation enables a relatively deep field penetration with the small-diameter coil required to fit into the acoustic cavity, and induces current in a direction that will have a strong interaction with cracks originating in the relief radius and growing toward the acoustic cavity. A second coil with its axis parallel to the acoustic cavity provides a local reference for the inspection. The probe has been prototyped, tested, and used at NASA.

Potential uses include commercial aerospace applications for inspection of shuttle-like thruster motors for launching satellites or crew vehicles, and nuclear power plants for inspection to ensure the integrity of thick tubing structures.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-74.

Eddy Current Probe for Surface and Sub-Surface Inspection

This technology can be used in aerospace, manufacturing, materials, and energy applications.

Langley Research Center, Hampton, Virginia

NASA's Langley Research Center has developed a novel probe for eddy current sensor applications that improves detection depth and measurement resolution. Although the use of anisotropic magnetoresistive (AMR) sensors in eddy current probes to improve sensitivity at low frequencies and increase the detection depth is known, the high-frequency sensitivity and small size of these sensors is less explored. This new probe incorporates two induction sources (i.e., one high-frequency and one low-frequency) and an AMR sensor; the result is improved reso-

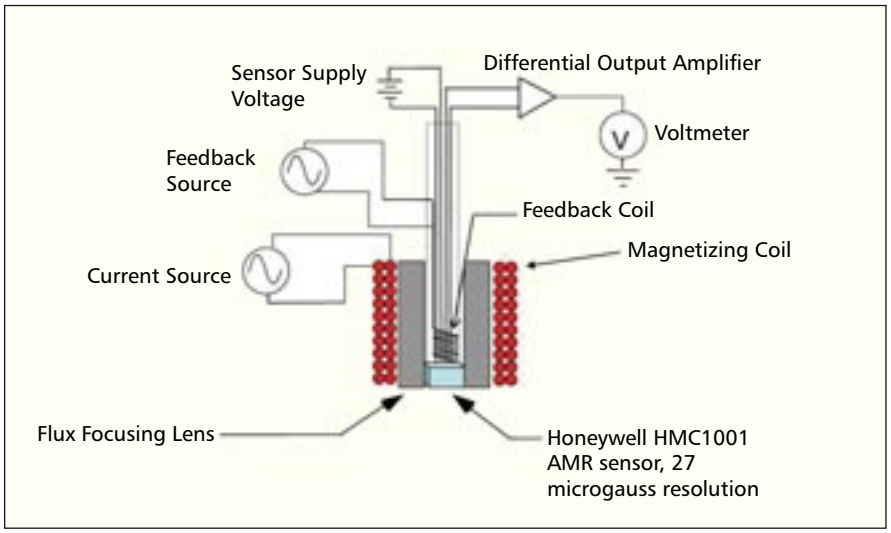
lution in near-surface material characterization, combined with simultaneous deep-flaw detection. Addition of a second high-frequency induction source, oriented to produce a magnetic field orthogonal to the first, allows for near-surface anomaly detection in two dimensions.

Eddy current probes are well known in the realm of nondestructive testing. Traditionally, these probes encourage the formation of eddy currents in a conductive material, and measurement of the magnetic field generated by the eddy currents allows for detection of defects and changes in material properties. Unfortunately, the resolution of this type of probe is limited by the probe diameter. Additionally, poor sensitivity at low frequency and the skin effect active in conductors at high frequency precludes inspection much below near-surface depths.

Incorporation of magnetoresistive materials as sensors in eddy current probes can improve instrument sensitivity. NASA researchers have developed a new probe, using a wide-bandwidth AMR sensor capable of operating from direct current up to megahertz frequencies. The probe incorporates two induction sources, one low- and one high-frequency. A magnetizing coil (approximately 6 mm in diameter) is the low-frequency source. The coil is separated from the sensor by a mu-metal flux-focusing lens to minimize direct coupling between coil and sensor. Because the AMR sensor itself is quite small, spatial resolution of the instrument is limited by the dimensions of the induction source.

To improve measurement resolution, the high-frequency source is a single strand of fine-gauge magnet wire located at the bottom of the sensor, positioned perpendicularly to the length of the probe. The large difference in operating frequency of the induction sources (low, approximately 500 Hz; high, approximately 1 MHz) allows for simultaneous operation. Incorporating a second high-frequency source, a wire positioned orthogonally to the first, allows for surface imaging along two axes at a resolution of up to 0.1 mm. The improved detection depth of this probe can eliminate the need for metal panels or other pieces to be removed from aircraft for inspection, and the higher-resolution near-surface imaging allows for precise characterization of surface properties.

Aerospace applications for this technology include detection of flaws in air and spacecraft fuselage and wings, as well as inspection of compression interfaces for high contact points. Other possible applications are thickness and surface property characterization in pipes, tanks, and reactors; detection of small particles and impurities in larger structures; and inspection of reactor components, heat exchangers, and piping systems.



A schematic diagram of an AMR sensor-based self-nulling probe.

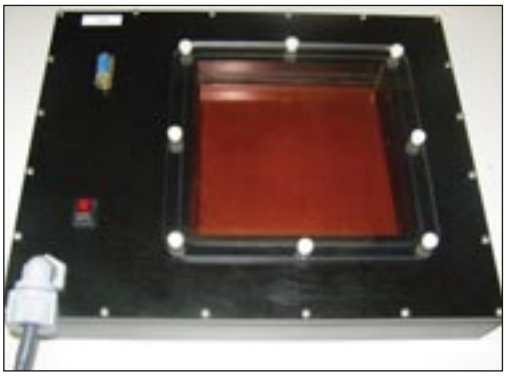
NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-96.

Damage Detection System for Flat Surfaces

This multidimensional system detects damage to surfaces and vessels.

John F. Kennedy Space Center, Florida

NASA's Kennedy Space Center (KSC) seeks to license its Multidimensional Damage Detection System for Flat Surfaces technology. The ability to detect damage to composite surfaces can be crucial, especially when those surfaces are enclosing a sealed environment that sustains human life and/or critical equipment or materials. Minor damage caused by foreign objects can, over time, eventually compromise the structural shell resulting in loss of life and/or destruction of equipment or material. The capability to detect and precisely locate damage to protective surfaces enables technicians to prognosticate the expected lifetime of the composite system, as well as to initiate repairs when needed to prevent catastrophic failure or to extend the service life of the structure.



The damage detection system uses layered composite material made up of two-dimensional, thin-film, damage detection layers separated by thicker nondetection layers.

The Damage Detection System consists of layered composite material, made up of two-dimensional thin-film damage detection layers separated by thicker nondetection layers, coupled with a detection system. The damage detection layers within the composite material are thin films with a conductive grid or striped pattern. The conductive pattern can be applied on a variety of substrates using several different application methods. The number of detection layers in the composite material can be tailored depending on the level of damage detection detail needed for a particular application. When damage occurs to any detection layer, a change in the electrical properties of that layer is detected and reported. Multiple damages can be detected simultaneously, providing real-time detail on the depth and location of the damage.

The truly unique feature of the system is its flexibility. It can be designed to gather as much (or as little) information as needed for a particular application using wireless communication. Individual detection layers can be turned on or off as necessary, and algorithms can be modified to optimize performance. The damage detection system can be used to generate both diagnostic and prognostic information related to the health of layered composite structures, which will be essential if such systems are utilized to protect human life and/or critical equipment and material.

This technology has potential applications in aircraft, military shelters, solar arrays, critical hardware enclosures, spacecraft, space habitats, inflatable structures, and smart garments.

NASA is actively seeking licensees to commercialize this technology. Please contact Lew Parrish at Lewis.M.Parrish@nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/KSC-TOPS-30.

Wireless Sensing System Using Open-Circuit, Electrically Conductive Spiral-Trace Sensor

This low-profile inductance-capacitance sensor is suitable for small packaging.

Langley Research Center, Hampton, Virginia

NASA Langley Research Center researchers have developed a wireless, low-profile sensor that uses a magnetic field response measurement acquisition system to provide power to the sensor and to acquire physical property measurements from it. Unique to this sensor is the shape of the electrical trace that eliminates the need for separate inductance, capacitance, and connection circuitry. This feature gives the sensor a smaller circuit footprint to enable a smaller, flexible, and easy-to-fabricate sensor package. The shape of the electrical trace can be readily modified to sense different physical properties. Also, arranging multiple low-profile sensors together can permit the wireless data acquisition system to read the responses from all the sensors by powering just one of them.

The low-profile sensor is configured with a spiral electrical trace on flexible substrate. In typical inductor designs, the space between traces is designed to minimize parasitic conductance to reduce the impact of the capacitance to neighboring electronics. In this low-profile sensor, however, greater capacitance is desired to allow the operation of an inductor-capacitor circuit. This allows the traces to be closer together, decreasing the overall size of the spiral trace.

The sensor receives a signal from the accompanying magnetic field data acquisition system. Once electrically active, the sensor produces its own harmonic magnetic field as the inductor stores and releases magnetic energy. The antenna of the measurement acquisition system is switched from a transmitting to a receiving mode to acquire the magnetic-field response of the sensor. The magnetic-field response attributes of frequency, amplitude, and bandwidth of the inductor correspond to the physical property states measured by the sensor. The received response is correlated to calibration data to determine the physical property measurement. When multiple sensors are inductively coupled, the data acquisition system needs to activate and read only one sensor to obtain measurement data from all of them.

The wireless sensor enables measurements in areas previously impractical to reach due to wiring constraints, and enables use under corrosive, radioactive, extreme temperature, and other hazardous conditions. It also eliminates the

risk of electrical arcing in explosive conditions.

This technology can be used in automotive, motor sports, and trucking applications to measure tire pressure, tread wear, wheel speed, fuel level, and engine temperature. It can also be used in aerospace applications for landing gear health and fuselage integrity, and in industrial systems to measure foundry kiln temperature and cryogenic liquid level.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-12.

Variable Permeability Magnetometer Systems and Methods for Aerospace Applications

This technology exploits the varying permeability of a magnetic material with ambient magnetic fields.

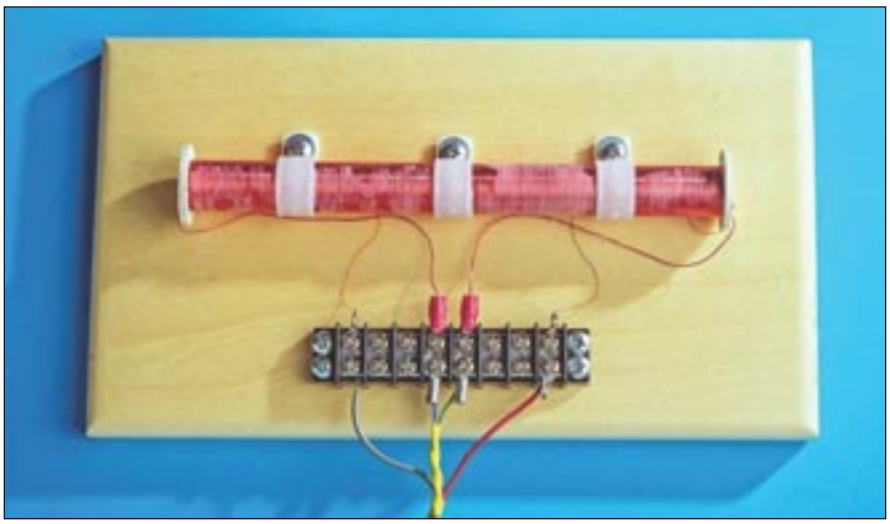
Langley Research Center, Hampton, Virginia

NASA's Langley Research Center has developed a magnetometer that takes advantage of the unique variable permeability properties of Metglas 2714A magnetic material. By measuring directly the inductive reactance of a simple right circular cylindrical search coil through the application of current from a high-output-impedance current source driven with a 10-kHz sinusoidal voltage, a magnetic field sensor having a 700-Hz bandwidth, good linearity, and excellent noise performance with sensitivity at least as good as the 0.1 nTesla range was produced.

The magnetometer consists of a circular cylindrical coil with a magnetic core. It is inherently stable with variations in environmental conditions such as temperature. The simplicity of construction is an advantage over the flux gate design. Circuit stability is achieved through the use of a crystal oscillator for frequency stability and matched resistor networks for amplitude stability in the voltage readout.

This technology can be used in aerospace applications, weather monitoring, EMP detection, magnetosphere research, monitoring Earth's magnetic field, solar system study, and tracking solar flare activity.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-113.



The magnetometer consists of a circular cylindrical coil with a magnetic core.

Methods for Intercalating and Exfoliating Hexagonal Boron Nitride

John H. Glenn Research Center, Cleveland, Ohio

Innovators at NASA's Glenn Research Center have developed a number of materials and methods to optimize the performance of nanomaterials by making them tougher, more resistant, and easier to process. Glenn's scientists are generating critical improvements at all stages of nanomaterial production, from finding new ways to produce nanomaterials, to purifying them to work more effectively with advanced composites, to devising innovative techniques to incorporate them into matrices, veils, and coatings. These advances can be used to deposit protective coatings for textile-based composite materials, layer carbon nanotubes to add reinforcement, upgrade the properties of carbon ceramic matrix composites (CMCs), and integrate nanomaterial fibers into polymer matrix composites (PMCs). The field of nanomaterials is expanding rapidly, and NASA's Glenn Research Center is just as rapidly creating newer and better ways to deploy nanomaterials in industry and research.

In one patented technology, NASA researchers invented a process in which the exfoliation of hexagonal boron nitride (useful as a lubricant and found in substances from cosmetics to pencil lead) is facilitated by converting a set of chemicals into a set of oxide nanoparticles. In another advance, NASA scientists discovered a novel method to purify nanomaterials by dissolving excess reactants and catalysts in a metal chloride salt. Eliminating these residual impurities allows these nanomaterials to be more reliable and predictable, particularly in the production of boron nitride nanomaterials and nanomaterial-based polymer and ceramic composites.

In addition to advances in nanomaterial production, NASA's Glenn Research Center has developed new ways to use nanomaterials in fabrication. One technique involves selectively placing organically modified clays into an aromatic/alkoxy blended resin to create a nanocomposite that has increased strength and stiffness without sacrificing toughness in the cured epoxy. Another patented technology centers on a new method of coating, which uses a cylindrical (or other) array of electrospinning needles to continuously apply a coating of nanofiber material to the surface of a composite precursor material. For those who are interested in ways of upgrading polymer matrix composites (PMCs), Glenn's innovators have invented a method for incorporating fibers into a PMC structure. The applications for nanomaterials are proliferating, and NASA's Glenn Research Center has many new approaches to take advantage of this technology.

Potential applications for these new materials and methods include aircraft, electronics, ultracapacitors, electronic sensors, batteries, windmill blades, textiles, furniture, fuel cells, solar cells, and race track memory for computers.

NASA is actively seeking licensees to commercialize this technology. Please contact the Technology Transfer Office at ttp@grc.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LEW-TOPS-27.

Method for Fabricating Diamond-Dispersed, Fiber-Reinforced Composite Coating on Low-Temperature Sliding Thrust Bearing Interfaces

John H. Glenn Research Center, Cleveland, Ohio

Innovators at NASA's Glenn Research Center have developed a method for fabricating a fiber-reinforced diamond composite coating on the surfaces of sliding thrust bearings at low and cryogenic temperatures. The innovative composite coating is a mixture of diamond particles, organic chemicals, and fibers or fabrics. The diamond particles provide high hardness, and the fibers and binding matrix provide high-fracture toughness. Glenn's fabrication method can be tailored to meet a range of performance requirements for lightweight, low-temperature sliding thrust bearing applications. For example, the volume fraction of diamond particles can be increased to enhance the hardness of the composite coating, or the volume fraction of binding matrix can be increased to enhance its crack or fracture resistance. Glenn's method offers a diamond composite coating that is more cost-effective, wear-resistant, and fracture-tough than existing alternatives.

The technology utilizes existing materials and commercially available equipment, and reduces the time and cost needed for production. Diamond particles are mixed with components of epoxy glue or other polymeric (olygomeric) materials. Fibers and mixture are placed onto metallic, ceramic, polymeric, or composite substrate and compressed under a pressure of less than 100 MPa at room temperature. Heat treatment is then done at ambient pressure and a temperature of less than 200 °C to yield the composite coating or solid parts.

This technology can be used for protective coatings, sliding bearings wear parts, and high-strength tools.

NASA is actively seeking licensees to commercialize this technology. Please contact the Technology Transfer Office at ttp@grc.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LEW-TOPS-65.

Enhanced Composite Damping Through Engineered Interfaces

John H. Glenn Research Center, Cleveland, Ohio

Material damping is important in the design of structures as it limits vibration amplitudes, increases fatigue life, and affects impact resistance. This is particularly true for composite materials, which are currently used extensively in applications that experience frequent dynamic loading. Furthermore, the damping capacity of composites can be significantly greater than that of standard engineering materials. Like other performance parameters of composites (e.g., stiffness, strength, density), the effective damping capacity of composite materials is dependent not only on the damping properties of the constituent materials, but also microstructural details such as fiber volume fraction, fiber orientation, ply stack up, fiber packing array, and weave pattern in woven composites. Therefore, like other performance parameters, composite damping capacity can be engineered.

The objective is to maximize the damping of structural composites while avoiding negatively impacting their mechanical properties. An extreme improvement (10×, and potentially more) in the damping properties of structural fiber-reinforced composite materials can be realized through engineering of the fiber/matrix interface.

The damping properties of unidirectional, laminated, and woven composites have been predicted using a multiscale implementation of the High-Fidelity Generalized Method of Cells (HFGMC) micromechanics theory. This model considers periodic repeating unit cell geometries on both the global and local scales, and utilizes the constituent material specific damping coefficients, mechanical properties, and local fields, along with the strain energy approach, to determine effective directional specific damping coefficients of the composite. In addition to comparisons of the HFGMC predictions with results from the literature, the effect of a degraded fiber/matrix interface was examined parametrically.

The multiscale HFGMC simulations presented in this work illustrate that the decrease in composite mechanical properties caused by such an engineered interface can be minimized when implemented within a technologically relevant laminate, while still maintaining an extreme improvement in the laminate damping properties. Strong maxima in the damping coefficients are present for a quasi-isotropic laminate, rather than simply for the transverse direction in a unidirectional ply. This is the first time that these maxima in the composite damping properties have been discovered, quantified, and analytically demonstrated. This could make possible significant improvements to the damping of real structural composite materials with only a small impact on the mechanical properties. This is important because this type of laminate is used extensively in structural applications, and often, modifications to the composite material can be made that improve the behavior of a ply oriented at 90 degrees, but the effect is washed out by the presence

of the strong and stiff fibers oriented in other directions in the laminate. Key to the present innovation is that the damping improvements persist for a practical laminate, and only result in a small (8.5%) decrease in the mechanical stiffness of a quasi-isotropic laminate.

A triply-periodic HFGMC is first enhanced to enable coupled multiscale analysis, wherein both the local (fiber/matrix/interface constituent) and global (laminate/woven) scales are synergistically linked. The HFGMC method determines the strain concentration tensors, which are used to establish the macroscopic constitutive equations of the composite, and also to provide the local stress and strain fields throughout the composite. This enables the prediction of not only effective composite properties, but also the strain energy distributions (and thus specific damping coefficients) in response to given external loading.

This work was done by Brett Bednarcyk and Steven Arnold of Glenn Research Center, and Jacob Aboudi of Universities Space Research Association. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact ttp@grc.nasa.gov.*** *LEW-19355-1*

Mechanoresponsive Healing Polymers

Polymer strands utilize mechanically responsive chemical groups to induce self-healing.

Langley Research Center, Hampton, Virginia

NASA's Langley Research Center is developing an innovative self-healing resin that automatically reacts to mechanical stimuli. Current structural materials are not self-healing, making it necessary to depend on complicated and potentially destructive repair methods and long down times. Unlike other proposed self-healing materials that use microencapsulated healing agents, this technology utilizes viscoelastic properties from inherent structure properties. The resulting technology is a self-healing material with rapid rates of healing and a wide range of use temperatures.

A prototype space exploration habitat that is susceptible to micrometeoroid damage.

The method chemically introduces mechanically sensitive chemical groups into the structure of a resin. By introducing mechanoresponsive functional groups to a polymer, it is possible to induce self-healing through the transformation of such chemical groups to a point at which the mechanical properties of a structure are almost completely restored. The forces imparted by a damage event can therefore be used to enable healing or repair of the structure.

The technology has healing capability at elevated temperatures, fast healing rates of less than 100 microseconds, and healing without the need of foreign inserts or fillers (via structural chemistry). Potential applications include aircraft, rotorcraft, and spacecraft.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-132.

Methodology for the Effective Stabilization of Tin-Oxide-Based Oxidation/Reduction Catalysts

Langley Research Center, Hampton, Virginia

NASA Langley researchers, in work spanning more than a decade, have developed a portfolio of technologies for low-temperature gas catalysis. Originally developed to support space-based CO_2 lasers, the technology has evolved into an array of performance capabilities and processing approaches, with potential applications ranging from indoor air filtration to automotive catalytic converters and industrial smokestack applications. The technology has been used commercially in systems that provide clean air to racecar drivers, as well as incorporated into commercially available filtration systems for diesel mining equipment. Backed with extensive research on these technologies, NASA welcomes interest in the portfolio for other commercial and industrial applications.

The low-temperature oxidation catalyst technology employs a novel catalyst formulation, termed platinized tin oxide (Pt/SnO_x). The catalysts can be used on silica gel and cordierite catalyst supports, and the latest developments provide sprayable formulations for use on a range of support types and shapes. Originally developed for removal of CO, the catalyst has also proven effective for removal of formaldehyde and other lightweight hydrocarbons.

NASA researchers have also extended the capability to include reduction of NO_x, and have developed advanced chemistries

that stabilized the catalyst for automotive catalytic converters via the engineered addition of other functional components. These catalyst formulations operate at elevated temperatures and have performed above the EPA exhaust standards for well beyond 25,000 miles. In addition, the catalyst can be used in diesel engines because of its ability to operate over an increased temperature range. For use as a gas sensor, the technology takes advantage of the exothermic nature of the catalytic reaction to detect formaldehyde, CO, or hydrocarbons, with the heat being produced proportional to the amount of analyte present.

Potential applications include automotive exhaust catalytic converters, industrial process control, smokestack emission remediation, indoor air treatment, cabin air treatment, contained breathing systems, and diesel-operated machinery.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-124.

Polymer-Reinforced, Non-Brittle, Lightweight Cryogenic Insulation for Reduced Lifecycle Costs

John F. Kennedy Space Center, Florida

The objective of this project was to develop inexpensive structural cryogenic insulation foam that has increased impact resistance for launch and ground-based cryogenic systems. Two parallel approaches were used: a silica-polymer co-foaming technique and a post-foam coating technique. Structures were fabricated using both techniques to formulate insulation for the specified applications. The insulation will survive in space and terrestrial environments, provide a good moisture barrier, and exhibit thermal insulation properties.

The cryogenic insulation was developed to meet NASA's need to reduce fuel losses through boil-off, minimize materials and costs, and increase mission duration for both ground and on-orbit applications. InnoSense LLC's (ISL) organically modified silicate technology was used to formulate cryogenic insulating foams (CryoPore) with superior performance over the baseline polyurethane (PU) foams used by NASA.

Tests demonstrated that aerogel-impregnated polyurethane foams improved the insulative and hydrophobic properties of the baseline (PU) foams. The CryoPore foams also exhibit good flexibility, and are pourable and sprayable. Additionally, it was demonstrated that halogen-free flame retardants can be easily integrated into the foams. The CryoPore foams offer a moldable insulation that is lightweight and can be applied to aluminum tank substrates. Another blowing agent was identified that produces carbon dioxide to further reduce foam density. These primarily closed cell foams reduce the base foam density by about 1/3 for aerogel-impregnated foams, and offer improved insulating capabilities at cryogenic temperatures.

ISL accomplished the following: fine-tuned foam formulations resulting in coherent, low-density foams of closed-cell and fine-cell structure; developed a two-part pourable foam formulation applicable to a variety of substrates; improved the thermal properties of the foam by adding aerogel to the base PU foam; demonstrated that non-halogenated, flame-retardant additives improve flame-retardant properties without hindering foam formation; and conducted tests on the foam samples at cryogenic temperatures (20 K) under vacuum.

The cryogenic insulation will be conformable to almost any shape, and will be usable with cryogenic gases like oxygen, nitrogen, and hydrogen. NASA applications include insulation for earthbound and in-flight cryogenic transfer lines, pumps, storage tanks, and vessels; in-flight fuel tanks; and modular structures. Ground and launch operations currently make up 45-60% of total costs.

This work was done by David Hess of InnoSense LLC for Kennedy Space Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact KSC-DL-TechnologyTransfer@mail.nasa.gov.*** *KSC-13852.*

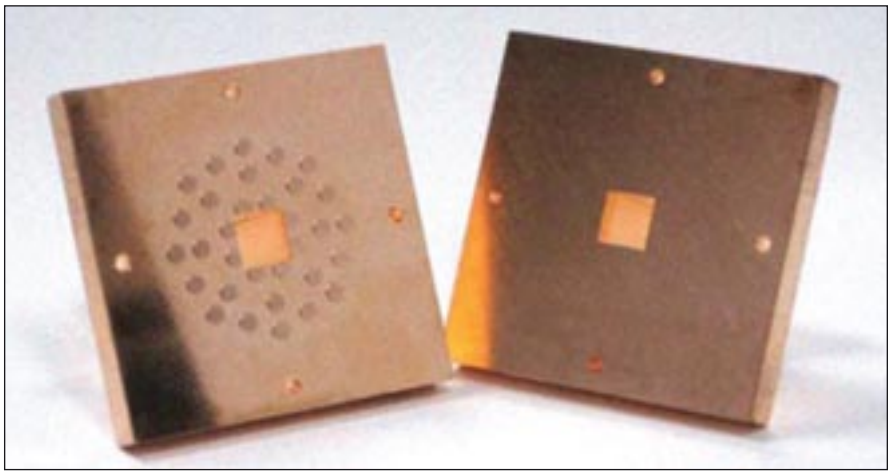
Optics

Photonic Choke-Joints for Dual-Polarization Waveguides

The joint is constructed from a conductive metal, and requires no maintenance or peripheral equipment to operate.

Goddard Space Flight Center, Greenbelt, Maryland

Photonic choke-joint (PCJ) structures for dual-polarization waveguides have been investigated at NASA's Goddard Space Flight Center for use in device and component packaging. This interface enables the realization of a high-performance, non-contacting waveguide joint without degrading the in-band signal propagation properties. The choke properties of two tiling approaches — symmetric square Cartesian and octagonal quasi-crystal lattices of metallic posts — are explored and optimal PCJ design parameters are presented. For each of these schemes, the experimental results for structures with finite tilings demonstrate near ideal transmission and reflection performance over a full waveguide band.



The fabricated waveguide flanges with octagonal tiling photonic choke-joint.

A waveguide joint is the location where two waveguides are connected to produce a reliable contact between them. In general, two waveguides must be accurately aligned and have good electrical contact at the joint. This can be done by having two waveguide flanges with flat surfaces physically contact each other.

The purpose of this innovation is to produce a reliable, highly efficient, and non-contact joint for waveguides with dual polarizations. The dual-mode waveguide interface is comprised of two flanges. One waveguide flange is a flat surface perpendicular to the waveguide wall. The other flange is made of rows of metallic pillars tiled in either Cartesian or Archimedean patterns. The spacing between two flanges has to be lower than a certain value to ensure low-loss and spurious-free power transmission in the operating band. Since the waveguide photonic choke-joint is constructed from metallic conductor, it can be operated at a wide temperature range without much degradation in its performance. It provides power leakage of less than 3% and is suitable for low-power waveguide applications. The PCJ is constructed from a conductive metal and requires no maintenance or peripheral equipment to operate.

This technology can be used for thermal breaks for telecommunication equipment and instruments; non-destructive testing for thin materials; waveguide switches, phase shifters, and rotating feed networks; and to provide housing for planar circuits to increase functionality of the waveguide.

NASA is actively seeking licensees to commercialize this technology. Please contact the Strategic Partnerships Office at techtransfer@gsfc.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/GSC-TOPS-24.

Smart Optical Material Characterization System and Method

This technology creates a flexible, unified platform for dynamic smart optical material evaluation.

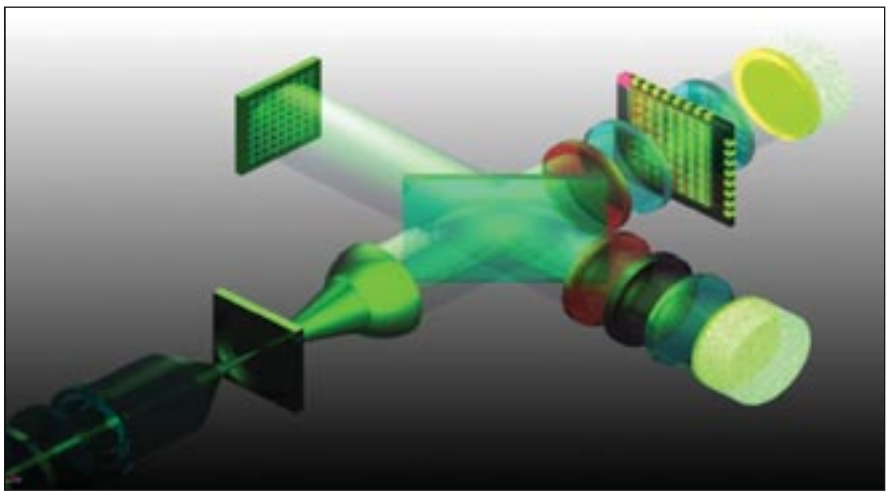
Langley Research Center, Hampton, Virginia

NASA's Langley Research Center has developed an adaptable and powerful interferometric test platform that uniquely enables multi-parameter evaluation of a wide variety of smart optical materials (SOM). The patent-pending SOM characterization system was created to measure the dynamic optical response of stimuli-responsive ("smart") optical materials while external physical/electrical/thermal/chemical/pressure/magneto stimuli are applied to the material. Using novel interferometric fringe analysis software and a multi-stimuli-capable SOM test cell, the SOM characterization system enables a wide variety of materials — such as liquid crystals, nonlinear crystals, electro- and thermo-active polymer optics, and magneto- or piezo-driven optics — to be optically characterized for real-time changes in intensity, phase, and polarization. The versatility of the SOM test platform combined with the powerful, efficient, and user-friendly software interface makes it a valuable tool for the research or commercial development of smart materials.

Using a Michelson interferometer platform and a single, custom SOM test cell capable of providing multiple types of external stimuli, the characterization sys-

tem software dynamically controls stimuli (e.g. physical, electrical, thermal, magneto, or chemical) to the SOM under test and then measures the resulting changes in intensity, phase angle, polarization state, and coherence of the transmitted or reflected light. The accompanying software records and analyzes the dynamic change of interference patterns on multiple pixels in a time sequence as the stimuli are applied, and presents a phase/intensity time ripple map for the SOM under test. The SOM characterization system provides variable (milliseconds to hours) acquisition rates for multipoint, full-aperture measurements.

The system supports evaluation of up to 10 key optical parameters from a single interferometric data set. These can include index of refraction, optical intensity, phase, and polarization. Dynamic SOM test cell control is combined with interferometric fringe analysis and data visualizations through a page-driven menu. The system provides a flexible yet material-specific test platform for evaluating smart optical materials. Using a common optical platform and multi-stimuli test cell, the system provides full-aperture (20-50 mm), full-transmitted, or reflected-wavefront measurements.



The smart optical material characterization system.

Applications include nonlinear and liquid crystal switching and waveguide device testing for telecommunications; liquid crystal materials, 2D pixel arrays, and device testing for 2D/3D displays; active and adaptive materials and component evaluation for precision and adaptive optics; and evaluation of the stimuli-responsive materials used in sensors and detectors.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-94.

Compact Planar Microwave Blocking Filters

Goddard Space Flight Center, Greenbelt, Maryland

Innovators at NASA's Goddard Space Flight Center have designed, fabricated, and characterized absorptive thermal blocking filters for cryogenic microwave applications. The device allows direct integration of the high-frequency signal and microwave readout, and mitigates spurious resonances in the circuit response. This leads to improved electrical performance and a reduction in the required circuit area. The transmission line filter's input characteristic impedance is designed to match 50 ohms and its response has been validated from 0 to 50 GHz. The observed return loss in the 0 to 20 GHz design band is greater than 20 dB and shows graceful degradation with frequency. The filter's response is calculable, repeatable under cryogenic cycling, and is capable of providing an intrinsically broadband matched impedance termination.

The prior art offers a variety of thermal blocking filter construction techniques and designs. In the device's most basic form, a large shunt capacitor forms a single-pole low-pass filter. More generally, multiple low-pass lumped element stages can be combined in series to produce compact and broadband non-dissipative filter structures. The challenges presented by these implementations include controlling interstage isolation and spurious transmission resonances, limiting the filter's total shunt capacitance, and achieving adequate control over circuit parameters as a function of temperature.

In this work, simple matched filter designs based on easily realized absorptive dielectric transmission lines are improved upon to create absorptive thermal blocking filters for cryogenic microwave applications. This technology is generally applicable in the realm of high-frequency circuits, is scalable, and can be modified for use in other applications. It can be used in wide ranges of applications. Its intended use is as an element of a superconducting planar spectrometer for astrophysics applications at NASA's Goddard Space Flight Center. More generally, the meta-material choke could find use in any microwave or sub-millimeter circuit application where high isolation is required between differing frequencies for signal, readout, bias, and so on.

NASA is actively seeking licensees to commercialize this technology. Please contact the Strategic Partnerships Office at techtransfer@gsfc.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/GSC-TOPS-65.

System and Method for Generating a Frequency-Modulated Linear Laser Waveform

Applications include manufacturing equipment, robotics, surveillance and security, military imaging, and spectroscopy.

Langley Research Center, Hampton, Virginia

NASA's Langley Research Center has made a breakthrough improvement in laser frequency modulation. Frequency modulation technology has been used for surface mapping and measurement in sonar, radar, and time-of-flight laser technologies for decades. Although adequate, the accuracy of distance measurements made by these technologies can be improved by using a high-frequency triangular-waveform laser instead of a sine waveform or lower-frequency radio or microwaves. This new system generates a triangular modulation waveform with improved linearity that makes possible precision laser radar (light detection and ranging [lidar]) for a variety of applications.

For decades, frequency modulation has been used to generate chirps, the signals produced and interpreted by sonar and radar systems. Traditionally, a radio or microwave signal is transmitted toward the target and reflected back to a detector, which records the time elapsed and calculates the target's distance. Reflected signals can be heterodyned (combined) with output signals to determine the Doppler frequency shift and the target velocity. Accuracy of these systems can be enhanced by increasing the bandwidth of the chirp, but noise generated during heterodyning at high frequencies decreases the signal-to-noise ratio, increasing measurement error.

Previous attempts at laser frequency modulation that relied on adjusting the laser cavity length have resulted in only sine wave or imperfect triangle waveforms. Heterodyning of imperfect, nonlinear waveforms or sine waveforms will significantly degrade the effective signal-to-noise ratio, making such systems impractical. In contrast, the current technology produces a single, high-frequency laser that is passed to an electro-optical modulator, which generates a series of harmonics. This range of frequencies is then passed through a band-pass optical filter so the desired harmonic frequency can be isolated and directed toward the target. By modulating the electrical signal applied to the electro-optical modulator, a near-perfect triangular waveform laser beam can be produced. Transmission and detection of this highly linear triangular waveform facilitates optical heterodyning for the calculation of precise frequency and phase shifts between the output and reflected signals with a high signal-to-noise ratio. By combining this information with the time elapsed, the location and velocity of the target can be determined to within 1 mm or 1 mm/s.

Users have the ability to measure air velocity, ground velocity, target distance and velocity, aircraft altitude, angle of attack, and atmospheric wind vector in one system. It is more accurate and reliable than current pitot-tube aircraft instrumentation that can ice up and requires frequent calibration. In addition, there is an order-of-magnitude improvement in accuracy over time-of-flight laser pulse systems, and multiple orders of magnitude improvement as compared to radar systems for distance and velocity measurements.

Potential applications include spacecraft landing and docking; planet topography measurement; precision alignment of

A coherent Doppler lidar developed for planetary landing applications utilizing a linear frequency-modulation technique.

large structures in manufacturing and construction; movement accuracy and maneuverability in confined spaces for robotics; replacement of pitot-static instrumentation systems for air velocity, ground velocity, altitude, and attitude measurements; target ranging and 3D visualization of structures and surfaces in aerospace systems; movement detection and target visualization for surveillance and security; ground and target imaging for military systems; and molecule identification for spectroscopy.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-95.

Systems and Methods for Mirror Mounting with Minimized Distortion

Goddard Space Flight Center, Greenbelt, Maryland

The use of larger, lighter, and more precise space optics requires not only a means of manufacture, but also a means of spacecraft integration and performance verification. Engineers at NASA's Goddard Space Flight Center (GSFC) have demonstrated a process capable of producing a high-precision, mounted, lightweight mirror, and have validated its on-orbit figure. This effort included the design of a mount capable of surviving the launch environment of a sounding rocket, as well as a mounting process that did not introduce performance-degrading figure distortion. Additionally, analysis techniques were developed and adapted to address the challenges in measuring an optic that exceeds its figure specification under the strain of its own weight.

The mirror mount and associated mirror mounting process enables ultra-lightweight high-precision mirrors to be mounted without distortions exceeding length scales of several nanometers (root-mean-squared, over the optical aperture); provides an on-orbit, or zero-gravity, mirror surface figure verification capability in the presence of much larger self-weight gravity distortions; and is proven to both mechanically survive a launch environment and optically maintain mirror surface figure.

This hardware design and mounting method are particularly innovative because they enable the in situ measurement of nanometer-sized, zero-g mirror figure distortions in the presence of large gravity-induced mirror distortions. Furthermore, the hardware and test results allow for the iterative analysis, isolation, and correction of any induced mirror distortions due to the mounting process before the mount is irreversibly locked. The core of this innovation is the means of integrating mount design, support hardware capabilities, modeling and analysis, and in situ optical testing.

A high-precision, ultra-lightweight 0.5-m mirror with ultraviolet grade tolerances on surface figure quality has been measured through the coating and mounting process, and shown to survive component vibration testing. This 4.5-kg, 0.5-m paraboloid mirror is the prime optic of two sounding-rocket telescopes: SHARPI (Solar High Angular Resolution Photometric Imager) and PICTURE (Planet Imaging Concept Testbed Using a Rocket Experiment). By integrating the analysis of interferometer data with finite element models, the ability to isolate surface figure effects comparable to UV diffraction limited tolerances from much larger gravity and mount distortions was demonstrated. Being able to measure such features, paired with in-situ monitoring of mirror figure through the mirror mounting process, has allowed for a diagnosis of perturbations and the remediation of process errors. Nanometer-scale measurement accuracy was achieved, and the final mounted surface figure was 12.5 nm RMS, maintaining UV diffraction-limited performance with an aggressively lightweight mirror.

The in situ test approach, mount concept, and methodology enable the verifiable distortion-free mounting of lightweight optics in a manner compatible with spaceflight. This is particularly applicable to the production of any system that employs precision lightweight optics that must withstand a harsh launch environment, then operate in a zero-gravity environment. This includes, but is not limited to, earth-observing systems, optics used in space exploration, and spaceborne astronomical observatories.

NASA is actively seeking licensees to commercialize this technology. Please contact the Strategic Partnerships Office at techtransfer@gsfc.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/GSC-TOPS-74.

Improved Approach to Exoplanet Coronagraphy

Goddard Space Flight Center, Greenbelt, Maryland

Visible nulling coronagraphy and interferometry requires that the wavefront errors be held to unprecedented precision in the presence of environmental disturbances. A Null Diversity algorithm is used to first attain the precision, but it does not execute at high enough temporal bandwidth to hold the precision for long periods of time (hours). The environmental changes, mostly vibration and jitter with some thermal drift, can be rapidly varying and thus require a fast control algorithm. To perform rapid control, an algorithm, based upon a series of approximations, has been developed and simulated at NASA Goddard Space Flight Center for the sensing and control, in closed loop, of extremely precise wavefront errors in an interferometer. It operates over the range of ~5 nanometers rms down to <100 picometers rms in closed loop at high bandwidth (~20 Hz) and is used to hold (i.e. maintain) the requisite wavefront error.

Potential applications include any type of coronagraph or interferometer with two or more output channels; and ultra-high precision testing for optics, defense, lithography, and other commercial applications.

NASA is actively seeking licensees to commercialize this technology. Please contact the Strategic Partnerships Office at techtransfer@gsfc.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/GSC-TOPS-47.

Apparatus and Method for a Light Direction Sensor

Goddard Space Flight Center, Greenbelt, Maryland

This invention, developed at NASA's Goddard Space Flight Center, was originally conceived as a high-accuracy, high-sensitivity, bi-axial Sun angle sensor, but has also been proposed for applications involving the general field of precisely measuring the direction in which light travels toward the sensor. It has applications in spacecraft navigation, formation flying in space, space beacons, and automotive collision avoidance.

The sensor is based on a carefully patterned Cartesian mask, an area array image sensor, and a very robust, proven image processing algorithm, and has dramatic advantages over conventional Sun sensors. In the new sensor, a perforated mask containing a grid of slit segments arranged in a Cartesian fashion is placed just in front of a radiation-hard image sensor having familiar rows and columns of pixels, with some gap between the mask and the image sensor. There are a nearly infinite number of different patterns of slit segments from which advantage can be gained, depending on requirements of a given sensor application. When illuminated by a beam of light, each slit segment creates its own single slit, Fresnel or Fruanhofer diffraction pattern, or simply a shadow of itself on the image sensor. Slit segments are arranged such that the patterns they produce on the image sensor do not influence each other.

The sensor applies, generally, to any light source (not just the Sun). For example, it applies equally well with the Moon. The layout details of mask features, the selection of an image sensor, and the arrangement of the mask with respect to the image sensor are all tailorable to numerous other light direction sensing applications. This would include applications such as measuring

the vector direction connecting any two objects, for example from one spacecraft having a beacon light source mounted to it to another having the disclosed sensor mounted to it, or for determining the direction of travel of an automobile whose headlights are turned on traveling toward another which possesses this light direction sensor.

NASA is actively seeking licensees to commercialize this technology. Please contact the Strategic Partnerships Office at techtransfer@gsfc.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/GSC-TOPS-84.

Apparatus and Method for Creating a Photonic Densely Accumulated Ray-Point

Langley Research Center, Hampton, Virginia

NASA's Langley Research Center has discovered a new approach to achieving a laser focal point size much smaller than the wavelength of light used, and smaller than that obtained using conventional micro zone plate lenses. The Photonic Densely Accumulated Ray-poinT (DART) technology relies on phase contrast along with interference phenomena, with or without the use of a micro zone plate lens. Coupled with the extremely small spot size, the technology also provides very high laser energy density at the pseudo focal point surrounded by destructive interference, thereby enabling a range of potential useful applications such as laser processing, lithography, nanofabrication, and optical data storage.

The NASA Photonic DART technology relies on two key aspects, one being the discovery of a new constructing interference point with an extremely fine pseudo focal point surrounded by destructive interference. A novel phase contrast method is used to achieve the constructive/destructive interference. While typical micro zone plates can be used to take advantage of the newly discovered focal point, they are not necessary; a phase contrast lens can also be used. This phase contrast method is similar in effect to the micro zone plate in the creation of constructive/destructive interference, but takes advantage of phase contrast obtained through novel 3D designs beyond the fixed binary micro zone plate design. The newly discovered central focal point in the Photonic DART technology is sharpened by the surrounding destructive interference rings present at the non-conventional focal point. The phase contrast phenomenon essentially removes the tail of the Gaussian energy distribution across the focal spot.

The ultra-small laser pseudo focal point is significantly smaller in size than the wavelength of the light used. An extremely high-intensity beam means that power density of beyond a few MW/cm^2 is achievable even with a typical low-power laser.

The Photonic DART technology has potential applications in high-resolution optical lithography, high-density optical and X-ray data storage, nanofabrication, optical nano tweezers, nano-controlled physical and chemical reactions, optical manipulation of molecules and nanostructures, and scientific research.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-60.

High-Quality Tissue Formation Method

This technology could be used in research and development, pharmaceutical development, regenerative medicine, and drug screening and testing.

Lyndon B. Johnson Space Center, Houston, Texas

NASA's Johnson Space Center seeks interested parties for the commercialization of the High Density Spot Seeding (HDSS) method to create 2D and 3D tissue models. This method can potentially be used to develop tissue models for a variety of applications, including wound treatment, therapy, and tissue modeling of skeletal muscle, cardiac muscle, nerve, and bone. The HDSS technique has an easy four-step method that does not require expensive reagents, such as specialized serum or growth factors, and compared to traditional methods, HDSS has the potential to yield superior-quality tissue samples.

The HDSS technique can potentially facilitate tissue patching or wound repair in the regenerative medicine field.

This technology is a simple, reproducible, and cost-effective process that creates 2D and 3D human tissue formations. The method entails the spot seeding of cells at a specific concentration onto a Petri dish, but without the need of extracellular matrix components. Cells are then incubated to allow attachment. The culture is rinsed with a medium to remove unattached cells, and a growth medium is added to enable the cells at the periphery of the spot to proliferate and differentiate outward from the center cells. This pattern of growth results in a 2D model of dense, organized, mature cells. It is proposed that the 2D formations can be stacked one on another via a lamination process to create 3D tissues.

By forming tissue using this method, the technology enables the creation of unique models for research and development, pharmaceutical development, and perhaps even regenerative medicine. For instance, for basic research and development, the study of mechanistic pathways involved in normal and/or diseased tissue becomes possible. This technology can also be used as an in-vitro tissue model for drug screening and toxicology testing in the pharmaceutical development field. The HDSS method may be advantageous for high-throughput screening assays, where a large volume of screenings is done simultaneously.

NASA is actively seeking licensees to commercialize this technology. Please contact Michelle P. Lewis at jsc-techtran@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/MSC-24314-2.

Filtering Molecules with Nanotube Technology

Lyndon B. Johnson Space Center, Houston, Texas

Innovators at NASA's Johnson Space Center have developed a filtration device to eliminate contaminants from water supplies. Originally developed to purify wastewater for reuse aboard the International Space Station, the innovation is applicable to numerous situations on Earth where there is a need to collect potable, medical-grade water from a contaminated water supply. The unique aspect of the technology is its use of acoustics, rather than pressure, to drive water through small-diameter carbon nanotubes. The invention requires less power than conventional filtration systems, and is well-suited to a variety of water processing needs.

This water filtration innovation is an acoustically driven molecular sieve embedded with small-diameter carbon nanotubes. First, water enters the device and contacts the filter matrix, which can be made of polymer, ceramic, or metallic compounds. Carbon nanotubes within the matrix allow only water molecules to pass through, leaving behind any larger molecules and contaminants.

An oscillator circuit attached to the filter matrix propagates acoustic vibration, further causing water molecules to de-bond and move through the filter. This use of acoustics also eliminates dependence on gravity (and thus filter orientation) to move water through the device. When water exiting the system diminishes to a pre-determined set point, a cleaning cycle is triggered to clear the sediment from the inlet of the filter, reestablishing the standard system flow rate. Unlike other filtration systems, flushing of the filter system is not required. The combination of acoustics and small-diameter carbon nanotubes in this innovation make it an effective and efficient means of producing contaminant-free, clean water.

Potential applications include municipal water facilities, medical facilities, laboratories, distilleries, ultrapure water filtration for a semiconductor fabrication facility, desalination plants, wastewater treatment facilities, and consumer markets.

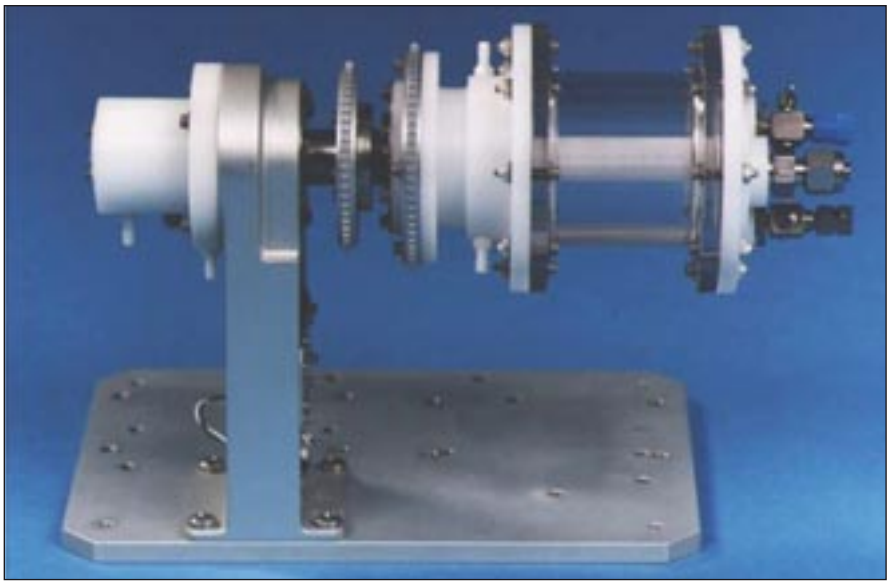
NASA is actively seeking licensees to commercialize this technology. Please contact Michelle P. Lewis at jsc-techtran@mail.nasa.gov to initiate licensing discussions.

3D Biomimetic Platform

This technology can be used for cell culture and drug discovery.

Langley Research Center, Hampton, Virginia

NASA's Langley Research Center has developed a method and apparatus to be used for cell culture that combines the effects of microgravity and low-dose radiation. The technology has been developed to simulate the effects of microgravity and chronic radiation exposure to cell culture experiments conducted on the International Space Station (ISS).



The microgravity bioreactor closely mimics the ISS environment.

Recent experiments conducted aboard the ISS have led to the rapid development of vaccine candidates for infectious diseases, including MRSA and salmonella. This is due to activation of biological pathways and expression of biomarkers indicative of enhanced virulence that are not normally observed in terrestrial environments. The technology integrates a radiation source with a microgravity-simulating rotating-wall vessel for cell cultures to express enhanced virulence or otherwise unexpressed biological pathways that could potentially assist in drug development efforts. The invention more closely mimics the ISS environment than microgravity bioreactors that are currently commercially available.

NASA is actively seeking licensees to commercialize this technology. Please contact The Technology Gateway at LARC-DL-technologygateway@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/LAR-TOPS-199.

Automated Behavior and Cohesion Assessment Tools (ABCAT)

Lyndon B. Johnson Space Center, Houston, Texas

An important consideration of long-duration spaceflight operations is interpersonal dynamics that affect crew cohesion and performance. Flight surgeons have stated the need for unobtrusive monitoring to help detect if crews are having difficulties coping with long-duration spaceflight environments.

NASA has tens of thousands of procedures for the International Space Station, and any new flight vehicles or habitats will also rely heavily on automation and have thousands of procedures. While procedures are, at the time of this reporting, authored in Microsoft Word, NASA is planning to use an XML representation of procedures that facilitates automatic translation. Nominal performance metrics can be determined during training and then compared during the actual missions. Deviations between the nominal and current performance can be flagged for additional attention. Since crewmembers can perform upwards of hundreds of procedures a week, there will be substantial data with which to assess crew behavioral performance. Social interactions are also a significant factor in team cohesion and performance that can be compared against social metric norms using Sociometric Badges and communications (spoken and text) analysis.

The long-term goal of this project is to develop a set of applied technologies that can monitor crew health and cohesiveness in an unobtrusive manner, and identify potential abnormalities for feedback to astronauts and flight surgeons for further investigation. A set of recommendations was developed regarding technologies and techniques to accomplish these. The conceptual design of an ABCAT system was developed that implements those recommendations.

The ABCAT approach is an innovative design that integrates commercial off-the-shelf (COTS) data acquisition technologies with specially designed, NASA-specific data acquisition software modules. It then cleans, integrates, and fuses the data through a two-staged processing architecture to create principled models of crew cohesiveness, performance, and mental state.

The military has teams of individuals working in high-stress environments over long durations. Examples include submarine crews, aircraft carriers, embedded special operations forces, and

ground-based pilots flying unmanned air vehicles for hours at a time. The ABCAT approach could transfer to military applications. A variety of commercial activities also have similar characteristics to NASA missions. Air traffic controllers work in a high-stress environment where small mistakes can be costly. Likewise, teams of operators control nuclear power plants, petrochemical plants, oil refineries, etc. They often perform standard operating procedures and need to be monitored closely for degraded performance. Even in situations in which lives or property are not at risk, monitoring and detecting problems with individual and team performance is useful for managers interested in achieving peak performance. Further possibilities include competitive sports teams in which team cohesiveness and performance are significant concerns.

This work was done by Marcus Huber of Cybernet Systems, David Kortenkamp of TRACLabs, Eduardo Salas of the University of Central Florida, and Daniel Olguin of MIT for Johnson Space Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact jsc-techtran@mail.nasa.gov.*** *MSC-25508-1*

Algorithm Measures Range of Motion and Applies Eccentric and Concentric Loads During Exercise

John H. Glenn Research Center, Cleveland, Ohio

Microprocessor-controlled exercise equipment that uses a servomotor has the capability to adjust the applied resistive load based on position, velocity, and acceleration. One method of applying the resistive load consists of applying a greater load during the eccentric phase of the exercise motion (muscles actively lengthening) than during the concentric phase of the motion (muscles actively shortening). This technique, called eccentric overloading, can improve the benefits of a strength training session significantly. Although the exercise device can alternate between concentric and eccentric loading based solely on the direction of the bar movement, this is undesirable for several reasons. First, when the velocity is close to zero, the system would rapidly switch between the eccentric and concentric loads. Second, if the exerciser is unable to complete a lift with the concentric load and wishes to lower the bar, the system would apply the high eccentric load, which is highly undesirable. Thus, it is necessary for the system to know the limits of the movement (range of motion, ROM) so that the system can identify when the user has completed the lift and the eccentric load can be properly applied.

Furthermore, it is desirable that the system only applies the resistive load when the exerciser has the bar within the exercise ROM, and applies a minimal base load when the user picks up the bar from the start position. For example, if the exerciser performs bicep curls with 100 pounds, then it would be ergonomically undesirable to require the exerciser to pick up the bar from ground level with 100 pounds applied. It would be greatly advantageous if the system applies a much lower force of, say, 20 pounds while the exerciser picks up the bar, and then applies the full 100 pounds only while the user is performing the bicep curls.

For these reasons, the system needs to adjust to the exerciser's ROM and have the capability of engaging and disengaging the load based on the exerciser's interaction with the bar. In order to maximize the user's experience and to minimize the time spent adjusting the equipment, it is beneficial if the ROM is measured automatically, and if the user can engage and disengage the resistive load with minimal interactions with a user interface. Fully automated exercise microprocessor-based equipment is not currently in use, and the control algorithms for such exercise devices have not yet been developed.

The algorithm developed in this work allows a system to automatically measure an exerciser's ROM and apply the desired eccentric and concentric forces while exercises are performed. The exerciser is able to engage and disengage the resistive load while maintaining the proper exercise position, and without the need to interact with a user interface.

The algorithm does not apply the eccentric load if the user does not complete the concentric lift for safety reasons, and it only applies the load within the ROM. The user only has to hold the bar steady for a number of seconds and the load will be released. The user can then "pick up" the load again by lowering the bar and raising it again. These intuitive methods for engaging and disengaging the resistive forces save time and decrease the chance of injuries.

This work was done by Douwe Bruinsma of TDA Research, Inc. for Glenn Research Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact http://technology.grc.nasa.gov.*** *LEW-19343-1*

Generalized Query Tool for Accessing the Database of the Mars Relay Operations Service (MaROS)

NASA's Jet Propulsion Laboratory, Pasadena, California

The Generalized Query Tool for accessing the database of MaROS can be utilized in three modes: (1) batch mode where a user's authentication data is inserted directly along with a desired query to the database, (2) interactive mode where a desired query is known and can be entered directly, and (3) interactive mode with a query "wizard" that walks a user through the steps needed to construct a valid query to the database. In all three cases, the successful execution of the script results in data from the MaROS database being made available to the user in a comma-separated output file. For new users, it is recommended to use the third mode to build a sample query and then tailor that as desired for use with the first or second modes.

MaROS is used to coordinate relay activities across the Mars Relay Network in support of the transference of science and engineering data to and from the surface of Mars via Mars orbiting assets, and for the publication of related accountability data. Before the creation of this script, there was no generalized solution to access the MaROS database except via the MaROS Web browser application.

The script is written in Python, and requires at least Python version 1.5. The script is to be typically run on Solaris or Linux systems, and provides a means for automated processes to regularly query the database for needed data using the first mode, as described above.

In addition to being utilized by the current missions participating in the Mars Relay Network — namely, the Mars 2001 Odyssey orbiter; ESA's Mars Express Orbiter; the Mars Exploration Rover, Opportunity; the Mars Reconnaissance Orbiter; and the Mars Science Laboratory, Curiosity — the script will be valuable to future missions, including InSight, ESA's ExoMars-TGO, ExoMars-EDM, ExoMars-2018 Lander/Rover, and NASA's Mars 2020 Rover.

This work was done by Roy E. Gladden and Franklin H. Hy of Caltech for NASA's Jet Propulsion Laboratory. ***This software is available for license through the Jet Propulsion Laboratory, and you may request a license at: https://download.jpl.nasa.gov/ops/request/request_introduction.cfm.*** *NPO-49813*

High-Performance Fault-Tolerant xEmbedded Computing (HPFEC) Benchmark Suite

NASA's Jet Propulsion Laboratory, Pasadena, California

This work arises out of the Next Generation Space Processor (NGSP) project, a collaborative effort among several NASA centers and the Air Force Research Laboratory. The goal of NGSP is to develop the next generation of radiation-hardened, fault-tolerant, space-worthy computing systems consisting of hardware and system software. To drive and evaluate the design, each of the NGSP collaborators contributed benchmarks. This article describes the benchmarks developed at the Jet Propulsion Laboratory (JPL). Collectively, these benchmarks are called the High-Performance Fault-Tolerant Embedded Computing (HPFEC) benchmark suite.

The HPFEC suite consists of four synthetic applications divided into 29 components. The synthetic applications are (1) real-time guidance, navigation, and control; (2) automatic scheduling and planning; (3) identification of closed shapes in an image; and (4) classification of features in an image according to their size, shape, surface reflectance, and texture. In developing these benchmarks, JPL adopted the following approach:

1. Study current and anticipated future applications that JPL develops or supports.
2. Extract key algorithm components from the applications. Emphasize capabilities that are beyond the capabilities of current flight systems, but that become feasible in an NGSP system.
3. Combine the components into synthetic applications, specifying both computation and dataflow.
4. Provide specifications of the components and of the synthetic applications. Leave the implementation details unspecified, so that a system designer can implement the benchmark specification in the best way for the target platform.
5. Provide reference implementations that illustrate the input, computation, and output.
6. Provide instructions on what to implement, run, measure, and report.

The HPFEC benchmark suite has the following key features:

- It provides synthetic applications that test the interaction of several compute kernels in a realistic setting.
- It provides a library of components that may be combined into new applications.
- It covers sequential, parallel, distributed, and real-time performance.
- It covers power management and fault tolerance, including injection of faults to simulate system failure.
- It specifies conditions for evaluating the behavior of an application when run to stress-induced failure.

The benchmarks are useful to anyone evaluating an embedded system.

This work was done by John Y. Lai, Robert L. Bocchino, Timothy K. Canham, Chris Flatley, Kim P. Gostelow, Raphael R. Some, David A. Rennels, Hans P. Zima, and William D. Whitaker of NASA's Jet Propulsion Laboratory. ***This software is available for license through the Jet Propulsion Laboratory, and you may request a license at: https://download.jpl.nasa.gov/ops/request/request_introduction.cfm.*** *NPO-49492*

JPF-NAS Extension of Java Pathfinder

Ames Research Center, Moffett Field, California

Java PathFinder (JPF) version 7 provides basic support for verifying the distributed Java applications. It can receive a distributed Java application as input that is perceived as multiple Java processes. However, JPF does account for communication between processes of the distributed application, and it thus cannot be used to verify any realistic distributed Java application. Applying JPF on distributed applications requires a model of inter-process communication (IPC) and process aware scheduling.

Model-checking distributed applications is nontrivial. Most existing model checkers can only be applied to single-process applications. One of the proposed techniques to model-check distributed Java applications is centralization, which maps separate processes of a distributed system into threads that are all executed by one process. Since every Java process provides a self-contained execution environment including an exclusive set of basic runtime resources, by applying centralization, parts that represent different processes share the same resources. In order to preserve the behavior of the original distributed system, one needs to ensure proper separation of types in absence of process boundaries enforced by the operating system. Most existing approaches use centralization at the system under test (SUT) level. These techniques modify the SUT code to separate types, and provide their own models of IPC mechanisms, which is conforming to the centralized SUT.

A major drawback of centralization at the SUT level is that they do not impose type separation to non-SUT code such as standard Java libraries. Therefore, different parts of the SUT representing different processes share the same standard classes, which may interrupt the correct behavior of the application. Moreover, it cannot support code that uses the Java reflection API or relies on native implementation. These problems are addressed by an alternative approach that performs centralization at the model checker level, requiring the model checker to directly support verification of multiple processes. JPF version 7 provides the basic building blocks for such a support. As an input, it can accept multiple Java processes.

The purpose of JPF-NAS is to provide these components. There are three key characteristics of JPF-NAS. First, it is the only existing IPC model that conforms to the multi-process support within JPF. Second, to mitigate the state space explosion problem, JPF-NAS uses a form of partial order reduction (POR) to reduce the state space of distributed systems under test (SUTs). Finally, JPF-NAS provides a functionality to inject network failures to the execution of distributed SUTs. Such failures are completely invisible from the system and cannot be detected by exercising all possible behaviors of the system.

JPF-NAS provides three main components: a Connection Manager that maintains a list of communication channels that are created along the current execution path and are back-trackable, a Scheduler that generates scheduling choices to capture different interleaving of processes, and a Failure Injector that injects failures occurring at the network layer upon certain process interactions. JPF-NAS is used as a runtime-configured JPF extension that allows for verifying Java processes that communicate with each other. It can be run through the normal JPF user interface. It can be run from the command line, from a Java-integrated development environment such as Eclipse and NetBeans, and from applications using a specialized JPF driver.

This work was done by Nastaran Shafiei of SGT Inc. for Ames Research Center. ***This software is available for use. To request a copy, please visit https://software.nasa.gov/software/ARC-17301-1***

Institutional Budgeting Tool (IBT)

NASA's Jet Propulsion Laboratory, Pasadena, California

The Jet Propulsion Laboratory's Institutional Budgeting Tool (IBT) was designed and developed to meet the needs of JPL's budget planners, numbering 1,600, who required a robust and state-of-the-art budgeting application. JPL's budgeting process had been constrained by legacy tools that presented usability and performance issues and lacked critical innovative budgeting features. IBT delivered superior user experience, system performance, and modern features necessary for essential laboratory budgeting.

IBT consolidates various first-generation budgeting tools into one institutional application. It brings the technology up-to-date to meet the needs of today's institutional budgeting workflow. It allows users to plan and forecast budgets by various elements — cost, organizations, people — employing planning rates and factors consistent with the institutional financial system. The application can be used by flight and instrumentation projects, earned value or non-earned value projects, burden-funded projects, and Research and Technology Development (R&TD) tasks according to their respective budgeting processes.

Other unique features include the maintenance of cost-estimating relationships and a built-in budget submittal and approval process. IBT can also run in online or offline mode, allowing users the flexibility of being offline, especially with secure projects that are behind the firewall.

IBT helped reduce cost and increase efficiency in the budgeting workflow. The existence of three disparate budgeting tools translated to high training costs for the Program Business Management Division and business administrators. This complicated any budgeting and planning process that involved cross-organizational and cross-functional players (engineers, business administrators, and project resource analysts) because too much time had to be spent understanding each tool and converting data from one tool to another. Further, these tools incurred unnecessary maintenance costs by operational IT personnel.

IBT's ease of use and its interface to earned value management systems allows engineers to be part of the EVM (Earned Value Management) planning process without the institutional need to purchase a large number of software licenses or training classes outside the project resource analyst community, or to incur the risk of compromising access to schedules by cost account managers.

This work was done by Nina W. Ko, Sharmon S. Keasler, Richard G. Markley, Sue J. Tynan, William R. Pateracki Jr., Joseph A. Kunkle, Carlo E. Sanchez, Ara Kassabian, Greg J. Horrick, David K. Fu, Raka A. Mehra, and Karen M. Schlue of Caltech for NASA's Jet Propulsion Laboratory. ***This software is available for license through the Jet Propulsion Laboratory, and you may request a license at: https://download.jpl.nasa.gov/ops/request/request_introduction.cfm.*** *NPO-49469*

Tubes Standards-Compliant C Header Library

Ames Research Center, Moffett Field, California

Due to limitations imposed by transistor physics as device geometries continue to get finer and finer, the time when each new generation of processors was clocked faster than its predecessors is largely over. Nevertheless, as individual processor cores get smaller, chip manufacturers have turned instead to cramming a large number of cores onto a single die. Consequently, nearly all commercially available CPUs (central processing units), even those used in smartphones, already depend upon a multicore architecture. Unfortunately, the programming languages used for nearly all commercial software projects are really intended for generating code for a single CPU core. Though extensions exist that support multiple cores, it is something that is essentially tacked on, not part of the core language's constructs.

Tubes is a standards-compliant C header library that extends the C language to include parallel dataflow constructs. The Tubes concept is essentially a generalization of the signals-and-slots metaphor, as made popular by the Qt graphical user interface library, extended to include most of the more common forms of parallelism. Tubes has the potential to make concurrent code easier to write, smaller, less bug-prone, and easier to debug.

The creation of Tubes was specifically motivated by a wish to move the IKOS static analyzer toward a multicore architecture. Previous experience of doing this on an earlier static analyzer, CGS, revealed that the conventional approach led to considerable difficulty. CGS was implemented in C, so parallelizing the code was quite difficult, resulting in a lot of overhead that made the code much harder to maintain and debug. IKOS is implemented in C, using modern template meta-programming techniques, and as such is currently a very clean design that is easy to maintain and extend.

As open source, Tubes would likely have significant impact, both as a natural successor to the already well known sigslot library, and as a potential new and easier way to implement parallel, multithreaded software.

This work was done by Sarah Thompson for Ames Research Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact David Morse at david.r.morse@nasa.gov or 650-604-4724.*** *ARC-16975-1*

Techniques for Conducting Effective Concept Design and Design-to-Cost Trade Studies

Goddard Space Flight Center, Greenbelt, Maryland

Concept design plays a central role in project success for space missions, as the product of concept design effectively locks in the majority of system lifecycle cost. It involves a concurrent investigation of requirements and multiple mission characteristics such as flight dynamics, design, performance, concept of operations, technology, verification approach, launch and ground interfaces, cost, schedule, and risk.

Done well, concept design can provide an executable system-level design baseline for project teams in preliminary design and later project phases. Not done well, concept design can lead to several undesired outcomes including cost overruns, schedule delays, the need for redesign or multiple redesigns, fluid technical baselines, and contract disputes or cancellations.

The extraordinary leverage concept design has on system lifecycle cost presents a business case for conducting concept design in a credible fashion, particularly for first-of-a-kind systems that advance the state of the art and that have high design uncertainty. A key challenge, however, is to know when credible design convergence has been achieved for such systems.

Using a space system example, this work describes a process suited for conducting comprehensive concept design and design-to-cost trade studies for such systems. Aspects discussed are: a) what concept design is and why it is important, b) the level of convergence needed for the concept design product in terms of customary technical and programmatic resource margins available in preliminary design, c) techniques for designing the mission-level trade space, and d) challenges in determining credible design convergence.

This work illustrates a systematic trade study process for exploring significantly different mission concepts over a few discrete design "cycles" with the objective of credibly converging the technical, cost, and schedule characteristics for a single baseline mission concept design to the first order before entering preliminary design. Trade study cases bound the trade

space, and the final (baseline) solution is deduced by interpolation. More like a root-finding algorithm than like the successive refinement approach typically used in preliminary and detailed design, it enables broad coverage of the trade space in minimum time. It also helps illuminate unexpected findings, including major "unknown unknowns" that otherwise may have remained hidden until preliminary design or later phases wherein their discovery could induce significant impacts.

Key in this process is focusing at the first order level for sizing and performance, and deferring second and third order considerations to later phases. Equally important is recognizing that early team system performance expectations and early team cost estimates tend to be optimistic. Cost estimates tend to increase as teams learn more about both the design and the work breakdown structure used for costing. Apparent only in hindsight, this effect often significantly moderates team performance expectations and advises against selecting a design baseline from early cycle results. Team learning typically tapers off for most designs after three cycles when truly bounding trade study cases have been evaluated.

The techniques described here have been used at NASA Goddard Space Flight Center for the development of mission concept designs.

This work was done by David Di Pietro of Goddard Space Flight Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact Scott Leonardi at Robert.S.Leonardi@nasa.gov.*** *GSC-17322-1*

HyDE Model-Based Diagnosis Engine for Stochastic Hybrid Systems

Ames Research Center, Moffett Field, California

Model-based diagnosis deals with the problem of diagnosing faults in systems using a model of the system for guidance. This problem is complicated by the presence of hybrid dynamics in the system (continuous evolution of the system interspersed with discrete events like commands to change configuration), as well as uncertainties in the form of model approximations and sensor noise. Several model-based technologies have been developed and successfully demonstrated using discrete abstractions of the system as models. These techniques are severely restricted in model expressiveness due to the discrete nature of the models. Moreover, sophisticated model abstraction techniques, as well as algorithms to convert continuous data to discrete form, need to be developed for such an approach to work. Recently, there have been efforts to develop diagnostic engines for hybrid and stochastic systems. However, these techniques have either focused on parametric faults, or use a probabilistic approach to fault identification. Consistency-based approaches that have been successfully demonstrated using discrete models have not been extended to work with stochastic and hybrid models.

HyDE is a model-based diagnostic engine capable of detecting and isolating discrete (possibly multiple) faults in physical systems. HyDE takes as input a model of the system to be diagnosed and the telemetry/data from the actual system or from simulations of the system, and diagnoses the health state of all components in the system. The current version of HyDE has been implemented in C++.

A model of the system is developed describing the structural, transitional, and behavioral properties of the system under nominal and fault conditions. These are expressed as models of components of the system and the interconnections between the components. Data from the system, in the form of commands to the system and the sensed observations from the system, is used in conjunction with this model for fault detection and isolation. HyDE uses a combination of a consistency-based approach and stochastic approaches in which the model is used to predict the expected behavior of the system, which is then compared against the data from the system to check for consistencies. Any inconsistencies drive a search process for possible candidates that can eliminate inconsistencies. The key innovation in HyDE is the ability to deal with stochastic (uncertain) and hybrid (discrete and continuous) models and data.

This work was done by Lee Brownston of Ames Research Center and Sriram Narasimhan of the Regents of the University of California, Santa Cruz. ***This software is available for use. To request a copy, please visit https://software.nasa.gov/software/ARC-15570-1A***

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POSITAL FRABA

Wednesday, February 22, 2017 at 2:00 pm U.S. EST

Posital has developed a new approach based on a magnetic sensing platform that delivers motor-feedback kits that meet the technical and economical requirements of today's and tomorrow's motor applications. In this presentation, we will compare existing solutions and show the technologies that have been used to design a magnetic kit solution that is both high-performance and cost-efficient.

Presenter:

Christian Fell
Vice President, Technology & Custom Solutions,
and COO, FRABA Inc.
FRABA Group

This 30-minute Webinar includes:
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- Application Demo
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LAPP GROUP

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Speaker:

Lucas Kehl
Global Product Manager
Lapp Group

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PEI

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Speaker:

Robert D. Ashman
National Sales Manager,
Precision Products
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- Live Q&A session
- Application Demo
- Access to archived event on demand

Please visit www.techbriefs.com/webinar351

New on the MARKET

Product of the Month

OriginLab, Northampton, MA, released Origin® and OriginPro 2017 data analysis and graphing software with more than 100 new features, enhancements, and apps. Features include Trellis plots for creating multi-panel graphs from grouped data, 3D stacked bars and 100% stacked bars with various bar shapes, a set of standard geology patterns and user-defined patterns, improvements to box plots, improvements to axis dialog including support for multiple reference lines, and enhanced multi-tabbed dialog for customizing graph annotations. Enhancements include simpler column/cell notation for defining column formulas, and the Origin Central Startup Dialog that provides graph and analysis samples, access to existing templates and projects, resources to explore and install apps, and videos and tutorials. The release includes 14 new apps for extending graphing and analysis features.

For Free Info Visit http://info.hotims.com/65848-120

Product Focus: Power Management

Power Supply Units

Mouser Electronics, Mansfield, TX, offers QUINT4 power supply units from Phoenix Contact that include near-field communications, real-time monitoring, coordinated surge protection, and a configurable DC output characteristic. User-definable settings allow engineers in the field to monitor DC current, power, or voltage in real time using a 4mA–20 mA analog output.

For Free Info Visit http://info.hotims.com/65848-100

Battery Drain Analysis

The Keysight N6781A source/measure unit for battery drain analysis from Keysight Technologies, Santa Rosa, CA, features seamless measurement ranging, programmable output resistance, and auxiliary DVM. The unit accurately emulates a battery, providing glitch-free sourcing and sinking (charge/eLoad). Programmable output resistance mimics the battery's internal resistance.

For Free Info Visit http://info.hotims.com/65848-101

Power Supplies

SL Power Electronics, Ventura, CA, released the TB110 Series internal power supplies for applications requiring electromagnetic interference (EMI) protection and electromagnetic compatibility (EMC). Features include up to 110 Watts of output power with airflow, or 80W when convection-cooled; and universal input of 90 to 264 Vac in outputs of 12V, 24V, and 48V.

For Free Info Visit http://info.hotims.com/65848-102

Power Inductors

Coilcraft, Cary, IL, introduced the XEL60xx high-current, low-loss power inductors that offer DCR as low as 1.35 mOhms and ultra-low AC losses at switching frequencies from 2 to 5+ MHz. They provide current handling up to 41.0 Amps with soft saturation characteristics to withstand high current spikes.

For Free Info Visit http://info.hotims.com/65848-103

Power Supply

TDK-Lambda Americas, National City, CA released the TPS3000-24 power supply that delivers up to 3200W output power (24V at 133.3A) in a 2U-high package. It operates from a wide-range Delta or Wye 350 – 528Vac three-phase input that eliminates step-down transformers and assists phase load current balancing.

For Free Info Visit http://info.hotims.com/65848-104

DC Power Supply

The DTI 250 kW HVPS Series switching mode power supply from Diversified Technologies, Bedford, MA, is a compact, solid-state, high-voltage DC power supply. It features 15 to 100 kV adjustable output with <0.1% ripple, and is packaged in a 24" W × 36" D × 74" H cabinet. It uses tap water for cooling, and eliminates the need to connect and control multiple smaller switching power supplies.

For Free Info Visit http://info.hotims.com/65848-105

The U.S. Government does not endorse any commercial product or service identified in this section.

Flow Switch

The FSW-160 heavy-duty paddle flow switch from OMEGA Engineering, Norwalk, CT, signals, starts, or stops electronically operated equipment when flow or no-flow conditions occur. The elastomeric sealing system is not subject to metal fatigue and corrosion. The NEMA 1 (IP10) enclosure and stainless steel paddle and shaft provide a solid design for monitoring flow switching applications such as automotive, manufacturing, chemical processing, HVAC, water, and wastewater.

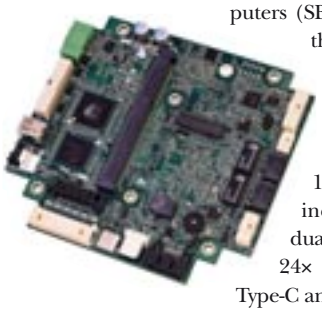
For Free Info Visit http://info.hotims.com/65848-106

Tube Fittings

A series of stainless steel fittings is available from Global Fittings Concepts, Titusville, FL, that provides metric (6-, 10-, 12-mm) and fractional (¼, ⅜, ½") tube modules and hybrid thread modules. Thread modules seal into ¼, ⅜, ½ NPT, BSPT, and BSPP female threads. The modules couple and lock to union, elbow, or tee bases, allowing users to assemble fluid or pneumatic connections in 375 configurations with 12 modules and bases.

For Free Info Visit http://info.hotims.com/65848-108

Single-Board Computers



WinSystems, Arlington, TX, offers the PX1-C415 single-board computers (SBCs) with dual Ethernet that feature the Intel® Atom™ Processor E3900 Series for industrial IoT and other embedded systems. They withstand temperatures from -40 to +85 °C, and support Microsoft® Windows® 10 and Linux operating systems. They incorporate dual video interfaces, dual Ethernet ports, four serial ports, 24× bidirectional GPIO lines, and USB Type-C and M.2 connectors.

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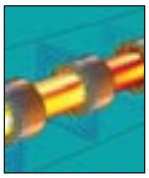

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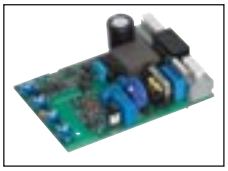

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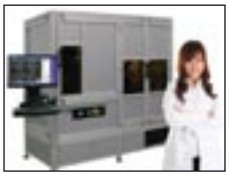

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Selected technological strengths: Information Technology; Biotechnology; Nanotechnology; Aerospace Operations Systems; Rotorcraft; Thermal Protection Systems.
David Morse
(650) 604-4724
david.r.morse@nasa.gov

Armstrong Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Laura Fobel
(661) 276-3967
laura.j.fobel@nasa.gov

Glenn Research Center
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High-Temperature Materials Research.
Kimberly A. Dalgleish-Miller
(216) 433-8047
kimberly.a.dalgleish@nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; Command.
Nona Cheeks
(301) 286-5810
nona.k.cheeks@nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Dan Broderick
(818) 354-1314
daniel.f.broderick@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
John E. James
(281) 483-3809
john.e.james@nasa.gov

Kennedy Space Center
Selected technological strengths: Fluids and Fluid Systems; Materials Evaluation; Process Engineering; Command, Control, and Monitor Systems; Range Systems; Environmental Engineering and Management.
David R. Makufka
(321) 867-6227
david.r.makufka@nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Kathy Dezern
(757) 864-5704
kathy.a.dezern@nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Terry L. Taylor
(256) 544-5916
terry.taylor@nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Duane Armstrong
(228) 688-2180
curtis.d.armstrong@nasa.gov

NASA HEADQUARTERS

Daniel Lockney, Technology Transfer Program Executive
(202) 358-2037
daniel.p.lockney@nasa.gov

Small Business Innovation Research (SBIR) & Small Business Technology Transfer (STTR) Programs
Rich Leshner, Program Executive
(202) 358-4920
rleshner@nasa.gov

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Laser Vision Helps Package Shippers See Clearly

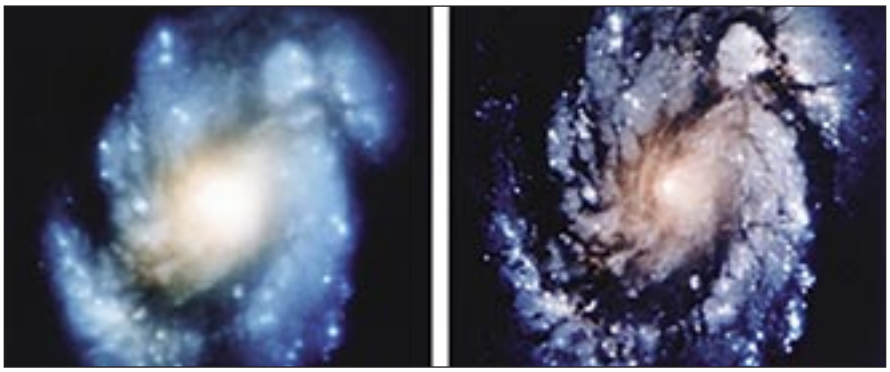
An analyzer developed for Hubble mirror testing helps FedEx scan packages.

For more than 25 years, the Hubble Space Telescope has provided stunning photos of the universe unequalled in their depth, detail, and distinction. But in its early days, Hubble wasn't capable of sending back such breathtaking photos. Within weeks of launch, the images beamed back to Earth were fuzzy and out of focus. It was determined that Hubble's primary mirror had been ground to the wrong shape and was too flat by 2.2 micrometers, causing reflected light from the edge of the mirror to be focused on a different point than light coming from near the center. It was determined that the device used to create the nonspherical mirror had been incorrectly assembled, and the mirror's manufacturer had failed to notice the problem before Hubble was launched.

NASA decided on a two-step approach to address the problem. During the first repair mission to Hubble, astronauts would replace the Wide Field Planetary Camera (WFPC) with an improved version featuring advanced detectors and more accurate contamination control, along with built-in corrective optics known as WFPC 2. Second, the astronauts would replace one of Hubble's original components, the High-Speed Photometer, with the Corrective Optics Space Telescope Axial Replacement (COSTAR), which would work like a pair of eyeglasses to better focus the telescope's view of the universe. But first, NASA wanted to make sure the repairs would indeed improve Hubble's ability to capture images, and not suffer from any undiscovered flaws.

NASA put out a call for optics companies to prove they could verify the shape of a mirror hidden from view and detect any defects, however slight. Along with other companies, AOA Xinetics, now a Cambridge, MA-based subsidiary of Northrup Grumman, went to Goddard Space Flight Center with its aberrated beam analyzer (ABA), which it built to meet NASA's specific requirements. AOA needed to use its analyzer to determine both the mirror's flaw and how to compensate for the fuzzy image using a static corrector.

Prior to creating the ABA, AOA had experience in measuring the way the atmosphere bends and distorts light, a process that requires split-second measurements but not high levels of accuracy relative to the measurements NASA needed. The team decided to illuminate the mirror using flat wavefronts of light from a laser, knowing that the waves bouncing back could allow the ABA to detect the unseen mirror's shape, right down to microscopic divots and bumps. The resulting instrument not only detected the mirror's shape accurately, but did so to within three-thousandths of a wavelength of light. NASA chose the tool used to verify that both COSTAR and WFPC 2 were perfect before being sent into space.



A misshapen mirror aboard the Hubble Space Telescope caused the first images beamed back to Earth to be fuzzy and out of focus (left). After the installation of new optics tested by the AOA analyzer, Hubble began sending back crystal-clear, vivid images (right).

Shortly after the work on Hubble, AOA used the ABA to create the Mass Scanning and Dimensioning System, originally used by FedEx to quickly and accurately create 3D images of packages that would need to be sorted and shipped in a given day. The scanning system creates a contour map of parcels as they travel down a conveyor belt past a laser ranging imager. Height contours are subsequently analyzed to determine the location of each parcel and its dimensions, which helps to identify packages that might require additional charges due to size or weight. Previously, someone would have to manually pull items off conveyor belts and use a tape measure to single out packages.

The imaging system, which has since been adopted by all major shipping services including the U.S. Postal Service, has been utilized by hundreds of machines running millions, if not billions, of hours for 20 years.

AOA also partnered with Kroger grocery stores to develop the Scan Tunnel to ease checkout at its stores. Customers put their products on a conveyor belt, which then travels through an upright tunnel with laser scanners on three sides, capturing product information for identification and pricing. This allows customers with larger orders to take advantage of self-checkout aisles. Scan Tunnel uses 14 scanning cameras and two types of dimensioners, an improvement over the seven cameras and one dimensioner used in FedEx's system.

Both products have roots in the initial work to save Hubble from obsolescence. Now, after more than 25 years, Hubble continues to provide breathtaking images of the galaxy, long exceeding the optimistic predictions that it would send back views of the heavens for only 15 years.

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ON THE COVER

Robotics technology, already ubiquitous on the factory floor, is increasingly visible in disaster relief, hazardous work sites, and even in the average home. In the Tech Briefs section starting on page 18, read how a group of Japanese researchers developed a rescue robot for disaster relief that's controlled remotely with the help of a UAV. Also, a proposed standard out of Yale University will provide researchers with universal benchmarks to measure and compare the performance of robots operating in home-based applications.

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The Basics of Encoder Selection

Many small motor applications, such as robotics, industrial equipment, and consumer products, employ digital incremental encoders for feedback sensing. Encoder selection is therefore an important part of the system design process. Choosing the best encoder for the job requires knowledge of the most important encoder properties as well as the application's control requirements.

What are the Typical Requirements?

Each application is different; for example, the main task may be position control or speed control. The level of accuracy in speed or position control can be very different and should be defined before encoder selection. Speed control at low speed (below 100 RPM) needs a better feedback than speed control at high speed (1,000 RPM and above).

The load may be coupled directly onto the motor, or there could be a mechanical transformation system such as a gearhead or screws. Encoders typically are mounted on the motor shaft, but can also be on the load itself. The mechanical properties of the transformation mechanism influence encoder selection because gear reduction and mechanical play have to be taken into account.

Environmental conditions such as temperature, vibration, and electromagnetic interference may also have an influence on encoder selection. Optical encoders, for example, should be protected against dust. Magnetic encoders may be sensitive to external magnetic fields — including those of the motor — and may require shielding.

What are Key Properties of Incremental Encoders?

The characteristic parameter of an incremental encoder is the number of rectangular pulses per motor revolution. Typically, there are two channels delivering the same pulse number. The two signals have a relative phase shift of one quarter of a pulse length. This arrangement allows the detection of the direction of motor rotation and gives four distinct states per pulse. Sometimes these states are called quadcounts. They represent the real resolution, which is four times higher than the number of pulses on one channel (Figure 1). An encoder with 1,000 CPT (counts or pulses per turn) gives 4,000 states per turn, or a nominal resolution of 360°/4000 = 0.09°.

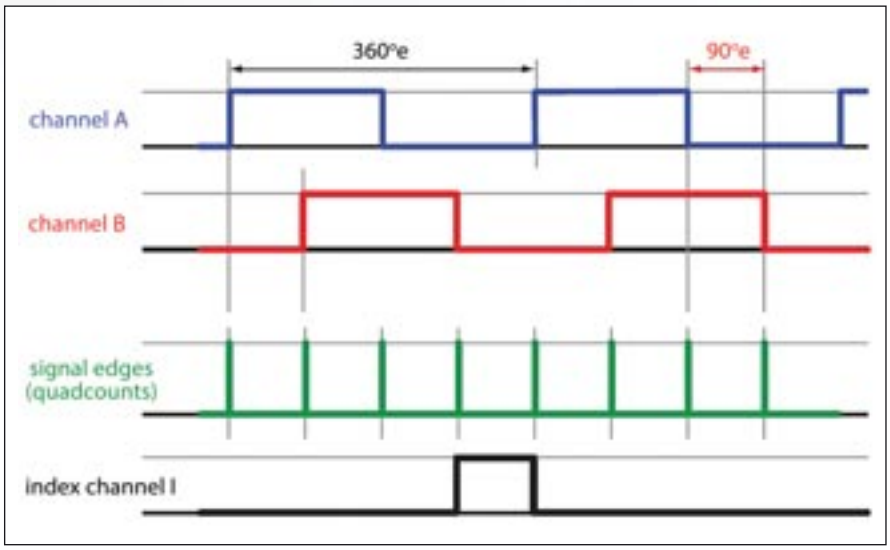

Figure 1. The signals of a digital incremental encoder. Counting the state changes (the signal edges of channels A and B) results in four times higher resolution than the number of counts per turn on one encoder channel.

Encoder resolution spans a wide range from a very simple 1 CPT (or 4 states) encoder that can be used simply to detect motion, up to several 10,000 CPT for highly accurate position or speed feedback. There are many factors that influence resolution, including the underlying physical principle (optical, magnetic, inductive), the primary signal type (analog or digital), the signal treatment (e.g. interpolation), and the mechanical layout.

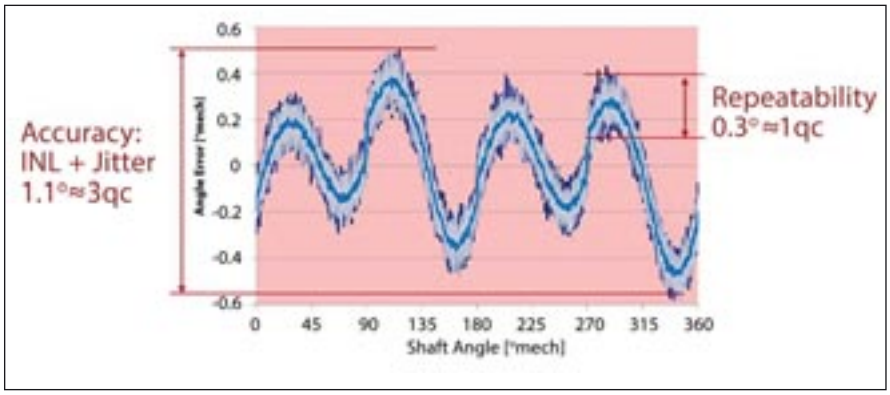

Figure 2. An example of measured non-linearity of a magnetic interpolated encoder with 256 CPT. The deviation from the perfect postion is shown as a function of the encoder signal (1,024 quadcounts).

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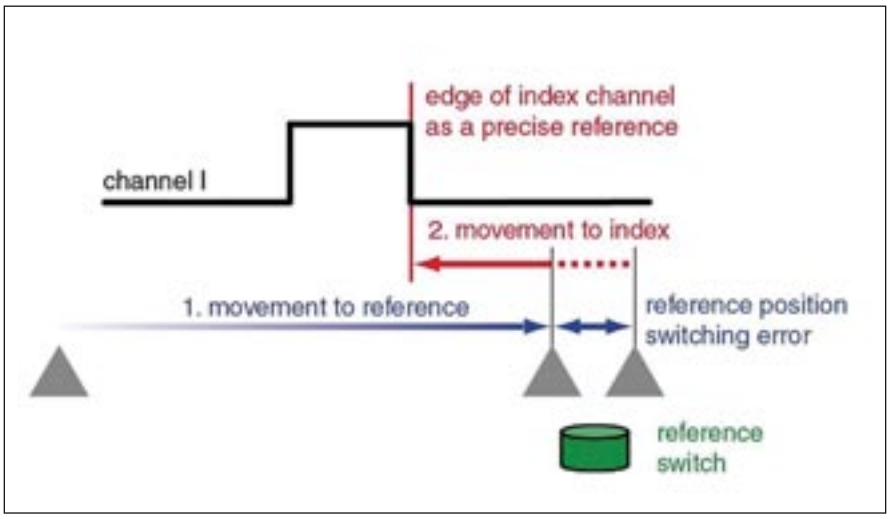

Figure 3. Improving the accuracy of the reference position by an additional move to the edge of the index channel signal.

How Accurate are Encoders?

Resolution — the number of states — gives the nominal accuracy; the position is known within an error of one state. However, encoder pulse lengths may vary due to mechanical tolerances (e.g. shaft runout and length of magnetic poles). The pulses in one range of motor rotation may be shorter than the pulses of other ranges. As a result, the measured position deviates from the real position in a periodic way over one motor revolution (Figure 2).

The maximum deviation (peak to peak) is called integrated non-linearity (INL). INL is important in applications that require absolute position accuracy. Repeatability is not affected by INL, but is rather a question of signal jitter, and typically amounts to less than one state.

Incremental Encoders and Absolute Positions

Incremental encoders give position changes. For absolute positioning, a reference or home position must first be established. This is achieved by moving the mechanism to an external reference that could be a mechanical end stop or a limit switch.

Some encoders feature a third channel with one pulse per turn. The edges of this index channel give absolute position references within one turn (Figure 3). The limited accuracy of external references can be improved by an additional move to one of the index channel edges. However, the index channel is not a prerequisite for positioning. In fact, machine builders try to avoid using the index for referencing because it requires new calibration if a motor-encoder unit has to be replaced. Also, some controllers use the index channel to crosscheck the encoder signal and supervise the encoder counts per turn.

What to Observe when Transmitting the Signal

Line drivers are recommended for transmission over long lines and for better signal quality. For positioning, a line driver is important to avoid missing encoder pulses.

Line drivers generate inverted signals (A, B, I) for each channel (A, B, I). Each signal pair is transmitted together and the difference is evaluated, thus filtering out any electromagnetic interference during signal transmission. As a beneficial side effect, the signal quality is improved, the signal edges are more clearly defined, and the driver function enables the transmission of the signal over longer distances (up to about 30 m).

Encoders need a minimum supply voltage. On long encoder lines, the line resistance and the corresponding voltage drop can be an issue. That's why it's important to check the cable cross-section and the supply voltage.

Environmental Conditions and Robustness

The standard operating temperature range of encoders is in the range of –30 °C to +100 °C. This covers most of the applications and the heat produced by the motor. In applications with strong vibrations and with mechanical shocks, a robust mechanical housing and a good strain relief of the cables are important.

While optical encoders are less sensitive to electromagnetic interference, magnetic encoders need a good shielding against magnetic stray fields. If the housing is not sealed tightly, optical encoders are sensitive to dust.

Position and Speed Control

The following basic rules can be used when selecting an encoder for positioning and speed control applications:

Rule 1: Encoder for Positioning — A good recommendation is to select an encoder with a number of pulses higher than 360° divided by the required angular position accuracy; in other words, a number of states that is four to ten times higher. For positioning, select an encoder with a line driver (differential signal).

Rule 2: Encoder for High-Precision Positioning — Select optical encoders with a line driver for high-precision positioning. They have a higher resolution, less jitter, and a lower INL than interpolated magnetic encoders.

Rule 3: Encoder for Positioning with Mechanics — Select a magnetic encoder with a line driver and with a moderate or low number of states. The mechanical reduction will increase the resolution. Due to the mechanical play, the system will not be able to benefit from a high-precision optical encoder.

Rule 4: Encoder for High-Speed Control (> 500 RPM) — Select an encoder with a moderate or low number of states and a sufficiently high maximum speed rating. There is usually not a need for a high-precision optical encoder. A good rule of thumb that is usually sufficient for most applications is (speed in RPM) × (encoder resolution in CPT) > 100,000.

Rule 5: Encoder for Low-Speed Control (< 100 RPM) — Select an encoder with a high or very high number of states in combination with a fast controller.

This article was written by Urs Kafader, Head of Training at maxon precision motors, Sachseln, Switzerland. For more information, visit ***http://info.hotims.com/65848-328****.*

To view the second part of this article, which covers encoder selection for position and speed control in more detail, go to ***www.techbriefs.com/encoder_selection****.*

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Figure 1. Beam coupling connecting a servomotor and ball screw.

Servo Couplings for High-Tech Systems

Proper coupling ensures a design will meet performance requirements and have a long, trouble-free life.

Couplings are a critical part of system performance in high-tech applications, yet they are often one of the last components to be specified. Selecting the proper coupling ensures the equipment will meet performance requirements and have a long, trouble-free life. Poor coupling selection can lead to high maintenance costs, frequent downtime, and imprecise positioning.

High-tech systems are found in almost all industries including semiconductor, medical, agriculture, printing, and aerospace. Precise positioning systems generally consist of a driving component, such as a stepper servomotor, and a driven component, such as a ball screw, with the coupling used for power transmission (Figure 1).

The diversity in industries using high-tech systems creates a wider variance in how couplings are applied, even if the applications are similar. For example, precision equipment is used to finely open and close panels controlling the amount of radiation being administered to a patient with brain cancer. This same application is used on the aperture mechanism of high-precision telescopes researching exoplanets from space. These applications, while serving the same function, have different system requirements. Focused radiation requires a coupling that meets hygienic requirements in a relatively controlled environment. Telescopes need a coupling that can survive the launch into space, operate in a vacuum, and perform for long periods of time without failing.

There are numerous considerations to make when designing a coupling (Figure 2). These may include:

- Physical space requirements. Shaft sizes, spacing between shafts, and overall envelope size should be the first considerations for specifying a coupling.
- Misalignment. Designers often misapply couplings where shaft misalignment is greater than the coupling can accommodate by failing to adequately calculate tolerance stacks and manufacturing inconsistencies (Figure 3). This can lead to poor performance and frequent system maintenance.
- Environmental conditions. Most high-tech applications exist in controlled climates without exposure to extreme environments. However, they can appear in environments including extreme temperatures (hot and cold), vacuum, and chemical exposure that can affect coupling performance.
- Operating conditions. Designers must account for factors such as speed (RPM), rotational cycling, torque, duty cycle, and acceleration/deceleration rates.
- Performance criteria. System performance expectations including level of positioning accuracy and repeatability,

Figure 2. Comparison of servo coupling performance characteristics.

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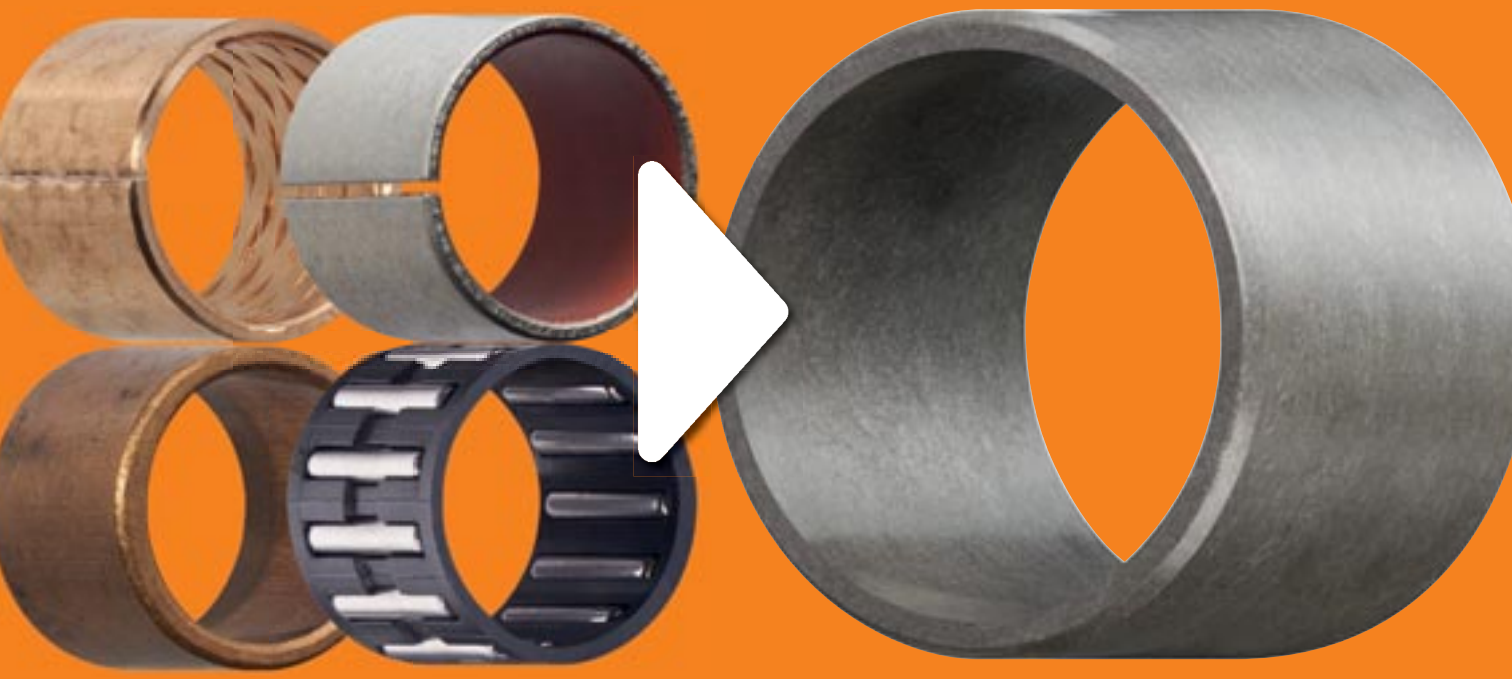

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settling time, and overall responsiveness must be considered when selecting a coupling.

Selecting a coupling that meets application requirements involves understanding the strengths and weaknesses of each style. This article reviews six different types of motion control couplings: rigid, beam, bellows, miniature disc, zero-backlash jaw, and oldham. They are all zero-backlash because this is critical to the performance of high-tech applications.

Beam Couplings

Beam couplings utilize continuous cuts in the body to transmit torque and accommodate misalignment. They are a good fit for high-tech systems that operate at a moderate speed (maximum of 6,000 RPM), have significant misalignment, and require some dampening.

Two common variations of the beam coupling are single-beam types with one long, continuous cut, and multiple-beam types that have one or two sets of shorter cuts overlapping each other. Multiple-beam type couplings offer higher torque, torsional stiffness, and parallel misalignment capabilities. Single-beam couplings have better angular and axial flexibility.

Beam couplings are generally available in aluminum for low inertia and stainless steel for increased torsional rigidity. Designers must be careful when using stainless steel as they have significantly higher inertia and cost. It is generally advisable to consider alternative coupling styles.

Rigid Couplings

Rigid couplings are manufactured out of several materials and are available in a number of styles. For high-tech applications, clamp style is preferred to set screw. Clamp type couplings do not mar the shaft, have higher torque capabilities, and require no maintenance. Aluminum is preferable due to its low inertia. The rigid coupling has the highest rated torsional rigidity, making them ideal for high-tech applications that require precise movements over short increments, such as 3D printers.

Rigid couplings have the highest bearing loads of all couplings and require perfect shaft alignment. Thermal expansion under high speeds is also something to monitor, as rigid couplings have no means to accommodate the resulting stresses that have the same effect as misalignment on the bearings.

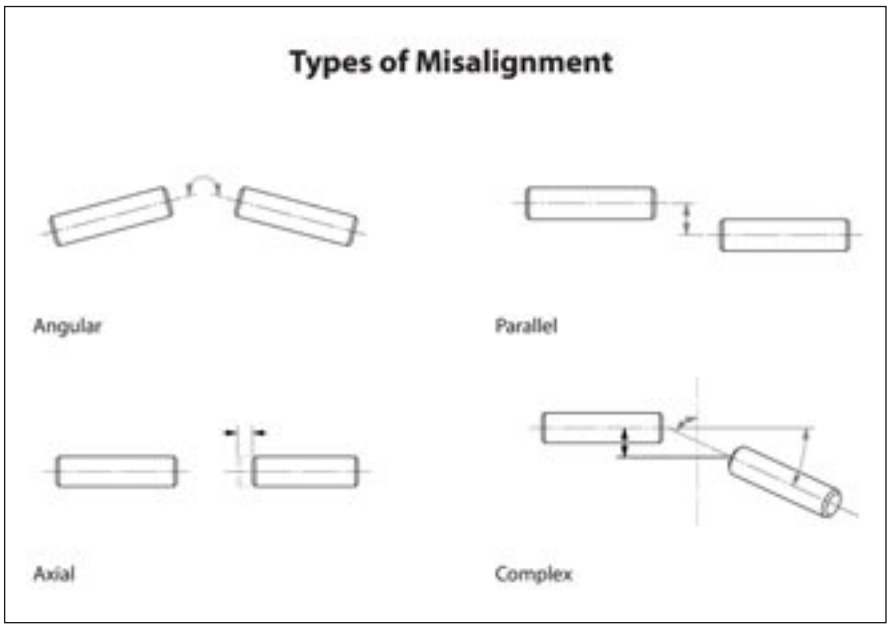


Figure 3. Visual representation of the different types of misalignment.

Disc Couplings

Disc couplings are either composed of two hubs joined by a flexible metallic center disc (single), or two hubs and a center piece joined by two metal discs (double). Double-disc couplings can accommodate parallel and angular misalignment. Single-disc couplings fit in a smaller envelope and only accommodate angular misalignment.

Both variations are torsionally rigid with low bearing loads and inertia. The flexible discs allow for high misalignment, especially in the double-disc design. Furthermore, disc couplings can handle upwards of 10,000 RPM. The combination of these factors makes disc couplings a common choice in semiconductor and solar equipment.

The disc coupling is best suited for applications where accuracy and strength are emphasized due to high torsional rigidity, and is not a good choice when dampening is needed. They are delicate and can damage easily if installed incorrectly.

Bellows Couplings

The bellows coupling is constructed of two aluminum or stainless steel hubs connected — either by welding or an adhesive — to a metallic bellows. The thin wall of the stainless steel, bronze, or nickel bellows adds to responsiveness and accuracy. Bearing loads are low and constant throughout all points of rotation, and bellows couplings can accommodate all forms of misalignment. The combination of high torsional stiffness and low inertia (with aluminum hubs) allows for a high level of system responsiveness.

All of these strengths do not compromise the coupling's torsional rigidity, which is even greater than the disc coupling. Running speed capability is on par with the disc couplings at about 10,000 RPM. Bellows couplings are also sensitive to installation and can be damaged easily if not properly installed (Figure 4). The bellows coupling is a great option for printing, which requires accuracy and no dampening to prevent banding.

Zero-Backlash Jaw Couplings

The zero-backlash curved jaw coupling is composed of three parts that press fit together — two aluminum hubs and an elastic insert referred to as the "spider." The design of the jaws of the hubs helps to reduce deformations that the spider may undergo during normal operation. Spiders are available in different durometers to balance stiffness with dampening capabilities. The high dampening characteristics of curved jaw couplings make them an ideal fit for stop-and-go inspection systems.

Jaw couplings can have high bearing loads and are not suited for systems requiring high misalignment. Another consideration is that jaw couplings are failsafe, meaning the jaws of the hubs will lock together and continue to transmit torque if the spider fails. This may or may not be desirable, depending on the system.

Oldham Couplings

Similar to the jaw coupling, the oldham coupling is also made up of three components — two aluminum hubs and an insert — that press fit together.

The oldham coupling is a good starting point for system design and has a few clear advantages: high parallel misalignment capabilities with low bearing loads, interchangeability of the center disc, and the ability to act as a mechanical fuse. They are commonly used in valve actuation applications where precise regulation of the valve is required.

Figure 4. Broken bellows coupling due to improper installation causing excessive misalignment.

Oldham couplings can only handle small amounts of angular misalignment and axial motion. Nylon inserts may be chosen to dampen vibrations; however, the press fit is not tight enough to ensure zero-backlash operation. Speed capability for all oldham couplings is relatively limited, around 4,500 RPM. Oldham couplings have long life capabilities, but eventually the disk will fail completely or wear to the point that it loses zero-backlash properties and needs replacement. When the disk is replaced, full performance of the coupling is restored.

Conclusion

High-tech systems only operate as well as the components that make them up. Each coupling has its own strengths and weaknesses that make it useful in a variety of applications. However, no one coupling can be applied to all situations. Based on this rationale, the zero-backlash coupling should be considered in the early stages of system development. If the coupling's performance characteristics meet the operating goals of the system, the user can be assured of maximum system performance and longevity.

This article was written by William Hewitson, President of Ruland Manufacturing Co., Marlborough, MA. For more information, visit ***http://info.hotims.com/65848-325****.*

Figure 1. Bulk metallic glass, a metal alloy, doesn't get brittle in extreme cold. That makes the material perfect for robotics operated in space or on icy planets. (Image: NASA/JPL-Caltech)

Metallic Glass Shatters Gear Limitations

Gears play an essential role in precision robotics, and they can become a limiting factor when the robots must perform in space missions. In particular, the extreme temperatures of deep space pose numerous problems for successful gear operation. At NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, technologist Douglas Hofmann and his collaborators aim to bypass the limitations of existing steel gears by creating gears from bulk metallic glass (BMG).

BMG is a specially crafted metal alloy that has the properties of glass. Metals have an organized, crystalline arrangement. When they are heated up into a liquid, they melt and the atoms become randomized. Cooling them rapidly — about 1832 °F (1000 °C) per second — traps their non-crystalline "liquid" form in place. The resulting amorphous material is technically a glass. It can flow easily and be blow molded when heated, just like windowpane glass. When this glassy material is produced in parts greater than about 0.04" (1 mm), it's called bulk metallic glass.

"Although BMGs have been explored for a long time, understanding how to design and implement them into structural hardware has proven elusive," said Hofmann. That's largely because researchers didn't understand the subtleties that composition and impurities during manufacturing play in the mechanical properties of BMGs. Metallic glasses have been used commercially for years, but almost all of the applications were composed of a single alloy. Once it was determined that the composition of the material dramatically affects the performance, design teams could then create metallic glasses explicitly for particular applications.

Materials Testing

The JPL researchers and engineers, in collaboration with groups at Caltech and the University of California, San Diego, have finally put BMGs through the testing needed to demonstrate their potential benefits in creating robotic gears for space. BMGs are very hard, have good wear resistance, and they can be used at extremely low temperatures without becoming severely embrittled (Figure 1). This combination of properties makes them attractive for robotic gears.

Hofmann explained that metallic glass is a compromise in properties between ceramics and conventional crystalline metals like steel or titanium. Ceramics are very hard and they make excellent gears and bearings, but they are very brittle. Traditional metal gears are strong, but have problems with wear and temperature, and they require lubricant. Metallic glasses fit in between. They're much tougher than ceramics, but much less brittle, and also have better wear performance than titanium or steel.

BMGs have a glass transition temperature that is lower than the melting temperature of the metals used to make them. The BMGs typically will begin to flow around 300 to 400 °C. That allows parts to be cast using injection-molding technology, similar to what's used in the plastics industry. BMGs also don't get brittle in extreme cold, a factor that can lead to a gear's teeth fracturing.

According to Hofmann, initial BMG gear testing has demonstrated strong torque and smooth turning without lubricant, even at –328 °F (–200 °C). For robots sent to frozen landscapes, that can be a power-saving advantage. NASA's Mars Curiosity rover, for example, expends energy heating up grease lubricant every time it needs to move.

Low-Cost Manufacturing

BMGs could also lower the cost of manufacturing strain wave gears (Figure 2). This type of gear, which includes a metal ring that flexes as the gear spins, is tricky to mass produce and is ubiquitous in expensive robots.

Figure 2. The components of a strain wave gear, which is currently one of the most expensive types of gears used in high-precision robotics. BMGs could lower the cost of manufacturing strain wave gears. (Image: NASA/JPL-Caltech)

Mass producing strain wave gears is difficult because parts of them have to be precision machined from steel using a very complicated manufacturing process. JPL intends to cast the BMG gears. Casting parts exploits the economics of injection molding, in which increased production lowers the price per part. This can significantly reduce the cost of robots that use strain wave gears, including those in the consumer robotics market.

The project's proof of concept and alloy material development were done at JPL, but they partnered with industry to manufacture the metallic glass gears when they reached the limits of JPL's manufacturing capabilities. Materion of Elmore, OH makes the BMG feedstock material. That raw material is then used by Visser Precision in Denver, CO, a company that specializes in injection molding of metallic glasses.

Besides gears, there are other potential applications for BMG materials in deep-space missions. The JPL researchers have been prototyping many applications for metallic glass, including compliant mechanisms and spacecraft shielding.

There's also the possibility of commercial implementation of the same materials into gears that would be used on Earth. A NASA spinoff out of Caltech is trying to commercialize the strain wave gears for low-cost robotics. Also, metallic glass can create low-density planetary gears that are useful in applications where weight is a factor. Gears made from titanium-based metallic glass are 40% lighter than steel gears, and deliver similar performance. Hofmann believes they have the technology to make the first viable titanium-based planetary gears, which would be key for applications like drones and low-cost air vehicles.

The Bulk Metallic Glass Gears project is funded by NASA's Space Technology Mission Directorate's Game Changing Development Program. The objective of that funding is to help get through the testing necessary to be able to use these gearboxes in future missions. Proposed missions that could potentially use the new gears include putting a lander on the surface of Jupiter's moon Europa, the asteroid redirect mission, a Mars sampling mission, or a comet sample return mission.

For more information, visit: ***http://scienceandtechnology.jpl.nasa.gov/metallurgy-facility.***

Adding SCADA to a Hydraulic Power Unit

With an increased focus on plant productivity and equipment reliability, Supervisory Control and Data Acquisition (SCADA) systems have become vital tools to reduce downtime while increasing asset reliability in hydraulic systems. A SCADA system is a computer system that essentially gathers and analyzes real-time data.

These systems monitor critical sensors and data points, providing information on a plant's network or localized human-machine interface (HMI). Having knowledgeable data and information related to a hydraulic system provides key values that help maintain and protect assets and improve productivity and reliability.

A SCADA system can be used to monitor the following elements of a hydraulic power unit:

- Reservoir temperature
- Fluid contamination/particle counter
- Pressure sensors
- Level sensors

Fluid Cleanliness Required for Typical Hydraulic Components

Components	ISO Code
Servo control valves	17/14/11
Proportional valves	18/15/12
Vane and piston pumps/motors	19/16/13
Directional & pressure control valves	19/16/13
Gear pumps/motors	20/17/14
Flow control valves, cylinders	21/18/15
New unused fluid	21/18/15

Figure 1. The ISO 4406:1999 fluid cleanliness standards for typical hydraulic components.

Reservoir Temperature

Maintaining a stable temperature within a hydraulic power unit will prolong the unit's life and improve hydraulic oil health. Over-temperature and under-temperature alarms can be monitored and recorded to provide information about temperature-related failures. Cold temperatures can cause cavitation due to viscosity change, and high temperatures can also affect system performance and loss of efficiency.

How hot is too hot? Hydraulic fluid temperatures above 180 °F (82 °C) damage most seal compounds and accelerate oil degradation. Hydraulic systems that operate above 180 °F should generally be avoided. Some fluid temperatures are also too high when viscosity falls below the optimum value for the hydraulic system's components, which can occur well below the 180 °F temperature, depending on the fluid's viscosity grade.

Fluid Contamination/Particle Counter

Most machine and component manufacturers specify a target ISO cleanliness level for equipment in order to achieve optimal performance (Figure 1). A SCADA system can track and record ISO codes to provide predictive and proactive equipment failure information related to contamination. Contamination types include:

- New oil: new fluid is not necessarily clean
- Generated contamination: abrasive wear, cavitation wear, fatigue wear, erosive wear, and corrosive wear
- External contamination: reservoir breathers, cylinder rod gland, and hydraulic hose

Figure 2. The Icount particle detector communicates the 4µ, 6µ, and 14µ channels to the SCADA system.

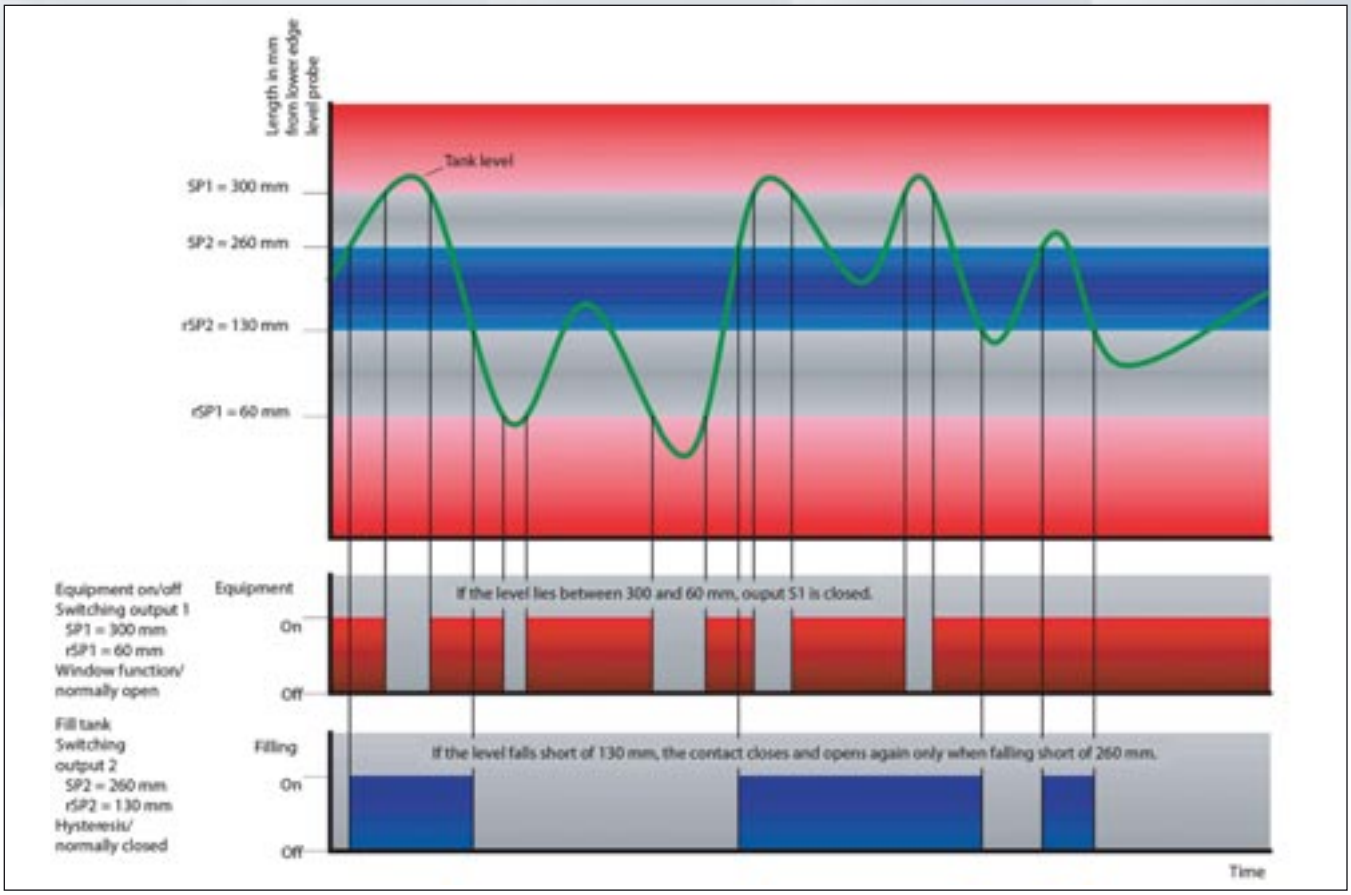


Figure 3. A level graph from Parker's SCLTSD level/temperature controller. The SCLTSD combines the function of a level/temperature switch, sensor, and display. The graph shows data points over time and can be displayed on network or local HMI.

To help meet the fluid cleanliness requirements for typical hydraulic components, a particle counter can communicate the 4µ, 6µ, and 14µ channels to the SCADA system (Figure 2). By collecting real time ISO codes, users can pinpoint specific system issues or internal maintenance processes that can be improved.

Pressure Sensors

Pressure sensors can be either pressure transducers or pressure switches. Most filters use a DELTA "P" pressure switch, which indicates when it is time to change a filter. A SCADA system can provide a date stamp for when the filter bypass switch has been indicated, and a local user can be notified via local display or network escalation. The ability to monitor the time it takes to change a filter can also provide management and stakeholders with viable information related to maintenance reliability.

Pressure transducers provide analog output to the SCADA system to maintain system performance within a predetermined range. Pressure transducers can be used to measure main system pump pressure and accumulator pre-charge pressure. This is important because pressure spikes and low pressure in the main system pump can indicate that system calibration is required. In addition, accumulator pre-charge pressure loss can drastically upset system function causing equipment failure, loss of production, and poor manufacturing quality.

Level Sensors

Level sensors provide critical information related to system reliability (Figure 3). The minimum level sensor would be a low-level switch tied to the SCADA system and pump-motor control. This process protects the pump from cavitating and degrading the system over time. Multiple level switches can also provide information related to premature failure.

Level transducers provide additional protection for hydraulic system performance, while offering information about oil loss. Oil leaks not only increase environmental concerns, but also raise issues concerned with unplanned cleanup and hazardous waste. Having the ability to capture and record proper oil levels can protect against unplanned downtime and environmental issues.

Other Areas for SCADA Hydraulic Performance

SCADA systems can also be used in a number of other applications related to a hydraulic power unit. These include: case drains for hydraulic pumps, horsepower consumption for prime movers, moisture sensors for hydraulic oil indicating heat exchanger failure, suction ball valve switches for pumps, and ITM (Interactive Technical Manual) upgrades.

This article was written by Matt Shelton, Certified Fluid Power Specialist and Sales Engineer for Kaman Fluid Power, Indianapolis, IN. For more information, visit ***http://info.hotims.com/65848-327****.*

PLCs Improve Control of Radio Broadcasts

PLCs are slowly replacing the outdated hardware and software used at many remote transmitter sites in radio and TV broadcasting applications.

Broadcasting employs the latest technology in many areas, but controlling the broadcast hardware connected to the antenna and the related transmission power, source, and facilities is usually still a low-tech operation. Typically, a broadcast engineer will drive to the unattended transmitter, translator, or repeater site to flip switches and make other manual adjustments (Figure 1).

In radio and TV broadcasting, it's important to focus on the transmission system because this is where all of the hard work in the studio is disseminated to listeners. iHeartMedia, which oversees ten radio stations in the Los Angeles metro area, has automated the switching and backup functions of its antenna and transmitter system using programmable logic controllers (PLCs). As a result, they have improved operations, cut costs, and increased reliability. In addition to radio stations, iHeartMedia owns outdoor advertising, and also has a large online radio presence in the form of the iHeartRADIO app.

Controlling the audio, antenna, and transmitter in a broadcasting system used to be a manual process. In more recent times, broadcast-specific remote control systems have been deployed to provide rudimentary control via dialup modem. With these systems, alarms can be set up to notify personnel by phone or email if there is an issue. The systems can also have macros programmed to handle automatic functions. However, the cost, reliability, and simplicity of these systems don't come close to what the PLC can deliver.

Interfacing and Control with PLCs

Although using PLCs to control transmitter functions is unfamiliar to many broadcast engineers, the hardware commonly used in industrial automation works well for control and monitoring of transmission facilities. A 50,000-Watt transmitter site consumes about 150 kW of power and contains air conditioning, power distribution, and backup power systems.

Over the years, broadcast engineers have upgraded manual monitoring of transmission facilities by applying custom electrical cabinets filled with relays, timers, diodes, and capacitors. Some are even taking a Raspberry Pi and interfacing it to a motor or blower fan using contactors and relays, which is not the simplest, most cost-effective, or the most robust design. By contrast, a PLC is designed to reliably control contactors, relays, and other components in an industrial setting.

Figure 1. Many transmitter sites, such as this KLAC radio station facility in Los Angeles, are remote and unattended. (Image: iHeartMedia)

Many broadcast engineers spend a lot of time developing interfaces among different components and items of audio equipment. They then figure out a way to integrate it all into a system, but the control hardware they use is often not suited to the task.

Automating Broadcast Functions

Automatic failure switchover and remote access are sorely needed in broadcast because many of the remote transmitter sites aren't readily accessible, particularly during periods of inclement weather. The discrete manufacturing and process control industries have been automating with PLCs for years to provide remote access and other advanced functionality, and iHeartMedia is now adapting this technology to broadcasting.

One application is at iHeartMedia's Dodgers Flagship station, KLAC AM 570 in Los Angeles. This system uses the AutomationDirect Productivity2000 controller as an antenna/transmitter controller for a number of reasons (Figure 2). KLAC's antenna/transmitter controller had to include email notifications any time the system did a transmitter pattern change or an error occurred, which is a built-in function of the Productivity2000 PLC. It also has a built-in proportional-integral-derivative (PID) loop, which will be needed for building environmental control when added in a future project.

KLAC is a directional, amplitude-modulated (AM) radio station. In the daytime, it operates using a single tower (antenna) in non-directional mode. At night, it uses two towers to produce a more directional signal to avoid interference with other stations on the same frequency, which is needed because AM signals travel farther at night.

The PLC automates the switching between daytime and nighttime patterns. Using the real-time clock in the controller, iHeartMedia designers built a table to control the switching time in compliance with FCC regulations. The PLC performs the automated pattern change and sends an email to confirm.

Figure 2. An AutomationDirect Productivity2000 PLC was used to automate transmitter pattern and backup switching at a remote facility. (Image: iHeartMedia)

Reliable Broadcasting

The Productivity2000 PLC and an AutomationDirect C-more touch panel display are the main components of the automation system that's also used to control and monitor the status of the station's main and backup transmitters. When broadcasting a Dodgers game, the station absolutely has to be on the air, and the reliability of the PLC ensures a continuous transmission signal.

The PLC monitors the status of the main transmitter and will try to restart it if it fails. If unsuccessful, it automatically switches to the backup transmitter. If the backup fails, it switches to a third-level transmitter and lowers power if necessary to keep at least a weak signal on the air.

The automation system duplicates what a human would do at the site, automatically handling antenna switching, pattern change, parameter monitoring, and other functions. It also performs datalogging per FCC guidelines, with this information available remotely. The PLC has a built-in Web server, so logged data can be accessed remotely via any browser. In this case, it is done through a Cisco firewall at the site.

PLCs have been very reliable compared to the custom control systems used previously. The PLC controls a wide variety of off-the-shelf audio switchers made by various companies. For the radio antenna switching, the PLC is controlling large RF contactors. These devices are controlled by mixing and matching the PLC's input and output modules including discrete, analog, relay contact, and serial I/O. Using these I/O points, the PLC can be interfaced to all of iHeartMedia's broadcast equipment.

Figure 3. An AutomationDirect C-more touch panel display provides functional information about the transmitter site, as well as manual control and calibration functions. (Image: iHeartMedia)

A C-more touch panel display was installed and used to create a main screen with buttons to change modes of operation or select a transmitter (Figure 3). The main screen also displays current time and transfer times for the month, along with a wide variety of analog parameters such as transmitter output, current to the antenna, and system status. And if needed, a calibration screen can be accessed to scale the analog values to actual engineering units.

Test, Installation, and Startup

Installation and startup of the antenna/transmitter automation system took significant planning to minimize impact on broadcasts. Several test jigs were built to verify operation of the automation system prior to installation, with simulated transmitters built to specifications to make the test as close to the actual installation as possible.

For testing, three simulated transmitters were plugged in and RF contactors were connected. The complete KLAC setup that the PLC would be controlling was simulated, and iHeartMedia performed weeks of testing. After some tweaking and optimizing of the PLC and C-more programs, the resulting automation system worked far better than anything that had been installed at KLAC.

The installation went as planned. There were more than 30 cables to install, and AutomationDirect ZIPLink modules were used to reduce wiring time. To reduce off-air time to the absolute minimum, signals were bypassed with jumpers until tested so the station could continue transmitting while the new automation system was installed.

There were a few minor tweaks required to the program during onsite startup. When switching transmitter patterns from day to night, the RF signal from the transmitter must be muted to avoid putting 50,000 Watts through a contactor and damaging it. Tweaking was required to minimize the time that the station was off the air when switching. Actuation times of contactors and RF power-off delay of transmitters needed to be fine-tuned, and when this was completed, the pattern switching was barely audible.

iHeartMedia plans to use PLCs to automate many more broadcast systems including automatic FM antenna switching, power control, and transmission line pressurization and fault detection.

This article was written by Dennis Sloatman, Vice President of Engineering and Information Technology at iHeartMedia, Los Angeles. For more information on the AutomationDirect equipment used in this application, visit ***http://info.hotims.com/65848-326****.*

Rescue Robot Has Remote Control Function

A group of Japanese researchers developed a prototype construction robot for disaster relief situations.

Osaka University, Osaka, Japan

A group of researchers at Osaka University, Kobe University, Tohoku University, The University of Tokyo, and Tokyo Institute of Technology developed construction robots for disaster relief that solve the various challenges of conventional construction machines used in such situations. Using a prototype machine, verification tests were performed in places that represented disaster sites to confirm successful performance. This prototype looks like an ordinary hydraulic excavator, but uses the following technologies:

- Quickly and stably controls heavy power machines with high inertia by achieving target values regarding location and speed through fine tuning and by controlling pressures on a cylinder at high speeds.
- Estimates the external load of a multiple degrees of freedom (DOF) hydraulically-driven robot from the oil pressure of each hydraulic cylinder. The estimated force will be used for force control or force feedback by the operator of teleoperated rescue robots.
- Measures high-frequency vibration using a force sensor installed at the forearm of the robot, giving the operator vibrotactile feedback.
- Flies a multi-rotor unmanned aircraft vehicle (UAV) to the location of the operator's choice and obtains image information. Long flights and pinpoint landing of the UAV are possible due to power supplied through electric lines and a power-feeding helipad for tethering the drone.
- Presents the operator with real time images of an overhead view by using four fish-eye cameras mounted on the robot. The operator can use the images to assess the area surrounding the robot.
- Uses a far-infrared ray camera capable of viewing with long-wavelength light so that the operator can conrol the robot while assessing the situation even under bad weather conditions like fog.

The rescue robot is shown with a UAV. (Image: Hiroshi Yoshinada)

In addition to the previously mentioned technologies, this group is also developing robots with a double rotation mechanism and double arms to achieve higher operability and terrain adaptability.

For more information, visit ***www.osaka-u.ac.jp/en****.*

Small Robot Has Outstanding Vertical Agility

Power modulation increases the robot's peak jumping power by storing muscular energy in stretchy tendons.

University of California, Berkeley, CA

Roboticists at the University of California, Berkeley, have designed a small robot that can leap into the air and then spring off a wall, or perform multiple vertical jumps in a row, resulting in what they claim is the highest robotic vertical jumping agility ever recorded. The agility of the robot opens new pathways of locomotion, and the researchers hope that one day this robot and other vertically agile robots can be used to jump around rubble in search and rescue missions.

To build the robot, which is known as Salto (saltatorial locomotion on terrain obstacles), the engineers studied one of

The Salto robot shown by researcher Duncan Haldane. (Image: UC Berkeley/Stephen McNally)

the animal kingdom's most vertically agile creatures, the galago. The galago can jump five times in just four seconds to gain a combined height of 8.5 meters (27.9 feet). It has a special ability to store energy in its tendons so that it can jump to heights not achievable by its muscles alone.

To compare the vertical agility of robots and animals, the researchers developed a new metric they defined as the height that something can reach with a single jump in Earth gravity, multiplied by the frequency at which that jump can be made. Salto's robotic vertical jumping agility is 1.75 meters per second, which is higher than the vertical jumping agility of a bullfrog (1.71 m/s) but short of the vertical jumping agility of the galago (2.24 m/s). The Minitaur robot had the second highest vertical agility measured by the research team (1.1 m/s).

"Developing a metric to easily measure vertical agility was key to Salto's design because it allowed us to rank animals by their jumping agility and then identify a species for inspiration," said Duncan Haldane, a robotics Ph.D. candidate who led the work. Haldane is a student in the Biomimetic Millisystems Lab of Ronald Fearing, a professor of electrical engineering and computer sciences. The research was supported by the U.S. Army Research Laboratory under the Micro Autonomous Systems and Technology Collaborative Technology Alliance, and by the National Science Foundation.

Salto's design is based on the power modulation used by the galago. Power

modulation is an adaptation found in natural systems (and designed into some robotic systems) that increases the peak power available for jumping by storing muscular energy in stretchy tendons.

The galago jumps so well because its tendons are loaded with energy by its muscles when it's in a crouched position. Adapting this process to Salto enabled its high vertical agility, including the wall jump. Inside Salto, a motor drives a spring, which loads via a leg mechanism to create the kind of crouch seen in the galago. By using power modulation, Salto doesn't need to wind up before a jump; as soon as it jumps, Salto is ready to jump again.

Salto achieved 78% of the vertical jumping agility of a galago. Because of motor power limits, the best untethered robot before Salto had a vertical jumping agility of only 55% of a galago. "By combining biologically inspired design principles with improved engineering technology, matching the agile performance of animals may not be that far off," Professor Fearing said.

Salto weighs 100 grams (3.5 ounces), is 26 centimeters (10.2 inches) tall when fully extended, and can jump up to one meter. Salto's maximum jump height was roughly 1.008 meters (3.3 ft.). For the wall jump, Salto attained an average height gain of approximately 1.21 meters (3.97 ft.). Other robots can jump higher than Salto in a single leap. For example, TAUB, a locust-inspired jumping robot, can leap to 10.5 feet (3.2 meters) in a single jump.

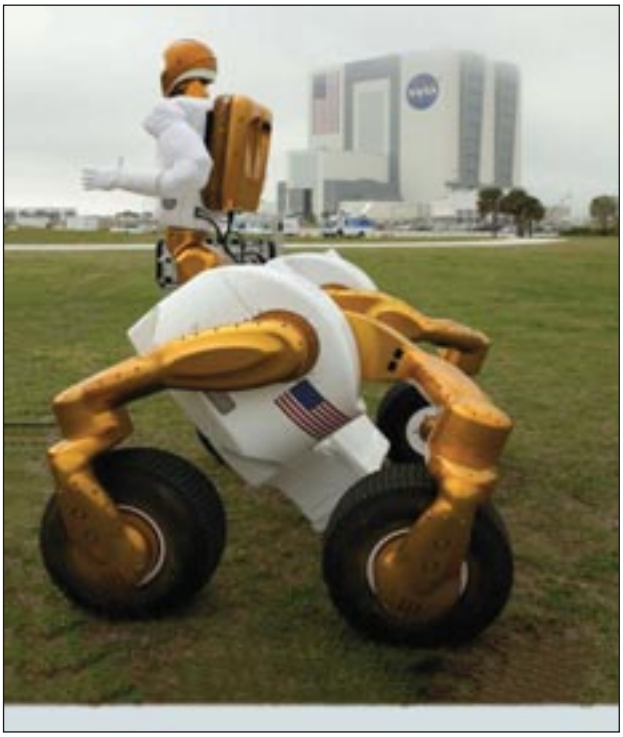
For more information, visit ***http://news.berkeley.edu/category/research/technology_engineering/****. Watch Salto in action on Tech Briefs TV at* ***www.techbriefs.com/tv/SALTO****.*

Interactive Robot Control System and Method of Use

Robonaut 2 can enter hazardous areas or tackle difficult terrain without endangering its human operator.

Lyndon B. Johnson Space Center, Houston, Texas

Researchers at NASA's Johnson Space Center (JSC), in collaboration with General Motors and Oceaneering, have designed a state-of-the-art, highly dexterous, humanoid robot: Robonaut 2 (R2). R2 is made up of multiple systems and subcomponents: vision systems, image-recognition systems, sensors, control algorithms, and much more. R2's nearly 50 patented and patent-pending technologies have the potential to be game-changers in multiple industries. One of the most promising applications for the R2 technologies is in the area of hazardous environments. R2 has the capability to work in remote locations separate from the human controller. R2 can function autonomously, or it can be controlled by direct teleoperations.



R2 has a rugged four-wheel base called the Centaur 2, which can turn in place and drive forward or sideways.

When functioning autonomously, R2 understands what to do and how to do it based on sensory input. R2's torso holds the control system, while the visor holds several cameras that are incorporated into the visual perception system. With these capabilities, R2 can reduce or eliminate the need for humans to be exposed to dangerous environments. R2 also has a very rugged four-wheel base called the Centaur 2 (see the figure). The Centaur 2 base can lower or raise itself to and from the ground and turn its wheels in any direction, allowing it to turn in place and drive forward or sideways. This enables the R2 to enter hazardous areas or tackle difficult terrain without endangering its human operator.

Robonaut 2 as a whole, or some of its components, can be an invaluable tool for land mine detection, bomb disposal, search-and-rescue, waste recycling, medical quarantined area, and much more. The suite of technologies provides an ability to manipulate tools to help with a task or tasks when a standard robot may not have the dexterity or sensing capability to get the job done. R2 can pick through nuclear waste, measure toxicity levels, and survey areas too remote or dangerous for human inspection. It can also deal with improvised explosive devices, detect and dispose of bombs or landmines, and operate equipment that can break through walls or doors.

NASA is actively seeking licensees to commercialize this technology. Please contact Michelle P. Lewis at jsc-techtran@mail.nasa.gov to initiate licensing discussions. Follow this link for more information: http://technology.nasa.gov/patent/TB2016/MSC-TOPS-44.

Piezoelectric Actuator with Dual Horns that are Separately Controllable to Drive Miniature Vehicles Along a Single Axis

The technology enables miniature vehicles to operate in extreme environments for space, military, and industrial uses.

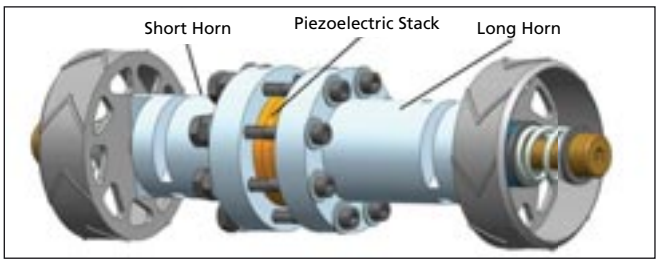
NASA's Jet Propulsion Laboratory, Pasadena, CA

Actuators are a critical driver of all the mechanisms used in space, and improvements of their operation mechanism enhance mission capabilities. The disclosed invention is a new type of actuator that simultaneously drives dual mechanisms (e.g., rotors, wheels, etc.) at opposite sides of a piezoelectric stack using the generated vibrations. The actuator consists of dual-sided horns and is capable of operating ratcheting mechanisms through walls.

The problem that was addressed is the need to drive miniature vehicles through walls while operating along a single axis and using a single motor. The use of more than one actuator that drives each of the two wheels on the opposite sides, or the use of a gear train, requires greater mass and complexity due to the need to use motors on each wheel and have additional drive electronics.

The actuator was designed using a piezoelectric stack as a transducer to produce vibrations, and rather than a horn on one side and a backing on the other, the stainless steel backing used for pre-stressing the stack was replaced with a second horn. Thus, the pre-stress backing was converted to an additional actuator on the other side of the transducer. Further, the dual-horn actuator was designed based on the piezo-ratcheting motor, providing actuation on both sides of the piezoelectric stack. This design allows rotation of wheels with no moving parts besides the rotors.

The two horns are not made identical, allowing steering capability where the use of different driving frequencies leads to changing the relative speed of the wheels along the drive axis. Also, the horns are designed to be sufficiently similar to allow operating them well within the same range of frequencies, while causing one to outperform the



The dual-horn actuator was designed on a piezo-ratcheting motor, providing actuation on both sides of the piezoelectric stack. This design allows rotation of wheels with no moving parts besides the rotors.

other. By controlling the frequency, the direction of travel of a rover driven by these horns is controlled. The piezoelectric stack was made of lead zirconate titanate (PZT) with multiple steel backing plates and clamping screws.

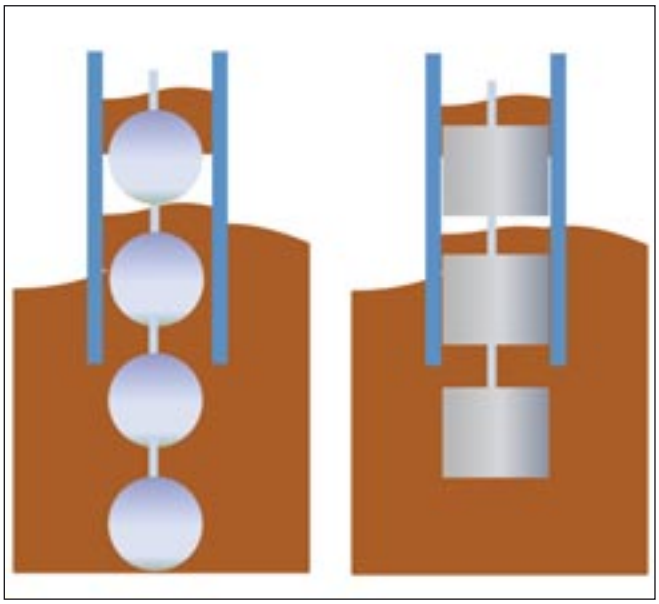
This work was done by Yoseph Bar-Cohen, Stewart Sherrit, Xiaoqi Bao, Mircea Badescu, Phillip E. Walkemeyer, and Grayson T. Adams of Caltech for NASA's Jet Propulsion Laboratory. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov.***
NPO-49438

Chain Drive Dust Conveyer

This method clears cutting fines from a sampling tool without the use of fluids.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Mars 2020 coring drill will generate a significant amount of dust and debris (known as fines) due to the volume of milled material displaced by the corer's annulus. These cuttings must be removed to ensure that the drill does not jam. The typical method involves fluids, which may not work on Mars due to the atmospheric conditions.



A chain drive through a tube is used to convey dust and fines. The chain can maneuver in any angle within a certain allowable bend radius. The catch features can be spherical or cylindrical.

The proposed solution is to use a chain drive through a tube to convey dust and fines. The catch features on the chain push the dust and fines through the tube (see figure). The chain is compliant, which allows it to maneuver in any angle within a certain allowable bend radius. The concept was successfully demonstrated using a ball chain to transport dust through a tube.

This work was done by Donald B. Bickler and Charles M. Dandino of Caltech for NASA's Jet Propulsion Laboratory. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov.***
NPO-49629

Robot Powertrain Moves Toward Energy Autonomy

A smart gear box can significantly reduce energy consumption for future dyke inspection robots.

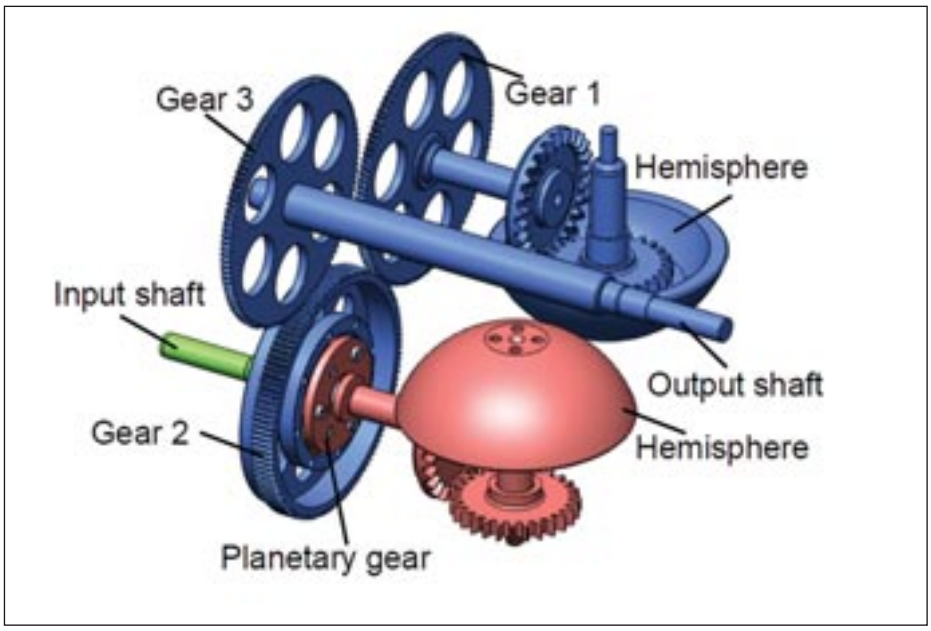
University of Twente, Enschede, The Netherlands

Inspecting the condition of dykes and other sea defense structures is typically a task for a team of robots. They consume a lot of energy to move across the dykes, perform tests, and communicate the results for six hours a day. Because charging stations are not a realistic scenario, University of Twente researcher Douwe Dresscher looked at making the robot as energy autonomous as possible. He obtained good results by having the robot store mechanical — rather than electrical — energy, and by introducing an innovative automatic gear box. The gear box is a modern version of the "variomatic" model used in Dutch DAF automobiles. While the variomatic uses a belt drive, the inspection robot uses two metal hemispheres.

The first factor Dresscher had to consider was the best way for the robot to move on the dyke — using wheels, caterpillar tracks, or legs. Wheels work well and are energy efficient on an even surface, but a wet and muddy slope is something quite different. Tracks are more powerful in this case, but they can damage the dyke by the way they turn and they are energy inefficient. A walking robot with four to six legs would perform best. Walking robots do consume a lot of energy, and existing commercial walking robots always wear a big battery pack.

Electromotors are primarily responsible for this high level of energy consumption. They perform best at high revolution speeds and low torques, but in the walking movement they often work at low revolutions and high torques instead. By storing energy in a mechanical rather than an electrical way, the electromotors can do their job using the best operation regimen, and mechanical energy can be reused. This is what Dresscher calls Controlled Passive Actuation.

The system can store mechanical energy in a spring, for instance. A gear box takes care of the optimum transmission. Two half-turning half hemispheres therefore are constantly in contact. The angle changes when the torque changes — resulting in another relative radius. The difference in effective radiuses determines the transfer ratio and the best mechanical load. The electromotors join in only to compensate for mechanical losses. By



The robot gearbox with continuously variable transmission using two hemispheres. (Image: University of Twente)

doing so, they can work within the high-rev, low-torque system.

To eventually make the dyke robots fully self-supporting (sensing and communication also require energy), they will need to "harvest" energy when moving. Solar energy, wind energy and biomass are viable options. Dresscher didn't examine this aspect in detail; his work focused on the locomotion part of the robot and the powertrain. The new powertrain is specifically designed for future dyke inspection robots, but it could also be applied to improving the energy efficiency of existing robots and robot arms.

For more information, visit ***www.utwente.nl/en/news/****. To watch Douwe Dresscher explain the principles of the new drive train for robots on Tech Briefs TV, visit* ***www.techbriefs.com/tv/dyke_inspection****.*

Evaluation Standard for Robotic Research

Universal benchmarks can standardize the measurement of robotic manipulation tasks.

Yale University, New Haven, CT

The Yale-CMU-Berkeley (YCB) Object and Model Set provides universal benchmarks for labs specializing in robotic manipulation and prosthetics. About two years ago, Aaron Dollar, an associate professor of mechanical engineering and materials science at Yale University, came up with the benchmark idea to bring a

In addition to the objects, the project also provides five examples of manipulation tasks (such as pouring water from a pitcher to a mug) and benchmarks for each.

level of specificity and universality to manipulation tasks in robotics research. He enlisted the help of two former colleagues in the robotics community, Dr. Siddhartha Srinivasa from Carnegie-Mellon University and Dr. Pieter Abbeel of the University of California, Berkeley.

The set contains 77 objects, including things like hammers, a pan and spatula, a cordless drill, a can of Spam, and a nine-hole peg test. These household items could create a new kind of standardization for robotics. For instance, a research paper might describe a task as "robotic hand grasps hammer" without specifying whether it is a big hammer or a little one. That's a problem for a robotics researcher looking to replicate the results. With the YCB Set, everyone would be working with the same 23.45-ounce Stanley hammer included in the set.

In addition to the objects, the project provides five examples of manipulation tasks — such as pouring water from a pitcher to a mug or setting the table — and benchmarks for each. A website for the project allows other laboratories to expand on these tasks by contributing their own protocols and benchmarks. When laboratories work solely by their own standards and protocols, Dollar said, there's often an unconscious bias toward that lab's particular strengths. Universal standards would provide a more impartial way to evaluate results.

The YCB objects and example tasks are just a beginning. Manipulation research progresses quickly and covers a wide range of technical interests and research approaches, so the five manipulation tests Dollar and his team provide are only examples of protocols that labs can use with the objects. That's why on the YCB Object and Model Set website, the research team has also provided a framework for other labs to contribute their own manipulation tests and benchmarks. There, researchers can see protocols from other labs and have a forum for discussion.

The objects are divided into categories. The food group, for example, includes a cereal box, a cylinder of Pringles chips and a can of Spam. Tools range from small nails to wood blocks and a cordless drill. Dollar said he aimed for a wide variety of sizes (the smallest item is a washer, the largest a water pitcher). Some items have simple geometric shapes that are relatively easy to grasp, while the complex shapes of others pose a greater challenge for robotic hands.

The items also include various task-based objects: a "box-and-blocks test" in which wooden cubes are to be placed in a box; a toy airplane that can be assembled and disassembled; and a variety of Lego pieces for building structures. The set also comes with a digital timer to measure how quickly certain tasks are performed.

For the project to succeed, Dollar needs to convince other labs to adopt the YCB Set. About 100 robotics labs around the world now have the YCB Set, which costs about $350.

For more information, visit ***www.ycbbenchmarks.org.***

NEW PRODUCTS

Bore Cylinder

The MP5 Airpel Plus bore cylinder from Airpot Corp. (Norwalk, CT) has a bore size of 5.6 mm and a maximum outside diameter of 9.8 mm. The air cylinder is fitted with a graphite piston matched to fit a borosilicate glass cylinder enclosed in a stainless steel outer tube. It is available in six stock strokes from 10 mm to 100 mm, performs best at an operating pressure of 0.2 to 0.7 MPa, and operates in temperatures from –20 °C to + 85 °C. It is designed to be used without lubrication and reduces friction to a maximum of 0.5% of the load. The MP5 Airpel is configured with a threaded ball joint rod end to accommodate mounting misalignments, and is available in front or rear mounting styles. It is one-way acting with pressurization in the rod-extend direction only.

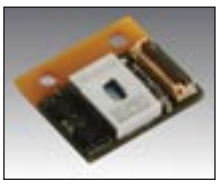
For Free Info Visit http://info.hotims.com/65848-300

SCR Control

American Control Electronics (South Beloit, IL) announced the MGB Series, a regenerative SCR (silicon controlled rectifier) control that maintains the industry-standard mounting pattern and footprint. The drive's minimal design includes power in, power out, speed pot, direction switch, and stop/start switch. A microprocessor allows for custom programming where needed. The MGB Series is specifically engineered for applications that require a controlled deceleration, braking, or instant reversing. It is for use with permanent magnet DC motors only. AC voltage input is 115/230 VAC, armature output is 90/180 VDC, and armature current is 8 amps (11 amps if heat synced).

For Free Info Visit http://info.hotims.com/65848-301

Precision Encoder



The MicroE Optira™ Series encoders from Celera Motion (Bedford, MA) provide a resolution of up to 5 nm with automatic gain control (AGC), interpolation, and signal processing carried out in the sensor head. The Optira sensor head comes with two mounting options and a standard FFC connector. A 3.3-VDC version is available for use in precision instruments powered by batteries. The Optira sensor head measures 11.4 × 13 × 3.7 mm. No additional PCBs, adapters, or dongles are necessary for the full functionality and resolution of the sensors. Optira sensors can be universally applied with MicroE linear glass scales (to ±1 µm/m accuracy), linear metal tape scales (to ±5 µm/m for Optira), and rotary scales (to ±2 arc-seconds). The interfaces options are A-quad-B or 1Vpp sin/cos.

For Free Info Visit http://info.hotims.com/65848-302

Electric Actuator

Curtiss-Wright Sensors and Controls Division (Gilbert, AZ) introduced the second frame size of its Exlar® brand FTX Series actuators. The FTX125 electric rod style actuator has a continuous force rating to 44 kN (10,000 lbf), speed to 1166 mm/s (46 in/s), and stroke lengths from 150 mm (6 inches) to 900 mm (3 feet). The IP65-rated actuator employs a high-capacity planetary roller screw, uses an Idler pulley design, and includes a grease Zerk fitting and a removable front seal bushing. Bolt-on mounting hardware allows mounting style reconfiguration in the field using commonly available tools.

For Free Info Visit http://info.hotims.com/65848-303

Paint Robot

The EcoRP E043i Ecopaint Robot from Dürr Systems AG (Bietigheim-Bissingen, Germany) automates the painting process with a seven-axis kinematic system that eliminates the need for a linear displacement rail. The seventh rotatory axis is directly incorporated into the robot's kinematic chain. The paint robots can be installed on the floor, wall, ceiling, or at an angle in the paint booth. They are controlled by the company's EcoRCMP2 process and movement control system that features modular control and drive components, a digital encoder interface, and integrated safety control for monitoring of the working area and speed. An integrated interface makes the robot system "cloud ready" and provides all relevant data for the Industry 4.0 environment.

For Free Info Visit http://info.hotims.com/65848-304

Clutches and Brakes

Formsprag Clutch (Warren, MI) introduced a line of electromagnetic brakes designed to start, stop, and hold loads in position with precise control. The brakes are targeted at aerospace applications including flap actuators, drones, munitions, motor brakes, winch and tensioning systems, satellites, ball screw drives, and robotic arms. The product line includes permanent and electromagnetic power-off friction and holding brakes. In addition, the company's new aerospace electromagnetic clutches are designed to transmit rotational energy with the speed of a contact closure. The clutches can be used on aircraft alternators, instrumentation, starters, pumps, motors, transmissions, valves, and gearboxes.

For Free Info Visit http://info.hotims.com/65848-305

Tube Fittings

Configurable, push-to-connect, stainless steel fittings from Global Fittings Concepts, Inc. (Titusville, FL) provide metric (6, 10, 12 mm) and fractional (1/4, 3/8, 1/2 inch) tube modules, along with hybrid thread modules. Thread modules seal into 1/4, 3/8, and 1/2 NPT, BSPT, and BSPP female threads. The modules couple and lock to union, elbow, or tee bases. Users can assemble fluid or pneumatic connections in 375 unique configurations with twelve modules and bases.

For Free Info Visit http://info.hotims.com/65848-306

Hybrid Servo Motors

QuickSilver Controls, Inc. (San Dimas, CA) announced a line of NEMA 23 frame direct drive hybrid servo motors. Four stack sizes provide 80 oz-in (0.56 Nm) through 430 oz-in (3 Nm) continuous torque, with top speeds from 1000 to 4000 rpm. The control system's damping methods handle inertial mismatch without retuning or notch filters. The programming environment provides for two programming threads in addition to an active motion. Serial communications include MODBUS® RTU, 8-bit ASCII, 9-bit binary, and DMX512. CANopen® is simultaneously available with the serial options. Seven IO are provided for external interfacing. Programmable terminations allow the IO to be pulled high, pulled low, or floated while in input mode. All of the IO may also be used as analog inputs, with one channel also supporting 0-10 V analog control.

For Free Info Visit http://info.hotims.com/65848-307

Torque Limiters

The STF series of flange-mounted torque limiters from R+W America, L.P. (Bensenville, IL) feature a heavy-duty configuration for adaptation to flange mounted torque transducers, gearboxes, Cardan shafts, and more. The torque limiters are available in five sizes and can be configured for disengagement torques from 200 Nm to 45,000 Nm. Users can individually adjust the safety elements to fine-tune the disengagement torque level, or change the number of safety elements to make large adjustments to the disengagement torque range. This series comes with an optional "plate" for re-engagement.

For Free Info Visit http://info.hotims.com/65848-308

Rotary Unit

SCHUNK (Morrisville, NC) offers the SRM universal rotary unit for production automation. The SRM features internal shock absorbers and a larger pinion mounting surface than previous models for better stability and large center bore for feeding through items like cables and hoses. Modular air feed-though and electrical feed-though versions are available as factory options or as field installed items. The SCHUNK SRM is available in sizes 16, 32, and 40, with other sizes and options to follow.

For Free Info Visit http://info.hotims.com/65848-309

Leveling Sets

J.W. Winco, Inc. (New Berlin, WI) offers the GN 350.2 leveling sets with spherical washer. The sets, which are made from steel, have a zinc-plated and blue passivated finish and are used for leveling, adjusting, and linking operations. The RoHS-compliant leveling sets consist of a threaded upper sleeve and a tapped lower sleeve. The fine thread allows precise, stepless setting and locking using a hook wrench. An anti-rotation disk also serves as a height limiter. The spherical washer allows installation of two non-parallel planes at a required gradient up to ~4°.

For Free Info Visit http://info.hotims.com/65848-313

DC Motors

A family of three size-15 permanent magnet DC motors from Torque Systems (Billerica, MA) can be used in applications such as semiconductor processing equipment, robots, UAVs, and medical devices. The longer stack size 15 DC motor (model MS1525-A) reaches a rated torque value of 10 ounce-inches at 6700 RPM. Rated power output is 50 watts. Shorter models MS1509-A and MS1515-A provide 30 and 40 watts, respectively. All models have a top speed of 10,000 RPM. The theoretical acceleration performance ranges from 45K radians/s^2 up to 65K radians/s^2. Peak torque on the MS1525-A model can reach 77.8 ounce-inches.

For Free Info Visit http://info.hotims.com/65848-311

Integrated Servo Motor

Tolomatic (Hamel, MN) introduced an integrated servo motor/drive/controller for single-axis applications. The ACSI servo motor controller can replace pneumatic cylinders and automate other axes of motion. It has built-in configurations for all of Tolomatic's electric actuators, and creates linear motion in the desired linear units (mm or inch) via a USB or Ethernet port. The ACSI also supports rotary axes and third-party actuator control. It's available in two sizes (NEMA 23 and 34) and is designed to be controlled from a PLC or master controller via 24-Vdc digital I/O, 0-10 Vdc or 4-20 mA analog I/O, EtherNet/IP, or Modbus TCP. Additional features include a standard IP65 rating, industry-standard M12 connectors, dual Ethernet ports with LED indicators, and a USB programming port.

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Programming Software

UniLogic™ version 1.18 from Unitronics Inc. (Quincy, MA) includes new features for the UniStream™ All-in-One HMI + PLC controller, including SQL connectivity, conversion of HMI screens to web pages, and HMI custom controls. Programmers can build SQL queries and execute them via ladder functions, including data transfer between UniStream's data tables and remote SQL databases. They can also create an HMI custom control and then drag and drop it from the Solution Explorer, export/import it between projects as .uluce files, or add it to the library. Tags that are local to a specific custom control can be defined, and local tags are exported/imported along with the control.

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Piezo Nanopositioning Stages

Aerotech (Pittsburgh, PA) introduced the QNP2 series XY, parallel-kinematic, piezo positioning stages with sub-nanometer resolution. The QNP2-100-XYA has a 50 mm × 50 mm clear aperture with closed-loop travels up to 100 µm × 100 µm and open-loop travels to 120 µm × 120 µm. All QNP2 piezo stages are available with closed-loop feedback (-C) or with open loop (no feedback). The capacitive sensor parallel-metrology design directly measures the output of the positioning carriage enabling 0.15-nm resolution, 0.01% linearity, and 1-nm bidirectional repeatability. An optional mounting plate allows direct mounting to English or metric breadboard optical tables, and a solid tabletop is available. QNP2 piezo stages are also offered in custom materials and vacuum-prepared versions. Software options include tools such as learning control, harmonic cancellation, and command shaping to help improve tracking errors and increase step-and-settle times.

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Voice Coil Actuator

BEI Kimco (Vista, CA) announced a moving magnet voice coil actuator (VCA) with a flexure design to prevent unwanted shaft rotation. The housed linear actuator model LAH13-11-000A incorporates a shaft with flexures at both ends of travel that support the moving magnet field assembly. The flexure design helps eliminate friction and side-loads at non-vertical angles, removes particulate accumulation caused from bearing/bushing shedding, and can return the magnet to mid-stroke when re-energized. The actuator has a peak force of 11.9 N and a continuous stall force of 0.7 N in a package that measures 36.00 mm × 30.00 mm and weighs 0.22 lb.

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Design Software

Galil Motion Control Inc. (Rocklin, CA) introduced the Galil Design Kit for the company's motion controllers and PLCs. The software includes six tools. Scope emulates a traditional digital oscilloscope, Tuner assists in optimizing a system's performance, and Terminal sends commands and receives responses from the controller. The Editor writes, saves, and executes application programs. Viewer enables real-time viewing of the controller's I/O status and motor position, and the Setup tool reads, edits, saves, and restores all controller memory. All the tools are customizable by editing the XLM.

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Curved Linear Guides

igus Inc. (East Providence, RI) offers linear rails bent to custom radii, and adaptable carriages that can self-align between straight linear runs and curves without binding. The curved rails and self-aligning carriages operate without any external lubrication or maintenance. To compensate for rail spacing, a pivoting spherical ball made of self-lubricating iglide plastic materials is used in the self-aligning carriage. This allows for movement on flat, convex, or concave curved rails. The carriage is also available with manual clamping options, allowing the carriage to be fixed at any point of travel.

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Brushless Motor

The 22ECT brushless slotless motor from Portescap (West Chester, PA) is designed for high continuous torque at low to medium speeds, maximizing power between 10K and 20K RPM. It is constructed with a high-efficiency magnetic circuit that helps reduce both iron and joule losses, the primary causes for motor stator heating. Maximum continuous torque goes up to 98.5 mNm with higher stall torque. The 22ECT uses a multipolar design and is available in 60- and 82-mm length versions, with Hall sensors and three different coils to match speed and voltage requirements.

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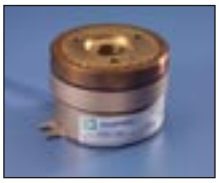
Tooth Clutch



SEPAC Inc. (Elmira, NY) introduced the Stationary Field Tooth Clutch (SFTC Series) built with a bearing supported design. It can operate dry or in oil, and has less than one degree of backlash. The magnet body of the SFTC is held stationary by the means of an anti-rotation screw or post anchored to a hole provided. It is typically installed on a motor or gearbox shaft with the option for a hub, coupling, gear, pulley, or sprocket mounted to the armature. Static torque is 40 to 5200 lb-ft and maximum speed is 1400 to 3500 RPM. The eight standard sizes have a magnet body diameter of 3.16" to 10.65", an overall length of 2.07" to 6.18", and a rotor bore measuring 0.50" to 2.75".

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Rotary Stages

The ServoBelt rotary stages from Bell Everman (Vaughan, Ontario, Canada) are available with 50-, 100-, and 200-mm center openings to accommodate large bundles of power, signal, and pnuematic conductors. Standard-sized models with 16- or 25-mm through holes offer a more economical choice when fewer utilities need to pass through the center of the stage. They are designed for NEMA 23 and 34 motors, and offer speeds up to 1,000 RPM, continuous torque to 6.6 N-m, and resolution down to 0.16 arc-sec with Renishaw ring encoders or tape scales for partial rotation. The stages support both continuous rotation and variable indexing applications, and incorporate full-duplex angular contact bearings.

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Valves

Fabco-Air, Inc. (Gainesville, FL) announced the RLT Series lockout/tag-out valve product line. Connection to these three-way, rotary turn valves can be made with NPT port or manifold interface items. The valves are available with 1/4", 3/8", and 1/2" inlet port sizes. These manually operated valves are used to prevent undesired operation. While in the exhaust position, the valve can be locked to prevent an unintentional system start-up. Furthermore, this prohibits the unexpected cycling of equipment due to any stored energy in the airline.

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Angle Sensors

Novotechnik, U.S. (Southborough, MA) offers the Vert-X 2800 Series of sensors that measure angular position. They can be configured to include start- and end-angles for less than 360° maximum range, index points, cw or ccw indication, calibration settings, and nonlinear curves. The sensors are available in single and fully redundant versions. Measurement range is 0 to 360° with repeatability of 0.1°. Available analog outputs are 4 to 20 mA, 0.1 to 10 V, 10 to 90% of supply voltage, and 5 to 95% of supply voltage. Digital output choices are SPI or PWM. Other features include up to two programmable TTL-level switches, 28-mm housing base diameter, up to 14-bit resolution, and linearity to ±0.1 % of measurement range. The sensors are sealed to IP65, life is ≥ 50 million movements, and MTTF is over 100 years.

For Free Info Visit http://info.hotims.com/65848-322

Hoses and Coupling

Kurt Hydraulics (Minneapolis, MN) offers two hydraulic hose styles and a single coupling style that can handle pressure ranges of 3,000 to 6,500 PSI. The Kurt Tuff™ Spiral Flex hose is reinforced internally with four spiral layers of high tensile steel wire braid and has a durable oil, ozone, and abrasion resistant synthetic outer cover. It withstands temperatures from -40 °F up to 250 °F and meets flame resistant MSHA designation. The E-Z Bend™ hydraulic hose has a tight bend radius using minimal installation force. With a working hose pressure range from 5,000 psi to 6,000 psi, E-Z Bend has a working temperature range of -40 °F to +212 °F and meets flame resistant MSHA designation. The W-Style couplings are designed for non-skive, high-pressure spiral hose (6,000 psi) and all wire braided hose applications. These couplings are available in 742 different end types.

For Free Info Visit http://info.hotims.com/65848-330

Accelerometer

PCB Piezotronics (Depew, NY) released the Model 357A100 high-temperature differential charge accelerometer with a UHT-12™ sensing element. This accelerometer is for use during gas turbine engine research and testing, and has an industry standard 3-hole mount. A well-balanced, differential output is isolated from case ground to reduce the electrical noise found near airplane and helicopter gas turbine engines. Its charge output is self-generating and does not require an external power source. The UHT-12 crystal technology features absence of pyroelectric noise spikes up to 900 °F (482 °C); shear mode crystals isolated from base strain and transverse measurement errors; and no depletion of oxygen at high temperatures, eliminating the need for a vent or window in the housing.

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Smart Drive

Smart Products from Lenze Americas (Uxbridge, MA) help simplify commissioning and operation of roller and chain conveyors. These products assist the process of defining the conveying system, selecting the installation version, and fixing the payload. Smart Product solutions are supplied with engineering documentation and design of ready-made modules, including CAD blueprints, dimensioned drawings, and EPLAN macros for integration by machine builders. The products can be paired with a smartphone for remote authenticated user access in Industry 4.0 systems. A Lenze smartphone app enables selection of the motor fixed speed and gearbox torque variation. The products are available in outline and inline versions covering six payload classes ranging from 2,200 to 11,460 lbs.

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What's On

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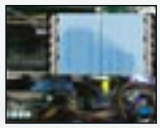
Featured Sponsor Video: Prescription for Productivity

Machines that package pharmaceuticals need exceptional versatility to handle a constantly changing array of materials and sizes. PharmaWorks achieves these aims with packaging machines that replace outdated pulleys, belts, and driveshafts with the precision of Yaskawa servos and motion control systems.
techbriefs.com/tv/PharmaWorks



Motion Planning Chip Turns Robot's Long Pauses into Quick Action

Duke University researchers have sped up robotic motion planning by three orders of magnitude while using one-twentieth the power. Their custom processor performs the most time-consuming part of the job — checking for potential collisions across the robot's range of motion — with unprecedented efficiency.
techbriefs.com/tv/motion-planning

Autonomous "Swarmboats" Demonstrate Harbor Defense

U.S. Navy drone boats have learned to work together like a swarm with a shared hive mind. In a recent "swarmboats" demonstration, the boats showed off improved control and navigation. If they spotted a possible threat, the swarmboats would collectively decide which of them would go track the intruder vessel.
techbriefs.com/tv/swarmboats

Feathered Drone Dives Almost like a Bird

After observing birds in flight, EPFL researchers had the idea of building an energy-efficient winged drone capable of changing its wingspan, flying at high speed, making sharp turns, and moving through tight spaces. By changing its geometry mid-flight, the research team's new drone meets all these criteria.
techbriefs.com/tv/feather-drone

www.techbriefs.tv

NEW PRODUCTS

Servo Motor and Drive

Siemens Industry, Inc. (Elk Grove Village, IL) announced the Simotics S-1FG1 servo geared motors and Sinamics S120 drive system. The products are offered as part of the company's Totally Integrated Automation (TIA). Pre-fabricated Motion-Connect signal and power cables connect the components. The motors are connected via the Drive-Cliq system interface. The Simotics S-1FG1 servo geared motor is available with helical, parallel shaft, bevel, and helical worm gearboxes with up to 25 transmission ratios, depending upon the type of gear and gear size required. The S120 drives have a scalable number of axes, and are available in blocksize and booksize hardware types. The power units or motor modules in booksize format operate in the 3–30A range.

For Free Info Visit http://info.hotims.com/65848-333

Turbomolecular Pump

Edwards Ltd. (Burgess Hill, UK) offers the nEXT85 turbomolecular pump targeted at R&D, high energy physics, and analytical instrument uses. The pump's built-in infrared temperature sensor directly measures the rotor temperature for thermal control. An on-board USB port allows communication with the company's free nST software. The pump is available in standard or higher compression versions.

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Brushless Motors

The EC044A and EC042B Series brushless motors from Pittman Motors (Harleysville, PA) have been released into the company's 24-Hour Pittman Express e-Commerce store. Both series come with the E30 encoder and PLG42S planetary gear. The EC044A is a 44-mm brushless motor with performance ranging from 0.04 Nm (6 oz-in) to 4 Nm (600 oz-in) of rated torque with rated speeds from 40 to 4500 RPM. The newer EC042B has a 42-mm diameter. Performance ranges from 0.06 Nm (9 oz-in) to 8.8 Nm (1200 oz-in) of rated torque with rated speeds from 40 to 4500 RPM in stock solutions. Motors can be specified with a range of different windings, speeds, gear ratios, and encoder outputs.

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Digital Piezo Controller

PI (Physik Instrumente) L.P. (Auburn, MA) introduced a 4-channel version of its E-727 digital piezo controller. It is designed for multi-axis nanopositioning applications. The controller offers a choice of digital high-speed interfaces, such as SPI, Ethernet, USB, and RS-232, as well as three additional analog inputs. It includes four integrated piezo power amplifiers with an output range of -30 to +130 V as well as circuitry for capacitive feedback sensors, piezoresistive sensors, and traditional strain gauges. The digital servo provides PID control with two programmable notch filters for higher bandwidth by suppression of mechanical system resonances. Digital linearization is based on 4th order polynomials, and optional Dynamic Digital Linearization (DDL) firmware eliminates phase lag and dynamic non-linearities at high operating frequencies. Features include a data recorder for high-speed tracing, ID chip compatibility, and exchange of system components without recalibration. The controller comes with software support for LabVIEW and shared libraries for Windows and Linux.

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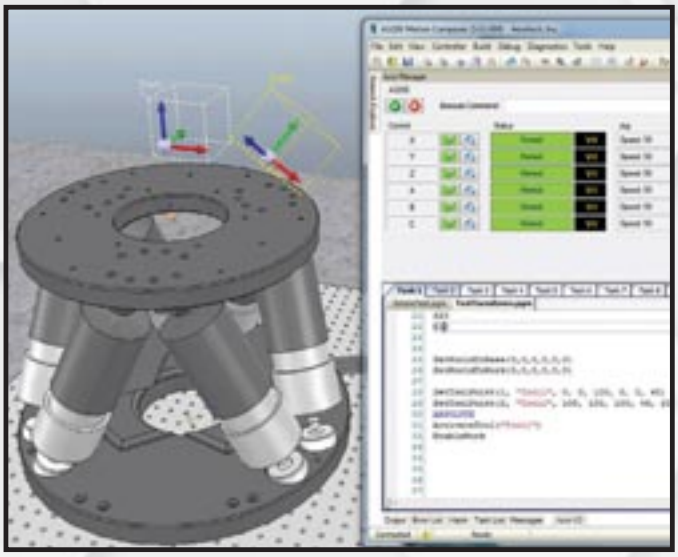

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