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Cov **Cover:** Click on this icon to quickly turn to the front cover.

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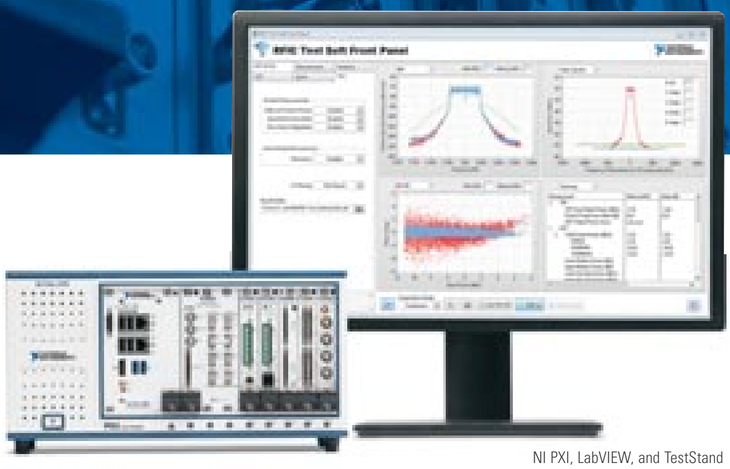

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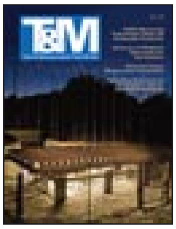

Product of the Month

The identiFINDER® R200 wearable detector from FLIR Systems (Wilsonville, OR) provides continuous radiation monitoring without any user interaction.

66

On the cover

Over the past few decades, average global temperatures have been on the rise, and this warming is happening two to three times faster in the Arctic. The Arctic Radiation – IceBridge Sea and Ice Experiment (ARISE) is a NASA airborne campaign that collected data on thinning sea ice, and measured cloud and atmospheric properties in the Arctic. The red plane is a DHC-3 Otter, the plane flown in NASA's Operation IceBridge-Alaska surveys of mountain glaciers. See page 6 to learn more about how NASA technology keeps track of the state of the planet as we celebrate Earth Day this month.

(Image: NASA/Chris Larsen, University of Alaska-Fairbanks)

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UP FRONT

Linda Bell
Editorial Director

Editor's Choice

Saliva is an easily accessible body fluid that contains important biological markers that can be used to monitor the health of an individual. A saliva collection device called the Saliva Procurement and Integrated Testing (SPIT) booklet was developed for use in remote locations, and doesn't require any special storage conditions. The booklets contain filter paper pages that are used to collect saliva samples over a specified time. The samples are dried at room temperature, and are stable for up to six months. Find out more on page 28.

App of the Month

It's free, it's dazzling, and it puts Earth in the palm of your hands. NASA's "Earth Now" app displays real-time global satellite data of our planet's vital signs. Great for anyone interested in Earth science, this 3D app can be your go-to source for carbon dioxide conditions, gravity anomalies, ozone levels over Antarctica, and more. Visit **http://climate.nasa.gov/earth-apps/** to download it to your Apple or Android device to keep your eye on the Earth.

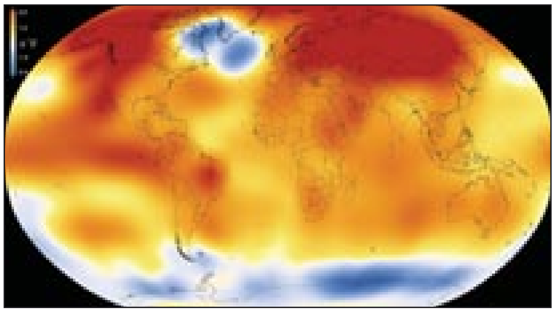
Next Month in NTB

The May issue will have special coverage on 3D printing and additive manufacturing. Find out how NASA is using this technology to make everything from parts on the next generation of Mars rovers, to rocket engine components, to full-size habitats for astronauts on other planets.

The State of Earth

U.S. Senator Gaylord Nelson created Earth Day in 1970. Over the years, Earth Day grew in popularity and in 2009, the United Nations officially named April 22 as International Mother Earth Day. Earth Day (**www.earthday.org**) is now celebrated by over one billion people in nearly 200 countries.

While NASA always keeps its eyes on the Earth, Earth Day is an especially important time for NASA to take a closer look at the state of the Earth. Since 1959, with the launch of the first weather satellite, NASA has been studying our home planet on a global scale. NASA's decades of Earth-watching have made the agency an expert on our environment: the water and oceans, ice and snow, land, air, and the planet's living ecosystems.



This visualization from Goddard's Scientific Visualization Studio illustrates Earth's long-term warming trend, showing temperature changes from 1880 to 2015 as a rolling five-year average. Orange colors represent temperatures that are warmer than the 1951-80 baseline average, and blues represent temperatures cooler than the baseline.

Based on analysis by scientists at NASA's Goddard Institute for Space Studies, managed by Goddard Space Flight Center, 2015 was the warmest year since modern recordkeeping began in 1880. Most of the warming occurred in the past 35 years, with 15 of the 16 warmest years on record occurring since 2001. Phenomena such as El Niño or La Niña can contribute to short-term variations in global average temperature. A warming El Niño was in effect for most of 2015.

Goddard's Scientific Visualization Studio, which creates animations and images of Earth and space science research, created "Dynamic Earth: Exploring Earth's Climate Engine," a full-dome, high-resolution movie that illustrates how equilibrium between Earth's climatic systems sustains life, and what could happen if the balance is tipped. See an excerpt from the film on Tech Briefs TV at **www.techbriefs.com/tv/dynamic-earth**.

For more information about NASA's Earth science activities, visit: **www.nasa.gov/earth.**

It's Time to Create the Future

Create THE Future
DESIGN CONTEST 2016

The 14th annual Create the Future Design Contest (**www.createthefuturecontest.com**), sponsored by COMSOL and Mouser Electronics, and produced by Tech Briefs Media Group, is open for entries. The contest recognizes outstanding innovations in product design worldwide, awarding a Grand Prize of $20,000. There is no cost to enter.

Entries can be submitted by individuals and/or teams in seven categories. Prizes will be awarded for each category, and for the ten most popular entries as voted on by site registrants. If you choose to post your entries on the contest site, they will be seen by business and technology leaders across the globe who could help bring your ideas to market.

For complete information and the official entry form, go to **www.createthefuturecontest.com**.

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Products of Tomorrow

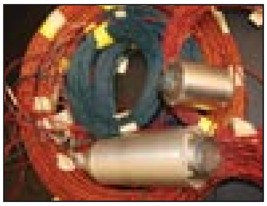
The technologies NASA develops don't just blast off into space. They also improve our lives here on Earth. Life-saving search-and-rescue tools, implantable medical devices, advances in commercial aircraft safety, increased accuracy in weather forecasting, and the miniature cameras in our cellphones are just some of the examples of NASA-developed technology used in products today.

This column presents technologies that have applications in commercial areas, possibly creating the products of tomorrow. If you are interested in licensing the technologies described here, use the contact information provided. To learn about more available technologies, visit the NASA Technology Transfer Portal at http://technology.nasa.gov.

▶ Conical Seat Shutoff Valve

Stennis Space Center developed a moveable valve for controlling flow of a pressurized working fluid. The valve consists of a hollow, moveable floating piston pressed against a stationary solid seat, and can use the working fluid or an external pressure source to seal the valve. This open/closed valve has a novel balanced piston so it can be designed to always seat with the same amount of force, allowing the use of metal-to-metal seats as well as soft seats. The valve, even when used with large, high-pressure applications, does not require large conventional valve actuators, and the valve stem itself is eliminated. Actuation is achieved with the use of small, simple solenoid or hand valves. The design reduces downtime and maintenance costs, while increasing valve reliability and seat life.

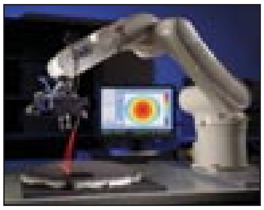
Contact: Stennis Space Center
Phone: 228-688-3605
E-mail: ssc-technology@nasa.gov



▶ Self-Healing Wire Insulation

Kennedy Space Center's flexible, low-melt polyimide film features self-healing properties provided by embedded microcapsules containing a solvent-soluble polyimide. When cut or otherwise damaged, these capsules release their contents, which dissolve and heal the damaged area. Aerospace and ground vehicles often contain miles of high-performance electrical wire insulation that are prone to damage from abrasion and cuts during operation and maintenance. Large portions of the wire are often buried within the vehicle framework, making it difficult and time-consuming to locate and repair damage. A self-healing capability in the wire insulation would provide self-repair of minor nicks, cuts, and abrasions without intervention by service personnel, and help reduce the danger of electrical shorts that could lead to sparking and fires.

Contact: Kennedy Space Center
Phone: 321-867-5033
E-mail: Lewis.M.Parrish@nasa.gov

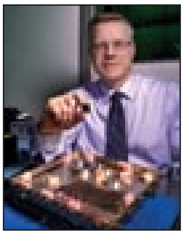


▶ ShuttleSCAN 3-D

Ames Research Center offers its patented ShuttleSCAN 3-D surface scanning and profiling technology. Originally developed for critical, real-time inspection of damage to the thermal protection tiles of the Space Shuttle, the system can be used for a wide range of commercial applications from product quality control to autonomous navigation. ShuttleSCAN provides real-time analysis of surfaces ranging from the small (such as circuit boards) to the large (such as panels or roads). The scanner's operation is based on the principle of laser triangulation. ShuttleSCAN also can be used as a wireless instrument. The system scans at speeds greater than 600,000 points per second, with a resolution smaller than .001", and results are available in real time.

Contact: Ames Research Center
Phone: 855-627-2249
E-mail: ARC-TechTransfer@mail.nasa.gov

Who's Who at NASA



Mike Krainak, Laser and Electro-Optics Branch Head, Goddard Space Flight Center, Greenbelt, MD

In 2020, NASA's first-ever integrated-photonics modem will be tested aboard the International Space Station. Mike Krainak leads the development of the modem, which integrates optics-based functions such as lasers, switches, and wires onto a microchip. The technology will improve the way NASA sends and receives data during space missions.

NASA Tech Briefs: What are the advantages of using light in communications?

Mike Krainak: Light has made it possible to have this incredible bandwidth. You can have a phenomenal amount of data that you transmit over these now very-low-cost transmission media: glass fibers. That has led to the terrestrial revolution in communication. You can transmit this light from here to California, or from here to Europe, or all the way across China.

NTB: What are the advantages of using light in space communications specifically?

Krainak: In space communications, the size of the transmission antenna, or telescope, [is reduced]. Early satellite TVs are a great example. Your neighbor, because of the wavelength being used, had a satellite dish that took up his whole yard, and it was a big eyesore. Once you make the wavelength shorter, moving up to the Ka-band or the 30-GHz band, the wavelength becomes a fraction of a meter. The optical antenna, or telescope, can then be a fraction of a meter. Both the transmit antennas and the receive antennas can now have very, very small diameters.

NTB: How does the modem support NASA's Laser Communications Relay Demonstration?

Krainak: With our first geosynchronous Laser Communications Relay Demonstration, we are transferring data from one place to the other. For the astronauts, we're relaying the information from the space station or from the orbiting capsule. We're relaying the data from them, through a geosynchronous satellite, and then down to Earth.

We're going to demonstrate the relay between ground stations. That's just a stepping stone. Hopefully, over time, you would have a community of users in lower-Earth orbit that would use the geosynchronous relay to get information.

NTB: How are integrated photonics circuits being used to support new sensors?

Krainak: The blood oximeter was invented in the 1940s, but it couldn't be fully realized until it could be made in compact forms in the 1980s. Once you have an integrated form that's very small, you can clip a little red LED on your finger to look at your blood oxygen.

So why stop at oxygen? You can have a blood oximeter that runs over to your smart watch. But instead of just measuring your blood oxygen, it can measure all of the 200 constituents in your blood. As [the oximeter emits] more laser wavelengths, you can do more refined spectroscopy, along with electronics signal processing. You can conceivably analyze the constituents in your blood without taking blood.

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

Nissan Motor Company used NASA's research on NBP to design new car seats for the 2013 Altima.

NASA DRIVES AUTOMOTIVE INNOVATION

Dozens of commercial automotive technologies can trace their origins to NASA missions and research. Here are some important innovations in the auto industry that started as NASA developments.

Standards for Comfortable Seats

In the beginning, safety trumped comfort in spacecraft designs for human space travel. Early space capsules were small and had a seat-driven design in which most of the flight activities were performed while the crew was strapped into their seats. NASA devoted more attention to understanding how a spacecraft could provide comfort as well as safety and function. One of the first things NASA examined was the neutral body posture (NBP), or the posture the human body naturally assumes in microgravity.

By the 1980s, NASA had identified and documented the characteristics of NBP in the Man-Systems Integration Standards (MSIS), which specified ways to design spaceflight systems that support human health, safety, and productivity. Specifically, NASA used the NBP standard for the design of space workstations and tools.

A space shuttle study demonstrated that there is a range of NBPs for individuals. In another posture study, researchers found the spines of astronauts lengthened in zero gravity on the International Space Station (ISS) — information that has since influenced the size and design of the recently developed Orion Multi-Purpose Crew Vehicle. Lastly, NASA has future plans to perform a new study on the changes that occur to body shape, size, and NBP onboard the ISS.

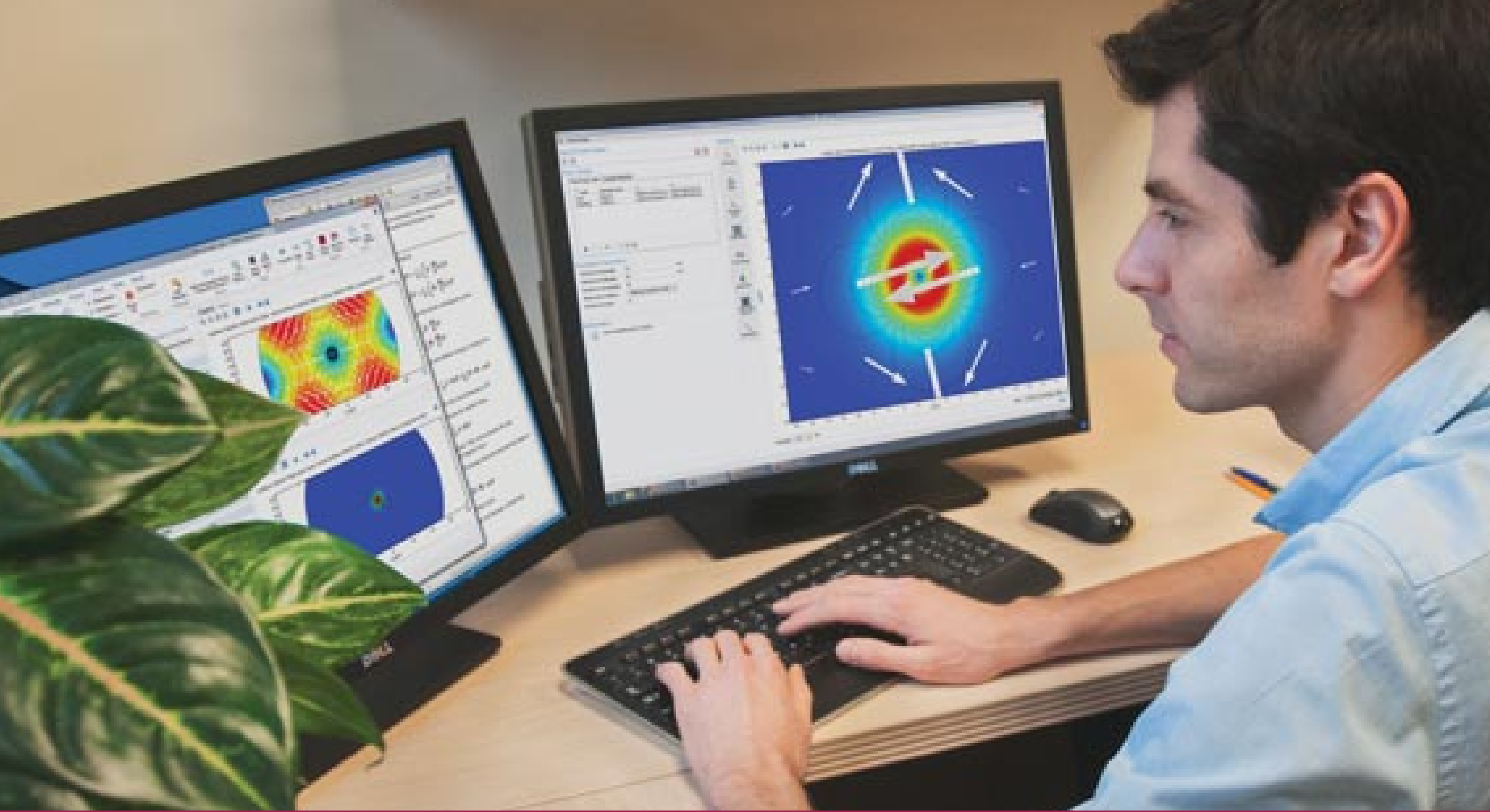
NASA's work on NBP has governed the development of everything from work areas in the ISS to comfortable new car seats in vehicles here on Earth. In 2005, engineers at Nissan Motor Company turned to NASA's NBP research as a starting point for the development of a new driver's seat for their vehicles. Because Nissan had observed that a person's posture appeared to play a direct role in how physically tired he or she became while driving, the company decided to use NASA's NBP as a benchmark for a comfortable, balanced posture, with the intention of lessening fatigue on a person's body.

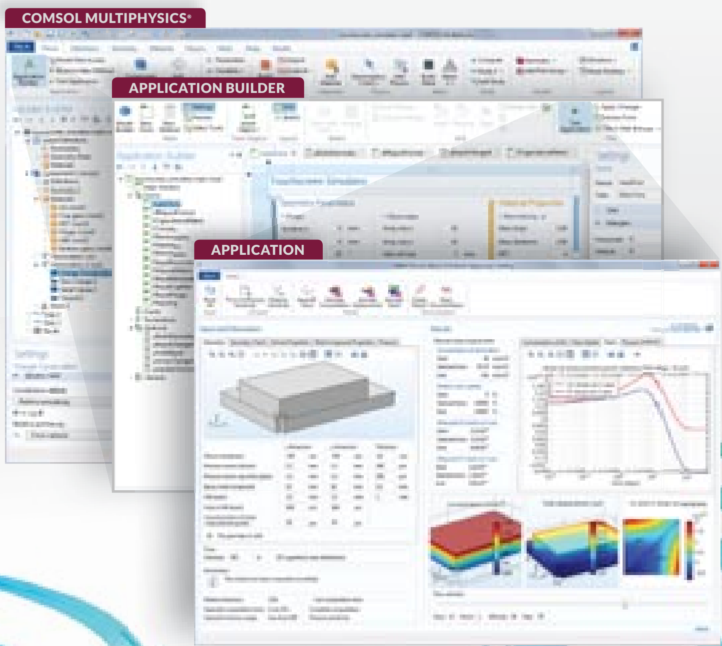
To decrease driver exhaustion, Nissan aimed to ensure the driver's spine was supported to relax in its natural position, as outlined in NASA's NBP studies. The company thought such a design would successfully minimize the muscular loading on a driver's back, pelvis, and torso. In 2006, Nissan published the results of its first study on its new experimental seat with a two-piece backrest to maintain NBP. The results confirmed that the seat supported the spine and areas from the pelvis to the chest and improved blood flow.

The second phase of the company's research, published in 2007, evaluated the prototype seat in dynamic long-term driving conditions on a freeway. The results showed a 50 percent reduction in physical exhaustion during driving. The authors maintained that the new driving posture supported by the seat was close to the NBP documented by NASA in microgravity conditions.

Nissan debuted the seat derived from NASA research in the 2013 Altima, and the company now has plans to include it in many upcoming Nissan and Infiniti vehicles. In addition, the technology will be applied not only to the driver's and front passenger's seats, but in the rear seats of the vehicles as well.

Visit ***http://spinoff.nasa.gov/Spinoff2013/t_4.html.***





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Lubricants Protect Against Corrosion

The Mobile Launcher Platform at Kennedy Space Center was used as a transportable launch base for the space shuttle. When it carried the weight of an unfueled space shuttle, it weighed about 11 million pounds. To transport a fully assembled space shuttle and the Mobile Launcher Platform from the Vehicle Assembly Building to the launch pad, NASA used a vehicle called a crawler. The crawler features eight tracks fitted with 7.5 × 1.5-foot shoes that help roll the massive vehicle and its payload along.

Back in 1994, NASA sought a new type of lubricant that would be safe for the environment and would help "grease the wheels" by making the 1-mile-per-hour, 3-mile trek of the shuttle-bearing launcher platform to the launch pad an easier process. To satisfy the environmental requirement, the lubricant had to be biodegradable. To account for the size and the weight of the space shuttle/platform combination, as well as the tortoise-like pace and the distance being traveled, the lubricant had to sustain a long operating life while in use. In addition, it had to provide complete protection from the corrosive sand and the heat that are a part of everyday life at Kennedy.

When they were built, Kennedy Space Center's crawlers were the largest tracked vehicles ever made. The two crawlers were used for transporting the space shuttles.

With the help of Lockheed Martin Space Operations — the contractor for launch operations at Kennedy — and private industry, NASA realized that a new kind of lube could go a long way to protect the environment as well as the integrity of a space shuttle mission.

To develop a special lubricant that could meet the stringent requirements for shuttle transport, NASA and Lockheed Martin Space Operations looked to The X-1R Corporation in Daytona, FL, which made lubricants for racecar engines and transmissions. The company formulated an advanced, environmentally friendly spray lubricant to replace the standard lubricant used during transport. The new biodegradable, high-performance lubricant, coined the X-1R Crawler Track Lube, first succeeded in trial tests and then succeeded when applied directly to the crawler.

The company created a full line of standard automotive and specially formulated racing products, including the X-1R Engine Treatment Concentrate, a formula that treats engine cylinder walls, bearings, cams, rings, and valve guides. It creates a molecular bond with ferrous metal, which leads to a dramatic reduction in friction and wear. It also protects against the harsh metal-to-metal contact that commonly occurs during cold starts. Other benefits are increased engine life and horsepower, improved fuel economy, and reduced engine noise and operating temperatures.

Visit ***http://spinoff.nasa.gov/Spinoff2007/ch_5.html.***

The X-1R lubricants developed originally for use on the crawlers now provide consumers with superior lubricating qualities in environmentally safe, long-lasting products.

Heat Management Materials

For six years prior to the retirement of the space shuttle, the shuttles carried an onboard repair kit with a tool for emergency use: two tubes of NOAX. The sealant flew on all 22 flights following the Columbia accident, and was designed to repair damage that occurred on the exterior of the shuttle.

Although the sealant never had to be used in an emergency situation, it was tested by astronauts on samples of reinforced carbon-carbon (RCC) during two shuttle missions. The material handled well on orbit, and tests showed the NOAX patch held up well on RCC. While NASA funded the full-scale development of NOAX, the sealant was actually invented by Alliant Techsystems (ATK). Under NASA funding, ATK contracted with Starfire Systems in Schenectady, NY to supply the unique polymer material that was incorporated into NOAX.

Starfire Systems manufactured a unique polymer as a space shuttle sealant. A formula incorporating the polymer is now being used in test platforms for a new exhaust management design for Formula 1 race cars.

Called SMP-10, Starfire's polymer was designed to convert into a ceramic at high temperatures. As it heated above 1,500 °F, it would start to convert to ceramic, where it could take much higher temperatures, allowing it to seal during the shuttle's re-entry. SMP-10 was formulated and processed for incorporation into NOAX, which laid the groundwork for Starfire to achieve a repeatable process for a reliable product.

Starfire developed StarPCS for high-temperature applications on Earth. Today, the company manufactures a family of StarPCS products for lightweight components that need to withstand extreme temperatures. Domestic and foreign auto manufacturers are testing StarPCS for passenger vehicles. StarPCS formulas are also being tested for heat shields in vehicles with extremely hot engines.

Specifically, StarPCS is being used in the test platforms for Formula 1 race cars. The teams are currently looking for a new exhaust management design to divert exhaust by routing it through body panels. It would use the aerodynamic suction to pull the gases out of the engine faster and allow a 1 to 3 percent increase in horsepower. Auto manufacturers outside of racing are also looking for alternative materials for heat management in turbo chargers. Manufacturers want to make exhaust pipes out of something other than metal so the pipe can withstand higher temperatures.

Even though NASA no longer uses the innovative solution for space shuttle repairs, the Agency is incorporating SMP-10 into some of the safety components for Orion, NASA's next multi-purpose crew vehicle.

*Visit **http://spinoff.nasa.gov/Spinoff2012/t_5.html**.*

Insulating Foam

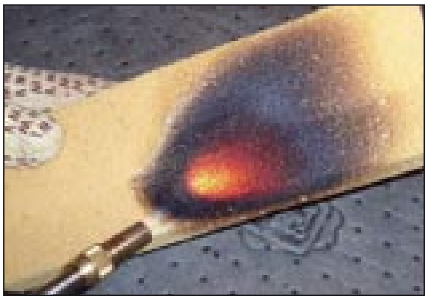
Langley Research Center created a superior polyimide foam as insulation for reusable cryogenic propellant tanks on the space shuttle. At the time, the foam insulation on the tanks had a limited lifetime: one launch. The foam on the shuttle's external tanks needed to insulate the super-cooled liquid propellant, preventing ice from forming on the tanks and surrounding areas, and posing catastrophic risk from debris during launch. The insulation also needed to be able to withstand the high temperatures the tanks would experience during ignition and launch. The researchers named their new foam TEEK.

A partnership with Florida-based PolyuMAC improved the chemical structure of the NASA-developed foam, leading to a new product, FPF-44, with commercial applications. PolyuMAC was looking for advanced foams to use in the customized manufacturing of acoustical and thermal insulation. During this search, the founder and president of PolyuMAC came across information about the TEEK foam developed at Langley. He read about TEEK and contacted Langley for samples and technical data sheets.

He determined that TEEK was not the right density for his needed applications, but rather than dismiss the endeavor altogether, he contacted the inventors and asked for help tweaking the TEEK chemistry to bring it more in line with his needs. He licensed the foam from NASA to begin modifications. They named this new generation of foam FPF-44.

The NASA-PolyuMAC team is continuing to collaborate on the foam, trying to further reduce density while maintaining its insulating properties. The commercial version of the joint NASA-PolyuMAC foam is called Polyshield, and offers the same qualities as the NASA next-generation, high-performance, flexible polyimide foam, and shows promise for use in automobiles and automotive products, recreation equipment, and building and construction materials.

It features flame-retardant qualities, thermal insulation, and acoustic insula-



The commercial Polyshield foam is flexible, flame-retardant, and provides excellent thermal and acoustical insulating properties.

tion factors, as well as weight reduction. The finished product can be flexible or rigid, structural or non-structural. The insulating foam can also be applied to gaskets and seals, vibration damping pads, spacers in adhesives and sealants, extenders, and flow-leveling aids. The products provide excellent insulation for sound, cryogenics, and heat, and can be used for fire protection. While it holds at very high temperatures, if it does burn, it will not produce smoke or harmful byproducts.

*Visit **http://spinoff.nasa.gov/Spinoff2009/t_2.html**.*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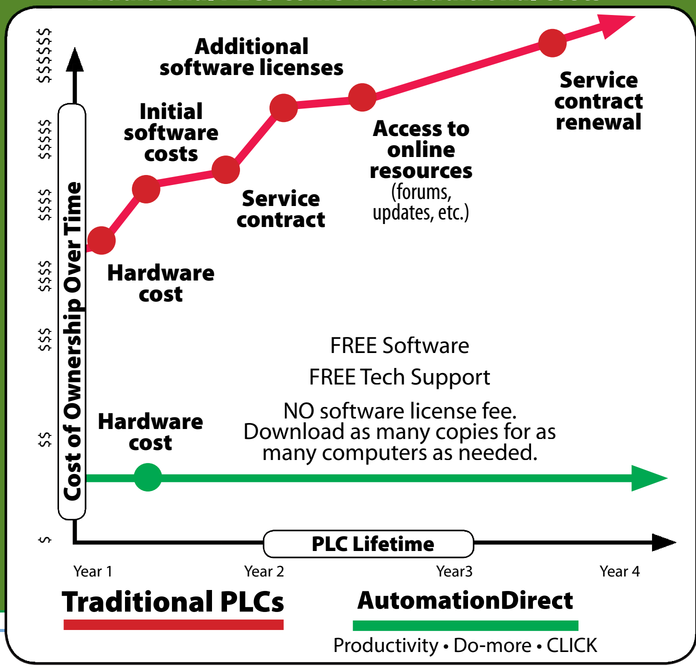

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SAE 2016 World Congress: Powering Possibilities

The SAE 2016 World Congress, presented by SAE International and taking place April 12-14 in Detroit, will gather experts, management teams, engineers, and executives from the automotive industry to collaborate and address current challenges, seek new windows for discovery and exploration, and promote the multitude of opportunities fundamental for a successful future. This year's theme, Powering Possibilities, represents a world of untapped discoveries in the automotive industry.

The event will include keynotes, technical sessions, workshops, and more covering the spectrum of automotive engineering. Attendees will be exposed to new ideas and new perspectives, and will have the opportunity to participate in Q&A sessions with subject matter experts. Management programs will let you listen in on fascinating dialogue, realize trends, and gain valuable insight from respected industry leaders.

Visit **www.sae.org/congress** for more information.

Keynote Speakers

As Director of the Michigan Department of Transportation (MDOT) since 2006, Kirk Steudle oversees MDOT's $3 billion-plus budget. He is responsible for the construction, maintenance, and operation of nearly 10,000 miles of state highways, and more than 4,000 state highway bridges. He also oversees administration of a variety of multi-modal transportation programs and projects that range from aviation to the Zilwaukee Bridge. Kirk's keynote will focus on transportation and technology fusion.

Gary Silberg, Partner and National Automotive Leader at KPMG LLP, is also the Global Lead Partner for Delphi Corporation and Ford Motor Company. With more than 14 years in the automotive industry, he advises domestic and multinational companies in areas of mergers, acquisitions, divestitures, and joint ventures. Gary's closing keynote will discuss "The Clockspeed Dilemma: What it Means for Automotive Innovation."

Kirk Steudle

Gary Silberg

Tech Hub

The Tech Hub, which debuted in the center of the Innovators Only exhibit floor at last year's SAE World Congress, spotlights provocative, innovative, and disruptive ideas intended to engage and challenge attendees to examine the future of the mobility industry. The theme of this year's Tech Hub, sponsored by Nissan, Omron, and Ricardo, is "Influences on the Future Vehicle."

The Tech Hub is made up of 20-minute SAE TechTalks, expanded Q&A, and networking opportunities between the audience members and speakers. Featured experts from consumer, aerospace, government research institutions, and other mobility industries speaking this year include Mark Moore, who serves in two roles at NASA's Langley Research Center, where he is Senior Advisor for On-Demand Mobility, as well as the Principal Investigator for the Scalable Convergent Electric Propulsion Technology Operations Research X-Plane (SCEPTOR), a manned plane scheduled to fly in 2017. This unique aircraft pushes the state-of-the-art in electric power with advanced electric motors. Developed to achieve high power-to-weight and high efficiency, the objective is to achieve a 5x reduction in the energy required to cruise at 175 mph, compared to existing light aircraft.

As cities grow and the "Uberization" of the world continues, transportation behaviors around the world are changing. In particular, alternatives to vehicle ownership offer big opportunities as car ownership in the traditional sense becomes obsolete. To better understand behavior and personal attitudes toward these changes and opportunities, Frog Design conducted a global survey of 1,200 general population participants across China, Denmark, Germany, and the United States. Anthony Gregorio, Associate Strategy Director for Frog Design, will explore both findings and actionable insights from that research in his talk, "Navigating the Ride Ahead — Personal Mobility." Anthony has helped companies identify and vet adjacent market opportunities, understand user needs within new customer segments, define new product and service offerings, and make difficult decisions regarding growth investments.

Find a complete schedule of Tech Hub TechTalks at **www.sae.org/congress/attend/program/tech_hub.htm.**

The Tech Hub enables hands-on opportunities for audience members and speakers to interact.

Matt Heverly, lead driver for the Curiosity Mars rover at NASA's Jet Propulsion Laboratory, talked about "Driving on Mars" at last year's Tech Hub. (Kami Buchholz)

Technical Program

The solutions-oriented Technical Sessions at SAE World Congress provide the perfect opportunity for engineering professionals to discover, collaborate, and engage with peers from around the globe. These Technical Sessions, developed by industry professionals to maximize relevance, are designed to allow industry members of all levels to gather relevant and stimulating information to enhance skills and creativity.

Technical Session categories include Integrated Design & Manufacturing, Propulsion/Powertrain, Management & Marketplace, Electronics, Materials, Emissions/Environment/Sustainability, and Body/Chassis/Safety/Structure.

For a complete schedule of Technical Sessions, visit **www.sae.org/congress/attend/program.**

Special Events

Back by popular demand, the SAE Young Professional Program is designed to inform, encourage, and motivate the leaders of tomorrow. This initiative is designed to help new professionals transition into the "real world" while providing solid leadership principles they can carry throughout their career. These activities also provide the valuable opportunity to learn from and network with executives from major corporations. As technology continues to change and critical issues are being resolved, these skills are more important now than ever.

The SAE 2016 World Congress Career Fair will provide the opportunity for mobility industry engineers and professionals to explore available jobs, network, and meet with professional recruiters, and representatives from OEMs and suppliers.

Innovators Only Exhibition

This exclusive opportunity is limited to companies that have accepted the "Innovators Only" challenge, and proven to be top industry innovators and solution providers. You'll see what's new from OEMs, top-tier suppliers, and other related companies from around the world. Check out all the exhibiting companies and plan your show floor strategy by visiting **www.sae.org/congress/exhibit.**

APPLICATION BRIEFS

Super Pressure Balloon Provides NASA with Valuable Data

Super pressure balloon
Raven Aerostar
Sioux Falls, SD
605-336-2750
www.ravenaerostar.com

A super pressure balloon (SPB) designed by Raven Aerostar, and the largest SPB ever built, surpassed 31 days amid the stratosphere's harsh elements as part of a NASA mission, demonstrating the scientific balloon's extended flight duration and ability to maintain constant altitudes. The balloon carried a two-and-a-half-ton NASA payload.

Raven Aerostar personnel provided balloon preparations, integration, and flight operations support to Orbital ATK, the prime contractor of NASA's balloon program. The SPB lifted to the stratosphere at a rate of ~1,000 feet per minute, and successfully entered float within 99% accuracy of its targeted altitude.

The SPB exceeds 18 million cubic feet in volume (the size of a sports stadium), and is designed to maintain a constant float altitude at 110,000 feet, conserving helium and increasing flight endurance. These improvements provide better altitude stability for science instruments requiring more accuracy, creating new opportunities for scientific research on balloons. SPB's also provide an opportunity to test groundbreaking instruments before they're considered for free-flying spacecraft.

While long duration was an important objective for this mission, engineers were more keenly focused on the challenge of maintaining a constant altitude during the flight. Most standard, heavy-lift, zero-pressure balloons can vary in altitudes as great as 45,000 feet due to the alternating warming and cooling of the day and night cycle. In response, flight operators typically release excess weight in the form of ballast to maintain altitude. The SPB, however, is designed to maintain a positive internal pressure in relationship to its environment, which keeps the balloon at a constant float altitude. In much the same way a car tire maintains its pressure despite changes in the environment around it, so does the SPB.

The science and engineering communities have previously identified long-duration balloon flights at stable altitudes as playing an important role in providing inexpensive access to the near-space environment for science and technology.

For Free Info Visit http://info.hotims.com/61060-115

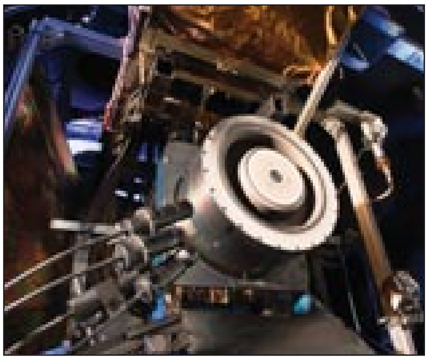
New Spacecraft Design for Asteroid Redirect Mission

Geostationary (GEO) satellite
Space Systems/Loral (SSL)
Palo Alto, CA
650-852-4000
www.sslmda.com

NASA's Jet Propulsion Laboratory (JPL) has chosen Space Systems/Loral (SSL) to conduct first-phase design studies for a spacecraft that can travel to an asteroid, remove a boulder, and redirect it into a lunar orbit to prepare it for a visit by astronauts in the 2020s.

In keeping with NASA's strategy to leverage commercially available capabilities, SSL's spacecraft design for the Asteroid Redirect Robotic Mission (ARRM) will be based on its commercial geostationary (GEO) satellite.

Once the boulder is secured, the Capture and Restraint System legs will provide a mechanical push off that will separate the boulder from the surface and provide an initial ascent without the use of thrusters to limit the amount of debris created. (NASA)



The solar electric propulsion system will propel the first mission to redirect an asteroid. (NASA)

SSL is one of four companies that received contracts from JPL for design studies for the spacecraft. Its experience with solar electric propulsion (SEP) includes 18 spacecraft on orbit today, the first of which launched in 2004. The acquisition strategy for the ARRM spacecraft will leverage commercially available U.S. industry capabilities to reduce costs and cost risk. The strategy includes procurement of the ARRM spacecraft bus through two phases. The first phase is design work accomplished through studies by U.S. industry working in cooperation with the mission's project office at JPL to support mission formulation. The second phase, to be awarded via a second competition, will include development and implementation of the flight spacecraft bus by one of the study participants.

ARRM is being planned to perform a number of demonstrations including the use of a 20-fold improvement in deep space SEP to move and maneuver large payloads; retrieve a boulder up to 20 tons in mass from an asteroid and redirect it to a crew-accessible orbit around the Moon; and be a part of integrated crewed and robotic vehicle operations in deep space.

ARRM is part of NASA's plan for using cislunar space, the region between Earth and the Moon's orbit, as a proving ground for future human spaceflight beyond low-Earth orbit, in support of the agency's journey to Mars.

For Free Info Visit http://info.hotims.com/61060-116

Intro Cov ToC

SEA5: Space Environment Automated Alerts & Anomaly Analysis Assistant

Goddard Space Flight Center, Greenbelt, Maryland

The Community Coordinated Modeling Center (CCMC) provides a wide range of space weather tools and services for the general scientific community. One such product that facilitates space weather situational awareness is collectively known as the Integrated Space Weather Analysis (ISWA) System. Using the ISWA system and other tools, space weather forecasters are able to assess the space environment in both real time and for historical cases — both of which help mitigate potential space weather impacts on missions, as well as assist in spacecraft anomaly resolution. The Space Environment Automated Alerts & Anomaly Analysis Assistant (SEA5) will provide past, present, and predicted space environment information for specific missions, orbits, and user-specified locations throughout the heliosphere, geospace, and on the ground.

A software system will assist NASA robotic mission operators by allowing users to select a specific spacecraft and/or orbit of interest, and be presented with an interface displaying space environmental conditions for the selected spacecraft, orbit, and time. The system will also provide automated and customizable alert functionality, allowing users to define individual threshold and alert criteria, and to be notified whenever events of interest are detected for any specific mission/orbit.

A framework will extract space environment information from numerical simulations for specific locations, dates, and times. This will allow the SEA5 system to provide highly tailored space environment information for any spacecraft location throughout the heliosphere. Global simulation codes available at the Community Coordinated Modeling Center (CCMC) will be used, along with real-time and near-real-time space weather data from the ISWA System. Advanced 2D and 3D visualization techniques will be employed to determine the time-dependent positions of specific satellites and/or orbits within mission-relevant spatial domains including the heliosphere and geospace. Both observational data sets and the most advanced physics-based space environment models currently available will be used. Instead of mission operators, mission planners, and other stakeholders having to sift through, compile, and analyze massive data sets to extract and infer potential impacts to their individual missions, this unique mission-specific service will be used. A comprehensive data model will be created representing three key components of SEA5: simulation/model data, satellite/orbit objects, and observational data.

Relationships among these core components will also be modeled, effectively enabling the system to associate observational and simulation resources with user-specified missions and orbits. Once the data model has been successfully designed, user interface modules will be implemented, enabling dynamic generation of mission/orbit specific consoles (user friendly displays). An automated alert module will also be implemented, allowing users to specify custom thresholds and receive specialized notifications. This component-based framework will be extensible, providing a solid foundation for future feature and functionality expansion.

This work was done by Mario Maddox, Justin Boblitt, Tyler Schiewe, and Richard E. Mullinix of Goddard Space Flight Center. ***For more information, contact the Goddard Technology Transfer Office at (301) 286-5810. GSC-17254-1***

Extensible Data Gateway Environment (EDGE)

NASA's Jet Propulsion Laboratory, Pasadena, California

The NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) is NASA's designated data center for information relevant to the physical state of the ocean. Its core data-management and workflow system, Data Management and Archive System (DMAS), is responsible for processing hundreds of thousands of data products each day, around the clock. Its inventory captures over 800 datasets, several million granules, and millions of files. PO.DAAC is in need of a solution to help users quickly identify the relevant oceanographic data artifact. It also needs to export metadata according to the ISO-19115, FGDC, and GCMD specifications. Developing such a solution on top of its Oracle database has several issues. First, it is difficult to maintain since SQL needs to be updated when a schema changes or when new search criteria is needed. Second, multi-table joins yield poor performance. Third, query performance can be improved with additional indexes, but performance is negatively impacted on updates. Fourth, exposing the operational database as the direct backend to a publicly accessible service layer would subject Oracle to a Denial of Service (DoS) attack, which could halt the already very busy DMAS operation environment.

The Extensible Data Gateway Environment (EDGE) solves all four issues by leveraging indexed search technology and dynamically configurable response templates. EDGE uses a high-performance indexed search solution to index all PO.DAAC inventory data. Rather than requiring users to learn a new search syntax, EDGE comes with a Web service interface to implement the OpenSearch specification. It uses a template engine to dynamically generate a

metadata response that supports the ISO-19115, FGDC, and GCMD specifications.

EDGE uses Tornado Web Service as the platform for OpenSearch specification, metadata specifications, and as the proxy service to integrate with other data services. It uses Apache Solr for a fast indexed search backend. Inventory data stored in PO.DAAC's Oracle server is incrementally indexed every 15 minutes. Apache Solr provides an optimal search solution to all the data it manages. By offloading data from Oracle, this eliminates Denial of Service (DoS) attacks against the core data-management backend. To further ensure the reliable serving of data, EDGE's Apache Solr uses a Master and Slave model. The Master instance is for data indexing. One slave instance is used to serve the PO.DAAC Web portal, and another slave instance is used for Web service support with OpenSearch and Metadata export.

This work was done by Thomas Huang, Nga T. Quach, and Christian Alarcon of Caltech for NASA's Jet Propulsion Laboratory. ***This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-49884.***

Flight Test Maneuvers for Efficient Aerodynamic Modeling

Langley Research Center, Hampton, Virginia

Flight testing is expensive. It is therefore important that necessary flight data be collected in the most efficient manner possible. Inputs traditionally used for flight test maneuvers to collect aircraft stability and control data include doublets, impulses (stick raps), multisteps, and frequency sweeps. All of these input types are designed for single-axis response, although often the inputs are applied sequentially to different controls to collect multi-axis data.

Recently, an input design technique has been developed that combines the time efficiency of multi-axis excitation with optimized (minimum) input amplitudes, wideband frequency content, and multiple-input orthogonality in both the time domain and the frequency domain. This development in flight test input design has enabled new approaches to efficient stability and control flight testing that previously were not possible.

Several novel flight test maneuvers for efficient aerodynamic modeling were developed and demonstrated in flight. Orthogonal optimized multisine inputs were applied to aircraft control surfaces to excite aircraft dynamic response in all six degrees of freedom simultaneously, while keeping the aircraft close to chosen reference flight conditions, or while flying the aircraft through a range of flight conditions. Each maneuver was designed for a specific modeling task that cannot be adequately or efficiently accomplished using conventional flight test maneuvers. Real-time and post-flight modeling results were used to show the effectiveness and efficiency of the maneuvers, as well as the quality of the aerodynamic models that can be identified from the resultant flight data.

The general idea is to excite the aircraft using perturbation inputs with wideband frequency content over a range of frequencies that encompasses the expected modal frequencies of the aircraft dynamic response. The excitations are implemented as perturbations to the control surface deflections by summing the designed perturbation inputs with the actuator commands from the pilot and feedback control system.

Multiple excitation inputs are designed to be mutually orthogonal in both the time domain and the frequency domain, and they are optimized for maximum data information content in multiple axes over a short time period, while minimizing excursions from the nominal flight condition or flight path. The mutual orthogonality of the inputs allows simultaneous application of multiple inputs, which helps to minimize excitation time, and provides continuous multi-axis excitation as the aircraft flies through time-varying or precarious flight conditions.

Unique features of the flight test maneuver design method include good data information content in all degrees of freedom for many controls simultaneously, robustness to unknown dynamics, suitability for time-domain or frequency-domain modeling, ease of design, excellent flight test time efficiency, and the capability for effective use in precarious and/or unusual flight conditions, such as stall and departure.

This work was done by Eugene A. Morelli of Langley Research Center. ***For more information, contact Langley Research Center at LaRC-PatentLicensing@mail.nasa.gov. Refer to LAR-18120-1.***

JPL CO2 Virtual Science Data Environment (VSDE)

NASA's Jet Propulsion Laboratory, Pasadena, California

The JPL CO2 Virtual Science Data Environment (VSDE) (http://co2.jpl.nasa.gov) is a comprehensive effort to bring together the models, data, and tools necessary for atmospheric CO2 research. The VSDE site is designed to provide streamlined Web-based discovery and access to multiple global and regional carbon dioxide data sets. Furthermore, this site provides tools for conversion, manipulation, and transformation of the data to facilitate research.

Many of the well-known data warehouses and archives host data services, but none offers unified access to all the data relevant to this specific science theme in a single location. Currently, users have to visit several data archives or distribution centers to find CO2 data products from diverse instrument campaigns. The VSDE collects data (or links to data) served at NASA Langley's Atmospheric Science Data Center, the Goddard Earth Science Data and Information Services Center, and the TCCON Data Archive so users can search one site for the products they need, saving them time.

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Additionally, the CO2 VSDE provides data subsetting and gridding services. Users can request only the data in the files that are of interest to them, and download a much smaller and manageable set of files to their local system. Users can utilize simple gridding algorithms (such as an average or standard deviation) through this site so they do not have to develop the code themselves. Other more complex algorithms such as "window averaging" and "Kriging" are available as well.

The VSDE could assist in data validation efforts. Since it offers data from multiple sources, users can easily compare and contrast CO2 data from different missions. For example, users could generate data files from different sources on the same grid, during the same time period, from the same data system (the VSDE), and see how the data compares.

This work was done by Brian W. Knosp, Luca Cinquini, Cameron E. Goodale, Hai M. Nguyen, James E. Hofman, Erin M. Murphy, and Bryan Duran of Caltech; and Andrew Hart for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-49620.

Python Advanced Microwave Precipitation Radiometer Data Toolkit (PyAMPR)

Marshall Space Flight Center, Alabama

Advanced Microwave Precipitation Radiometer (AMPR) brightness temperature data from NASA field projects are in ASCII format. This Python script defines a class that will read in a single file from an individual aircraft flight and pull out timing, brightness temperatures from each channel, geolocation, and other information and store them as attributes using numpy arrays of the appropriate type.

The approach is to ingest the entire file as a text string and then parse and type-convert as necessary. The file is read and the data are populated when the class is instantiated with the full path and name of an AMPR file. Numerous visualization methods are provided, including track plots, strip charts, and Google Earth KMZs. In addition, polarization deconvolution is available. The PyAMPR software is intended for non-commercialized scientific research.

This work was done by Timothy J. Lang and Jason B. Roberts of Marshall Space Flight Center.

For more information, contact Ronald C. Darty, Licensing Executive in the MSFC Technology Transfer Office, at Ronald.C.Darty@nasa.gov. Refer to MFS-33219-1.

Data Ordering Genetic Optimization (DOGO) System

Ordering data from most to least useful replaces quality flags, improves climate science results, prioritizes images for analysis, and guides analysts for optimal data filtration.

NASA's Jet Propulsion Laboratory, Pasadena, California

Observations in modern datasets have a continuum of quality that can be hard to quantify. For example, satellite observations are subject to often-subtle mixtures of confounding forces that distort the observation's utility to a varying extent. For the Orbiting Carbon Observatory-2 (OCO-2) observatory, effects such as cloud cover, aerosols in the atmosphere, and surface roughness are three major confounding forces that can mildly, heavily, or totally confound an observation's utility. These complicating factors are not present in a binary fashion: clouds can cover a percentage of the scene, have variable opacity, and differing topology. Arbitrary thresholds are traditionally placed on the presence of such forces to yield a binary good/bad data flag for each observation. By instead generating a data ordering, users are guided towards the most reliable data first, followed by increasingly challenging observations. No harsh on/off threshold is applied to the data, potentially obscuring useful data to one user while leaving in confounded observations to another. Allowing users to create custom filters based on DOGO's data ordering leaves hard cutoff decisions in the hands of users, guided but not restricted by the project's expert knowledge.

Traditionally, quality flags provided a binary yes/no estimation of a datapoint's utility. Normally, scientists would first discard all "bad data" so indicated, and only work with the "good data" as defined by the project. However, in modern instrumentation, there is access to significant auxiliary information for each datapoint that enables prediction of the likely utility of the observation with finer resolution than 0 or 1. To do this, many different filters are developed that become increasingly more stringent in terms of a goal metric of data quality. With this sorted list of filters, each datapoint can be assigned a single integer ranging from 0 to 19, indicating how many of the filters would reject it. Ordering the data in terms of these integers communicates to the user the order in which they should be preferred, without actually filtering away any observations. A user is then free to define their own filter based on the integer range they accept, and rapidly communicate this dataset to another collaborator.

These ordering integers are called Warn Levels, and they can be developed for any metadata-rich data source to

help guide researchers in proper data filtration. One application of Warn Levels requiring spatial uniformity, minimized likelihood of convergence failure, and minimum scatter is the need to preferentially select only "the best" data to process in real time from the OCO-2 mission, enabling its level 1 requirement that at least 6% of the streaming data is successfully processed as quickly as possible. A second, related application produces Warn Levels that help users know the order in which to ingest the mission's output data for their analysis, in effect forming a "tunable filter" that lets users decide how much data to accept.

The algorithm described here is not simply a Warn Level generator for OCO-2, but rather an entire method to construct new Warn Levels for any metadata-rich data source. It is a genetic algorithm coupled with a voting scheme and feature selection for use on a supercomputer that explores the large dimensional space of all possible filters and combinations of filters to yield the best-performing singleton, pair, triple, etc. filters. These are then folded into a Warn Level estimate. By exploring all possible filters and then folding this information into a single data ordering, one is able to achieve far more than even an optimum quality flag could provide.

Moreover, during the creation of the final Warn Level ordering, a necessary exploration of the precise metadata that strongly predicts retrieval confounding yields great project insight onto sources of error. These can and were used to guide algorithmic improvements, a-priori tuning, and atmospheric science interpretation of the retrieval algorithm's behavior while yielding quick detection of serious yet subtle code abnormalities. In fact, this early "feature selection" phase may yield even more useful information and guidance than the final Warn Levels themselves.

This algorithm has been significantly sped up, further adapted to take advantage of OCO-2 data, minimized its footprint on the cluster computer hosting it, and processed its output into a more immediately interpretable form.

This work was done by Lukas Mandrake of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-49817.

Advanced Rapid Imaging and Analysis for Earthquakes

NASA's Jet Propulsion Laboratory, Pasadena, California

Advanced Rapid Imaging and Analysis for Earthquakes (ARIA-EQ) will be the first coordinated effort to automate geodetic imaging capabilities so they can be used for hazard response. The innovation is an automatic geodetic imaging data system that is the foundation for an operational hazard response center that integrates InSAR (interferometric synthetic aperture radar), GPS (Global Positioning System), seismology, and modeling to deliver actionable science and situational awareness products.

It supports automated processing of InSAR and GPS as the basis for continuous monitoring and processing of geodetic event data. Space-based geodetic measurements such as InSAR and GPS provide new assessment capabilities and situational awareness on the size and location of earthquakes following seismic disasters. Geodetic imaging's unique ability to capture the surface deformation in high spatial and temporal resolution allows viewing of fault geometry and slip that generated the earthquake. Remote sensing with radar provides change detection and damage assessment capabilities.

This work was done by Susan E. Owen, Angelyn W. Moore, Zhen Liu, Sang Ho Yun, Hook Hua, Gian Franco Sacco, Timothy M. Stough, Costin Radulescu, Eric J. Fielding, Paul A. Rosen, Frank H. Webb, Jennifer W. Cruz, and Mark Simons of Caltech for NASA's Jet Propulsion Laboratory.

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

Technology Transfer at JPL
JPL
Mail Stop 321-123
4800 Oak Grove Drive
Pasadena, CA 91109-8099
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-49110, volume and number of this* NASA Tech Briefs *issue, and the page number.

Novel Method to Collect Saliva for Cortisol and DHEA Measurement

This method is noninvasive, rapid, inexpensive, and does not require trained medical personnel, and samples can be stored at room temperature for at least six months.

Lyndon B. Johnson Space Center, Houston, Texas

Saliva is an easily accessible body fluid containing important biological markers of physiological regulation in the body. The ability to use saliva to monitor the health and disease state of an individual is a highly desirable goal for health promotion and healthcare research. Saliva can reflect tissue levels of some natural substances and a large variety of molecules introduced for therapeutic use, emotional status, hormonal status, immunological status, neurological effects, and nutritional and metabolic status. A major drawback of using saliva as a diagnostic fluid has been that analytes (substances undergoing analysis) are generally present in lower amounts in saliva than in blood.

As a research tool, saliva has many advantages over blood. Saliva is easy to collect, store, and ship, and it can be obtained at low cost and in sufficient quantities for analysis. For patients, the noninvasive collecting techniques dramatically reduce

The Saliva Procurement and Integrated Testing (SPIT) booklets contain multiple filter paper pages that allow for the collection of multiple saliva samples over a specified time.

anxiety and discomfort, and simplify the gathering of repeated samples for longitudinal monitoring over time. Saliva does not clot, lessening the manipulations required. Saliva-based diagnostics are therefore more accessible, accurate, and less expensive than current methodologies.

A novel collection device for human saliva samples was developed. The primary goal was to assess salivary cortisol and dehydroeiandrosterone (DHEA) during spaceflight. However, the collection device can be used at any remote location, including space, and does not require any special conditions for storage. The Saliva Procurement and Integrated Testing (SPIT) booklets contain multiple filter paper pages that allow for the collection of multiple saliva samples over a specified time. Saliva samples are collected on the filter paper and are dried at room temperature. The samples are stable for as long as six months for measurement of both cortisol and DHEA, two important stress and immune regulatory hormones. These booklets are currently being used to collect saliva samples from International Space Station crewmembers before, during, and after spaceflight. The innovation can be used for rapid collection of saliva in remote locations, and analysis is performed upon return to a laboratory.

Five saliva specimens are collected using the SPIT booklet. Steroid hormones are then measured using commercially available, high-sensitivity kits. Subjects moisten a filter paper immediately after waking, 30 minutes later, before lunch, 10 hours after waking, and before going to bed at night. They collect these samples on a typical collection day. On the booklet cover, the time of collection is recorded. Samples associated with poor wetting or missing a sample are addressed by a mixed models analysis. After drying, the booklets are placed in a plastic bag and returned via the mail. The 10-hour interval is required for a fixed-minute time frame to determine the area under the CORT and DHEA curves, and for computing molar ratios of CORT/DHEA while remaining within the detection limits of the assay.

This work was done by Duane Pierson of Johnson Space Center, Satish Mehta of EASI/Johnson Space Center/NASA, and Mark Laudenslager of the University of Colorado Health Sciences Center. ***For more information, contact the JSC Technology Transfer Office at (281) 483-3809. MSC-25155-1***

Cryogenic Propellant Feed System Analytical Tool

This parametric tool rapidly predicts heat leak into cryogenic propellant distribution lines.

Lyndon B. Johnson Space Center, Houston, Texas

The Propellant Feed System Analytical Tool (PFSAT) predicts heat leak based on insulation type, installation technique, line supports, penetrations, and instrumentation. It also determines the optimum orifice diameter for an optional thermodynamic vent system (TVS) to counteract heat leak into the feed line, and ensures that the temperature constraints at the end of the feed line are met. PFSAT was developed primarily using Fortran 90 code because of its computational speed and its ability to access directly real fluid property subroutines in the Reference Fluid Thermodynamic and Transport Properties (REFPROP) database developed by NIST.

A Microsoft Excel front end user interface was implemented to provide convenient portability of PFSAT among a wide variety of potential users, and for its ability to use a user-friendly graphical user interface (GUI) developed in Visual Basic for Applications (VBA). The focus of PFSAT is on-orbit reaction control systems and orbital maneuvering systems, but it may be used to predict heat leak into ground-based transfer lines as well. PFSAT can be used for rapid, initial design of cryogenic propellant distribution lines and thermodynamic vent systems. Once validated, PFSAT will support concept trades for a variety of cryogenic fluid transfer systems on spacecraft, including planetary landers, transfer vehicles, and propellant depots, as well as surface-based transfer systems.

This analytical tool is in the form of a Microsoft Excel workbook. The default worksheet when the workbook is opened contains two buttons that are assigned VBA macros to obtain inputs from the user through a series of VBA input forms, and initiate the solver, respectively. The solver macro sets up the discretized thermal circuit to be solved, and uses compiled dynamic link libraries (DLLs) to access the Fortran 90 code that executes the thermal analysis. Throughout the solution sequence, fluid properties are obtained from the REFPROP database at each element for each iteration to ensure that accurate real fluid properties are used to find the solution.

The analytical tool obtains inputs from the user through the VBA input forms. The user initiates the solver by clicking a button on the main Excel worksheet. Once the solver converges, the results are populated onto three worksheets. Six graphs are generated for the user to examine. All results are reported in English and SI units. Initial testing shows that the tool produces outputs consistent with baseline test data from the JSC Cryogenic Feed System Testbed.

This work was done by Brian Lusby, Bruno Miranda, and Jacob Collins of Johnson Space Center. ***For more information, contact the JSC Technology Transfer Office at (281) 483-3809. MSC-25181-1***

Electrical/Electronics

Radiation-Hardened, High-Voltage, Quad-Channel Amplifier

Goddard Space Flight Center, Greenbelt, Maryland

A radiation-hard, 130-Volt, 100-KHz-capable, quad-channel operational amplifier with corresponding power supply and 6th-order Bessel filter circuitry has been designed, fabricated, and successfully tested. To control two-axis microelectromechanical systems (MEMS)-based mirrors, a differential high-voltage amplifier is required. The bandwidth of these mirrors is generally <2.5 KHz, and it is important to avoid exciting the mechanical resonance frequency of the unit to prevent damage. Therefore, a 6th-order low-pass Bessel filter was included in the design.

The design has been fabricated and demonstrated to meet the requirements of the MEMS mirrors it is intended to control. This amplifier has application in any spaceflight mission requiring MEMS mirrors or high-bandwidth, high-voltage operational amplifiers.

This work was done by Nathaniel Gill and Michael Mahon of Goddard Space Flight Center. ***For more information, contact the GSFC Technology Transfer Office at (301) 286-5810, or techtransfer@gsfc.nasa.gov. Refer to GSC-17214-1.***

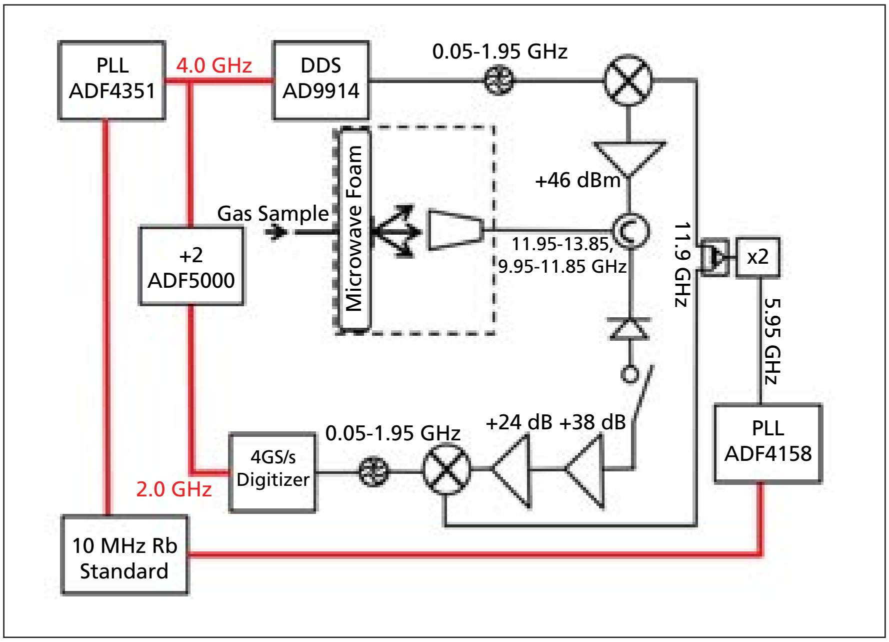
Reduced-Cost, Chirped Pulse, Fourier Transform Microwave (CP-FTMW) Spectrometer Using Direct Digital Synthesis

This technology could be used to further extend the bandwidth of the instrument.

Goddard Space Flight Center, Greenbelt, Maryland

Microwave spectroscopy is an invaluable tool for studying the structure, dynamics, and even the handedness of gas phase species. In particular, the specificity of microwave spectroscopy has been central to the unambiguous identification of the great majority of molecules detected in the interstellar medium. Applications of microwave techniques to problems in physical chemistry and molecular astrophysics have been greatly accelerated by developments in laboratory techniques.

There are three major components of CP-FTMW spectrometers that enable the collection of broadband spectra: high-sample-rate digitizers for acquisition of the microwave emission, broadband high-power amplifiers (based on either solid-state or traveling wave tube technology) to ensure sufficient power for sample polarization, and arbitrary waveform generators (AWGs) for producing the chirped polarization pulse. In state-of-the-art, multi-GHz-bandwidth instruments, each of these major components carries significant cost. AFGs only lower the overall cost by significantly truncating the instrument bandwidth. AFGs and AWGs are expensive in part because they are designed to generate extremely complex pulse sequences.



The microwave circuit of the DDS-based chirped pulse spectrometer. Microwave reference connections are highlighted for clarity.

Chirped pulse Fourier transform microwave spectrometers have become the instrument of choice for acquiring rotational spectra due to their high sensitivity, fast acquisition rate, and large bandwidth. However, the high cost of the required circuitry has hindered the truly widespread adoption of this approach. A newly constructed CP-FTMW spectrometer using direct digital synthesis was developed for chirped pulse generation.

Direct digital synthesizers (DDS) are Nyquist devices with good frequency agility and low phase noise. Using an external sample clock and digital control word, a DDS generates a tunable digital signal with a numerically controlled oscillator, which is then converted into sinusoidal output with a digital-to-analog converter (DAC). Their frequency agility and low phase noise capabilities have been utilized for longer broadband frequency sweeps at millimeter-wave frequencies for radar imaging applications, as well as slow, narrowband frequency

sweeps (3 MHz) in a millimeter-wave fast scan absorption spectrometer.

In this work, a DDS chip was used to generate short (~1 μs), broadband (1.9 GHz) linear frequency sweeps. The DDS and phase locked loop (PLL) frequency synthesizer clock source evaluation board combination used here reduces the chirp generation cost to well under $1,000/GHz. A second PLL board functioning as the local oscillator (LO) source is also one to two orders of magnitude less expensive than the microwave synthesizers and phase locked oscillators used in other CP-FTMW spectrometers. The total power requirement of the DDS and PLL boards is only 3W, considerably less than the power draw of an AWG, which is 100-500W. The DDS and PLL boards are also much smaller and lighter. These improvements could further enable the development of compact, in situ instruments for (inter)planetary measurements, especially if integrated into a mm-wave spectrometer.

This work was done by Ian Finneran, Daniel Holland, P. Brandon Carroll, and Geoffrey Blake of the California Institute of Technology for Goddard Space Flight Center. ***For more information, contact the GSFC Technology Transfer Office at (301) 286-5810, or techtransfer@gsfc.nasa.gov. Refer to GSC-16899-1.***

Signal Digitizer and Cross-Correlation ASIC

The device can correlate outputs from a large number of receivers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Microwave interferometry provides a means of synthesizing large scanning antennas that are not otherwise physically practical for spaceborne Earth observational systems. By cross-correlating multiple receivers of an array, high-resolution images are synthesized from a sparse — or thinned — array of small antennas rather than relying on extremely large mechanically scanned antennas. For Earth observations from space, high-data-rate cross correlators are required that operate with low power and have low mass and complexity. ASIC (application-specific integrated circuit) cross-correlators are an enabling technology for space-based interferometry. An ASIC CMOS (complementary metal-oxide semiconductor) cross-correlator was developed to correlate outputs from a large number of receivers.

The ASIC can digitize up to 128 analog signals at 1 Gsample/s with 2-bit accuracy, then cross-correlate 64 of these signals with the remaining 64 signals synchronously, and then serialize the resulting data through an 8-bit bus. This ASIC is targeted for application in NASA's GeoSTAR system for high-spatial-resolution sounding of atmospheric temperature and water vapor at 50 to 183 GHz from geostationary orbit.

Highlights of this mixed-signal ASIC include the integration of 128 high-speed analog to digital converters (ADCs) on the same chip with the digital totalizer and cross-correlator matrix. Each of the 128 analog inputs to the ASIC contains independent blocks with a 3-stage VGA (variable gain amplifier), ADC, and automatic gain correction loops. Each digitized signal is accumulated in a totalizer circuit that is later used to measure signal amplitude. In parallel, each of the digitized signals is paired with 64 signals from the opposing inputs for cross-correlation. Each of these 4,096 cross-correlators consists of a look-up table to generate the 3-bit product, followed by an accumulator that records a weighted sum of the signal cross-products. The accumulation period, or integration time, is typically 9 ms. This corresponds to 9 million multiply-accumulate cycles at the 1-GHz sample rate. The totalized and cross-correlated data is used to generate high-resolution radiometric images using a Fourier-transform. As viewed from a geostationary platform, these radiometric images of the

Earth are used to retrieve contiguous water vapor and temperature profiles with very high temporal and spatial resolution.

The power consumption of the ASIC's digital part is approximately 2 W. Due to a 4-bit full-adder and 22-bit ripple counter, the ASIC accumulates 26 bits of integration data over the integration period.

This work was done by Alan B. Tanner, Pekka P. Kangaslahti, and Boon H. Lim of Caltech; and Dalius Baranauskas, Denis Zelenin, and Gytis Baranauskas of Pacific Microchip for NASA's Jet Propulsion Laboratory. ***For more information, contact iaoffice@jpl.nasa.gov. Refer to NPO-49637.***

Image Capture to Stereo Correlation in an FPGA

NASA's Jet Propulsion Laboratory, Pasadena, California

In this work, there were four independent vision modules implemented in an FPGA: a CameraLink camera interface, rectification, bilateral filtering, and stereo disparity correlation. Each module was originally designed to run from end to end, not in a pipeline with the other modules. This limited throughput to 3.75 Hz.

The specifications are 15 frames per second and 1024 × 768 resolution, using stereo images to produce stereo disparity maps. A system was built in an FPGA that would handle all four of the steps necessary to compute stereo disparity. Previous work solved the problems of rectification, correlation, and filtering; this work focuses on combining those systems into a single FPGA as a single pipeline. Images were captured at 15 Hz from the CameraLink system. It would then be rectified, filtered, and correlated against without interaction from the CPU. When complete, an interrupt would be sent over the PCI bus to the CPU so the output disparity image could be read over the PCI bus.

The CameraLink library provided by the board vendor was used. Customizing the library allowed input images to stream directly into the next module (rectification) as the pixels were received. Rectification handles the de-warping of the input image so that correlation can be done upon it. A bilateral filter operates on both input images simultaneously once the rectification has finished, creating warped images. The correlation function produces stereo disparity data.

The primary improvements to each step were in the interfaces between the modules. The control logic that drives each module was largely re-written to take each module from being standalone to running in series as an end-to-end pipeline. At the software level, only the left warped image and the disparity image were needed, not left and right images and the disparity image. In order to achieve the desired throughput speed, the left warped image could be read out while it was being fed into the bilateral filter. Because both the bilateral filter and the image transfer operations were occurring simultaneously, 10 ms per frame was saved. The bilateral filter operates in a slave mode, meaning it is fed data rather than fetching data. This is to allow the PCI bus to read the left warped image out of SRAM, and feed the bilateral filter at the same time.

The stereo correlator was configured to read data streaming from the bilateral filter, instead of reading it from SRAM. C++ code was written to handle the timing and control of the system. This is the device driver layer that handles starting the FPGA, and reading the left warped image and the disparity image into main memory for obstacle detection. Five independent SRAM banks on the FPGA board are used to handle the parallel processing of data.

The visual algorithms needed to compute stereo disparity on large imagery can now be done in an embedded system that acts as a preprocessor before the CPU ever sees the imagery. This is useful for satellites as well as for descent imagery that needs to be very fast, such as during entry, descent, and landing. It is also applicable for future rover missions so the navigation imagery can be preprocessed, unloading the processor for other tasks. This will be used to great effect soon, as this work has been repackaged as part of the "Fast Traverse" system, a flagship baseline functionality of the Mars 2020 rover.

This work was done by Arin C. Morfopoulos, Carlos Y. Villalpando, and Larry H. Matthies of Caltech; and Steven B. Goldberg of Indelible Systems for NASA's Jet Propulsion Laboratory. ***This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-47190.***

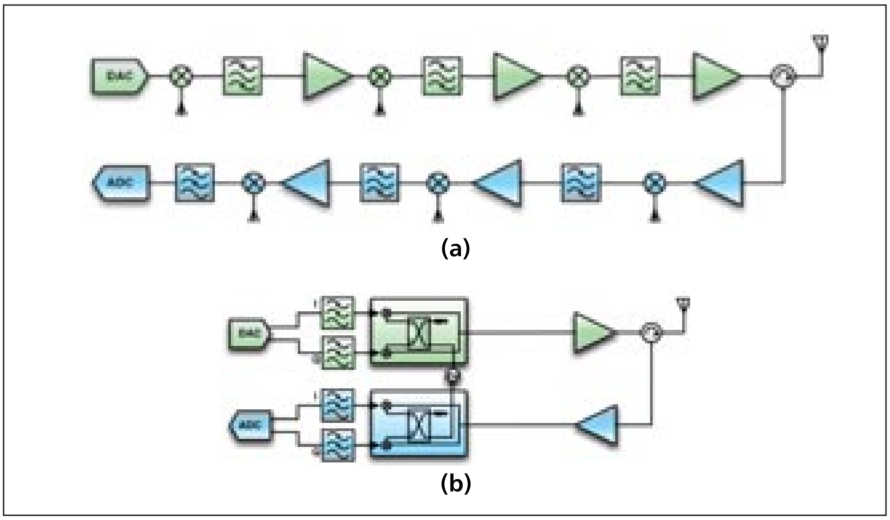
Offset IQ Modulation Technique for Miniaturized Radar Electronics

This innovation can be used in aerospace and commercial weather radar applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

Constellations of low-cost, small instruments provide global, distributed, and frequent coverage, enabling unique science observations. However, radars are active instruments with size, mass, and power requirements that are often not compatible with small satellite platforms such as CubeSats or SmallSats.

Radars traditionally use offset video modulation, which requires multiple stages of mixing, filtering, and amplification (see figure, a). Pulse compression (also known as matched filtering) is often used in radar systems because it allows the use of long pulses for high signal-to-noise ratio without sacrificing resolution. IQ (in-phase quadrature) modulation simplifies the up and down conversion processing chain by converting the signal directly from/to baseband to/from the output transmit frequency (figure, b). The largest problem with IQ mixers is that gain and phase imbalances create unwanted spurious signals, such as single sideband image and local oscillator (LO) leakage. This is particularly detrimental for pulse compression, because the sidelobe suppression is approximately given by the time-bandwidth product plus the level of image/LO leakage suppression. This can significantly degrade the performance due to clutter contamination. A common approach to improve the image suppression and LO leakage rejection of IQ mixers is digitally pre- and/or post-distortion of the signal to compensate for the mixer imbalance. However, the imbalance drifts with temperature and aging, and complete suppression would require complex feedback loops that are impractical.



Traditional offset video architecture (a) and IQ architecture (b).

A novel modulation scheme was developed for Ka-band precipitation profiling radar that reduces the size, mass, and power of the electronics by about an order of magnitude compared to similar radars. It is based on pulse compression and direct IQ up-conversion to reduce the number of components. Through an optimum selection of transmit signal and digital signal processing, spurs are suppressed, the system is not highly sensitive to LO leakage and image suppression, and can achieve high-purity signals with exceptional sidelobe suppression.

This work was done by Eva Peral, Simone Tanelli, Chaitali R. Parashare, Douglas L. Price, and Ninoslav Majurec of Caltech for NASA's Jet Propulsion Laboratory.

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

Technology Transfer at JPL
JPL
Mail Stop 321-123
4800 Oak Grove Drive
Pasadena, CA 91109-8099
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-49670, volume and number of this* NASA Tech Briefs *issue, and the page number.

Materials & Coatings

Flexible, High-Temperature Polyimide/Urea Aerogels

Cross-linked polyimide/urea aerogels are potential candidates for insulation for clothing, wrap-around items such as hoses, and refrigeration units.

John H. Glenn Research Center, Cleveland, Ohio

Cross-linked silica-based aerogels with polymeric materials, as well as incorporating a flexible linkage into the underlying metal oxide, have been proven to improve strength and resilience over their native, or non-cross-linked, counterparts without adversely affecting porosity and density. In this invention, high-temperature, stable, all-organic polyimide aerogels are prepared as reacting linear polyimide chains with a functional monomer to create branchings that are further room-temperature-cured with multifunctional isocyanate to form a three-dimensional network.

Silica aerogels are highly porous materials that consist of mostly air. They are potential candidates for many aerospace applications including insulation for spacesuits and multipurpose structures. However, their use is restricted due to their inherent fragility and environmental instability. Efforts in conformal coating of the skeletal structures of the aerogels with a different polymer, as well as incorporating flexible linkage into the underlying structures, have shown improvements in mechanical strength and recovery without adverse effect on density, % porosity, shrinkage, and surface area. However, it is most desirable to have a flexible, foldable, high-temperature material for various applications including inflatable re-entry vehicles.

Previous studies have proven that organic polyimide aerogels could be prepared from a linear polymer in which the three-dimensional network is formed by intermolecular physical bonding. However, it is anticipated that these thermoplastic polymer gels could collapse under higher-temperature conditions or in the presence of certain solvents, losing the pore structure.

To meet the requirements for high-temperature, flexible, and foldable materials, branched polyimides with amine endcaps are further reacted with multifunctional isocyanate and cured at room temperature to generate a 3D, covalently bonded network with flexible urea linkages. With the addition of a multifunctional isocyanate, mechanical properties of these highly cross-linked materials also improved. Addition of different organic clays also shows an increase in mechanical properties, as well as an increase in viscosity, enhancing their ability in casting thin films. The cross-linked polyimide aerogels are 500 times stronger than traditional silica aerogels, offer 2 to 10 times improved performance over polymer foams in ambient conditions, and offer up to 30 times improved performance in vacuum conditions. They are moisture-resistant, do not shed dust particles, and are heat-resistant to 200 – 300 °C. They can be formed into whatever configuration is required, providing an advantage over aerogels that exist in block form and must be modified or chemically altered to function as a form-fitting insulation.

The unique feature of this innovation is to further react branched polyimides with a multifunctional isocyanate to provide a strong, flexible, and foldable polyimide/urea thin film or a strong, resilient monolith via urea linkage while providing higher cross-linking units throughout the three-dimensional network. In addition to tougher, more resilient, and flexible material, the final product can be obtained at room temperature without further reaction.

This work was done by Baochau Nguyen and Mary Ann Meador of Glenn Research Center, and Baochau Nguyen of Ohio Aerospace Institute. ***NASA Glenn Research Center seeks to transfer mission technology to benefit U.S. industry. NASA invites inquiries on licensing or collaborating on this technology for commercial applications. For more information, please contact NASA Glenn Research Center's technology transfer program at ttp@grc.nasa.gov or visit us on the Web at https://technology.grc.nasa.gov. Please reference LEW-18825-1.***

Multilayer Insulation Systems

Applications exist where cryogenic fluids or liquefied gases are required, and in magnetic resonance imaging (MRI), power transmission in big cities, food freezing, and blood banks.

John H. Glenn Research Center, Cleveland, Ohio

Cryogenic fluid management (CFM) is a critical technical area that is needed for the successful development of future space exploration. A key challenge is the storability of LH_2, LCH_4, and LOX propellants for long durations. The storage tanks must be well insulated to prevent over-pressurization and venting, which lead to unacceptable propellant losses for long-duration missions to Mars and beyond.

There are two methods for meeting mission storage requirements that can be divided into two general types: those that use boil-off gases from the cryogen, and those that have zero boil-off. Methods that utilize boil-off for cooling include thermodynamic vent systems and vapor-cooled shields, each of which requires additional fluid mass to compensate for the boil-off losses. Methods that enable zero boil-off include actively cooled shields that use a cryocooler refrigerator and a simple, well-insulated tank. The required insulation material must outperform the current standard insulation for thermal performance and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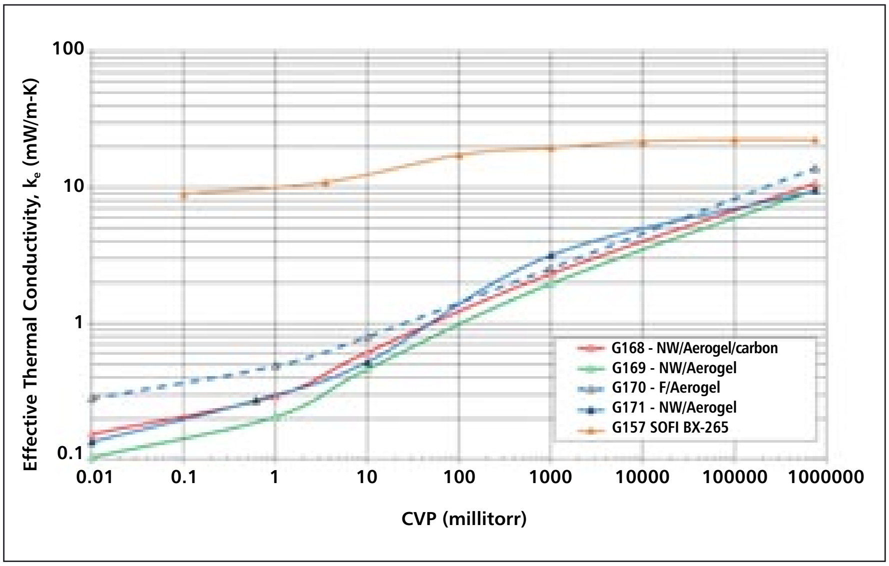

A performance comparison was done using the MLAI test data obtained during the program by considering the overall weight (areal density) of both systems.

provide additional features such as durability, reliability, and cost effectiveness.

A comparison of Multi-Layer Aerogel Insulation (MLAI) with Spray-On Foam Insulation (SOFI) was done using test data from Cryostat 500 at NASA Kennedy Space Center's Cryogenics Test Laboratory, operated by Vencore. Two MLAI test articles (G170 and G171 prototypes) tested using Cryostat 500 were compared to the SOFI BX-265 test data. Both G170 and G171 consisted of three aerogel layers separated by 0.25-mil perforated aluminized Mylar. The aerogel composites (G170 and G171) had different reinforcement materials. G170 was made using a reinforcement with a density of 0.01 g/cc and 2-mm thickness. G171 used a non-woven reinforcement and was <1 mm thick, with a density of 0.04 g/cc.

When analyzing the Cryostat 500 test results and normalizing the heat flux for SOFI and MLAI by unit areal weight, both MLAI prototypes outperformed SOFI by more than 90% in a vacuum environment (see figure). At atmospheric pressure, one MLAI prototype, G170, outperformed SOFI by 40%. Therefore, weight can be saved, or thermal performance improved, for the same weight as a SOFI system when using this type of MLAI system. Consequently, MLAI could serve as an improved replacement for SOFI for atmospheric and vacuum cryogenic thermal insulation.

This work was done by Redouane Begag, David Mihalcik, and Shannon White of Aspen Aerogels, Inc. for Glenn Research Center. ***NASA invites and encourages companies to inquire about partnering opportunities. Contact NASA Glenn Research Center's Technology Transfer Program at ttp@grc.nasa.gov or visit us on the Web at https://technology.grc.nasa.gov/. Please reference LEW-19339-1.***

Colorimetric Indicator for Detection of AF-M315E

John F. Kennedy Space Center, Florida

An easy and instant method of detection was needed for AF-M315E, a "green" propellant that produces very little vapor. This makes it hard to detect by smell or other active sensors.

Several different techniques were evaluated as possible detection methods for hydroxylammonium nitrate (HAN) and ammonium dinitramide (ADN), two of the primary components of AF-M315E. The technique selected for the detection of these commodities was colorimetric analysis. The reason for choosing this method stems from the nearly nonexistent vapor pressure of the AF-

M315E, which made the use of commercial off-the-shelf sensors not feasible.

An indicating absorbent detection system for HAN/AF-M315E was developed that is capable of both detecting (via a distinct color change) the presence of AF-M315E, and helping to contain any spill/leak that occurs. The detection system utilizes an indicator solution containing Methyl Red, which exhibits a distinct color change from red to yellow at a pH range of 4.5 – 6.5. The indicator solution is basified prior to use because AF-M315E has a pH of ~3.65.

The absorbent socks are prepared from commercially available, polystyrene-based chemical absorbent booms that are compatible with a wide range of chemicals (with the exception of hydrofluoric acid). These booms/socks are immersed within the prepared indicator solution, removed, allowed to dry, vacuum sealed (to prevent carbon dioxide absorption), and stored until needed. Additional unaltered booms are included for containment of a leak/spill once detection has occurred. Additionally, indicating chemical wipes are included in the detection system for detection of spills too small for detection using the sorbent socks.

The surfaces of several 3" × 2" stainless steel test panels were wetted using a swatch of microfiber high-performance cleaning cloth saturated with AF-M315E or deionized water, and then wiped using the indicating wipes. When the AF-M315E was wiped, it displayed a vivid color change upon direct exposure to the residual AF-M315E. The deionized water control sample showed no change upon exposure, demonstrating that the indicating wipes are not susceptible to false positives from moisture.

This work was done by Brint Bauer, Robert DeVor, James Captain, Tracy Gibson, and Mary Coan of Kennedy Space Center. ***For more information, contact the Kennedy Space Center Technology Transfer Office at (321) 867-5033. KSC-13977***

Oriented Nanofibers Embedded in a Polymer Matrix

Lyndon B. Johnson Space Center, Houston, Texas

A method of forming a composite of embedded nanofibers in a polymer matrix with a high degree of alignment has been created using a nanofiber continuous fiber (NCF) system. This innovation incorporates nanofibers in a plastic matrix forming agglomerates, and then uniformly distributes them by exposing the agglomerates to hydrodynamic stresses that force the agglomerates to break apart. In combination, or additionally, elongational flow is used to achieve small diameters and alignment.

In this system, nanofibers are embedded in polymer matrices in micron-sized fibers, including fibrils with diameters of 100 nm, multiwall nanotubes, single-wall nanotubes, and their various functionalized and derivative forms. Orientation is induced by high shear mixing and elongational flow singly or in combination. The polymer may be removed from the nanofibers, leaving micron-sized fibers of aligned nanofibers.

These micron-sized fibers provide easy handling and distribution of nanofibers for manufacturing into a range of parts for mechanical, electrical, and thermal applications. NCFs can be produced in continuous fiber lengths (1000s of km, for example) to be filament wound, woven, laid up, processed in rows or bundles, or used for thread or yarn to produce a range of products requiring the enhancement from the nanofiber additions. The polymer matrix system can easily be processed into various shapes, or processed with other polymer systems or non-polymeric additions.

The NCFs are a system that can deliver aligned nanotubes for strengthening (including improved impact strength), or electrical or thermal anisotropic features (properties varying in different directions). By extension, the NCF system can also be applied to nanofibers embedded in matrix, and then formed into a tape or film to provide control of distribution and alignment, and to enable a variety of subsequent processing steps.

This work was done by Enrique V. Barrera, Fernando J. Rodriguez-Macias, Karen Lozano, Luis Paulo Felipe Chibante, and David Harris Stewart of Johnson Space Center. ***For more information, contact the JSC Technology Transfer Office at (281) 483-3809. Refer to MSC-24047-1.***

Low-Scatter Starshade Edges

This technology has applications in flexible optical masks, apertures, and encoders where sharp edges and material robustness are important.

NASA's Jet Propulsion Laboratory, Pasadena, California

A starshade occulter is a large space structure whose shape is specially designed to produce a diffraction pattern in starlight that can aid a telescope in direct imaging of exoplanets. The diffraction pattern produces extremely high-contrast dark regions in the starshade's shadow on the order of 10^{-9} or 10^{-10}. To do so, the edge shape of the structure must be held to extremely tight tolerances. In addition, potentially obscuring glint light from the Sun must be minimized to prevent loss of contrast.

This project sought to find suitable materials for the space environment that could be used to manufacture flat edge segments up to 1 meter in length, with tight in-plane shape tolerances on the order of tens of micrometers, along with sharpened edges with sub-micrometer, out-of-plane radii at the edge tips to reduce sunlight glint and loss of contrast.

In addition to the above requirements, the parts should be flexible so as to be stowed within a launch shroud prior to deployment in space. They must be able to survive thermal cycling on the order of ±50 to 100 °C, and not unduly distort the shape of the low-thermal-expansion host structure.

The solution is the use of thin, highly elastic, amorphous metal foils carefully shaped by a photo-chemical etching process. The combination of the manufacturing process and amorphous material inherently produces sharp edges that are sub-micron in radius. Two similarly shaped foils are bonded on either side of a thicker carbon fiber-reinforced polymer laminate for stiffening. The overall laminate is thermally balanced. One of the foils is slightly oversized with respect to the others, and is the "optical edge" layer. This layer's sharp edge is the only edge encountered by the target star's light on its way to the telescope. The undersized foil is referred to as the "dummy," "shadowing," or "baffle" layer.

The amorphous metal alloys are a combination of various metallic elements, and are quenched rapidly from the melt to prevent the growth of crystalline grain structures, and freeze the atoms in a random, glassy state. This increases the materials' elastic yield limits, and minimizes the materials' plastic deformations experienced during handling and application use, i.e. permanent wrinkling, creasing, etc. typically experienced with other thin metal foils.

The carbon fiber-reinforced polymer laminate used for mechanical stiffening is constructed from a stack of unidirectional plies. The fiber laminate plies are optimally oriented to obtain good thermal expansion performance with respect to the system requirements in both longitudinal and transverse directions. The dummy foil layer allows for the stack-up to be neutral in bending under temperature changes, since the entire stack-up is symmetric about the midplane. It also provides extra shading for the actual optical edge for off-axis stray light sources such as the Sun. Sunlight coming towards the starshade off-axis would need to scatter around both foils' edges to enter the telescope aperture. Note that this added double scattering benefit only applies to the half of the starshade oriented

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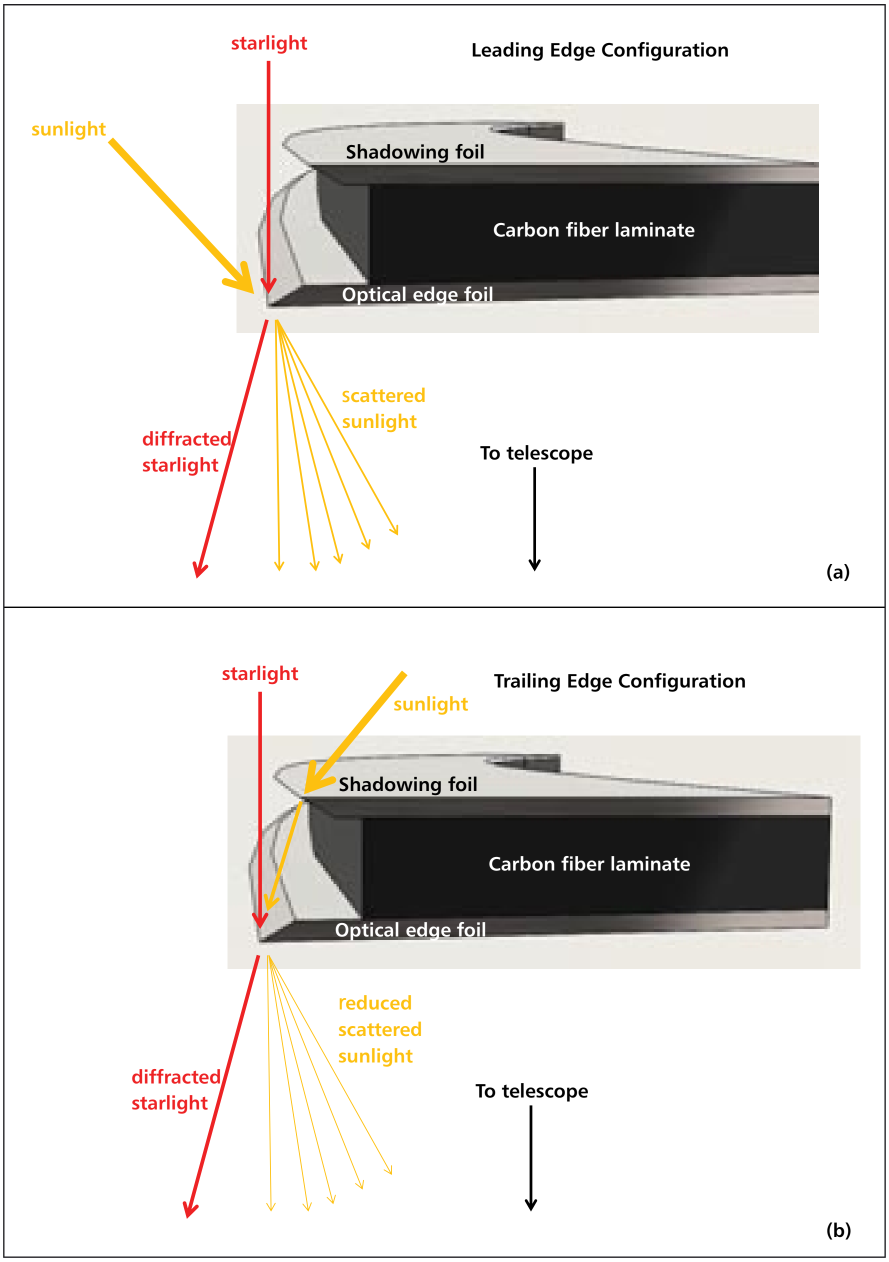


The starshade occulter consists of two similarly shaped foils bonded on either side of a thicker carbon fiber-reinforced polymer laminate. One of the foils is slightly oversized and is the "optical edge" layer. This layer's sharp edge is the only edge encountered by the target star's light on its way to the telescope (a). The undersized "shadowing" foil provides extra shading for the optical edge for off-axis stray light sources such as the Sun. This double scattering benefit only applies to the half of the starshade oriented opposite the stray light source — the so-called trailing edges (b).

opposite the stray light source — the so-called "trailing edges."

This work combines the use of etched amorphous metal materials and carbon fiber-reinforcement to create 1-meter-long parts with precision-controlled edge geometries and sharp edge profiles that are robust. These precision, sharp-edge parts are one of the key "high tent-pole" enabling technologies that would allow successful construction and operation of a high-contrast-producing starshade occulter. Without these edge parts, the carefully contrived dark shadow behind the shade would be partially filled by bright sunlight glint.

This work was done by Keith D. Patterson, Douglas C. Hofmann, Stefan R. Martin, P. Douglas Lisman, Stuart B. Shaklan, Eric J. Cady, David R. Webb, Mark W. Thomson, and Blake A. Ives of Caltech for NASA's Jet Propulsion Laboratory. ***For more information, contact iaoffice@jpl.nasa.gov. Refer to NPO-49923.***

Method to Improve the Synthesis Process of High-Purity Bulk Multi-Element Compounds

Marshall Space Flight Center, Alabama

Multi-element compounds have been used ubiquitously in various applications, including electronics, optics, opto-electronics, thermoelectrics, superconductivity, and the recently developed application of spintronics. Besides being the main components of some of these devices, the bulk form of these compounds is needed as a standard for fundamental property characterizations as well as the starting materials for thin-film deposition. Hence, the chemical purity and crystalline quality of these bulk compounds are critical for the applications.

The typical process of synthesizing high-purity bulk multi-element compounds involves sealing a fused quartz/silica ampoule loaded with the elements under vacuum condition, heating the sealed ampoule to above the melting point of the compound, cooling the ampoule in a controlled manner, and finally, retrieving the synthesized material. In many instances, the resultant sample reacts with and adheres to the inner wall of the ampoule, also known as wetting. Since the samples usually have larger thermal expansion coefficients than that of the ampoule, the samples shrink more than the ampoule during cooling. Consequently, the wetting, or the adhesion of samples to the ampoule inner surface, causes interior cracks and the resultant inferior crystalline quality and low yield of the sample. This problem is especially prevalent when the more reactive elements, i.e., group I to IV in the periodic table, are involved. Certain methods, such as coating the internal surface of the ampoule with carbon, have been adopted to reduce this interaction between samples and the ampoule wall. The coating is usually not uniform, thick enough, or reproducible such that local wettings cannot be completely eliminated. It also causes the undesired contamination of the sample by the introduction of carbon.

In this invention, because the wetting is caused by the chemical reactions of the sample elements and the impurities in the ampoule — specifically free oxygen at elevated temperatures — the crystalline quality of the resultant materials can be vastly improved by the following two steps: 1) specifically preparing the fused quartz/silica ampoule, and 2) carefully processing the heating procedure of the alloying to minimize the wetting. The chemical purity will be maintained near the level of that of the starting elements since no extraneous chemicals, such as carbon, will be introduced during the synthesis.

The purpose of the procedure in step 1 is to reduce the OH species content in the synthesis ampoule by continuously subliming and evacuating them from ampoule interior and exterior surfaces as they are diffusing from the inside of the quartz/silica tubing toward the surfaces. The procedures for the preparation of the synthesis ampoule are:

1. Procure fused quartz/silica tubing with lower OH content.
2. Make the synthesized ampoule from the selected tubing by glass blowing with a hydrogen/oxygen torch.
3. After cleaning the empty synthesis ampoule, place it inside a larger fused quartz/silica ampoule.
4. Connect the whole ampoule assembly to a vacuum pump and evacuate it to a vacuum level lower than 10^{-4} Torr.
5. Slide a tubular furnace to cover the majority length of the ampoule assembly.
6. Heat the furnace to the baked temperature (at least 1180 °C) and bake for the planned time — at least 16 hours for an ampoule with a 2-mm-thick wall (longer time for a thicker wall) — before cooling to room temperature by turning the power to the furnace.

This work was done by Ching-Hua Su of Marshall Space Flight Center. ***For more information, contact Ronald C. Darty, Licensing Executive in the MSFC Technology Transfer Office, at Ronald.C.Darty@nasa.gov. Refer to MFS-33302-1.***

Laser Subdivision of the Genesis Concentrator Target Sample 60000

Lyndon B. Johnson Space Center, Houston, Texas

A need arose for approximately 1 cm^2 of a diamond-like-carbon (DLC) concentrator target for the analysis of solar wind nitrogen isotopes. The original target was a circular quadrant with a radius of 3.1 cm; however, the piece did not survive intact when the spacecraft suffered an anomalous landing upon returning to Earth. An estimated 75% of the DLC target was recovered in at least 18 fragments. The largest fragment, Genesis sample 60000, was designated for this allocation, and is the first sample to be subdivided using a laser scribing system. Laser subdivision has associated risks, including thermal diffusion of the implant if heating occurs, and unintended breakage during cleavage. In order to minimize the possibility of unintended breakage of the actual target wafer during subdivision, a careful detailed study involving numerous laser scribing plans was undertaken. The innovation described here involves the results of this study that yielded a cutting plan essentially guaranteeing ~100% cleaving success of this precious space-exposed wafer.

In order to maximize the probability of a successful cleave, the system needed to scribe at least 200 µm into the wafer.

Attempts were made to scribe completely through practice wafers by varying the parameters of the laser system holding the laser power fixed at 95% maximum power. The parameters varied were cutting speed, total number of scribe passes, depth advance of the wafer stage per scribing pass, and the hold time between passes. It was determined that if a cut could be made completely through the wafer at 95% power with a given set of parameters, the power could be reduced and only cut to a 200-µm depth, minimizing heating in the wafer. The benefit of these initial tests indicated that a cut roughly 125 µm could be made into a 550-µm-thick wafer. Scribing back and forth along a single line created a scribe cut that was ~10 µm wide. The cutting plan then evolved into scribing multiple lines separated by 5 µm. However, once again, the cut depth seemed to bottom out at just over 125 µm.

The scribing plan began by orienting the wafer on the laser cutting stage such that the 100 and the 010 directions of the wafer were parallel to the corresponding X and Y directions, respectively, of the cutting stage. The laser was programed to scribe 31 lines of the appropriate length along the Y stage direction. The scribe lines were separated by 5 µm in the X direction. The laser parameters were set as follows. The laser power was 0.5 Watt, each line consisted of 50 passes with the Z position being advanced 5 µm per pass, and there was a built-in wait time of 30 seconds before scribing the next line to allow for wafer cool-down from any possible heating via the laser. After the laser finished scribing, the oriented wafer and mounting plate were removed from the cutting stage and placed on the "stage area" of a lighted binocular microscope. This allowed ablated silicon from the laser scribing to be "teased" out of the "scribed" pattern using an ultrasonic-aided, sharpened micro-tool. The loosest Si "fluff" was then removed (vacuumed and or brushed) from the wafer surface. After all of the ablated Si was removed from the scribe channel, the mounted wafer was then repositioned in exactly the same orientation on the laser stage. The laser was focused using the bottom of the wafer channel and the 31-line scribing pattern reprogrammed using the Z position of the groove bottom as the starting Z value instead of the top wafer surface previously used. After the laser completed the second set of scribes, the ablated material was removed from the groove using the described technique.

The wafer was remounted on the stage using exactly the same orientation as before. Again the laser was focused on the bottom of the groove. This time, however, it was programed to scribe only one line down the exact center of the channel. The final scribe line consisted of 100 passes with a Z advance of 5 µm per pass, and the laser power set at 0.5 Watt. Using this scribing plan yielded an ~100% cleaving success rate on non-flight FZ silicon wafers ~550 µm thick with a scribe length of <4 cm.

This work was done by Howard Lauer Jr., Patti Burkett, Melissa Rodriguez, Keiko Nakamura-Messenger, Simon Clemett, Carla Gonzalez, and Thomas See of Johnson Space Center. ***For more information, contact the JSC Technology Transfer Office at (281) 483-3809. Refer to MSC-25607-1.***

Fabrication of an Integrated Photonic Waveguide Joint in Micromachined Silicon

This technology could be used in any MEMS or micromachined structure that requires multiple levels of topography.

Goddard Space Flight Center, Greenbelt, Maryland

High-aspect-ratio silicon structures are necessary components in many MEMS (microelectromechanical systems). Aspect ratio is defined as the ratio of the height of the structure to its lateral width. The structures are typically fabricated through bulk micromachining steps such as deep reactive ion etching. In some cases, multiple levels of high-aspect-ratio structures are required. For instance, one may want to etch completely through a silicon wafer to thermally isolate a bolometer or provide waveguide coupling to an antenna defined on an insulating membrane, and at the same time have integrated high-topology structures required for microwave coupling or filtering. Definition of the structures typically uses photolithographic technology. But for high-aspect-ratio structures, spin cast resist becomes difficult to incorporate due to the non-uniform thickness of the resist around tall structures. One can cast very thick layers of photoresist, but this limits the minimum feature size, and additionally, very thick layers of photoresist are difficult to work with due to solvent release and moisture that can cause the resist to crack or swell. For electromagnetic reasons, the structures would preferably be made from conductive material such as metal or degeneratively doped silicon. The objective of this work was to incorporate multiple levels of conductive high-aspect-ratio structures with standard micromachining processes.

The new microfabrication technology incorporates multiple levels of high-aspect-ratio structures into a single piece of silicon. The technology can be used to incorporate photonic waveguide joints with through wafer-etched structures. The process starts with a silicon wafer that may have completed microwave or other device processing. In the case where a conductive layer is required, the silicon may be degeneratively doped. A layer of metal is deposited and patterned by standard processes. The metal may be used as a wirebond contact or to improve thermal and electromagnetic coupling. Next, a layer of photoresist is spin cast at the desired thickness of approximately 12 μm so that it will protect the silicon wafer during subsequent processing steps, such as etching completely through a 500-μm thick wafer.

The photoresist is then partially exposed through a photomask. Then, a different photomask is used to fully expose the resist. The photoresist is developed for the time required to completely remove the fully exposed photoresist in those areas where etching of the silicon is required. In the remaining areas where the photoresist was partially exposed, the photoresist absorption is such that only the surface of the photoresist has received enough UV dose to cause the resist to become soluble in developer. Therefore, photoresist will remain in those areas after development.

In the next step, the silicon is etched by deep reactive ion etching. Then, the photoresist is etched in an oxygen plasma such that the first level of resist is removed, exposing the silicon in those areas where the second level of topography is required. The silicon wafer is further etched. In this case, the original silicon layer is also etched. By stopping the first silicon etch at the correct depth, the second etch can be optimized such that two or more layers can be completed at the same time. It should be pointed out that often with a through wafer etch, an etch stop layer is incorporated with a very low etching rate. This simplifies balancing the rates between the two structures, and allows optimization of the depth of the second structure with minimal effect on the first. The process has been demonstrated for building silicon microwave backshorts with integrated photonic choke structures.

This work was done by Kevin Denis of Goddard Space Flight Center. ***For more information, contact the GSFC Technology Transfer Office at (301) 286-5810 or techtransfer@gsfc.nasa.gov. Refer to GSC-16931-1.***

Very Large Inflatable Antenna Structures

This methodology enables production of very large, but lightweight, structures in space.

Langley Research Center, Hampton, Virginia

Future space exploration past Earth orbit has a significant need for manufacturing in space beyond simple assembly of prefabricated parts. The next generation of very large aperture antennas will exceed the size achievable with conventional folding mesh technologies and new concepts are needed to support football-field-size structures. Technologies to address the problem have been developed using the formation of polyurethanes in a vacuum environment. Large inflatable structures can be stabilized by the formation of polyurethane foams of controlled density. For use in a vacuum environment, the availability of oligomeric precursors is important. Low-molecular-weight components would immediately evaporate, changing the stoichiometry of the reaction and potentially contaminate a space environment, but high-molecular-weight precursors have a much more limited range of properties.

Two technologies for ultra-light space structures and antennas were developed. The first, the Rigidization on Command™ (ROC™) concept, uses UV-curing resins to stabilize inflated structures. This removes the need for make-up gases inherent in typical inflatables. This technology is suited for extremely low-areal-density construction, but the thermal and mechanical dampening in these structures is low. A self-deploying foam antenna concept was developed at ATI for small aperture sizes, and a 0.6-meter antenna was fabricated and tested at NASA's Jet Propulsion Laboratory.

The dish side of the inflatable antenna with foam support after inflation.

These foam antennae have an areal density of approximately 5 kg/m^2, which was achieved with a foam density of 48 kg/m^3 (3 lb/ft^3). While the areal density of these foams was as low as any state-of-the-art solution, it was still a factor of 5 above the threshold for very large aperture designs. The use of the foam technologies in combination with ROC™ systems was investigated to achieve the required low-areal-density antenna structures. The new foam materials would be used as a basis for an in-space foamed structure, using the ROC™ technology to provide the necessary shape control. The advantages of the new system include low areal density, high volumetric packing efficiency (with a target density of 10 kg/m^3, the theoretical packing density is 100:1 from the liquid precursor to the foamed structure), and self-deploying characteristics.

The design fills a correctly shaped double-layer membrane with high-expansion polyurethane foam. The first chamber is inflated to give the antenna its desired shape. Then, the antenna reflector is "frozen" into the desired shape by UV rigidization to prevent possible distortion during the subsequent foam stabilization process. After rigidization, the second, smaller chamber is filled with foam to permanently stabilize the membrane shape and protect it from damage. This foam is made from open-cell material, allowing all gases used during expansion to rapidly diffuse out of the foam after deployment, greatly reducing the tendency to absorb heat under solar irradiation and thereby reducing the chance for thermal deformation due to changes in orbital solar exposure.

The critical part for this application was the controlled volume expansion to give a low-weight structural foam. Initial experiments showed that a completely unrestrained system foamed highly inconsistently, with volume variability of 500%, depending on the speed of skin formation. If the foaming took place in a perforated mold, however, the ratio of foam expansion became very controllable. Adding a third of a percent of water to the urethane mixture provided the desired foam density of 10 kg/m^3 when expanded *in vacuo*.

To demonstrate the ability to produce a larger-scale antenna, both a 2-m ROC™-based antenna surface and a separate prototype foam backing unit were designed and fabricated. The antenna surface was measured via 3D laser position scanning. This allowed modeling of the antenna performance without extensive testing.

This work was done by Jan-Michael Gosau and Ronald E. Allred of Adherent Technologies, Inc. for Langley Research Center. ***For more information, contact LaRC-PatentLicensing@mail.nasa.gov. Refer to LAR-17964-1.***

Constraint Force Equation (CFE) Solver for Multi-Body Dynamics and its Implementation in POST2

Langley Research Center, Hampton, Virginia

Existing aerospace flight trajectory programs simulate the motion of aerospace vehicles by modeling external forces and moments acting on each body, but lack provisions for determining reaction forces and moments exerted by one body on another through a connecting joint. These reaction forces and moments are also known as constraint forces and moments because they permit specified motion of one body relative to another, and, at the same time, prohibit all other relative motions. In other words, a joint imposes certain constraints on relative motion.

Previous techniques for simulating the motion of aerospace vehicles having multiple bodies connected by joints fall into one of two categories. The first category consists of simulations that are created for specific vehicle configurations. They are often performed in a single simulation environment, highly customized for a particular vehicle configuration, and require significant effort to develop. Such specific, customized simulations cannot be easily modified for different applications. Techniques that fall within this category usually approximate the constraint forces and moments with spring/damper systems to simulate constrained motion in a launch vehicle staging environment.

A second category involves approaches that subdivide the trajectory simulation problem into distinct phases, each of which is handled by a different software program. Typically, a conventional trajectory simulation program is used to model the unconstrained motion, and a specialized mechanical analysis and design program solves the constrained-motion (separation) segment of flight. Performing end-to-end mission simulation with this approach involves linking of multiple codes and ensuring proper input/output interfaces.

This innovation, known as the Constraint Force Equation (CFE) Solver, is a physics-based approach for simulating the constrained motion of aerospace vehicles or vehicle segments that are connected by simple joints. The CFE Solver can be easily implemented in a conventional trajectory simulation software program used to simulate unconstrained motion, thus providing a means for these existing, widely used tools to accurately simulate vehicle motion that is constrained by joints.

The CFE Solver computes the internal joint loads (constraint forces/moments) acting at the joints connecting multiple bodies in motion, and applies them as additional external forces/moments. The CFE solver enables users to simulate the dynamics of systems of multiple rigid bodies connected by multiple joints that permit certain relative motion between the bodies. The CFE method is not new, but this approach of using CFE Solver to compute internal joint loads and apply them as external loads is new. This new approach enables users to solve equations governing complex multi-body dynamics in a simple manner, and also enables implementation of CFE solver in a trajectory optimization environment like POST2 (Program to Optimize Simulated Trajectories II) without major modification to the basic trajectory optimization code. The CFE Solver implemented in POST2 enables users to perform trajectory optimization and end-to-end simulation of launch vehicle trajectories, including multi-body stage separation in a seamless and efficient manner.

The CFE Solver is based on Newton's laws of motion. In the literature, it is also known as the Lagrange multiplier method for treating the constrained motion of multiple bodies. The CFE Solver consists of an algorithm that is divided into several computer programs. These algorithms are designed so that the user can select the type of the joint(s) connecting multiple bodies, and selectively turn on or turn off the applicable degrees of translational or rotational freedom.

Once the user specifies all of the inputs to the CFE algorithm, the CFE code is compiled and ready for execution. If the user wants to run it in a standalone mode, they can do that. However, if the user wants to run it in a trajectory optimization/simulation environment like POST2, then he or she compiles/links the CFE Solver with POST2 software and runs POST2 in the usual fashion.

This work was done by Bandu Pamadi, Paul Tartabini, Matthew Toniolo, Carlos Roithmayr, Chris Karlgaard, and Cindy Albertson of Langley Research Center. ***For more information, contact Langley Research Center at LaRC-PatentLicensing@mail.nasa.gov. Refer to LAR-18349-1.***

Cyclops: the Space Station Integrated Kinetic Launcher for Orbital Payload Systems (SSIKLOPS)

Lyndon B. Johnson Space Center, Houston, Texas

The Space Station Integrated Kinetic Launcher for Orbital Payload Systems (SSIKLOPS), also known as "Cyclops," deployed the largest satellite ever from the International Space Station (ISS) on November 28, 2014. The satellite, SpinSat, a Naval Research Laboratory (NRL)/Department of Defense Space Test Program (DoD STP) satellite, is pioneering the utilization of electronically controlled solid propellant thrusters as well as acquiring vital atmospheric density data. It is a spherical satellite 22 inches in diameter, weighing 115 pounds, and will remain in orbit for over two years.

Following its successful deployment of SpinSat, Cyclops is being housed within the ISS pressurized environment in anticipation of future satellite deployments. Future deployable satellites will be delivered to the ISS in a soft stowed configuration aboard one of the ISS's resupply vehicles and then stowed onboard the ISS until their scheduled deployment date. Once mated to Cyclops by the ISS crew, the satellite will be processed to the unpressurized external environment of the ISS through the Japan Aerospace Exploration Agency's (JAXA) Japanese Experiment Module (JEM) Airlock. Outside the ISS, it will then be transported from the area near the JEM to its deployment location through the use of JAXA's Small Fine Arm (SFA). There, actuation through the SFA is performed and the satellite is deployed by Cyclops. Cyclops also has the capability to utilize the ISS's Special Purpose Dexterous Manipulator (SPDM) for satellite deployment if required. Following satellite deployment, Cyclops will be returned to the JEM Airlock and transferred back inside the pressurized ISS volume for future use.

The Cyclops system was designed, analyzed, manufactured, tested, and certified in-house at NASA Johnson to serve as a system that allows the ISS to accommodate and deploy payloads that are significantly larger than the standard CubeSat size. The Cyclops deployment unit and supporting hardware is comprised of various structural and mechanical subsystems, which together allow it to interface with the ISS crew, the JEM Airlock, the SFA and SPDM robotic arm systems, and the deployable satellites. These interfaces facilitate the transfer and deployment of satellites by Cyclops. Cyclops requires that each deployable satellite use its single standard attachment interface, designed and developed at JSC purposefully for use with Cyclops. The interface is provided by the ISS program to satellite developers by request.

After seeing Cyclops successfully delivered to the ISS in September of 2014, and then working to successfully deploy SpinSat two months later, the team that developed Cyclops is continuing to work closely with groups from JSC Engineering, the University of Texas at Austin, and Texas A&M University for their upcoming deployment of the LoneStar Satellite. Also, opportunities for additional satellite deployments are in work with DoD STP, other NASA organizations, and several academic and industry partners. Cyclops will remain indefinitely onboard the ISS supporting deployment of small satellites and experiments as a key resource in the utilization of the ISS.

This work was done by Daniel Newswander, Matthew Hershey, Joseph Anderson, Brent Evernden, Gabriel Ortiz-Sanchez, Peter Taylor, Jeff Hagen, Katherine Dithmer, Charles Mccann, Ronald Lewis, Oscar Guzman, James Smith, Ross Patterson, William Decker, Jason Weeks, Carlos Ortiz-Longo, Priscilla Kelly, Khadijah Shariff, Anju Gupta, Raymond Patin, Hung C. Lo, Daila Gonzales, Jon Figert, Robert Blaine, Ted Tsai, Alex Tovar, Michael Waid, Pete Fantasia, Monica Visinski, Michael Wright, Lebarian Stokes, Shanda Norman, Barton Smith, John Harrison, Sharla Fults, and Jay Bennett of Johnson Space Center, with support from Wyle, Jacobs Engineering, the DoD STP office, and the ISS program. ***For more information, contact the JSC Technology Transfer Office at (281) 483-3809. Refer to MSC-25646-1.***

Vacuum-Jacketed Cryogenic Flex-Through

John F. Kennedy Space Center, Florida

A vacuum-jacketed, cryogenic flex hose was designed with an integrated flange to be able to pass through a vacuum chamber wall. This design increases the quality of the cryogenic fluid at the exit of the hose (i.e., more liquid, less vapor) by extending the hose vacuum-jacket through the chamber wall, where usually a non-insulated fluid fitting would be required.

Cryogenic liquid was to be supplied to a heat exchanger inside a vacuum chamber for extended periods of time. In order to ensure the highest-quality fluid was being supplied, achieving the highest heat exchanger performance, the feed line needed to be vacuum-jacketed all the way from the source to the exchanger.

The new design integrates a flange to the hose outer vacuum-jacket so the line could be passed through the chamber wall, yet still form a vacuum seal. Commercial off-the-shelf (COTS) vacuum-jacketed flex hoses have standard, non-insulated, flared end terminations that require tube fittings to attach to the end item. These terminations allow unwanted heat into the cryogenic liquid, which results in lower-quality fluid at the test apparatus.

The flex-through consists of two main elements: a vacuum-jacketed, insulated flex hose and an integral vacuum flange operating at near ambient temperature. In this particular case, a 40-mm type KF vacuum flange was used for an 18-mm diameter flex hose. The parts make up a cryogenic supply system that is fully vacuum-insulated from the source, through the chamber wall, and to the test apparatus. The innovation provides a cost-effective way to increase the overall system thermal performance.

This work was done by Adam Swanger and James Fesmire of Kennedy Space Center. ***For more information, contact the Kennedy Space Center Technology Transfer Office at 321-867-7171. Refer to KSC-13933.***

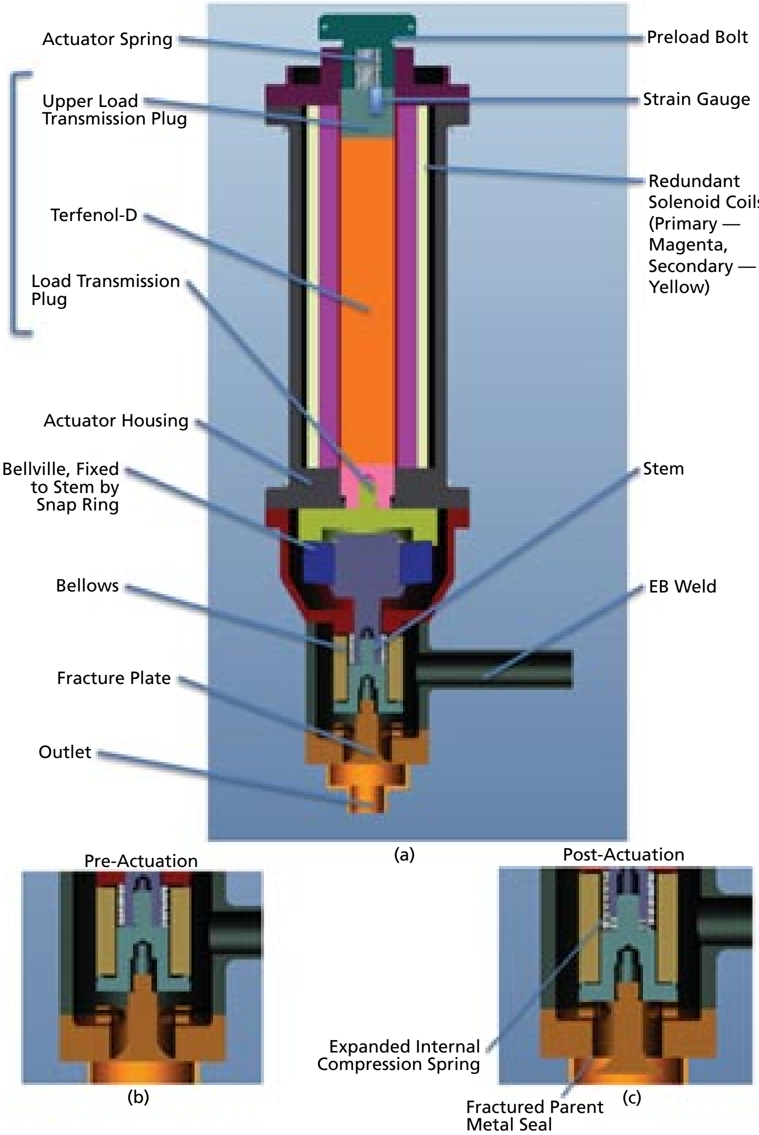
Normally-Closed Zero-Leak Valve with a Magnetostrictive Actuator

The valve can be used wherever normally closed valves are required.

Goddard Space Flight Center, Greenbelt, Maryland

A hermetically sealed, normally closed (NC) zero-leak valve has been developed. Prior to actuation, the valve isolates the working fluid in the upstream volume from the downstream volume with a parent metal seal. The valve utilizes the magnetostrictive alloy Terfenol-D for actuation. This alloy experiences a phenomenon known as magnetostriction, i.e., a gross elongation, when exposed to a magnetic field. This elongation fractures the seal within the wetted volume of the valve, opening the valve permanently and establishing fluid flow. The required magnetic field is generated by redundant coils concentric to the Terfenol, but isolated from the working fluid. The response time for this phenomenon to occur and subsequently for actuation is on the order of milliseconds. The wetted volume consists of entirely parent-metal 6Al-4V titanium, compatible with all storable propellants, helium, nitrogen, argon, isopropyl alcohol, and argon. When coupled with the parent metal seal, this design gives the valve internal and external leak rates of zero.

The valve was designed as a drop-in replacement for the pyrovalve for both in-space and launch vehicle propulsion systems. Due to safety concerns of fluid leakage while personnel work around the vehicle or spacecraft prior to launch, these valves are used to isolate hazardous propellant or high-pressure gas from the downstream components. Once clear of personnel, the valves are opened, priming the system with the work fluids. The priming sequence usually occurs after launch, but this valve could be used for any normally closed permanent isolation application



The cross-sectional view of (a) the magnetostrictive valve prior to actuation, (b) flow cavity prior to actuation, and (c) flow cavity after actuation showing the fractured parent-metal seal.

wherever a working fluid must be isolated from the downstream volume by a leak-free seal, and upon valve actuation, the valve is opened and fluid flow is established permanently.

The valve consists of two major subassemblies: the actuator and the flow cavity. The actuator is preloaded to 1,250 N by adjusting the preload bolt, pressing the Terfenol-D against the now-deflected belleville springs. When actuation is desired, either solenoid coil is charged in a pulsed mode, causing magnetostriction in the Terfenol-D. The elongation deflects the belleville spring stack, supplying an increasing load to the stem until the parent metal seal is fractured. Once fractured, the spring inside the bellows drives the bellows base downward, onto a raised boss at the top of the fracture plate. Once fracture has occurred, the stem and its spring stack is left, separated from the actuator column. The Terfenol-D is unloaded and returns to its original length. The spring inside the bellows ensures the valve remains open.

This work was done by Daniel Ramspacher and James (Jim) Richard of Goddard Space Flight Center. ***For more information, contact the GSFC Technology Transfer Office at (301) 286-5810 or techtransfer@gsfc.nasa.gov. Refer to GSC-16965-1.***

Scenario Power Load Analysis Tool (SPLAT) MagicDraw Plug-in

The SPLAT tool could be applied to any project that needs to track time-dependent power consumption; it computes power usage profiles based on modeled component information and scenarios.

NASA's Jet Propulsion Laboratory, Pasadena, California

Power consumption during all phases of spacecraft flight is of great interest to the aerospace community. As a result, significant analysis effort is exerted by both system and electrical-domain engineers to understand the rates of electrical energy generation and consumption under many operational scenarios of the system. Previously, no standard tool existed for creating and maintaining a Power Equipment List (PEL) of spacecraft components that consume power, and no standard tool existed for generating power load profiles based on this PEL information during mission design phases. Projects have traditionally either developed ad-hoc spreadsheet-based tools, or adapted complex simulation tools to compute such resource predictions; both of these approaches have significant limitations.

The Scenario Power Load Analysis Tool (SPLAT) is a model-based systems engineering tool (a plug-in for the MagicDraw modeling tool) that aids in creating and maintaining a PEL, and generates a constraint set in Maple language syntax that can be solved in Maple to show electric power load profiles (i.e. power consumption from loads over time). SPLAT creates these load profiles from three modeled inputs: 1) a list of system components and their respective power modes, 2) a decomposition hierarchy of the system into these components, and 3) the specification of at least one scenario, which consists of temporal constraints on component power modes (indicating how the power states of the individual components change over time). Once these modeled inputs have been read into the SPLAT tool, it combines them to produce a Timeline representation of the power load constraints, which is stored as OWL2 ontology individuals in an RDFXML file and then transformed into Maple language syntax.

The constraints are solved within Maple, which is a symbolic solver, and load profiles can be generated for any level of aggregation specified in the decomposition hierarchy. SPLAT supports parameterizing both power load values as well as scenario time durations, which allows users to quickly assess impacts of different parameter values in Maple without the need to re-execute SPLAT. Due to the flexibility of modeling components in SPLAT and its ability to incorporate parameterized variables, the tool is useful for both low-fidelity models (e.g. as used in the formulation phase) as well as high-fidelity models (e.g. as used in mission operations). Additionally, while SPLAT is specialized for the power domain, the transformation from scenario constraints to Maple code is generic enough to be used for any time-dependent domain, such as data generation rates.

SPLAT improves upon the existing spreadsheet-based power loads analysis approach by maintaining a single source of truth (the system model) that can be easily maintained. This approach has several additional benefits, such as reducing human-induced errors (e.g. copy-paste or math errors) because transformations are scripted, improving end-product quality as scripts perform error checking, and increasing productivity because automated scripts allow analysis results to be generated/updated in the background without much human intervention (less time to obtain a higher-quality product).

This work was done by Justin D. Kaderka, Michel D. Ingham, Matthew L. Rozek, and Seung H. Chung of Caltech, and Kenneth Donahue for NASA's Jet Propulsion Laboratory. ***For more information, contact iaoffice@jpl.nasa.gov.***

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-49814.

Wideband, GaN MMIC, Distributed Amplifier-Based Microwave Power Module

The solid-state module operates as a radar, communication, or navigation system.

John H. Glenn Research Center, Cleveland, Ohio

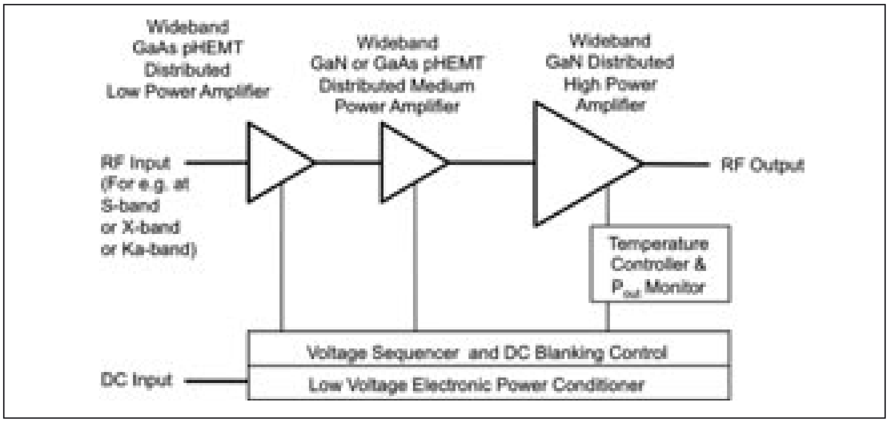
Historically, the term microwave power module (MPM) has been associated with a small, fully integrated, self-contained radio frequency (RF) amplifier that combines both solid-state and microwave vacuum electronics technologies. Typically, the output power of these MPMs is on the order of about 100 Watts CW over an octave bandwidth. The MPMs require both a solid-state amplifier at the front end and a microwave vacuum electronics amplifier at the back end. However, such MPMs cannot be utilized for communications because the MPMs are not optimized for linearity or efficiency. Also, the MPMs can be very expensive to manufacture, particularly when modules are produced in very small quantities for space applications. Also, a kilovolt (kV) class power supply is required to power the traveling-wave tube amplifier, which is a part of the microwave vacuum electronics.

The innovation presented here is a wideband, high-power, high-efficiency, solid-state microwave power module (SSMPM) or amplifier for a multifunction spacecraft payload that operates, depending on the need, as a radar system, communication system, or a navigation system. The construction of the module is based on a wideband multistage amplifier design. The low-power stage is a high-efficiency GaAs pHEMT-based MMIC distributed amplifier. The medium-power stage is either a high-efficiency GaAs pHEMT or GaN HEMT-based MMIC distributed amplifier. The high-power stage is a high-efficiency GaN HEMT-based MMIC distributed amplifier.

The gate and drain voltages and currents for the amplifier stages are provided by an electronic power conditioner (EPC). The EPC is a DC-to-DC power converter that transforms the spacecraft bus voltage into appropriate voltages required by the amplifier stages. In addition, a DC power management circuit is included to manage the correct power-up and power-down sequence to ensure that the negative gate voltage is applied before the amplifier is turned on. A DC blanking control is also provided to quickly turn the amplifier off if a fault condition arises. Moreover, an RF output monitor such as a temperature sensor or a detector/reference diode pair is located near or on the high-power GaN die, in the output stage, to monitor an over-temperature condition. The detector/reference diode pair also monitors the RF output power level. The packaged unit is conduction cooled. The mode of operation involves amplifying the incoming signal in the pre-amplifier stage, and boosting the power to a level sufficient to drive the medium-power amplifier across its dynamic range. Likewise, the output of the medium-power amplifier then drives the high-power amplifier across its dynamic range. The dynamic range is the difference between 1dB compression point (P=1dB) and the minimum detectable output power (P_{out} min).

The module can also be constructed with three or more narrow-band GaAs pHEMT low-power MMIC amplifiers that cover different frequency bands designated for radar, communications, and navigation at the input. A wideband SP3T PIN diode then switches each amplifier in and out of the circuit as required. The advantage of this circuit is that the noise figure of the low-power stage can be optimized for a particular function. As an alternate, the switch can be replaced by a bandpass filter. The bandpass filters prevent any cross talk among the three signal paths. The advantage of this approach is that it eliminates the PIN diodes and the switch control circuitry.

Typically, the navigation and radar functions are performed at S-band and X-band frequencies, respectively. However, for communications, a K-band



Schematic of a fully solid-state microwave power module with cascaded MMIC distributed amplifier stages having decade bandwidth.

or a Ka-band narrow-band, high-linearity, GaAs pHEMT, medium-power MMIC amplifier is employed, which directly drives the high-power GaN MMIC distributed amplifier. The two bandpass filter circuits at the input to the high-power amplifier ensure that the cross talk between the two signal paths is minimal.

This work was done by Rainee N. Simons and Edwin G. Wintucky of Glenn Research Center. ***NASA invites and encourages companies to inquire about partnering opportunities. Contact NASA Glenn Research Center's Technology Transfer Program at ttp@grc.nasa.gov or visit us on the Web at https://technology.grc.nasa.gov/. Please reference LEW-18717-2.***

Integrated Solar Array Power Management System

Marshall Space Flight Center, Alabama

When solar cells are electrically connected to form solar arrays, they are organized into strings. Each string represents a specific number of cells connected in series to produce a specific voltage. The strings are then connected in parallel to add their currents to meet the array power requirement. This requires that the strings have the same voltage. Blocking diodes are used to take out strings with voltage that is too low, resulting in loss of power. When the arrays are mounted to a non-coplanar surface such as a spacecraft body or inflatable structure, many strings will have voltages lower than the rated voltage. This regulator manages the voltage of each string individually so that its power may be used, regardless of its voltage. It does this by converting each string's energy into a series of high-voltage pulses that charges a reservoir capacitor to one of a set of common voltages used by the spacecraft bus. This allows for use of all of the illuminated strings in producing well-regulated power at pre-programmed voltages.

The two methods previously used are the use of blocking diodes to simply "disconnect" strings that are not producing the required voltage, and a DC-DC converter that converts each coplanar surface to a common voltage. Then the power for each surface is connected in parallel.

A power management system for deployable or body-mounted solar arrays integrates the following functions into a single package:

1) Array shunt regulation capable of combining solar cell strings of varying illumination and voltage.

2) Real-time programmable voltage conversion and regulation for two different power busses. Voltage of each bus may be set remotely at any time.

3) Battery charge control. This too may be controlled remotely and modified for specific flight operations.

Each string is individually connected to the power management circuit so that it charges a capacitor when illuminated. As the capacitor is charged, it stores the energy produced by the string, and as it does, its voltage increases to the voltage of the string charging it. The circuit samples each capacitor in turn, and converts the energy stored in it to a high-voltage pulse using an inductor. The pulse is then transmitted to a collection circuit. After it samples all of the strings, it returns to the first string and begins another cycle. Thus each capacitor for each string is sampled and converted on each cycle. The cycle time is always the same, and is a fraction of a second. The capacitor for each string is sized to be able to hold all of the energy produced by the string in a single cycle time.

As the pulses arrive at the collection circuit, they are used to charge one of several reservoir capacitors. There is a reservoir capacitor for each bus voltage specified for the spacecraft: one for the battery charge circuit, and another that is connected to a shunt resistor that dissipates its energy into space as heat. The collection circuit routes pulses to each capacitor, charging it up to its required voltage by varying the width of the charge pulses. When all reservoir capacitors are charged to required voltage, the pulses are sent to the shunt to be dissipated.

This work was done by Leo Fabisinski of International Space Systems Inc. for Marshall Space Flight Center. ***For more information, contact Ronald C. Darty, Licensing Executive in the MSFC Technology Transfer Office, at Ronald.C.Darty@nasa.gov. Refer to MFS-33316-1.***

High-Energy-Density Solid-State Li-Ion Battery with Enhanced Safety

John H. Glenn Research Center, Cleveland, Ohio

High-energy-density and safe rechargeable batteries are required for NASA's future exploration missions. Lithium-ion (Li-ion) batteries are attractive energy storage systems due to their relatively high energy and power densities. However, the unfavorable side reactions between the electrodes and the liquid electrolyte adversely impact performance. These interfacial reactions are in the form of either anodic oxidation of the electrolyte, or dissolution of the cathode into the electrolyte. As a result, the practical capacity and cycle life of the battery are limited. More importantly, the reactions at the cathode-electrolyte interface pose a serious threat to safety due to the electrolyte decomposition and formation of gaseous products within the cell. In addition, growth of lithium dendrite on the anode can cause cell short circuit and lead to fire or even explosion in the presence of liquid electrolyte.

A new method was developed to process sulfide-based solid electrolyte powders so they can be cast in the form of a thin and flexible tape. This represents a major step toward transitioning solid-state electrolyte materials to a viable commercial product, and implementing a rechargeable, all-solid-state lithium-ion battery. It was demonstrated that the solid-state electrolyte dispersion can be cast in single and bi-layer tapes on a current collector. Cells using the cast solid electrolyte tape and cathode were assembled and activated with lithium metal as anode. It was demonstrated that the cell can be reversibly cycled with the newly developed solid electrolyte architecture. Additionally, the sulfide-based solid electrolyte has a relatively wide electrochemical stability window (nearly 6.0 V) and is stable against lithium anode. A wide electrochemical stability window in the solid electrolyte assists the cycling stability of the battery.

Non-NASA applications for the innovation include automotive applications such as Li-ion battery packs in hybrid electric vehicles and electric vehicles; consumer electronics such as laptops, mobile phones, cameras, camcorders, and power tools; medical devices; electric bikes/scooters; and military applications such as air, ground, emergency, and pulse power applications.

This work was done by Nader Hagh, Mohit Jain, Runqing Ou, Ganesh Skandan, and Swapnil Mhatre of NEI Corporation for Glenn Research Center. ***NASA invites and encourages companies to inquire about partnering opportunities. Contact NASA Glenn Research Center's Technology Transfer Program at ttp@grc.nasa.gov or visit us on the Web at https://technology.grc.nasa.gov/. Please reference LEW-19252-1.***

An On-Demand Gas Generator for CubeSat or Low-Mass Propulsion Systems

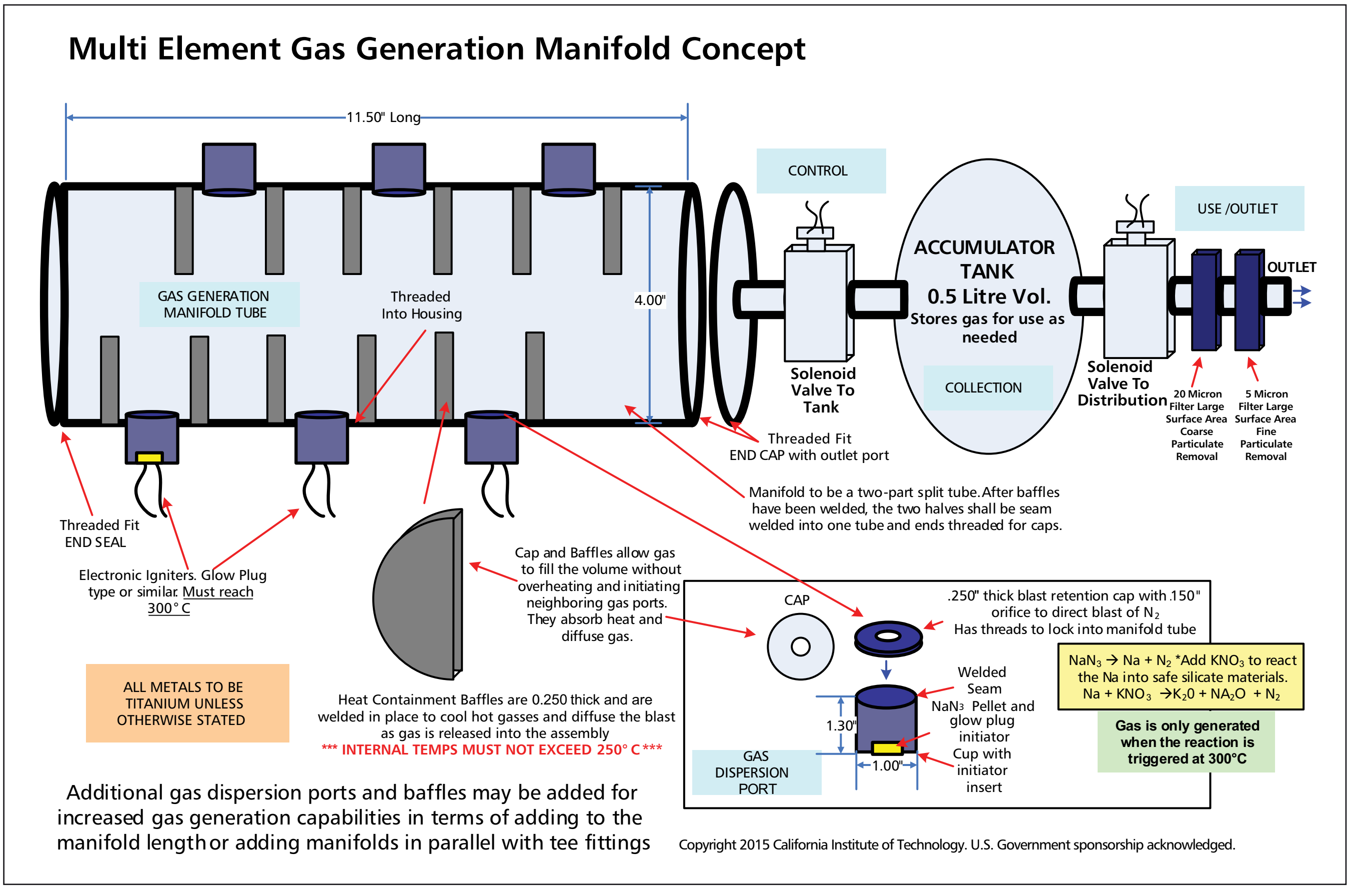
This system is applicable to aerospace, automotive, ocean/marine, or limited-resource environments.

NASA's Jet Propulsion Laboratory, Pasadena, California

There are difficulties related to storing enough gas to propel a CubeSat within an onboard tank. Currently, a CubeSat requiring a large volume of gas for extended propulsion (outside Earth orbit) would need to store liquefied gases that require heavy-bodied tanks that add significant weight to the spacecraft. Safe storage of gases is difficult and not suited well to the CubeSat platform.

Modern automotive airbags use simple chemical gas generators (sodium azide or MNP352) to provide massive volumes of nitrogen gas in an instant, for the purpose of inflating large airbags for cushioning or mass deceleration. The device charges are small and can be placed into small tanks. When triggered, large volumes of nitrogen will immediately be released. Treatment of the chemicals to create safe byproducts is easily accomplished with the addition of a simple salt. If massive volumes of gas can be generated from a diminutive compact solid at will, then it would follow that by combining several of these into a larger tank assembly and initiating them when needed, multiple sources of gas could be provided when desired. A large, heavy tank of compressed liquid gas designed to withstand thousands of psi can be effectively replaced with a smaller tank with multiple generator sources in which each actuation would yield a rise of only a few hundred psi. Because many of these can be combined in one collection, "refills" of this tank could be provided within the considered trajectory.

Solid generator pellets would be placed into miniature cylinders (charges) capable of safely containing the reaction. These miniature cylinders would be installed into a multiple-port manifold tank through threaded ports in the collection tank. To avoid overheating and initiation of neighboring ports, a series of baffles and focus orifices would be employed to reduce the temperature of the discharge. Each time an electronically controlled charge is initiated, the resulting gas will fill the cylinder. An electronic solenoid valve will allow the gas to fill a sec-



The multi-element gas generation manifold concept.

ondary accumulator cylinder that would hold gas, cool it, and serve as a main gaseous nitrogen tank reserve. Gas would be removed from that tank for use through a solenoid valve-controlled outport, and any resultant particulate would be removed through a series of filters. Clean gas would flow out for use in the spacecraft's cold gas propulsion system. When the accumulator tank runs low, the next charge will be initiated, and a new source of gas will be supplied ready to be moved to the accumulator tank. This repeats until all charges are used. Potentially, the number of charges available is only limited by the spacecraft's size and calculated safety margin in the unlikely event all charges execute at once.

This work was done by Thomas Reynoso of Caltech for NASA's Jet Propulsion Laboratory. ***For more information, contact iaoffice@jpl.gov. Refer to NPO-49689.***

Suppression of Unwanted Noise and Howl in a Test Configuration Where Jet Exhaust is Discharged Into a Duct

This method is permanent to a test facility, and does not need to be changed from test to test.

John H. Glenn Research Center, Cleveland, Ohio

This technology is based on a model-scale experiment simulating a test facility where an engine exhaust is discharged into a duct. Such a configuration sometimes encounters unwanted noise in the form of high-amplitude spectral levels in certain frequency ranges or, in worst cases, a howl that can raise structural concern. The innovation involves placement of a velocity fluctuation damper at the end of the duct. Such a damper is shown to suppress not only the broadband unwanted noise, but also the howl when it occurs. Even though placing the damper on the upstream end of the duct works, the preferred location is the downstream end.

Previously, to alleviate the unwanted noise, various methods were used, such as water injection, "dragon teeth" (tabs), or a rod inserted perpendicular to the flow. These methods are ineffective, especially when the unwanted noise is simply due to the duct modes excited by broadband flow disturbances, manifested as broad peaks in the noise spectrum.

In the flow configuration, the jet discharges into the duct placed at a standoff distance, *s*. The duct can be of various cross-sectional shapes or it can be a diffuser. In Figure 1, the duct is a 1-in. (≈2.5-cm) diameter by 2-in. (≈5.1-cm) long cylindrical pipe placed in the path of a 0.58-in. (≈1.5-cm) diameter circular jet. The damper device is a 70-mesh screen with four ¼-in. (≈0.6-cm) diameter holes provided to alleviate flow blockage. In practice, the jet may be non-circular and the duct may be of other cross-sectional shapes. The duct may be connected to other duct sections and diffusers. The damper can be a screen covering the entire cross-section, but when alleviation of flow blockage is desired, open passages may be placed on the periphery near the duct wall. The damper could also be a simple obstruction in the form of a center body.

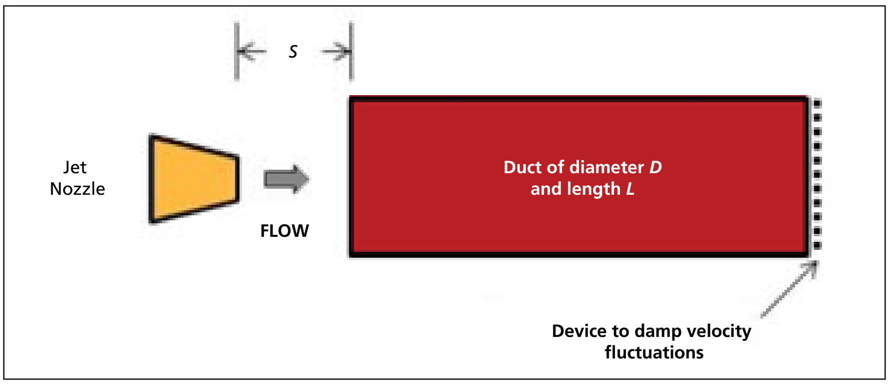


Figure 1. The duct is a 1 × 2 in. cylindrical pipe placed in the path of a 0.58-in. diameter circular jet.

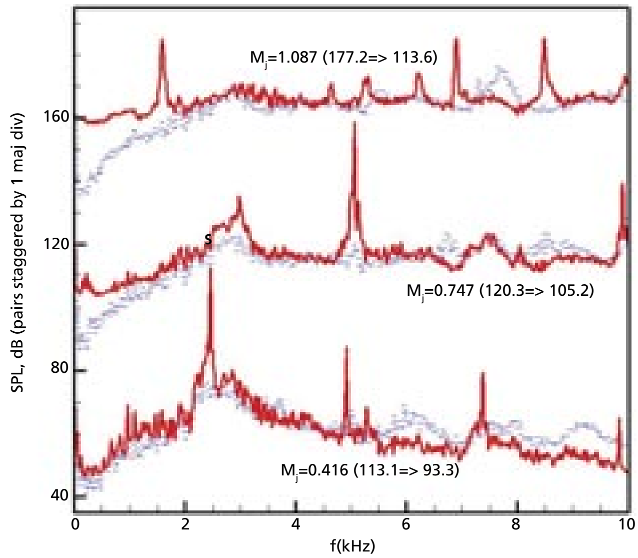


Figure 2. The noise suppression effect by the damper. Three pairs of sound pressure level spectra are shown for jet Mach numbers of 0.416, 0.747, and 1.087. In each pair, one spectrum (solid line) is without the damper when there is a loud tone represented by sharp spike(s) in the spectrum; the other spectrum (dashed line) is for the case with damper when the tone is eliminated by the damper.

Figure 2 shows the noise suppression effect by the damper. Three pairs of sound pressure level spectra are shown for jet Mach numbers of 0.416, 0.747, and 1.087. In each pair, one spectrum (solid line) is without the damper when there is a loud tone represented by sharp spike(s) in the spectrum; the other spectrum (dashed line) is for the case with damper when the tone is eliminated by the damper.

In the simplified model-scale geometry at low Mach number, the tone is generated due to a coupling of the jet "preferred mode" and the half-wave acoustic resonant frequencies of the duct. The damper location corresponds to the acoustic velocity anti-node (where the acoustic velocity fluctuation magnitude is the largest). By dampening the velocity fluctuation, the resonance condition is weakened, resulting in the noise suppression. At higher jet Mach numbers, the duct modes can be more complex, but the damper is still quite effective.

Figure 2 represents a case when there is a coupling, as described above, yielding a sharp tone (this corresponds to a howl in larger practical configuration). Often, the unwanted noise appears as a broad peak at the duct resonant frequencies when the dimensions of the jet and the duct are disparate and there is no coupling. The damper is found to be effective in suppressing such broad peaks that remain unaffected by other previously known suppression methods. The damper also works quite well when placed at the upstream end of the duct. This could be a suitable location in practice due to easy access. However, there is some penalty at high frequencies due to impingement of the high-velocity jet on the damper.

This work was done by Khairul Zaman, Michelle Clem, and Amy Fagan of Glenn Research Center. ***NASA invites and encourages companies to inquire about partnering opportunities. Contact NASA Glenn Research Center's Technology Transfer Program at ttp@grc.nasa.gov or visit us on the Web at https://technology.grc.nasa.gov/. Please reference LEW-18890-1.***

Intro Cov ToC

Distributed, Fast, Intelligent Infrastructure Health Monitoring System

Improve operation and reduce maintenance costs with intelligent systems.

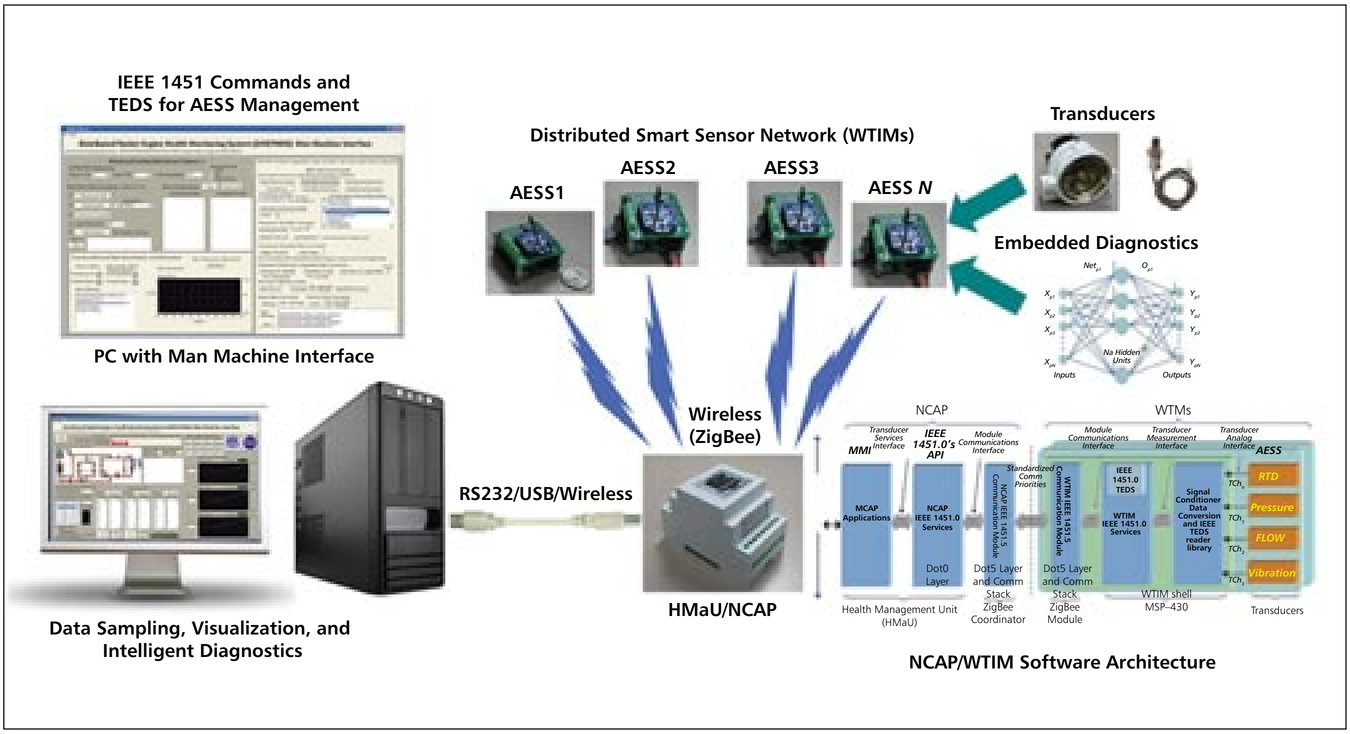
Stennis Space Center, Mississippi

NASA needed an innovative solution to conduct system assessments of frameworks and to characterize subsystems of interest. This tool would be required to determine anomalies; examine their causes (root-cause analysis); make predictive statements (prognostics); provide intelligent health monitoring with incremental knowledge for working with unknown scenarios; and provide maintenance support for a complex collection of systems, subsystems, and elements in rocket engine test platforms.

To meet this need, the Distributed Rocket Engine Testing Health Monitoring System (DiRETHMS) technology and software toolsets were developed. DiRETHMS enables real-time, online health monitoring and failure detection. It comprises a distributed, modular, scalar, and flexible architecture with efficient and embedded processing at multiple levels (sensor, subsystem, and system) to provide health monitoring.

The foundation of the architecture is a network of Advanced Embedded Smart Sensors (AESS/WTIM) and Health Management Units acting as Network Capable Application Processors (HMaU/NCAP) to provide distributed intelligence. The DiRETHMS architecture enables embedded health monitoring functions (e.g., self-identification, self-diagnostics, and self-calibration), and because a distributed scheme with standardized communication methods is provided, DiRETHMS is also able to satisfy the computational requirements by providing an integrated awareness of the condition of every element of interest. The goal in creating DiRETHMS was to provide innovative, reliable, fully embedded, and intelligent algorithms with an artificial-intelligence-based diagnostic framework, smart sensors (both hardware and software with embedded intelligent functions such as self-healing), IEEE 1451 methods [commands and Transducer Electronic Data Sheets (TEDS)], and a wireless communication framework for health monitoring within a highly distributed system that supports intelligent functions in sensors and system modules with the ability to learn new failures and conditions. While the innovation's focus is being able to provide a set of novel technologies and software toolsets, it also is capable of being customizable for complex systems, such as reusable liquid rocket engines.

This technology has a wide range of uses for NASA, including space transportation



DiRETHMS comprises a distributed, modular, scalar, and flexible architecture with efficient and embedded processing at multiple levels (sensor, subsystem, and system) for providing health monitoring. The foundation of the architecture is a network of Advanced Embedded Smart Sensors (AESS/WTIM) and Health Management Units acting as Network Capable Application Processors (HMaU/NCAP) to provide distributed intelligence.

propulsion systems; performing rocket engine ground testing; and health monitoring of other space, lunar, or planetary vehicles/systems. It could also be customized for a wide range of machinery application areas, including the aerospace industry (aircraft engines and turbo-jets), on-ground maintenance, manufacturing, and other applications requiring smart sensors with embedded health monitoring. The tool's capabilities could also be used for upgrading current (already deployed) assets (e.g. diagnostic systems' software and sensors). Other potential applications include: (1) embedded autonomous learning and self-expanding pattern recognition (such as for computer vision, hyperspectral imagery analysis, incremental knowledge for health monitoring, etc.); (2) health monitoring of turbines and rotating machinery; (3) intelligent data-acquisition systems for machinery health monitoring; (4) fluid and hydraulic systems (such as cooling systems); (5) motors; (6) pumps; and (7) health monitoring of vehicles and autonomous systems.

Overall, DiRETHMS provides a distributed system with embedded health monitoring functions with the potential to significantly improve the capabilities for rocket engine testing and maintenance operations while reducing costs, and also has the potential opportunity for use in the commercial sector for numerous other monitoring applications.

This work was done by American GNC Corp. for Stennis Space Center. ***For more information, contact Tasso Politopoulos or Stephen Oonk at (805) 582-0582, soonk@americangnc.com, or 888 Easy St., Simi Valley, CA 93065. Refer to SSC-00391.***

Net Radiation and Evapotranspiration (Rn/ET) Download Product Tools and Interfaces

NASA's Jet Propulsion Laboratory, Pasadena, California

This toolset automates downloads of global, multi-year Moderate Resolution Imaging Spectroradiometer (MODIS) and related data necessary for performing net radiation and evapotranspiration (Rn/ET) modeling, and provides an application programming interface (API) for simple and reliable access of these data from Python or MATLAB applications. Several useful utilities for validating and curating/indexing the downloaded data are also included.

The MODIS and National Centers for Environmental Prediction (NCEP) datasets used by Rn/ET have been sourced from several providers, including the U.S. Geological Survey (USGS), Lawrence Berkeley Lab (LBL), and the National Oceanic and Atmospheric Administration's Earth System Research Laboratory (ESRL).

Given the number of data providers, data sizes, formats, and ranges, the software provides necessary functionality in three key areas: data acquisition, data validation, and data access. The process of downloading full, multi-year collections of MODIS and NCEP data often takes days or weeks at a time, and is complicated by the high probability of a server or data connection failure at some point during the process. It is essential, then, that the procedures be highly automatic and that, should a failure (invariably) occur, restarts be made as straightforward and complete as possible.

Even after a successful download, it is highly likely that some files will have been truncated or skipped altogether. If not detected in advance, such data gaps can lead to runtime application failure or implausible analysis results. Automatic validation of the downloaded data is essential and, in the case of the software described here, is based on log file scans for typical signatures of success or failure, and checksum tests for file completeness.

Once the downloaded data are complete and validated, data access at the application program level is generally still complicated by the non-uniform file and directory organization schemas adopted by the various providers. Rather than attempting to enforce consistency by renaming files and directories (thus introducing a host of other data curation and administrative issues), the toolset described here implements a simple Python-based indexing layer and functional interface that, together, enable uniform access to the underlying directories and geospatial data files.

This work was done by Joshua B. Fisher, Gregory J. Moore, and Manish K. Verma of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-49731.

Software Tools for Fault Management Technologies

Marshall Space Flight Center, Alabama

Several key areas of improvement in effect design, development, verification, and validation of fault management processes have been identified in NASA's Fault Management Handbook. The majority of these guidelines are focused on making the modeling tools more user friendly and reducing the modeling cost and time, as well as enhancing the analytic capabilities.

The ability to detect, diagnose, and respond to faults and anomalies in a timely and cost-effective fashion is a major concern in space missions. Several of the recent mission programs have encountered major cost overruns and schedule slips during test and verification of fault management objectives. These cost and time overruns could be attributed to lack of transparency and lack of availability of a collaborative platform for information sharing early on in the development cycle.

The overall target of this project is towards better utilization of TEAMS® (Testability Engineering and Maintenance System) in NASA's Fault Management (FM) initiative through enhancement of its capabilities. It specifically addresses the key requirement of reducing the cost and time of diagnostic model development, maintenance, and analyses. Key focus is on efficient library implementation of modeling constructs, automation, and enhancement of analyses.

The major emphasis of this project is to reduce the cost and time required for TEAMS Model Development, primarily focusing on introducing capabilities for reuse of modeling elements for productivity improvements. It also will enhance analytic capabilities by introducing a Batch Analysis capability along with options for interfacing with applications to manipulate and export the information/results/reports for post-analysis, evaluation, and model validation purposes. Finally, it will improve the Failure Modes, Effects, and Criticality Analysis (FMECA) Process by introducing capabilities in TEAMS Designer for ensuring consistency and coverage of FMECA-related aspects of a design. Integration of missions and phases with all relevant analysis will be a major element in this task.

Because capabilities planned to be introduced through this effort enhance both design-phase and post-design-phase fault management-related utility of TEAMS, utilization in a range of space missions and applications is anticipated. In addition to NASA applications, the capabilities will make TEAMS a worthy candidate for providing decision support for fault management diagnostics and operations for systems on military aircraft, surface ships, submarines, and even modern ground-fighting vehicles. Additionally, nascent commercial space systems, civilian aircraft and maritime systems, transportation, power generation, and distribution equipment are potential areas for commercial application.

This work was done by Sudipto Ghoshal and Deepak Haste of Qualtech Systems for Marshall Space Flight Center. ***For more information, contact Ronald C. Darty, Licensing Executive in the MSFC Technology Transfer Office, at Ronald.C.Darty@nasa.gov. Refer to MFS-33304-1.***

Tool to Analyze a Leaking Source of Saturated Ammonia

Lyndon B. Johnson Space Center, Houston, Texas

Containers of ammonia are used to supply cooling to different modules of the International Space Station. Each container has an attachment piece used to extract the ammonia. The attachment piece may allow ammonia to exit when not connected, and may also allow ammonia to exit to an outside area even when connected. The ammonia that has exited the container may accumulate in different compartments of the spacecraft. The ammonia is not desirable when accumulated in a compartment with a certain concentration.

This invention is a process to analyze the gaseous ammonia leakage from a source of saturated (2-state: liquid and gas) ammonia. The process creates an ammonia tank model and combines the use of a proprietary multiple-compartment venting program (VENTCON) with the commercial fluid dynamics program SINDA/FLUINT to estimate the amount of gaseous ammonia leaked out of the tank as a function of time.

A data processor unit identifies a rate of the gas leaking from a container in a first compartment by a selected time based on the rate of the gas leakage and total time. The system comprises a bus system, a storage device connected to the bus system, and a processing unit connected to the bus system. The storage device includes a set of instructions. The processor executes the set of instructions to identify a rate of the gas leaking from a container in a first compartment. The processor unit then identifies an amount of gas in a number of compartments associated with the first compartment. The unit determines whether the amount of gas is outside a desired amount.

This work was done by William D. Ward of The Boeing Company for Johnson Space Center. ***For further information, contact the JSC Technology Transfer Office at (281) 483-3809. MSC-24990-1***

Mixed-Integer Convex Programming Algorithm for Constrained Attitude Guidance

NASA's Jet Propulsion Laboratory, Pasadena, California

A general problem in spaceflight since its beginning is attitude guidance: how to turn a spacecraft — also called a slew — so as to point science instruments at their targets. The slew must be done while avoiding pointing sensitive science instruments (e.g., a camera) and attitude sensors (e.g., a star tracker) at bright objects in the sky (e.g., the Sun or the Moon).

To formalize pointing constraints, the spacecraft instruments and sensors — referred to collectively as sensors — are specified as direction vectors in a spacecraft body frame. The bright objects are specified as direction vectors in an inertial frame. Each sensor also has a field of view that bright objects must not enter. Hence, the pointing constraints consist of a list of body vectors with each body vector having an associated and independent list of pairs of inertial vectors and "keep-out" angles. For example, the star tracker cannot be pointed within 30° of the Sun nor within 15° of the Moon. These types of constraints are called hard pointing constraints.

The constrained attitude guidance (CAG) problem considered is to find a spacecraft attitude history that points a specified body vector in a specified inertial direction in a given time while not exceeding spacecraft acceleration and velocity limits, and while satisfying all hard pointing constraints. The CAG is solved by formulating it as a mixed-integer convex optimization (MICO). Then standard tools for MICO problems can be used when computing on the ground.

Hence, the significant contribution in this report is the formulation. The formulation includes all the required constraints, handling an arbitrary number of hard pointing constraints, and can be extended to include soft constraints at the cost of drastically increased computation time. The formulation is conservative, with a design parameter that allows the conservatism to be reduced at the cost of computation time. Finally, for a given slew time, the minimum-energy slew is found, in that the sum of the acceleration is minimized in the formulation. While nominally a minimum-energy solution, an approximate minimum time slew can be found with this new formulation by reducing the specified slew time and repeating the optimization until the MICO solver fails to find a solution.

The significant advantage of the MICO formulation is that it is global: it finds a best slew. And even though solving a MICO problem can be time-consuming, slew sequences for flybys of celestial bodies are planned well in advance to maximize science return. With MICO-based CAG, slews will be optimal and more science should be achieved from each flyby.

This work was done by Utku Eren and Behcet Acikmese of the University of Texas at Austin, and Daniel P. Scharf of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-49685.

A Robust, Real-Time Collaboration Technology for Decision Support using Common Operating Picture (COP) Environments

This software provides remote geobrowser control for collaborative decision-making.

Stennis Space Center, Mississippi

StormCenter Communications, Inc. software takes advantage of cloud computing solutions to solve the growing need for real-time collaboration when accessing a Common Operating Picture (COP) from any device without having to give up all the vital tools and display functionality; all this is performed without disrupting current workflows. A COP is a platform shared by multiple stakeholders to provide a single, identical display of relevant operational information (i.e., mapping information, network operations and cyber security, sensors, weather, critical infrastructure) and tools to mark and manipulate the data. In the era of Big Data and the need for improved decision-making with the presence of multiple stakeholders across different disciplines, collaboration when using a COP is essential to success. This is especially important when dealing with decision-makers who are frequently non-data experts who need to take action immediately based on their situational awareness.

Workflows with high levels of information sharing require a robust, collaborative technology to improve decision-making. In the past, data sharing efforts were often referred to as collaborative in nature, even though there was no actual collaboration occurring; it was simply data updating and sharing for individual user display. Other technologies based on remote desktop control allowed for collaboration of two users on one user desktop, but in actuality, the end result was only one desktop displaying the relevant COP information. When the remote control was disengaged, remote users ceased to have control over, and could no longer see, the COP or related information.

StormCenter has designed and developed collaboration interfaces that transmit commands between different COPs over the Internet, and enables a presenter (or LEAD) to take control over all the COPs actively connected to the collaboration. This one-of-a-kind software allows for cross-COP collaboration, regardless of whether the users connect from the same or different COP, devices, platforms, browsers, software, or servers. This is particularly valuable when dealing with special functions or unique capabilities that are required for the increased complexity of intra- or inter-organizational decision-making, and in the presence of multiple stakeholders with multiple disparate

COPs. With the collaborative interface, participants connect to a session from their own COP to see all the functions performed on the presenter's COP. The leadership role can be handed over to any of the participants at any time. Additionally, StormCenter has designed and implemented a common sequence command messaging structure that can be extended to support cross-platform (computer) and cross-client (COP) collaboration. As participants relinquish lead functions, new presenters can add and, therefore, fuse their own datasets without losing the datasets and annotations that had been shared by other participants up to that point during the collaboration. At the end of each collaboration session, all participants have the full set of data shared, as well as annotations created during the collaboration on their personal COP still active on their individual computers. The COP collaboration can be conducted across multiple geobrowser technologies and computer operating system platforms through implementation of the common sequence command messaging structure developed, based on XML.

The collaborative software client can run as a standalone application, or as a server-based Web application. As more and more services migrate to the Web, browsers like Internet Explorer, Firefox, and Chrome have become a "universal client" that allows access to any COP. (Note that even services that are entirely "server-based" may require some kind of minimal software installation on a client device, such as a plug-in for an Internet browser.)

StormCenter's collaborative software, which uses a COP, enables total and true commonality and collaboration across all stakeholders accessing data. This technology empowers multiple users, in multiple locations, using a variety of digital display devices, to simultaneously share, manipulate, and interact with one another and the same sets of data. This simple yet efficient approach to accessing and manipulating data collaboratively becomes critical to delivering the right information to the right people at the right time.

This work was done by Rafael Ameller and David Jones of StormCenter Communications, Inc. for Stennis Space Center. ***For more information, contact Rafael Ameller at 410-203-1316, or 1450 S. Rolling Rd., Baltimore, MD 21227; rafael@stormcenter.com; www.GeoCollaborate.com. Refer to SSC-00441.***

New on the MARKET

Product of the Month

FLIR Systems, Wilsonville, OR, announced the identiFINDER® R200 handheld radiation detector that delivers American National Standards Institute (ANSI) N42.48-compliant identification and weighs less than one pound. The wearable detector provides continuous radiation monitoring without any user interaction. The detector combines FLIR's Silicon Photomultiplier (SiPM) technology with a Cesium Iodide (CsI) detector to provide high-resolution identification so the user can quickly determine whether a gamma radiation source is a true threat or a benign source from medical patients, normal occurring radiation, or industrial use. The detector utilizes Bluetooth® and Web server technologies, and features a OneTouch Reachback™ feature that provides the wearer with large-scale situational awareness, and enables instant notifications to help improve communications with command and control.

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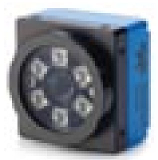
Product Focus: Imaging/Cameras/Displays

Vision Sensors



Teledyne DALSA, Waterloo, ON, Canada, announced BOA™ Spot vision sensors that combine a BOA vision system with integrated LED lighting, lens cover, and software. Available with 640 × 480 or 1280 × 960 image resolution, the sensors can inspect multiple part features at the same time. Embedded vision tools for part locating, feature finding, counting, and measuring applications offer a graphic user interface and can be combined and used numerous times for inspection tasks.

For Free Info Visit http://info.hotims.com/61060-100

SWIR Camera

The 1280SCICAM shortwave infrared camera from Princeton Infrared Technologies, Monmouth Junction, NJ, is a lattice-matched indium gallium arsenide (InGaAs) sensor that features 1280 × 1024 resolution at frame rates greater than 95 frames per second (fps) at full-frame size, and operates in the visible to shortwave infrared spectrum from 0.4 µm to 1.7 µm. A 3-stage thermoelectric cooler is integrated into a vacuum package to provide three temperature setpoints for different conditions.

For Free Info Visit http://info.hotims.com/61060-101

Day/Night Cameras

D-Link, Austin, TX, announced the 5-megapixel day/night IP DCS-6517 dome network camera and the DCS-7517 Bullet network cameras. Supporting 2560 × 1920 resolution and digital WDR image enhancement, the cameras provide real-time video compression using the H.264 and MJPEG codecs, and support three separate profiles for simultaneous video streaming and recording. Both cameras have built-in IR LED illuminators for use in complete darkness.

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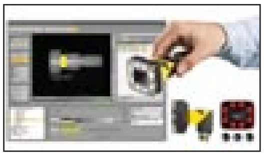
Vision Sensors



Cognex Corp., Natick, MA, introduced the In-Sight® 2000 vision sensors that include an integrated, high-performance image formation system consisting of field-interchangeable lenses and a patent-pending LED ring light that produces diffuse illumination across the entire image, eliminating the need for external lighting. The lens can be swapped out and the color of the integrated ring light changed as needed.

For Free Info Visit http://info.hotims.com/61060-103

Touch Display Kit

Avnet, Phoenix, AZ, released the AES-ALI3-AMPIRE10-G 10-inch Touch Display Kit. The kit demonstrates an embedded display system, allowing for video output to an integrated 10" LVDS display. The kit combines a 1280 × 800 WXGA TFT-LCD display with a PCAP touch sensor overlay, I2C touch controller, LED backlight supply, haptic feedback driver, 3-axis accelerometer, and all necessary cables for connecting to a development board.

For Free Info Visit http://info.hotims.com/61060-104

SWIR Camera

Xenics, Leuven, Belgium, offers the Bobcat-320 SWIR camera, a medium-resolution camera yielding low noise and low dark current. It features a thermo-electric cooler for sensor stabilization, an onboard image processing unit, and windowing and auto-exposure functionality. Other features include standard CameraLink or GigE Vision with Power over Ethernet interfaces, and an InGaAs imager.

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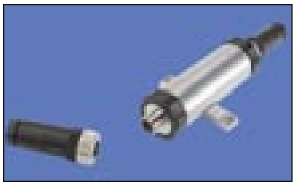
The U.S. Government does not endorse any commercial product or service identified in this section.

In-Line Signal Conditioner



OMEGA Engineering, Stamford, CT, offers the OMEGA® IN-UVI in-line signal conditioner housed in a rugged stainless steel enclosure that is connected between the transducer and a readout instrument. It supplies a regulated bridge excitation voltage for the transducer or load cell, as well as two selectable excitation voltages, wide zero adjustment range, and an isolated shunt calibration relay for field setup. All output options and excitation voltages are field-selectable.

For Free Info Visit http://info.hotims.com/61060-106

Marking System

The battery operated FlyMarker® mini dot peen marking system from Equipment Sales Co., Sioux City, IA, features a strong magnet and powerful battery to produce markings on nearly any material ranging from plastics, to aluminum, to steel. It also marks round parts, with automatic height compensation up to 5 mm. The marking files can be programmed on the unit itself, which includes storage space for several hundred files.

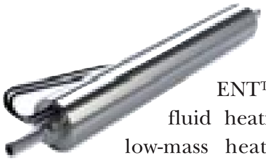
For Free Info Visit http://info.hotims.com/61060-107

Power Supplies

TDK-Lambda Corp., National City, CA, introduced TDK-Lambda DT100D and DT150D adapter power supplies compliant with level VI efficiency standards. Accepting a 90 to 264VAC input, the 100 to 150W adapters are available with 12V to 48V outputs, and can operate in ambient temperatures up to 60 °C. They are housed in a rugged, vent-free enclosure. AC is applied using a standard IEC 60320-C13 cable; DC is provided through a four-pin Power-DIN connector.

For Free Info Visit http://info.hotims.com/61060-108

In-Line Heater



Watlow®, St. Louis, MO, offers FLUENT™, a lightweight in-line heater for use in fluid heating applications. The high-Watt-density, low-mass heater enables on-demand heating, and includes an internal baffle to promote turbulent flow. A layered heater circuit, low-profile axial lead exit, and an internal thermocouple for high limit control also are included. Standard sizes ranging from 250 to 4,000 Watts are available.

For Free Info Visit http://info.hotims.com/61060-109

Locking Connector

MEGA Electronics, New Brunswick, NJ, introduced the IEC C13 locking re-wireable C13 IEC connector designed to guard against accidental disconnection of computers, PDUs, servers, and network devices. The mechanism is combined with a simple release mechanism that allows disconnection from all sides. It requires no other equipment or special inlets to secure it. It can be implemented in areas where access is limited, and ease of removal is important.

For Free Info Visit http://info.hotims.com/61060-110

Signal Analyzers

Keysight Technologies, Santa Rosa, CA, announced X-Series signal analyzers that feature a multi-touch user interface for setting up measurement parameters in no more than two touches. The UXA offers frequency coverage to 44 or 50 GHz, and integrated 1-GHz analysis bandwidth. The PXA offers benchmark phase noise performance of -136 dBc/Hz at 1 GHz, 10 kHz offset, and real-time bandwidth of 510 MHz with spurious-free dynamic range greater than 75 dBc over the full span. The UXA and PXA support real-time data streaming at up to 255 MHz bandwidth with 16-bit resolution at 300 MSa/s.

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Pressure Transmitters

AutomationDirect, Cumming, GA, offers ProSense SPTD25 pressure transmitters that feature an all-stainless-steel thin film sensing element that senses any compatible media. They are resistant to vibration, shock, and EMI/RFI. The transmitters are available with a 1/4-inch NPT male threaded process connection, an M12 quick-disconnect electrical connection, and have a linear 4-20 mA output with sensing ranges from 100 to 5000 psig.

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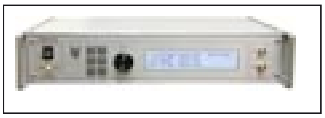
REVERSE RECOVERY TIME TESTERS



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Eddy-10 is a programmable six-step sensorless trapezoidal controller designed for 12-48VDC BLDC motors rated up to 10 AMPS. Programming variables include: motor speed range, pole count, current and torque limits, acceleration and deceleration, and on/off set points. It also includes voltage, current, temperature protection and a status LED for feedback. www.controlresources.com

Control Resources

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FREE DOWNLOAD: TWO TORQUE WHITE PAPERS

Our experts have put together two white papers to help with your torque measurement needs, going over the basics on how to select a torque sensor and taking that one step further with instructions on how to install one. The white papers, available to download, are How to Select a Rotating Torque Sensor and 21 Tips on How to Install a Torque Sensor. www.techbriefs.com/hbm201604

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PhotoMachining, Inc.

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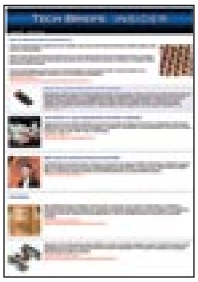

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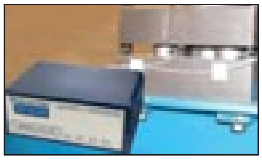
New on the Market

Signal Conditioner

PCB Piezotronics, Depew, NY, offers the Model 482C24 4-channel signal conditioner that includes DC coupling selectable on a per-channel basis. It is suited for use with ICP® force and pressure sensors that have long discharge time constants, allowing temporary measurements down to 0 Hz. An autozero function automatically negates DC bias. A clamped output feature (when AC coupled) provides a positive-only signal that electronically re-zeros each pulse before the next cycle. Features include a front panel keypad and display, and an RS-232 port for computer control.



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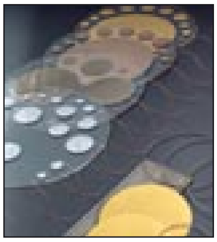
Custom Alloys

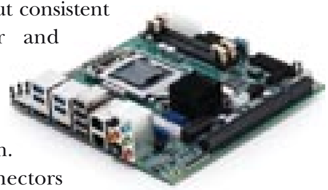
Goodfellow, Coraopolis, PA, offers a custom alloy service. Custom alloys have been produced with gold, silver, palladium, platinum, copper, and/or nickel as major constituents, with other elements sometimes added. Such alloys are usually vacuum-cast and made by combining a number of different master alloys. A limited range of items is available produced through mechanical alloying, a process similar to metal powder processing. Custom alloys are generally available as foil, wire, and sheet.



For Free Info Visit http://info.hotims.com/61060-118

Embedded Board

The AmITX-SL-G Mini-ITX compact embedded computing platform from ADLINK Technology, San Jose, CA, features sixth-generation Intel® Core™ i7/i5/i3 processors and the Mini-ITX form factor. It measures 170 mm square and approximately 35 mm thick, and features a layout consistent for connector and pinout locations. It serves as a base for a scalable system. External connectors include dual GbE ports, four USB 3.0 and four USB 2.0 ports, HD audio I/O, and three display ports.



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Upcoming...

Webinars

Managing Inherent and Environmental Thermal Effects on High-Power Laser Systems

Wednesday, April 13, 2016 at 2:00 pm U.S. EDT

A laser will only perform as designed if it emits the correct amount of power or energy and if the beam size is correct for the intended use. The same is true for high-powered lasers; however, the thermal effects that these lasers have on the system add a level of complexity to the application.

This Webinar will discuss the thermal effects that are common to high-power lasers, how to measure them, how to identify when these thermal effects will be a problem in the process, and how they are being managed

Speaker:

John McCauley
Midwest Region Sales Manager, Photonics (U.S.),
Ophir-Spiricon

This 30-minute Webinar includes:
- Live Q&A session
- Application Demo
- Access to archived event on demand

Please visit www.techbriefs.com/webinar337

Automotive/Industrial Microcontroller Applications Made Easy

Thursday, April 14, 2016 at 9:00 am U.S. EDT

Developing automotive and ultra-reliable industrial applications is expensive, difficult, and time-consuming. It's not…provided you know a few simple tricks. In this Webinar, we will show you how to start your project using the NXP Kinetis EA series microcontroller, along with complementary S32 Design Studio (S32 DS) integrated development environment for ARM-based MCUs.

Speaker:

Kushal Shah
Systems and Applications Engineer,
Automotive Microcontrollers and Processors,
NXP

This 30-minute Webinar includes:
- Live Q&A session
- Application Demo
- Access to archived event on demand

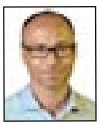
Please visit www.techbriefs.com/webinar338

Identifying the Root Cause of EMC Compliance Problems at a PCB Level

Tuesday, May 3, 2016 at 2:00 pm U.S. EDT

Detection of emissions hot spots using handheld sniffer probes can be effective, but it is slow and does not deliver a full board picture of the problem. The probe array-based Very-Near-Field scanning technique developed by EMSCAN allows real-time evaluation of the spatial distribution of emissions over the entire board. In this Webinar, test results from real-world PCBs and ICs will be shown, along with applications of how the spatial distribution of emissions can be used to solve problems.

Speaker:



Ruska Patton M.Sc.,
Director of Product Management,
Emscan

This 60-minute Webinar includes:
- Live Q&A session
- Application Demo
- Access to archived event on demand

Please visit www.techbriefs.com/webinar340

NASA's Technology Transfer Program

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of laboratories and business support entities. The network includes ten NASA field centers, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. To explore technology transfer, development, and collaboration opportunities with NASA, visit **technology.nasa.gov**.

NASA's Technology Sources

If you need further information about new technologies presented in NASA Tech Briefs, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center

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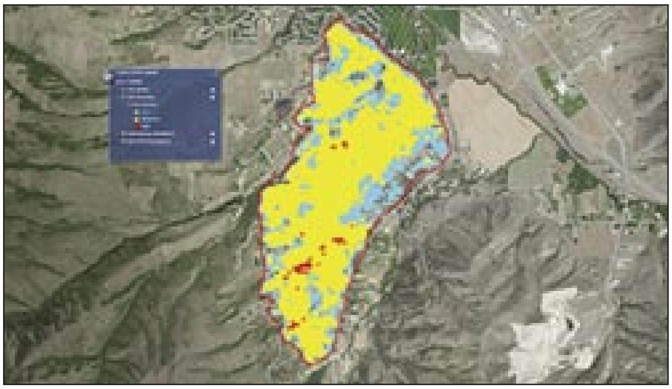
Software Helps Restore Fire-Ravaged Habitats

NASA system uses the cloud to give land managers and wildlife experts a post-fire plan.

The Department of the Interior's Bureau of Land Management (BLM), in addition to coordinating firefighting efforts on federally held lands, is also responsible for the post-fire restoration process that's meant to limit the harmful fallout.

By law, before the BLM can commit to restoration work, it first must submit an Emergency Stabilization and Rehabilitation (ESR) plan that lays out the proposed course of action and the estimated costs. Producing such a document within the mandated 14 days after a fire is extinguished is a tall order.



Using RECOVER, the Idaho BLM can quickly access more than 20 geospatial datasets for a given area that assist with active fire containment and post-fire restoration work. Shown is a RECOVER client Web map for a wildfire that occurred in Idaho in 2012. The colors represent the extent of the fire severity, or loss of organic matter, in different areas.

"We have to survey multiple Web sites for information on soil layers, plant species composition, burn severity mapping, and other data," said Gregory Mann, a fire ecologist with the BLM. "When we're dealing with large fires, it's extremely difficult, and that's not taking into account occasions when we have multiple fires going at the same time."

A wildlife biologist by training and founding director of the Geographic Information Systems (GIS) Training and Research Center (TReC) at Idaho State University, Keith Weber has used various sources, including NASA satellite data, to examine wildfires' impacts on ecosystems, with a particular focus on rangeland habitats. With NASA funding, Weber has also worked with the BLM on a number of pre-fire and long-term post-fire recovery research projects.

Not long after NASA's Applied Sciences Program put out a call for wildfire abatement-related proposals, Weber talked with BLM staff on the sheer amount of information that needed gathering in order to prepare an ESR. They ran the gamut from endangered species habitat and elevation data, to soil composition and vegetation indices.

"I began thinking of geospatial datasets," Weber recalled. "I said to myself, 'a lot of that data could be staged and prepared for them.'" As a result, Weber drew up a proposal for developing a GIS-based software program that quickly pools requested information and presents it through a simple Web-based map interface. He formed a partnership with John Schnase, an ecologist and senior computer scientist at Goddard Space Flight Center who, in addition to his work on climate research and ecosystems, had also worked with Weber on fire-related projects. In turn, Schnase tapped his NASA colleague Mark Carroll, an expert in wildfire ecology and remote sensing technology, to join in on the effort.

Following more than a year of programming and logistical work, they completed the first iteration of NASA's Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER) system. RECOVER utilizes Amazon Web Services' cloud computing technologies to wrangle the requested data from a multitude of sources, whether it be the U.S. Geological Survey's Landsat, NASA's Moderate Resolution Imaging Spectroradiometer datasets, the U.S. Department of Agriculture's soil surveys, or any other publicly available database available on the Web. Once compiled, they are converted into an easily understandable visual interface that's accessible on a standard Web browser.

The system underwent its first field testing during Idaho's exceptionally active wildfire season of 2013. Once a wildfire was contained, the BLM, the Idaho Department of Lands, or the U.S. Forest Service would provide Weber with coordinates for the fire's extent, and Weber and his students would then plug those coordinates into the cloud-based software program, which he said acts "like a cookie cutter, clipping out all of 20 layers for that spatial extent," then stores them in a folder held in the cloud. That data was then sent back to GIS TReC at Idaho State University, where it was assembled into a RECOVER client Web map and delivered to the requesting agency through a URL link. Today, the entire process, from request to map delivery, takes five minutes.

The software's unexpected application in active fire management spurred Weber and his colleagues to develop smartphone and tablet versions of the program that can be accessed by firefighters in the field. The app's latest iteration allows fire crews to map hazards in real time using GPS technology. For example, a firefighter would be able to note the site of a weakened tree that's at risk of toppling. The information is then available on the map interface for all users to see. "Now when their fellow firefighters are in that area, they can look at the Web map on their phones and know to avoid that tree, whereas in the past, they may not have had any idea of the danger," Mann said.

*Visit **http://spinoff.nasa.gov/Spinoff2016/ee_3.html***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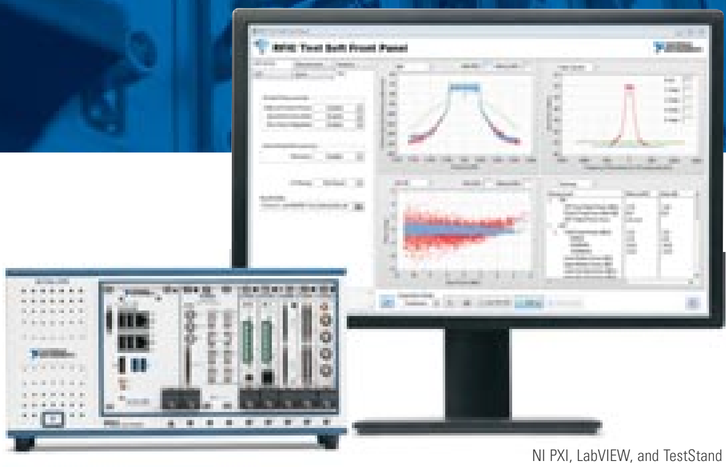


NI PXI, LabVIEW, and TestStand

April 2016

MOTION CONTROL and Automation Technology

On the cover: Today's robots require less programming to accomplish complex tasks. See page IIa.

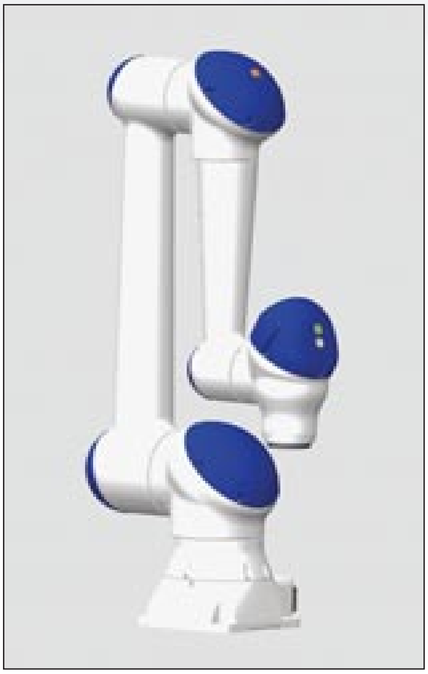
www.techbriefs.com/motion

ROBOTS AND HUMANS— LET THE COLLABORATION BEGIN

A collaborative robot is essentially an industrial robot with additional safety capabilities. These safety features include:

- Safety-rated monitored stop (zero speed limiting)
- Speed and separation monitoring (limiting)
- Hand-guiding
- Power and force limiting (PFL)

The collaborative features listed above are meant to make it easier to interact with or use the robot by allowing for alternate safety solutions to help protect the operator instead of using the time-tested, but restrictive method of hard guarding. An example would be a large palletizing robot system utilizing ESPE (Electro Sensitive Protective Devices), in conjunction with speed and separation monitoring to reduce the robot speed when an operator presence is detected, and to limit the robot range of motion (in lieu of hard guarding around the robot). Another example would be a machine load/unload application where an industrial robot is using the safety-rated monitored stop feature to allow an operator to interact with the robot in the collaborative workspace. The PFL feature allows an operator to work alongside a moving robot with reduced risk of injury in the case of an operator-robot collision. This is done by limiting the power or force transmitted to the operator during either a transient (dynamic) event or in a quasi-static (clamping/crushing) situation.



Yaskawa's HC10 collaborative robot (2017 availability) offers power and force limiting along with a geometry that reduces pinch points.

Major industrial robot brands have supported items one and two of the above capabilities for over a decade. Hand-guiding has also been implemented on industrial robots as an application-level add-on. Power and force limiting have not been supported until recently on industrial robots.

From the customer perspective, a collaborative robot can limit its power and force, thereby limiting the injury it can cause an operator who is working in close proximity to the robot. Additionally, customers perceive these robots to be smaller, slower, lighter, and easier to use (all factors geared toward easy and safe operator interaction). The PFL feature is the one that is actually being used to target new applications that involve the use of robots in unstructured environments driven by flexible plant layouts and frequent human intervention. This intervention may be continuous where a human works alongside the robot, or intermittent where a human may intervene in the robot workspace to recover from errors or take over some tasks, or as a result of operator error.

Human assist is an application area where customers can augment a robot's precision and load-carrying capacity with human judgement. The hand-guiding feature of a collaborative robot will be utilized for such applications. Hand-guiding will also be useful in easy recovery from fault conditions as opposed to what's common today, where a well-trained operator has to jog a robot in three-dimensional space from its faulted position to a safe position using a teach pendant.

Intro Cov ToC

Transforming Manufacturing

In practice, a collaborative robot is only different from a traditional industrial robot because it is power- and force-limiting. For example, these robots are not necessarily any smarter in terms of dealing with unstructured environments or recovering from faults that may occur during complex assembly processes. However, customers do expect collaborative robots to have easy-to-use interfaces that are suited for applications that involve frequent operator interaction, and for a workforce that is not familiar with industrial robots. As such, the intelligent aspects of these robots are mostly in their operator interface, which makes complex robot programming easily accessible to a minimally trained operator. This ease of use allows customers to self-deploy these robots and reprogram them with ease. This reduces overall cost, thereby justifying the return on investment for a low-volume robot user.

Programming Task	Palletizing using industrial robot (a)	Collaborative handling using collaborative robot (b)	Handling using industrial robot (c)
Configuration (tool setup, zones, limits)	5	3	3
Teaching Points	5	3	4
Program Logic	5	2	2
Peripheral Integration (IO, PLC, Fieldbus, laser scanner, safety)	5	2	4
Startup and Shutdown	10	3	3
Error Recovery	10	3	3
Cycle Time Optimization	5	1	1
Risk Assessment and Mitigation	5	10	8
Total Effort	**50**	**27**	**28**

Ranking is from 1 to 10 (1 = least effort, 10 = most effort), and is relative across both columns and rows.

There are still significant safety concerns when robots and humans work side-by-side, and these concerns involve the overall system/solution and not just the robot arm. To date, highly trained engineers who are exploring automation possibilities have been the ones who have mostly deployed collaborative robots. Some of these deployments have involved overall solution-risk assessment. As these robots proliferate, their deployment will move from the first adopters to more process-driven plant personnel. As this happens, the safety standards will increasingly require systematic risk assessment before a solution is deployed.

Using Kinetiq Teaching™, a technician hand-guides the robot arm to a weld point, thereby teaching the robot its job.

Programming Challenges

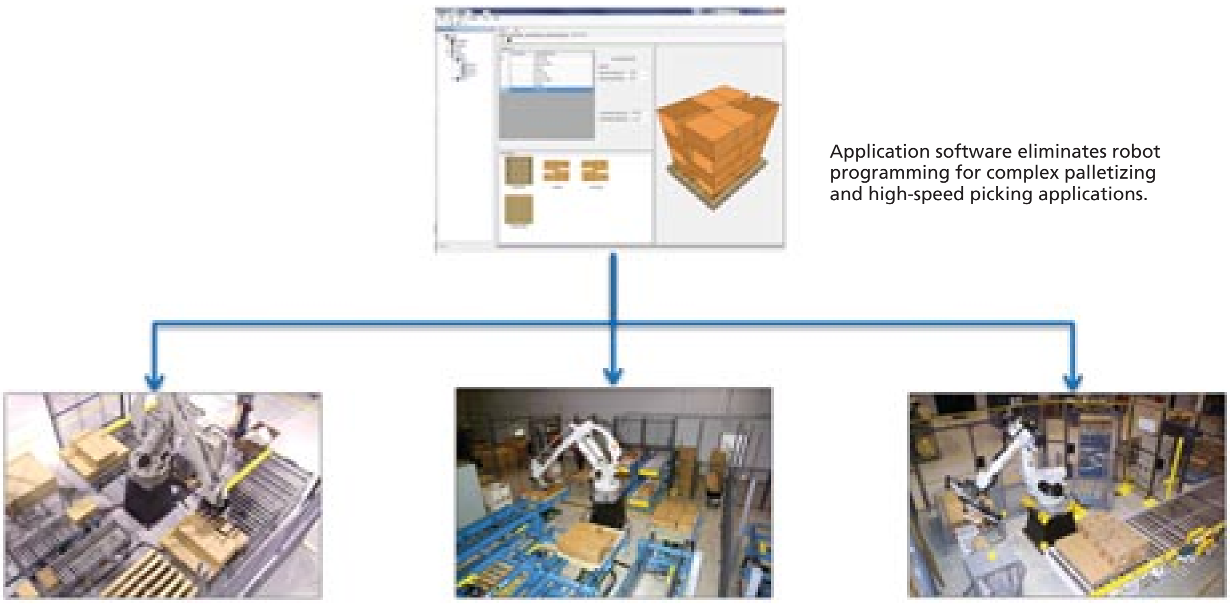
The table on page 1a lists the tasks a typical robot programmer must complete for a given application. This analysis covers three scenarios:

1) A traditional industrial robot deployed in a high-production-rate palletizing application without any palletizing application software.
2) A collaborative robot deployed in an isolated handling application that involves safe human intervention using the PFL capability of the robot.
3) An industrial robot deployed in the same application as 2), though in this case, the ingress into the robot's workspace will be monitored using a laser scanner in order to automatically reduce the robot's speed on operator entry.

Most industrial robot applications involve integration with quite a few peripherals as the robot is part of a larger overall automation process. This leads to difficulty in initial machine building as well as complex startup, shutdown, and error recovery routines. Additionally, industrial robot applications are driven generally by cycle time, and programmers often devote a large portion of their development to optimization. Conversely, most collaborative robot applications are isolated applications that are not driven by cycle time. Teaching points and programming robot logic are considered smaller "pain points" when compared to other tasks. Using an industrial robot in a collaborative application will involve additional sensors (e.g., laser scanner) that detect the presence of a human. The robot can then limit its workspace and speed based on this presence. In the case of a collaborative robot, it can rely on its power and force limitation to mitigate risk of injury to the operator. Also, the hand-guiding supported by the collaborative robot will simplify fault recovery and enable lesser trained operators.

Industrial robots could do the following to reduce the complexity associated with programming: provide application software (such as MotoSight™ for vision); offer guidance to the operator through the startup and shutdown implementation processes; offer an organized way to define error states that can easily be linked to error recovery routines; and support cycle-time optimization by continuously providing cycle-time information and recommending changes to teach points and placement of various objects in the robot cell.

In addition to robot programming, significant time is devoted to the development of the end-effector tool. Although



Application software eliminates robot programming for complex palletizing and high-speed picking applications.

engineers have successfully standardized robot arms for different applications, there is still very little standardization of end-effector tooling.

Supporting Return on Investment

Robot integration costs depend on labor (e.g., programming, design, wiring, risk assessment, testing, tooling, etc.) and peripherals (e.g., tooling, safety guarding, conveyance, IO, PLC, HMI, etc.). Labor cost is reduced by providing customers with easy-to-use software that reduces programming time and eliminates the need for hard-wiring (digital vs. analog). Easy-to-use programming can again be achieved in multiple ways. For example, many (material handling) robots get deployed with PLCs, and the number of PLC programmers is significantly higher than robot programmers. As such, a PLC robot controller that is central to all peripheral integration reduces the number of software environments required to create the solution, eliminates redundant hardware between the robot controller and PLC (such as IO, fieldbus interfaces, etc.), reduces factory acceptance costs, and reduces troubleshooting time and costs.

Another way to achieve ease of use is by creating high-level application software modules that reduce the amount of programming required. These are often used in palletizing applications (to automatically create pallet patterns) or high-speed picking applications (to automatically schedule workpieces across multiple robots). Another often overlooked means of achieving ease of use is the development of user interfaces that are better aligned with current consumer technology and design principles.

Peripheral cost is reduced by adding features to robot arms and their software that eliminate the need for external hardware. For example, collaborative features may reduce the need for hard-guarding (e.g., fencing, light curtains, etc.). Also, software-based safety systems can be reprogrammed to expand application scope; for instance, a handling application that automatically reconfigures safety zones that the robot can enter and operate in. Another example is when networked safety is used to eliminate hard-wired drops for safety IO and emergency stops.

Almost all industries that involve humans doing non-process applications such as handling (which includes pick and place) and assembly will benefit from collaborative robots. The applications that benefit the most will be able to tolerate a slightly more variable and slower production rate, and will have tooling and peripherals that are conducive to human safety. Let the collaboration begin.

This article was written by Chetan Kapoor, senior director of technology innovation for Yaskawa Innovation, Inc., Austin, TX. For more information, contact Chetan at chetan.kapoor@yaskawainnovation.com, or visit ***http://info.hotims.com/61060-321***.

Motion Control Challenges for Deep-Sea ROVs

Deep-sea remotely operated vehicles (ROVs) present motion control design engineers with some difficult challenges. Applications may include ROV propulsion, position thrusters, dive vanes, rudders, or robotic arms. Some problems are common to all of them.

Corrosion. Seawater is very corrosive, and materials that are commonly used in electric motor construction are not suitable for seawater exposure. While 303 and 304 stainless steel are reasonably corrosion-resistant, for long-term exposure, 316 stainless steel, or some of the more exotic materials such as titanium, is preferred.

It is not possible to make the entire assembly of this material since metal fittings and hardware have to be carefully selected and protected to avoid galvanic corrosion that occurs when dissimilar metals are in contact with each other when wetted with seawater. At the same time, connectors, cables, gaskets, and seals need to be of suitable materials, and they must be properly installed to avoid leaks. Standard machine operations that result in spiral metal finishes can result in seal seepage despite meeting RMS requirements for metal finish. Corrosion, sand, mineral deposits, and marine life can cause additional problems if they are not considered in the product design.

Pressure. Depending on the intended depth of operation, pressure can be substantial. For the US Navy, 5000 PSI is a common specification. At such pressure, standard sealing techniques fail. By providing oil-filled, pressure-compensated units, equalizing internal and external pressure allows a smaller unit to be deployed, as the vessel walls need not support large differential pressures. But there is more to this than simply filling a unit with oil. A common sealing technique is a double seal or a double-lipped seal. The assumption behind this is that if one seal fails, the second is there to prevent failure. However, in a high-pressure situation, the space between the two seals becomes a failure point. Internal to the motor assembly, any void such as an air bubble in the varnish of the motor winding is a potential failure point. Under pressure, the bubble collapses, and hardened varnish cuts the wire. Other components such as Hall Effect switches must be built to withstand the pressure, or they will fail.

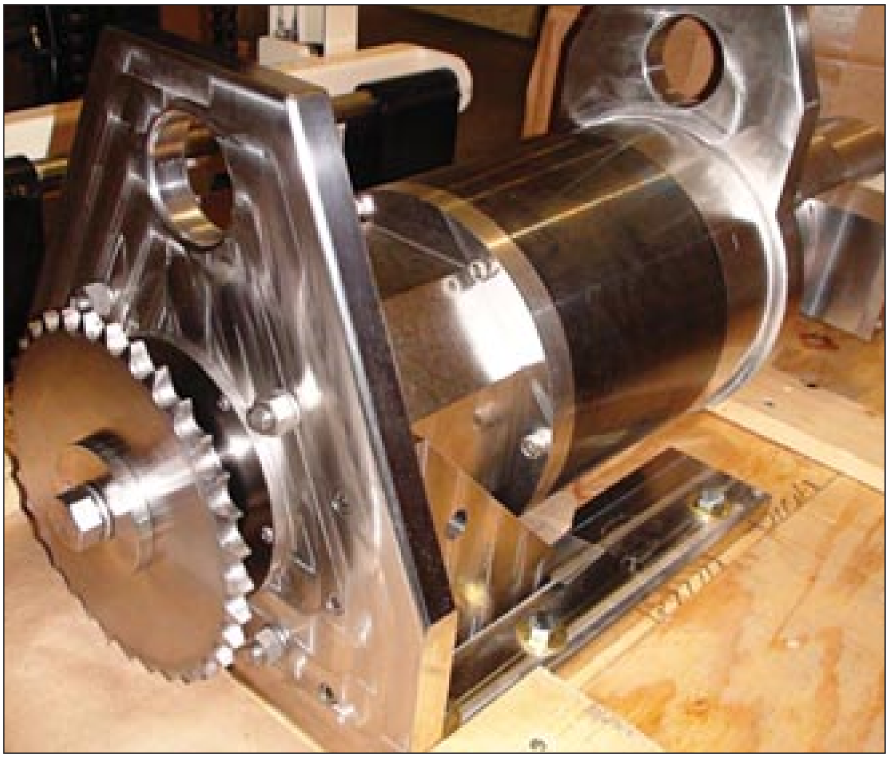
A common issue with connectors is their size, as they are quite large.

Fluid expansion. Once the unit is full of oil and is pressure-compensated, operating at depth is viable, but applications typically require that the units operate out of the water as well as being submerged. Operating in air, the motor heats up, the oil expands, and unless it is well designed, the internal pressure blows the seals out of the unit before it ever gets to the sea.

Low voltage. Nearly all of these ROVs are battery operated; since salt water is conductive, a commonly used voltage is 24 VDC, as this voltage does not represent a danger to the people working on the equipment. However, to get any substantial amount of power, the current has to be quite high, and copper losses increase as the square of the current. Further, the voltage generated by the spinning magnets in the motor (back electromotive force, or BEMF) puts a significant limit on the top speed of the motor.

Viscous drag. Moving in or through a liquid such as seawater requires power, and the power required increases as the cube of the speed. Doubling the speed requires eight times as much power. In general, engineers have to significantly reduce the speed of motion as compared to what is typical in air, as the alternative is bigger, heavier, more power-consumptive motors.

Cable length. A typical starting point for a design concept is to have the electronics above the water, with an umbilical cable that goes to the ROV. But the practical issues involved with this become apparent when doing the math. If the motor is to provide five horsepower, or 3,730 Watts of power at the output shaft, at 24 volts this is 155.4 Amps if the motor is 100% efficient and there is no cable loss. A 2,500-foot-long cable has 5,000 feet of wire in the circuit. A conductor suitable for 155 Amps is an AWG 1 — this wire has a resistance of 0.1239 ohms per 1,000 feet, so this 5,000-foot conductor would have a resistance of .6195 ohms at 155 Amps, and the voltage loss in the cable would be 96 Volts. But if one had 24 Volts to start with, the system will not work. To



The size of the assembly and the overall weight are design issues. Frequently it is necessary to work around existing mechanisms requiring creative mechanical designs.

overcome this problem, larger cables can be considered, but the weight of the cable becomes unmanageable. Alternatively, higher voltages can be used, but this creates battery issues.

A common solution is to place the motor drive electronics and power supply in proximity to the motor. This is accomplished by using a "dry tank" that is completely sealed and built to withstand the expected pressure. Electrical fittings rated to 20,000 PSI are available. Batteries need to be in separate compartments so the fumes do not attack the electronics.

Connectors. For a number of reasons, connectors are desired on the motor assemblies. There are dry mate and wet mate versions. The dry mate units are waterproof once they are assembled, while wet mate versions can be assembled wet and still be expected to function. A common issue is the size of the connectors, as they are quite large.

A fairly common error that is made is the result of assuming that the cable jacket is all that needs to be sealed. However, if the individual conductors and the spaces between the conductors are not blocked, oil from the motor under high pressure will flow into the cable, and the pressure compensation of the motor will be lost. If there are any pinholes in the cable jacket, seawater will fill the spaces and the salt water will short out the conductors. Proper cables and connectors for deep-sea applications are relatively expensive and are a common failure point.

Size and weight. Since most of the applications are for mobile devices, the size of the assembly and the overall weight are design issues. Frequently it is necessary to work around existing mechanisms requiring creative mechanical designs in addition to the challenges mentioned above.

After working on a number of deep-sea design projects, the common thread has been that initial estimates of speed and power are typically off by orders of magnitude. The size, weight, and cost of meeting the requirements become unacceptable, and eventually the speed requirements are reduced to the point where a solution becomes practical.

This article was written by Richard Halstead, President of Empire Magnetics, Rohnert Park, CA. For more information, visit ***http://info.hotims.com/61060-322****.*

Linear Motor

Nippon Pulse America (Radford, VA) released the SL083 scaleless linear motor with a built-in linear encoder for positioning applications that would benefit from the repeatability, reliability, and robustness of a linear motor, with up to 5 µm in resolution. The motor consists of a tubular stainless steel shaft and a non-contact forcer. It requires no lubrication, and features a non-critical air gap that eliminates variation in the force. The housing is made of non-magnetic aluminum.

The design integrates a non-analog magnetic linear encoder into the linear motor, and simplifies the integration of the motor into applications, as it can utilize existing bearings in order to become an actuator. In addition to a built-in encoder, the motor has a built-in interpolator and Hall sensors. It offers real-time signal processing and a maximum speed of 4 meters per second.

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Panel-Mount Piezo Drives

The Ndrive QLe digital, panel-mount nanopositioning piezo drives from Aerotech (Pittsburgh, PA) are designed for use with the Aerotech Automation 3200 (A3200) motion controller. The drives enable coordinated motion between piezo stages and servo axes at higher rates than other controller/drive products. Featuring a dual-core, 456-MHz, floating-point DSP, the drives feature position latching and single-axis or multi-axis position synchronized output (PSO) to generate pulses based on actual position feedback.

The drives use high-resolution A/D and D/A converters to enable sub-nanometer positioning resolution at high bandwidths. In addition to four optically isolated digital inputs, two high-speed digital inputs, and four optically isolated digital outputs, the drives are equipped with two analog inputs and two analog outputs. They offer an 18-bit analog input that can be programmatically configured to accept an external feedback sensor or position command. This analog input also allows the high-voltage power amplifier to be controlled directly by an external low-level analog input.

For Free Info Visit http://info.hotims.com/61060-301

Encoders

Celera Motion (Bedford, MA) introduced the MicroE Veratus™ Series encoders incorporating VeraPath™ technology. All interpolation, automatic gain control (AGC), and signal processing is performed in the sensor head that measures 35 × 13.5 × 10 mm.

Interpolation in the sensor head provides resolution from 5 µm to 20 nm for linear applications, with speeds up to 5 m/s. The encoders feature multiple mounting configurations, industry-standard analog and digital incremental encoder outputs, built-in limits, flexible index selection, and status LED in the sensor head.

No additional PCBs, adapters, or dongles are necessary for the full functionality and resolution of the sensors. They can be universally applied with MicroE's linear glass scales, linear metal tape scales, and rotary scales. The interface options are A-quad-B or 1 Vpp sin/cos. VeraPath technology is designed to filter out signal disturbances caused by scratches on gratings and by typical variations of metal scale flatness.

For Free Info Visit http://info.hotims.com/61060-302

Brushless DC Motors

Crouzet Motors (Vista, CA) introduced brushless DC motors with CANopen® technology. The new communications protocol allows design engineers to connect multiple brushless motors to the various components in a system. The CANopen interface permits connection of up to 127 brushless DC motors with a single, shielded, two-wire cable. Data may be transmitted at speeds up to 125 kBd at distances over 550 yards. At lower baud rates, the transmission distance can exceed three miles, making communications flexible to virtually any location. Under the communications protocol, motors can be controlled separately or together.

The motors can operate over a wide voltage range, withstanding up to 80 volts DC regenerative energy. In addition, the CANopen-enabled motors utilize two safety inputs to cut down power in the motor, even if the microprocessor has failed. Embedded Fieldbus control enables integral protection in severe environments, and immunity to external noise and vibration.

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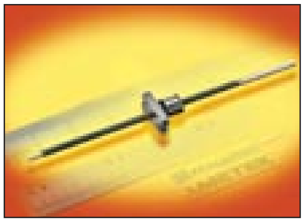
Lead Screw Assembly



The Micro Series ZBM anti-backlash lead screw assembly from Haydon Kerk Motion Solutions (Waterbury, CT) can be customized to specific applications that require unique geometry and custom materials such as Kerkite® composite polymers. The anti-backlash nut utilizes a special nut thread system that, when combined with a radial force, provides simple backlash compensation. The nut is suited for applications in which smooth motion is required and space is at a premium.

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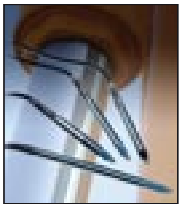
Intro Cov ToC

NEW Products

Position Sensors

Macro Sensors (Pennsauken, NJ) offers the BBP Series air extended, spring-loaded LVDT position sensors to measure range of motion in pneumatic cylinders. The 3/8"-diameter, pencil-type gaging probes measure the position of a target surface. They feature a probe that moves out and makes measurements only near the very end of the probe movement when it is almost fully extended, and then retracts so the probe gets out of the way of damage.



The sensors utilize a linear ball bearing assembly precisely fitted to a hardened-and-ground, non-rotating probe shaft to minimize radial play and the effects of side loading. This results in the probes' repeatability of 0.000006" (0.15 μm). The other end of the shaft is internally threaded to accept an interchangeable tungsten carbide contact tip. The units are available in three standard ranges: ±0.040" (±1.0 mm), ±0.100" (±2.5 mm), and ±0.200" (±5.0 mm).

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Drive Couplings

AutomationDirect (Cumming, GA) offers SureMotion drive couplings in four styles: jaw/spider, double loop, Oldham, and beam-style servo. The jaw/spider coupling is a clamp-style coupling with 14- to 65-mm aluminum hubs, and bore diameters ranging from 3/16" to 32 mm. Double loop coupling hubs are made of series 300 stainless steel with corrosion protection, and are available in 10- to 40-mm hub sizes. Oldham drive couplings feature aluminum hubs in 19- to 57-mm sizes. Beam-style servo couplings are stainless steel set-screw couplings that feature the flexibility of a bellows coupling plus the torsional stiffness and strength of a disc coupling.

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Track Motion Platform

ABB (Auburn Hills, MI) introduced the IRBT 2005 flexible, compact, modular, medium track motion platform for robots and transfer applications. It is designed to accommodate rapid product changes in applications that require an extended working range and high degrees of speed and accuracy. It is available with up to two carriages as a robot track, with additional carriage plates available to carry any necessary process equipment, and up to three carriages as a transfer track. The modular design is comprised of one-meter lengths that can be connected to form a track between 2 and 21 meters.

The platform is available in two variants: standard with covers on the rails and rack only, and fully covered. The system can also be combined with other accessories such as part positioners. With a maximum payload of 1200 kg (2,640 lbs.), the platform transfer version is suited for applications such as indexing different fixtures into an automation cell, and transferring materials such as car bodies between different working stations.

For Free Info Visit
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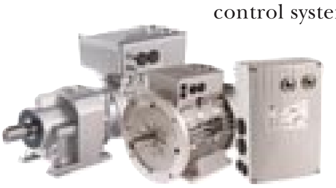
Rotary Actuator

The Hydraulic Unibody (HUB) Series rotary actuator from Parker Hannifin Corp. (Cleveland, OH) is built with a hard-coat anodized housing and hardened alloy steel pinion and racks for applications exposed to harsh weather extremes. The rack-and-pinion gear design minimizes hydraulic power unit (HPU) size. The one-piece housing eliminates leak paths and external connections, and the design allows for mounting directly on numerous process valves. Several add-on valve modules are available. A crossover vent module allows for flow between both cylinder ports, permitting free rotation of the process valve. A D03 Solenoid-ready module provides a manifold block directly mounted to the actuator.

For Free Info Visit http://info.hotims.com/61060-308

Drive Starters

NORD Gear Corporation USA (Waunakee, WI) introduced the SK135E/SK175E soft start drives designed for use in a distributed control system. They can be mounted directly on the motor or near the motor. The starters regulate the three major functions of a motor starter and control them in order to protect equipment. Basic features include two digital inputs and two digital outputs, four DIP switches, up to four configurable potentiometers, temperature sensor input, electromechanical motor brake control, motor overload protection, flux monitoring, and automatic phase sequence detection (minimum current).



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Brushless Motors

maxon motor (Fall River, MA) offers ECX high-speed brushless micro motors in diameters of 8, 16, and 19 mm achieving speeds of up to 120,000 rpm. They are available with different power stages and in standard or sterilizable versions (up to 2,000 autoclave cycles).

For Free Info Visit http://info.hotims.com/61060-306

Electronically Commutated Motors

EC Fans & Drives, a division of Epec Engineered Technologies (New Bedford, MA), announced EConomy and EXRi50 electronically commutated motors. The EConomy features a slim profile that enables use in applications where space restrictions are a concern. It is a single-speed, single-direction, entry-level EC motor with an operating range of output power at 1-16 Watts. The EXRi50 is a global voltage, single-speed, single-direction, EC fan assembly motor available as a fan-pack with integrated fan ring.

For Free Info Visit http://info.hotims.com/61060-311

NEW Products

Angle Sensors

Novotechnik, U.S. (Southborough, MA) introduced the RSC3200 angle sensors that feature shaft connectivity options and provide absolute rotary position measurement. Analog outputs are 0.25 to 4.75V or 0.5 to 4.5V. Built-in coupling accepts D-Shaft with shaft customization available. The non-contacting sensors are fully redundant, measure angles up to 360°, and have an operating temperature range of -40 to +125 °C. Repeatability is 0.5°, resolution is 12-bit, and absolute linearity is within ±1.0% FS at 360°.

For Free Info Visit http://info.hotims.com/61060-312

Brush DC Motors

Portescap (West Chester, PA) introduced the Athlonix™ 22DCP brush DC motors available in a 22-mm diameter. They feature a coreless design with a self-supporting coil and magnetic circuit, and are available in two configurations: precious metal commutation, and graphite commutation with Alnico magnet inside. An REE (Restriction of Electro Erosion) coil is an available option. The motors are compatible with encoders and gearheads of various sizes and ratios.

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Linear Actuator

The Servo Cylinder from Ultra Motion (Cutchogue, NY) is a compact brushless DC linear actuator with Phase Index™ absolute position feedback. The integrated Phase Index sensor is digital, high-resolution, and non-contacting with a wide operating temperature range, and is resistant to a range of harsh environmental conditions. The combination of Phase Index with the Servo Cylinder eliminates the need for homing, limit switches, potentiometers, LVDTs, optical encoders, and Hall Effect sensors. The actuator can provide forces up to 530 lbf., speeds up to 14 in/s, and linear travel up to 7.75" with a maximum supply voltage range from 7-48 VDC.

For Free Info Visit http://info.hotims.com/61060-314

Brushless Torque Motors

Electromate (Greenville, DE) offers QTR Series compact torque motors from Tecnotion that can be integrated directly into a machine structure, with an open inner diameter that enables wire and cable feedthrough. The motors come with completely sealed stators and integrated temperature protection and measurement sensors. The motors eliminate the need for mechanical transmission components such as gearboxes, belts, and speed reducers. They feature braided power and sensor cables with strain relief integrated in the stator housing. The motors are available with outer diameters of 105, 133, and 160 mm, and build heights ranging from 17 mm to 92 mm.

For Free Info Visit http://info.hotims.com/61060-315