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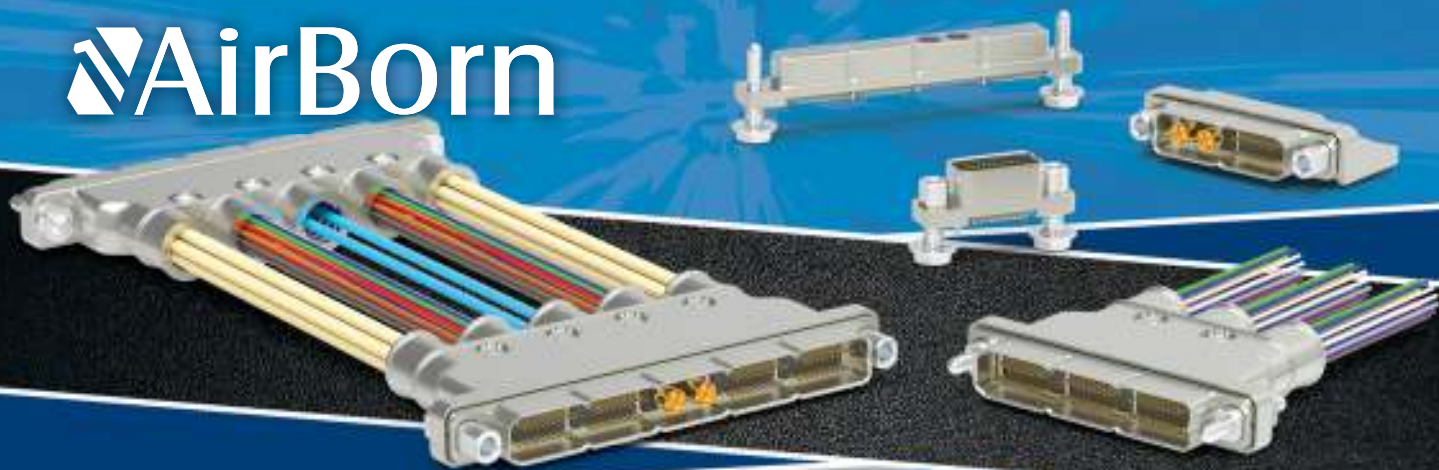
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Contents

FEATURES

Avionics & Displays

- 6 The Digital Cockpit of the Future

Aerospace Alloys

- 10 The Science of Joining Dissimilar Metals in Aerospace Manufacturing

Power Electronics

- 16 Designing A/D Converters for the James Webb Space Telescope

Testing & Simulation

- 22 Vibration Testing NASA's X-57 Maxwell Electric Aircraft

RF & Microwave Technology

- 26 Hybrid Circulators for mmWave Systems
30 Transforming Battlespace Communications

TECH BRIEFS

- 33 Pulsed Exposure Toxicity Testing: Method Development and Initial Evaluation for Stormwater Compliance
34 Upgrade Transonic Compressor Test Rig Data Acquisition System

- 35 Electrokinetics Models for Micro- and Nano-Fluidic Impedance Sensors
36 Evaluation and Test Requirements for Liquid Rocket Engines
38 GPS Radio Occultation and Ultraviolet Photometry-Colocated (GROUP-C) Early Orbit Testing Results

DEPARTMENTS

- 42 Application Briefs
47 New Products
64 Advertisers Index

ON THE COVER

Circulators used in transmit-receive systems such as point-to-point radio and radar allow a transmitter and receiver to share a common antenna while simultaneously isolating the transmitter and receiver from each other. NASA's JPL utilizes circulators in their high-throughput satellite communication systems for measuring cloud properties and upper atmospheric constituents. Some of these systems operate between 167 and 175 GHz with development near 240 GHz and beyond, necessitating a new type of hybrid circulator. To learn more, read the feature article on page 26.

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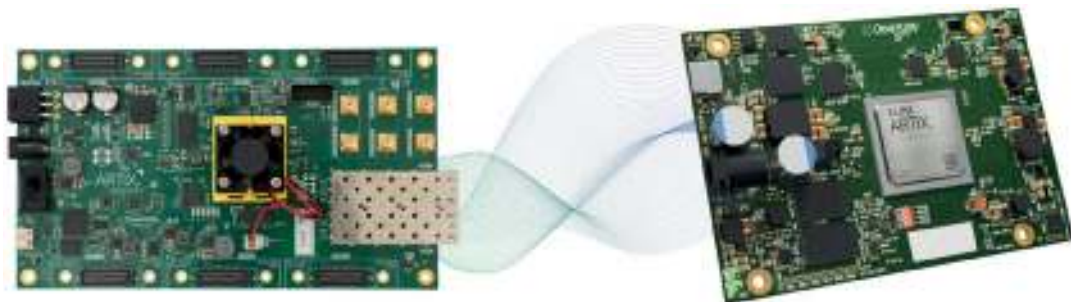
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INSIDE STORY

Vision Research manufactures Phantom high-speed cameras and imaging systems for research applications in defense, automotive, engineering and much more. In the following interview, Senior Test Engineer Lee Denaro discusses high-speed camera innovations involving the CXP-over-Fiber standard to improve throughput in high-speed machine vision applications.

A&DT: What is the camera capable of?



Denaro: Taking traditional machine vision to the next level, the Phantom S991 high-speed camera features a 9-megapixel (Mpx) CMOS sensor, a low exposure time of 5 microseconds (μ s) and speeds up to 52,080 frames per second (fps). As the world's highest-throughput machine vision camera, it combines world-class image quality with direct data transfer speeds of 9 gigapixels per second (Gpx/sec) and can capture 938 fps at full 9-Mpx resolution.

Using the standard CoaXPress (CXP) protocol, the S991 transfers data to backend frame grabbers, where data is processed on the fly either in the frame grabber field programmable gate array (FPGA) or in the graphics processing unit (GPU) plugged into the computer motherboard via the PCI-e bus standard. In a process called stitching, the camera divides the transmitted images by rows and then interleaves the images as they arrive in the frame grabber FPGA. Using a simple algorithm, each image is then "stitched" back together. This streaming ability avoids the time-consuming process of saving data to a camera's RAM before downloading it to a computer.

A&DT: How does CXP-over-Fiber work?

Denaro: An add-on to the recent CoaXPress 2.0 specification, CoaXPress-over-Fiber (CXPoF) provides a way to run an unmodified CXP-12 protocol over a standard Ethernet connection including fiber optics. In other words, it uses standard electronics, connectors and cables designed for Ethernet, but the protocol is CoaXPress instead of Ethernet or GigE Vision.

Because CXPoF combines the CXP-12 standard with optical fiber, this upgraded standard eliminates the need for multiple CXP-6 copper cables. As one of the industry's first CXPoF cameras, the Phantom S991 requires just two fiber cables as opposed to the 16 copper cables required by its predecessor, the Phantom S990.

A&DT: What are the components?

Denaro: Since CXPoF is an add-on to the existing CXP standard, you can leverage the same programming to upgrade your camera. Since it uses Ethernet components, CXPoF also only requires standard Ethernet connectors and cables, keeping your costs low. At the same time, it takes advantage of the "free" evolution of Ethernet as it progresses toward higher bandwidths. In addition to CXPoF frame grabbers and substantial PC power, you'll need the following components to get started:

- Quad Small Form-Factor Pluggable (QSFP+) transceiver modules. CXPoF achieves 4 x 10 Gbps on a single QSFP+ module for a total of 40 Gbps per camera – the same net bandwidth as four CXP-12 links over four copper coaxial cables.
- Fiber cabling. These cables are small and lightweight and can

handle higher bandwidths compared to copper cables. They are also immune to electrical noise.

Prior to CXPoF, you had to deploy expensive repeaters to translate the CXP-6 standard into fiber, driving up costs by several thousands of dollars. This setup also created very bulky cable interfaces with many potential points of failure. CXPoF simplifies this setup, eliminating the need for repeaters and their associated failure points.

CXPoF also expands machine vision to applications requiring recording at longer distances, an undertaking that previously relied on costly, complex repeaters. Now, you can simply set up your machine vision camera several miles away without worrying about the added complications associated with connecting external equipment. And, the availability of single-mode transceivers and cables significantly extends cable length. This ability simplifies the process of bringing machine vision to applications that involve ballistics or explosives, which, by their nature, require camera operators to remain far away from the recording process.

A&DT: What are the challenges?

Denaro: To realize all the benefits high-speed machine vision has to offer, you must have the right technologies in place to manage the vast amounts of data coming from the streaming cameras. Although stitching is a vital part of the streaming process, it takes up computing resources and can require lengthy processing times if not addressed properly.

A second issue that has emerged, particularly at higher frame rates, is image "thrashing," which occurs when the volume of incoming frames outpaces the CPU of the host PC. In other words, the computer, as it receives and processes the high number of frames, can't keep up and subsequently fails. Thrashing typically occurs at higher frame rates, usually around 20,000 fps and higher.

Fortunately, frame grabber manufacturers like Euresys and BitFlow offer innovative solutions to the data issues that arise from stitching and image thrashing at high frame rates, and their frame grabbers are a natural complement to Phantom high-speed streaming cameras.

A&DT: You have three machine vision cameras: the S990, S710 and S640. Why did you convert this one to fiber?

Denaro: By combining extremely high throughput (9 Gpx/sec), high resolution (9 Mpx), fast frame rates and CXPoF cable technology, the Phantom S991 enables extreme high-speed imaging, expanding machine vision to challenging applications that require real-time analysis or long record times like space shuttle launches. In addition, the integration of CXPoF technology opens the door to new high-speed machine vision applications while, at the same time, simplifying those applications where high-speed machine vision is already in use.

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The Digital Cockpit of the Future

How Human Machine Interface Technology Will Impact Avionics Displays

When Doug Hurley and Bob Behnken lifted off Earth in a SpaceX rocket in May 2020, there were a lot of firsts: it was the first manned rocket launch on American soil since the shuttle program ended in 2011, the first NASA flight with a private company, and the first time a space shuttle cockpit looked completely different to anything we've ever seen before. The human-machine-interfaces (HMI) of airplane cockpits will soon follow the same path. New technologies like 3D volumetric displays or virtual tactile sensation projections offer exciting possibilities for the cockpit of the future. Yet new tools will be necessary to develop, test and integrate those technologies in an economically sensible and safe way.

Robert L. Behnken, better known as Bob Behnken, has spent a lot of time in space. He first flew to the International Space Station (ISS) in March 2008 with the space shuttle Endeavour and took a second trip in 2012. Then the space shuttle program ended and Behnken had to wait eight years before he could return to the ISS. When he launched in SpaceX's Crew Dragon capsule on May 30, 2020, everything around him had changed. While spaceship cockpits already looked like the future



in science fiction films of the 1970s, the decade in which Behnken was born, the cockpits of space shuttles that flew up to the end of the US space program were reminiscent of jumbo jets — just crammed with more buttons, switches, knobs and flashing lights that shone as bright as the advertising signs in Times Square.

SpaceX has radically changed the cockpit design with the Crew Dragon. Of the more than 1,000 buttons and switches in the old space shuttles, now only around ten remain, all for potential emergencies only. The change in spaceship cockpits anticipates what will soon be seen in those of airliners. Software and automation have enabled a step forward in cockpit design, one that is stripped down to the essentials without sacrificing functionality.

The essence of the way an airplane is flown has hardly changed since it was first invented. The connection between man and machine via displays, switches, controllers, and lights has expanded, but remains fundamentally the same. The Crew Dragon represents a revolution in the human-machine interface in space flight. And the digital revolution will shortly take hold of aircraft HMI too. Yet which technologies will enter the cockpit?

HMI Development Platform

There are many technologies being developed by countless startups around the world that will connect people with machines in new ways. Augmented reality, voice control, virtual co-pilots powered by AI or even computer-brain interfaces. Today, it



Software and automation have enabled a step forward in cockpit design, one that is stripped down to the essentials without sacrificing functionality.

is difficult to predict which technologies will prevail. This makes it even more crucial for aircraft manufacturers to have a design platform that makes it easy to implement future technologies and allows efficient trial-and-error testing during development. An HMI design tool allows for new technologies to be used in an early stage of their development phase and offers a programmable interface for connecting third party software and hardware systems.

Incari is an HMI development platform that allows complex HMIs to be built without writing a single line of code. The node-based no-code approach allows non-programmers to build their own logic. This solution produces native C++ code that is compiled for the appropriate system.

Incari is segmented into the authoring system, *Incari Studio*, which is used to create HMIs, and *Incari Player*, a runtime environment that can be used to load and play HMIs. *Incari Player* is currently available for the x86, x86_64, ARMv7HF 32BIT, ARMv8 64BIT architectures and can be extended to other architectures as needed. The technology follows the 3D-first approach and works with a native OpenGL render engine. This allows 2D and 3D content to be assembled at the same time. The platform supports the programmable render pipeline starting

from OpenGL ES 3.0 or OpenGL 3.3.

The system's compatibility with new technologies comes from the wide range of ports Incari offers to communicate and interact with external systems. These include CAN-Bus, the standard web protocol HTTP, MQTT, as well as serial communication. Any device connected via the serial port can be used with the software platform, such as GPS, proximity, and temperature sensors. Thus, the supported feature set is continuously expanding and future hardware solutions can be integrated. This means working closely with developers of gesture control, eye tracking, ambient lighting or stereoscopic screen technology. Although these technologies may look futuristic, new HMIs in airplanes will not be introduced purely for the sake of it. They will help enhance safety.

3D Volumetric Displays

Technology has always helped minimize safety risks in aviation by assisting pilots. The accident statistics of the 1990s were driven primarily by Controlled Flight Into Terrain (CFIT). Pilots lost spatial situational awareness and planes crashed into terrain. The solution was a two-dimensional representation of the terrain on the navigation screen. Since then, this cause of accident has been eliminated, as HMI-researcher

Peter Marcus Lenhart at the Zurich University of Applied Sciences has shown.

New technology has the potential to further improve situational awareness in aircrafts. The Australian company Voxon is building 3D volumetric display technology. In Voxon's case, the term volumetric relates to the fact that the objects the technology creates do not reside on a screen but physically exist within a volume or 3D space. Where other 3D display technologies use multiple views of a scene to create a stereoscopic view, Voxon technology physically builds a model of the scene using millions of points of light.

How does it work? It operates much like a 3D printer. A Voxon display takes 3D data and slices it up into hundreds of layers. Those layers are then projected one at a time onto a specially designed high-speed reciprocating screen. Due to persistence of vision, the human eye blends the images together, and the result is a true 3D image that can be viewed in the same way one would view a real object, from any angle, and without the need for special effects, headgear, or glasses.

Ultrasound Technology

Not only are there new technologies to help us visualize information, there are also new ways for humans to interact with that information. The US company, Ultraleap, has developed a product that is making it possible to project virtual tactile sensations onto human hands. A small speaker emits ultrasound waves, which are too high a frequency for humans to hear. Many of those small speakers are then put into an array and, using algorithms, triggered with very specific time differences. These time differences mean the ultrasound waves arrive at the same point in space, at the same time, called the focal point. Where the focal point is positioned is programmable in real time and can change position from instant to instant.

Ultraleap uses a hand tracking device to track the exact position of a human hand and aim the focal point at a spot on it. The combined ultrasound waves have enough force to create a tiny dent in the skin. This pressure is used to create a vibration that nerve endings in



Example of an HMI created using Incari Studio software.

the hand can detect. By moving the pressure points around, Ultraleap technology creates tactile effects in mid-air. These pressure points can be used to create a wide range of tactile effects, from sculpting virtual lines and shapes to forming 3D controls in mid-air.

New Design Tools

Each of these technologies could transform flying as we know it today, to a greater or lesser extent. However, the high demand for safety and the associated high development costs for aircraft manufacturers represent a unique challenge to the industry. HMI development platforms like Incari Studio can solve this problem by enabling designers and engineers to work together from the idea stage, through the prototype and test phases, to the creation of a production-ready product. They can work in a shared software environment in which even users who lack programming skills can design complex interfaces. Using this approach, subsequent adjustments, which are often time-consuming and cost-intensive due to an inability to implement them — something that is usually only discovered later in the process — are eliminated.

The ability to work quickly and iteratively with new software platforms leads to a better and safer product. This is critical in aviation and leads to confidence in new possibilities. At the same time, costs are reduced so that R&D budgets do not grow immeasurably.

Things are changing fast and the HMI revolution in air travel is right around the corner. The confidence in new forms of human-machine interaction will soon be as great in airplanes as it now is in space travel. And if so, maybe the cockpit of the plane that takes Bob Behnken to Cape Canaveral for his next trip to the ISS will look a lot more like the spacecraft he is already traveling into space with.

This article was written by Alexander Grasse, Chief Product Officer and Co-Founder, Incari GmbH (Berlin, Germany). For more information, visit <https://www.incari.com>.

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The Science of Joining *Dissimilar* Metals in Aerospace Manufacturing

In aerospace, metal diffusion bonding is an essential joining method for achieving a high-purity interface when two dissimilar metals require superior structural integrity. The process involves applying high temperature and pressure to metals mated together in a hot press, causing the atoms on solid metallic surfaces to interperse and bond.

Today, there is no better commercially viable materials-joining process than hot press diffusion bonding, because it can produce consistently uniform results in a wide range of aerospace applications. The applied pressure induced by hot-press equipment, combined with software and loop-back sensors for precise control to within micrometer accuracy, can produce constant pressure over several square feet of area for component assembly. As a result, this technology has attracted the interest of design engineers in the aerospace, semiconductor, and energy industries.

With such a high degree of process control, the diffusion bonding process is increasingly used to join dissimilar metals in aerospace. Commercial processes of interest are titanium to iron-nickel alloys, titanium alloys to stainless steel, and even some aluminum to metal applications. The process also enables coupling between different alloys in the same material group, such as mild steel, tool steel, and metal-matrix composites.

To successfully use diffusion bonding in aerospace, an understanding of the complexities of the interface and its effect on the chemical and thermo-mechanical properties of the bond is required. However, with the industry's traditional focus on welding and brazing, there has been minimal formal education on diffusion bonding.



"Combining the beneficial properties of different metals is the main reason to explore diffusion bonding," says Thomas Palamides, Senior Product & Sales Manager - Industrial Furnaces, for PVA TePla AG, a global manufacturer of industrial furnaces and PulsPlasma nitriding systems. "However, when aerospace manufacturers reach out [to us about it], often the designers are not familiar with the best component design methods to optimize the bond uniformity or are unfamiliar with the best surface finish for the materials. Customers also have questions regarding the best methods for handling and fixturing the sub-components of parts prior to bonding. In addition to design concerns, most customers' engineers need guidance regarding the actual process conditions the components will undergo during the heating, cooling, and pressing cycles."

Consulting with an expert aerospace manufacturing partner is often the quickest way to consider the possible benefits of diffusion bonding. This approach can also help to tailor diffusion bonding to the manufacturer's process cost-effectively.

The Benefits of Diffusion Bonding

The importance of designing a dissimilar metal joint often lies in a desire to expose the correct metal surface to specific environmental conditions where a single alloy may not perform as well. Another reason is to introduce material systems that are lighter in weight or provide a level of corrosion resistance that can only be achieved by "packaging" dissimilar metals.

In aerospace, metal diffusion bonding is utilized in a variety of applications. Diffusion bonding is now a viable process for fabricating aerospace structural hardware or fluid and gas flow devices. This includes thermal

management devices for defense weapons, liquid rocket engines, and millimeter wave hybrid horns for land and space surveillance.

Additionally, diffusion bonding of titanium, steel and copper alloys is utilized to fabricate aerospace components with complex configurations. The method can be successfully used with blow forming to form near-net-shape aerospace components, including high-pressure tanks for attitude control of spacecraft, a combustion chamber with copper cooling channels, and lightweight structural panels.

Among aerospace and electronic warfare technologies, antennae detect polarized electronic radio waves. The geometry of the systems is at the heart of this technology, and diffusion bonding provides for more complex designs allowing the improved performance of the new generation of equipment.

Diffusion bonding also has tremendous potential applications for conformal cooling. The concept is to bond layers of sheet metal that contain machined channel/microchannel structures. When com-





Combining the beneficial properties of different metals is the main reason to explore diffusion bonding.

bined, the channels can provide for cooling or heat dissipation. The layers can be bonded up to a stack height of 600 mm in the MOV diffusion bonding press, retaining the strength as the parent materials.

Another application related to conformal cooling is for plastic injection molds made in 2-layer designs of low alloyed tool steel with stainless steel such as STAVAX.

Understanding Diffusion Bonding

Academia has researched dissimilar joining for decades, and much of the focus has been on high-performance

materials like titanium alloys. According to Palamides, expanding beyond commercially pure (CP) titanium, one often finds the existence of an intermetallic layer at the mating interface after processing. "The influence of the solute elements, such as Cu, Ni, and Ag, are the major drivers for the intermetallic layer formation in titanium," he says.

The diffusion bonding process can occur as either a solid-state or a liquid-phase bonding process. Similar pure material bonding has historically been as a solid-state operation. This

method simplifies the process from an assembly standpoint, as faying surfaces can be easily matched before placing a charge into the furnace. Alignment pins and tack welding may be used for this process as well. Because no liquid phase is present in diffusion bonding, slight deformation occurs at the surface. This results from applied pressure used to flatten surface asperities and break up residual surface oxides before bonding.

In the liquid-phase diffusion bonding process, an interlayer typically melts at the faying surfaces. In this instance, lower pressure than solid-state diffusion bonding is used, and even less deformation occurs at the surface. Depending on the thermal cycle and composition of the interlayer materials combination and the interlayer selected, an interdiffusion occurs between the interlayer and base materials on either side of the joint through the metallurgical processes known as a eutectic or peritectic phase change.

The thickness of the final intermetallic reaction layer is a result of, first, the liquid-phase diffusion and second, the solid-state diffusion. Bond strength is a function of the intermetallic compounds formed, the thickness of the intermetallic zone, and anomalies, such as voids, at the interface.

Exploring Diffusion Bonding

There are several ways for an aerospace manufacturer to investigate how diffusion bonding of dissimilar metals could benefit their process. Much scientific literature is readily available for specific material combinations and processing times and temperatures, depending on the application. For example, Kavian O. Cooke and Anas M. Atieh conducted an exhaustive review published in 2020 titled *Current Trends in Dissimilar Diffusion Bonding of Titanium Alloys to Stainless Steels, Aluminum, and Magnesium*. *Journal of Manufacturing and Materials Processing*.

While ample research exists on the subject, design engineers can still find it challenging to convert the information into real-world manufacturing of a specific part. When this is the case, it can be helpful to partner with experts with an exten-



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sive database of successful processing parameters from previous applications and access to industrial-scale equipment.

"In most cases, we start talking with the aerospace manufacturer about introducing new designs, and consult on possible materials, designs, and also conduct pre-bonding runs as needed," says Palamides. He notes that proper design will allow diffusion bonding of assemblies, whether an intimate interface or multiple interfaces that are planar parallel simultaneously. However, surfaces that are not perpendicular to the compressive force of the hydraulic ram will not bond properly.

Palamides says that the manufacturer begins by working with their mechanical, thermal, and modeling teams. Once a design is complete, the next step is to fabricate trial samples that are truthful to the characteristics of the final interface.

Advances in Diffusion Bonding Equipment

Despite its benefits, the use of diffusion bonding in aerospace has been limited by more practical considerations until recently. Specifically, the size limitation of the furnace chamber and limits to the amount and uniformity of the pressure applied across the entire surface area of the part. Run times are also long, often lasting an entire day. Advances in high-vacuum hot presses now allow superior pressure control and rapid cooling systems to improve the bond, increase yields and significantly decrease cycle time.

In the case of the pressure applied, for example, integrated single cylinder hydraulic presses can apply a consistent, measurable amount of force. However, this provides very little control over large parts with more complex geometries. To improve force distribution, thick graphite pressing plates (10"-15" in height) mate the metal layers together at a more consistent pressure. Unfortunately, this takes up furnace space while adding to the time to heat the surfaces of the metals.

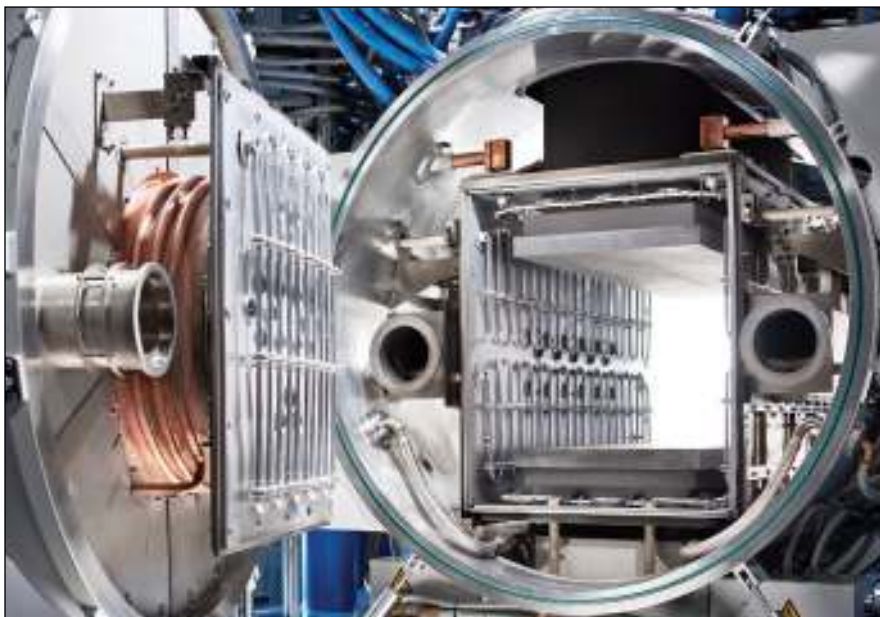
Today, manufacturers such as PVA TePla offer multi-cylinder systems with large pressing plates that can accommodate various parts. The largest, the company's MOV 853 HP, can process sub-

strates as large as 900 mm (35.43") × 1250 mm (49.21"), which is quite large for diffusion bonding. The pressing force is 4,000 kN.

By controlling each cylinder independently, the integrated press provides remarkably consistent pressure across the entire surface. The MOV also comes with built-in pressure transducers along the bottom of the

pressing plate. The individual hydraulic cylinders can be adjusted in the software to achieve uniformity even over large areas based on the sensor feedback. PVA TePla has optimized a physical ink test method that identifies areas on the substrate where uneven pressure is applied.

"Today's equipment provides detailed measurements of the material proper-



Advances in high-vacuum hot presses now allow superior pressure control and rapid cooling systems to improve the bond, increase yields, and significantly decrease cycle time.



A PVA TePla diffusion bonding system.



ties during bonding,” says Palamides. “This valuable feedback can show how the materials are compressing, if it is being crushed, and if a transient liquid layer is forming – and other KPIs of the procedure.”

Verifying the Integrity of the Bonding Interface

To ensure the quality of the interface, Palamides recommends analyzing samples through non-destructive inspection techniques, such as Scanning Acoustic

Microscopy (SAM), or more costly analysis performed using Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy (SEM-EDS). Subsequently, trial samples may be destructively analyzed and fabricated into standard mechanical test specimens to collect repeatable data.

While there is growing interest in diffusion bonding, all applications require thorough research to optimize the joining process. Only a few global firms can work with aerospace manufacturers through the process with the ability to advise on commercial system adoption. From the beginning, partnering with an expert in diffusion bonding will give manufacturers a competitive edge from part design through production ramp-up.

This article was written by Del Williams for PVA TePla America, Inc. (Corona, CA). For more information, visit <http://www.pvateplaamerica.com>.



In aerospace, metal diffusion bonding is an essential joining method for achieving a high-purity interface when two similar metals require superior structural integrity.

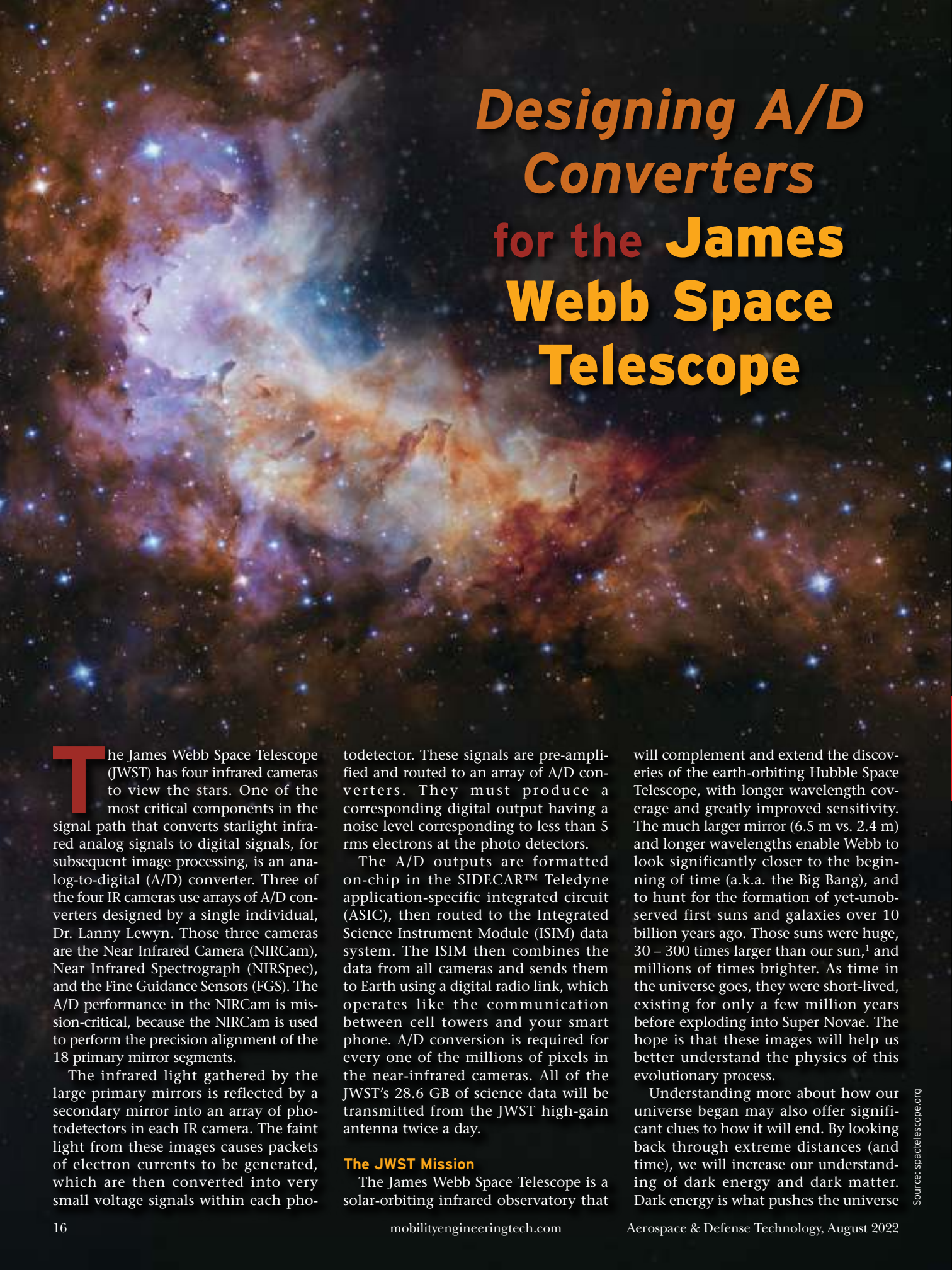
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Designing A/D Converters for the James Webb Space Telescope

The James Webb Space Telescope (JWST) has four infrared cameras to view the stars. One of the most critical components in the signal path that converts starlight infrared analog signals to digital signals, for subsequent image processing, is an analog-to-digital (A/D) converter. Three of the four IR cameras use arrays of A/D converters designed by a single individual, Dr. Lanny Lewyn. Those three cameras are the Near Infrared Camera (NIRCam), Near Infrared Spectrograph (NIRSpec), and the Fine Guidance Sensors (FGS). The A/D performance in the NIRCam is mission-critical, because the NIRCam is used to perform the precision alignment of the 18 primary mirror segments.

The infrared light gathered by the large primary mirrors is reflected by a secondary mirror into an array of photodetectors in each IR camera. The faint light from these images causes packets of electron currents to be generated, which are then converted into very small voltage signals within each pho-

todetector. These signals are pre-amplified and routed to an array of A/D converters. They must produce a corresponding digital output having a noise level corresponding to less than 5 rms electrons at the photo detectors.

The A/D outputs are formatted on-chip in the SIDECAR™ Teledyne application-specific integrated circuit (ASIC), then routed to the Integrated Science Instrument Module (ISIM) data system. The ISIM then combines the data from all cameras and sends them to Earth using a digital radio link, which operates like the communication between cell towers and your smart phone. A/D conversion is required for every one of the millions of pixels in the near-infrared cameras. All of the JWST's 28.6 GB of science data will be transmitted from the JWST high-gain antenna twice a day.

The JWST Mission

The James Webb Space Telescope is a solar-orbiting infrared observatory that

will complement and extend the discoveries of the earth-orbiting Hubble Space Telescope, with longer wavelength coverage and greatly improved sensitivity. The much larger mirror (6.5 m vs. 2.4 m) and longer wavelengths enable Webb to look significantly closer to the beginning of time (a.k.a. the Big Bang), and to hunt for the formation of yet-unobserved first suns and galaxies over 10 billion years ago. Those suns were huge, 30 – 300 times larger than our sun,¹ and millions of times brighter. As time in the universe goes, they were short-lived, existing for only a few million years before exploding into Super Novae. The hope is that these images will help us better understand the physics of this evolutionary process.

Understanding more about how our universe began may also offer significant clues to how it will end. By looking back through extreme distances (and time), we will increase our understanding of dark energy and dark matter. Dark energy is what pushes the universe

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to expand. We can't 'see' dark matter, but whatever it is, it accounts for an unseen mass within our galaxy. We know it is there, because the gravitational pull from that extra mass is necessary to keep the outer star systems in our galaxy from flying away, given their apparent angular velocity. Figure 2 shows how the universe might end; in a 'Big Crunch,' or a 'Big Chill,' depending on the balance between dark matter and dark energy.

The design of JWST's electronics was well under way by 2005 and the cameras were delivered by the prime contractors (Lockheed Martin and the University of Arizona) in 2012. The total cost of the JWST is over \$10 billion, involved three space agencies, and over 1000 people. One of them was Dr. Lanny Lewyn.

When I was President and co-founder of Snowbush Microelectronics, I was approached by Len Kozlowski from Rockwell who asked us to design an A/D converter. After reviewing the specifications and schedule, I told Len I couldn't do it, at least not successfully. This was difficult to say, as designing A/D converters is what most analog designers prefer. I told Len his only possibility for meeting his specifications and schedule was to subcontract the required A/D converter design to Dr. Lanny Lewyn.

Lanny and I became friends shortly after I became a Professor at UCLA (1980 – 1991). As electronics professors, we were encouraged to work actively one day per week with industry. Many times, I worked directly with Dr. Lewyn on a wide variety of projects. When Professor David Johns and I co-founded Snowbush Electronics in 1998, we often subcontracted design work to Dr. Lewyn's company (LCI), especially for A/D converter projects, so we knew well what his capabilities were.

Design Challenges for The Nircam A/D

Both the schedule and the specifications required for the NIRCAM SIDECAR ASIC were demanding. An array of 36 A/Ds was required to fit within a specific IC width limit. The power limit was 1.5 mW at 100 Kb/s. They also must have 16-bit ± 2.5 LSB INL accuracy and satisfy a special imaging requirement of

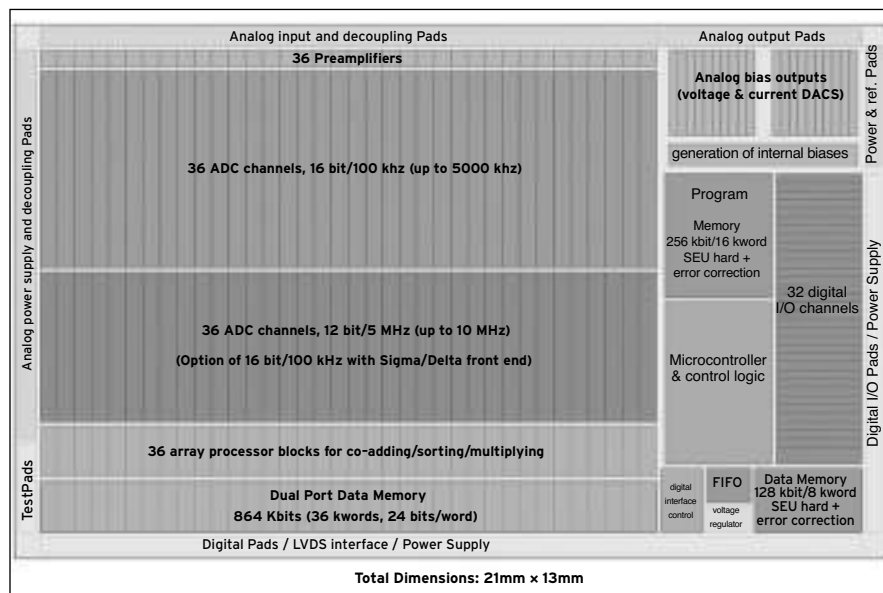


Figure 1. Loose, Lewyn, et. al. 'SIDECAR Low-power control ASIC for focal plane arrays including A/D conversion and bias generation.' Proc. SPIE, 2003, pp. 782 – 794

± 0.3 LSB DNL. A $10\times$ speed mode was required, but at a lower resolution (still way better than anything else available given the power increase limits).

The ASIC design program lead and system architect was Marcus Loose at Rockwell. Marcus and Dr. Lewyn worked directly together on a single-chip solution. For the A/Ds and imager readout control circuits, Dr. Lewyn did both the A/D transistor-level circuit design and the analog layout as well; in a typical development, this amount of work might be done by a team of four/five engineers.

To meet the demanding schedule, he used the dimensionless design methodology (Gamma rules) that he developed for the Pair-Gain 14b HDSL A/D. Dimensionless layout design rules can be ported to multiple technology scales and foundries. It was a significant improvement over an earlier dimensionless circuit design and layout approach (Lambda rules) created by his advisor at Caltech, Carver Mead.²

A successive approximation register (SAR) was devised, which used a precision capacitor array for the most-significant-bits (MSBs) and a precision resistive divider for the least-significant-bits (LSBs). To comply with the severe differential nonlinearity (DNL) requirements (usually ± 0.5 LSB), an algorithmic

method was used for perfectly matching the voltage switching boundaries of the MSB capacitors to those of the lower LSB resistors. For clarity, the ± 0.3 LSB DNL requirement specifies a random error of only one part in 218,453.³

No autocalibration methods were permitted to correct for small A/D linearity errors because of the low power requirement and the non-random nature of the signals. The INL requirements had to be satisfied by using a combination of centroiding algorithms that had been previously used by Dr. Lewyn to supply Toshiba with an 18 b audio DAC with an INL of ± 1 LSB. One of those algorithms, a perfect centroiding algorithm, involved duplication and rotation of elements rather than the side-by-side transistor method, invented several years earlier by Kiyoshi Kanekawa of Toshiba.

The Second Lagrange Point (L2)

So where is the JWST now? It is orbiting at the Second Lagrange Point, or L2. Since the photodetectors and camera electronics, operating below -200°C on the cold side of the telescope system, must be shielded from the sun, the L2 solar orbit (Figure 4) was chosen, rather than a near-Earth orbit like the Hubble Space Telescope (HST), because the heat shield must always be interposed

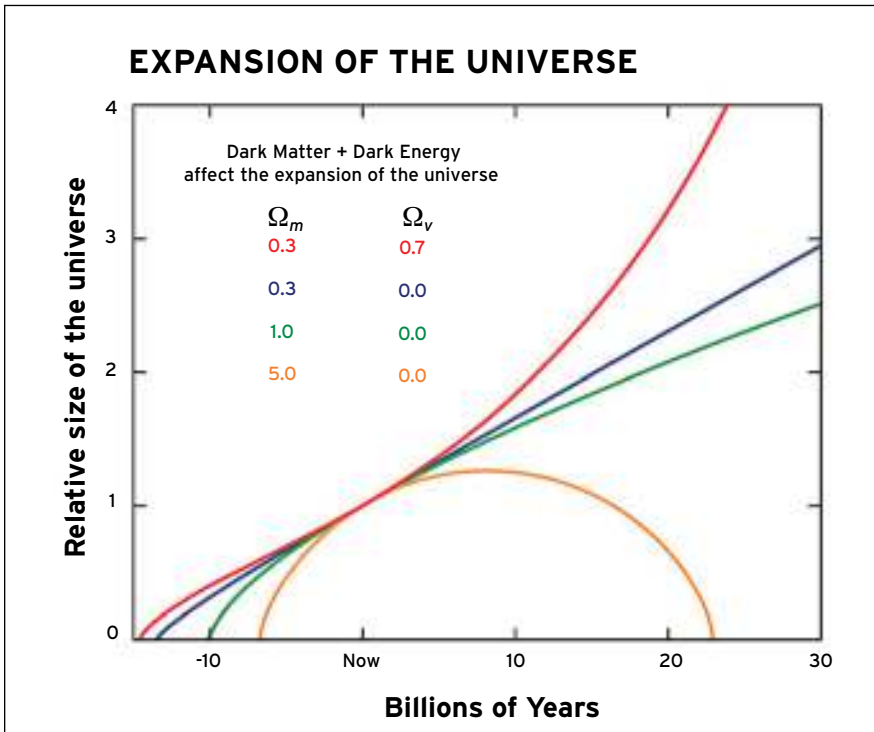


Figure 2. The fate of the universe is predicted from different cosmological theories as ending in an ultimate collapse, or 'Big Crunch' (yellow curve) where the attraction force of dark matter(Ω_m) greatly exceeds the expansion force of the dark energy (Ω_v). Where the converse is true (red curve), a 'Big Rip' occurs and acceleration continues until the fundamental particles of matter are ripped apart. If the force of both dark matter and dark energy are weak, the universe gradually drifts slowly apart and the end is the 'Big Chill' (blue and green curves) where objects continue to drift apart endlessly (Source: NASA GSFC).

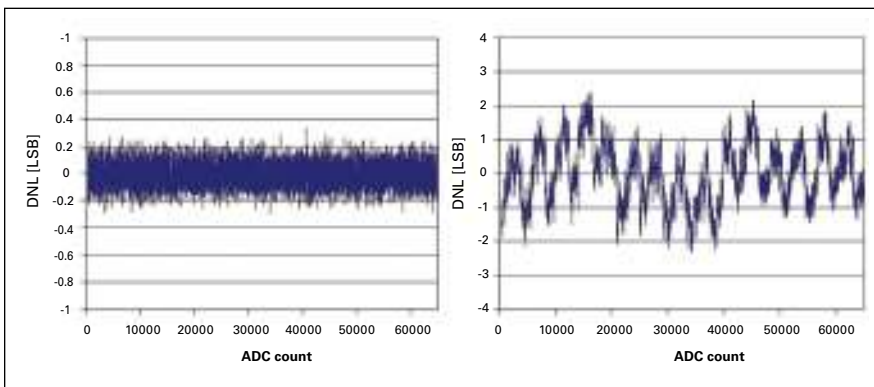


Figure 3. The A/D differential nonlinearity (DNL) requirement of ± 0.3 LSB required use of a new algorithm for matching MSB and LSB DAC voltage boundaries, while the integral nonlinearity (INL) requirement (without onboard calibration) of ± 2 LSB required a combination of two centroiding algorithms and extreme lithographic uniformity. (Source: Loose, et. al. in "The SIDECAR ASIC" SPIE 2005)

between the sun and the telescope when receiving images. In a low orbit, the Earth would block many observations for about half a day.

The distance of L2 is approximately a million miles from Earth, and 93 million miles from the sun. For compari-

son, the moon is only 238,855 miles from the earth.

The NIRCam

The Near-Infrared Camera (NIRCam) is JWST's primary imager in the wavelength range from $0.6 \mu\text{m}$ to $5 \mu\text{m}$. It

consists of two, nearly identical, fully redundant modules (Figures 5 and 6), which point to adjacent fields of view in the sky and can be used simultaneously. Each module uses a dichroic to also observe simultaneously in both the short wavelength channel ($0.6 \mu\text{m}$ – $2.3 \mu\text{m}$) and long wavelength channel ($2.4 \mu\text{m}$ – $5.0 \mu\text{m}$).

The first images from the James Webb Space Telescope released by NASA show the single sun-like star HD 84406 in the Ursa-Major Galaxy as seen from each of Webb's 18 primary mirror segments. At the time, those segments were not in alignment with each other, so the image effectively shows a single star from 18 different angles. The challenge was to align each mirror segment so that the star it sees coincides with the stars seen from the other mirrors to become a perfectly overlapping, single-star image.

The A/D and the Hubble Space Telescope (Hst)

Must we wait for the JWST telescope to be calibrated before we know if Dr. Lewyn's A/Ds work? No! While construction of the JWST was underway, a failure occurred in the electronics system for the Hubble Advanced Camera for Surveys (ACS) on January 27, 2007. The SIDECAR ASIC was selected to replace the original image processing system on the ACS, using Space Shuttle STS-125 HST Servicing Mission SM-4 in May 2009. This mission was successful, and now the x36 A/D array in SIDECAR currently processes all the image content from the 2 working channels of the ACS imager with lower noise and higher image fidelity than the previous electronics. The SIDECAR A/D array was also selected for the European Space Agency Euclid mission that is being launched in 2022 to map the geometry of the Dark Universe.

The A/D and Very Large (6-10m) Ground-Based Telescopes

As a result of the excellent overall performance of the SIDECAR signal processing system, it is currently deployed, or in the planning stage, for use with a new class of several large (6 – 10m) ground-based telescopes. In each camera application, it is paired with Teledyne HAWAII-



2RG 4 MP detectors. Several use an array of separate, guidable optical elements to reduce the effects of atmospheric distortion in order to begin the direct exploration of exoplanets. Most of them are in Chile, including the Gemini South 8.1m telescope on Cerro Pachon, the University of Tokyo Atacama Observatory (TAO) 6.5 m telescope on Chajantor, and the Magellan 6.5 m telescope pair (Baade and Clay) on Cerro Las Campanas. Also, two other large telescopes are in Mauna Kea, Hawaii: the Subaru 8.2 m telescope and the Keck 1 10 m telescope.

The Next-Generation A/D

When Dr. Lewyn was approached by NASA to provide an A/D array for the next generation Nancy Grace Roman Space Telescope ('The Roman'), he realized that his current architecture could not provide a 10x increase in speed while maintaining the same 1.5 mW power level as the JWST SAR-architecture A/D. He needed to start again.

Moving past the Roman requirement, he began a multi-year effort to design a next-generation A/D (Nex-Gen ADC) that was based on a pipeline architecture. A compelling reason for choosing a pipelined architecture is that the power efficiency of the high-gain op amp required for a SAR architecture is poor. While op amp power efficiency is optimum at a gain of 3, a pipeline A/D speed can be fastest when choosing a gain of 2, rather than 4. On the other hand, to achieve low INL and DNL, more innovative architecture, matching, and centroiding concepts were required for the capacitor weighting network arrays.

To take advantage of much higher speeds using advanced planar technology nodes, Dr. Lewyn updated his dimensionless layout design rule set. Improving lithographic fidelity, device matching, and eliminating odd-cycle errors using two-color decomposition were some of the objectives of the rule-set changes. A new basic device footprint and additional 'correct-by-construction features' were added to minimize systematic errors that are undetectable by simulation. Techniques similar to those used in sensitive linear

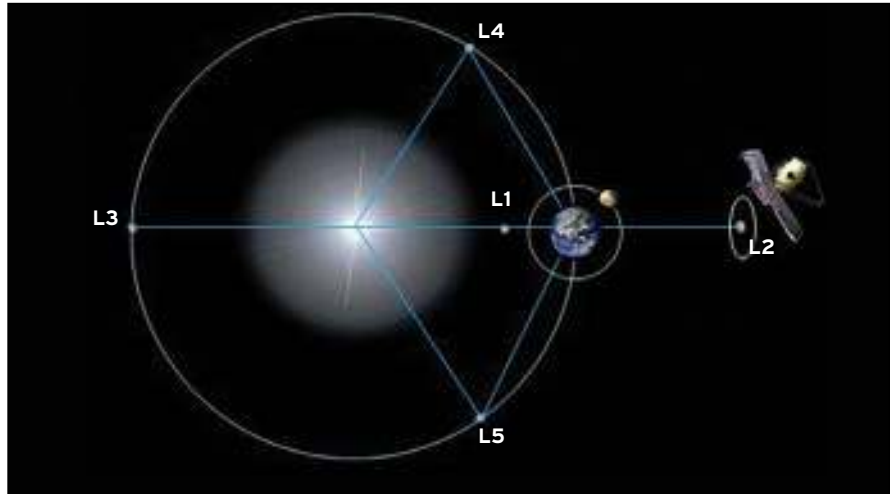


Figure 4. The orbit of the JWST around the Second Lagrange Point (L2) is quasi-stable, requiring a small amount of fuel to maintain position. The orbit around L2 permits the JWST batteries to recharge by the sun, when out of the earth's shadow. As a result of a highly accurate orbital insertion maneuver, the amount of fuel remaining may sustain observational accuracy for as many as 20 years, not the initial 10-year plan. (Source: NASA GSFC)

gy nodes, Dr. Lewyn updated his dimensionless layout design rule set. Improving lithographic fidelity, device matching, and eliminating odd-cycle errors using two-color decomposition were some of the objectives of the rule-set changes. A new basic device footprint and additional 'correct-by-construction features' were added to minimize systematic errors that are undetectable by simulation. Techniques similar to those used in sensitive linear

systems to provide substrate coupling isolation improved suitability for DoD applications that require radiation-resistant (rad-hard) technology.

The Nex-Gen 16b A/D is currently being ported into a multi-project-wafer (MPW) test chip system that will verify the design parameters of interest in two different basic versions. On this project, Dr. Lewyn is working co-operatively with IQ-Analog (a San Diego Microelectronics Company) using an advanced planar

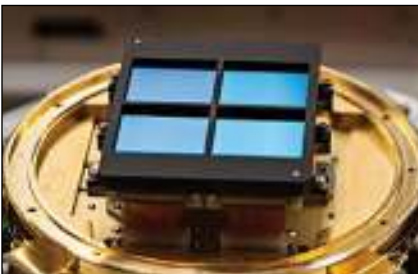


Figure 5. A single NIRCам sensor head is mounted on the Dewar for cryogenic temperature testing at 37 K, which is -236 °C. In the NIRCам a SIDE CAR ASIC is mounted directly behind each of the 4 Mpix photodetectors. (Source: U. Arizona)

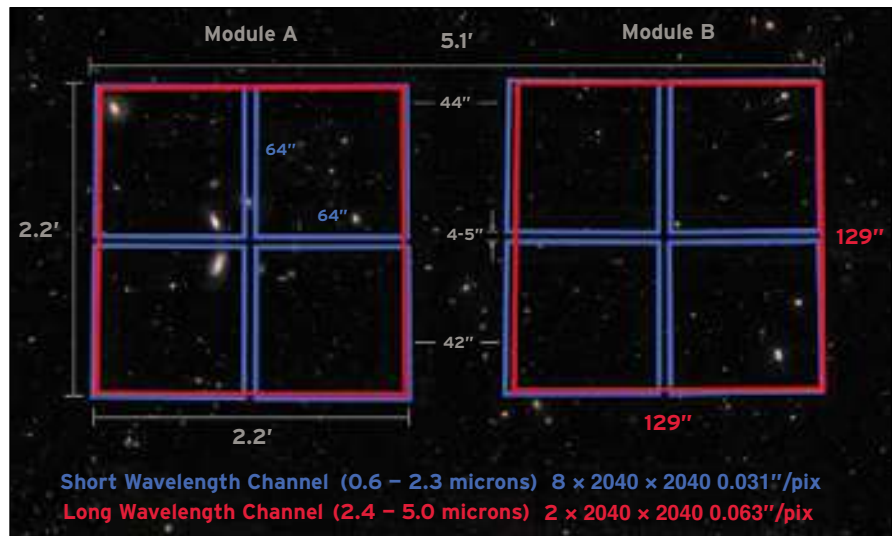


Figure 6. NIRCам imaging covers the two adjacent fields of total area 9.7 arcmin. The short wavelengths use four detectors (blue area) in each of the modules while long wavelengths are covered by two detectors (red area). (Source: Space Telescope Science Institute (STScI)).



Figure 7. The first published image taken by the James Webb Space Telescope shows a mosaic image created by a single sun-like star (HD84406) in the Ursa Major Galaxy, about 160 million miles away. It was created over 25 hours beginning on Feb. 2, 2022. It appears as many separate images because the 18 JWST mirrors were just beginning the alignment process. (Source: NASA)

CMOS technology. This technology is ten-times more advanced than what was available at design time for the JWST. The new A/D is also highly programmable so it can be optimized for a wide variety of applications without redesign. The narrow form-factor will permit its incorporation in a x32 array for multi-channel imaging, or alternatively, in multi-slice ultra-high-speed applications.

This article was written by Kenneth Martin President, Granite SemiCom Inc. (Toronto, Canada). For more information, visit <https://www.granitesemi.com>.

References

- 1 The sun is over 300,000 times heavier than the earth and contains 99.8 percent of the total mass of the solar system.
- 2 Professor Mead's text book, *Introduction to VLSI Systems*, co-authored with Lynn Conway, is widely credited for starting the VLSI Revolution. (Source: Wikipedia).
- 3 A 16-bit A/D converter outputs digital signals corresponding to 65,536 different levels of signal strength.

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Vibration Testing

NASA's X-57 Maxwell Electric Aircraft

It's not only automobiles that are going electric — airplanes are as well! And, to prove that aircraft can be electrically powered, NASA has developed the X-57 Maxwell, its first all-electric X-plane. The X-57 airplane, currently in the Mod II configuration, is a modified version of the Italian Tecnam P2006T. In place of the usual gasoline-powered motors, the X-57 has two all-electric motors powered by traction batteries. The X-57 Maxwell project has some lofty goals, including lower energy consumption (the X-57's motors use one-fifth the energy of a gasoline-powered aircraft), reduced emissions, and lower noise during flight.

The Challenge: Making It Real

As NASA engineers design new electrically powered aircraft, they must ensure that their designs not only use energy

efficiently but also that the aircraft can fly safely. One way they do that is to build an analytical model of the aircraft structure and simulate the stresses the aircraft will experience while in flight. By doing this, they can uncover weaknesses in their designs and fix them before making expensive prototypes. There's no substitute for physical ground testing, however. At some point, engineers must strap an airframe to a shaker and take some measurements. These physical tests are essential for validating the simulation models and understanding the structural characteristics of any new aircraft design.

A ground vibration test, or GVT, is performed before the first test flight is made. During a GVT, test engineers subject the aircraft to a number of different vibration profiles while measuring the response at hundreds of points around the airframe. Analyzing these measurements helps

engineers identify the modal frequencies and mode shapes of the airplane in a flight-ready configuration. This allows them to validate and update the aircraft's finite element model (FEM), which they will then use for flutter analysis predictions. In the end, the flutter analysis tells them whether or not a structure has the necessary aeroelasticity and flutter margins necessary for airworthiness.

Safety First

When running a GVT, it's important that the test article be as close to the final design as possible. This can lead to some interesting challenges for the test team. For example, during the GVT, the heavy and high-voltage electric motor batteries were not real. In normal operation, sixteen traction battery modules power the twin electric motors and amount to nearly a third of the airplane's total weight. To be safe, however, battery



mass simulators were used instead of energized batteries.

One challenge for the test team was to design and build simulators that have the same size, mass, and center of gravity as the actual batteries. They also had to be mounted to the fuselage in the same way as the actual batteries. Another challenge was that two battery control modules (BCMs) were not ready in time for the GVT. To get around this problem, NASA engineers designed and built two BCM mockup units. The BCM mockup units were lighter than the actual units, so the engineers added shot bags to bring the weight up to the expected flight weight. Weight is a crucial factor for modal characteristics, so the test team had to track missing weight and ballast areas when needed.

The airplane configuration for the GVT contained power cables in the wing in addition to other flight instrumentation cables and sensors (flight accelerometers and strain gauges). All the components were installed before the airplane arrived at NASA Armstrong. The airplane weight (including all of the GVT locking devices, hardware, and ballast) was measured at 2,782 pounds prior to installing the GVT external accelerometers.

Two Test Setups

Because the objective of this GVT was to test two main boundary conditions, there were two different test setups. The first setup, called the “soft support” system, was designed to simulate a free-flight environment. It used bungee cords to suspend the airplane at underside airplane hard points. This was a real challenge because manufacturers do not normally measure the characteristics of bungee cords for use in these kinds of tests. Prior to the GVT, NASA first performed numerous bungee characterization tests to ensure that the bungee cords selected could both handle the load and have a low enough frequency response to ensure separation from the first airplane modal frequency.

The second GVT setup was called the “on-tires setup.” For this test routine, the airplane had its landing wheels installed, and during the test, the aircraft rested on the ground. The tires were inflated to normal service pressures, and the airplane crew performed a shakedown of



Overview of GVT setup on the X-57 Maxwell Mod II Configuration. (Image: Courtesy of NASA)

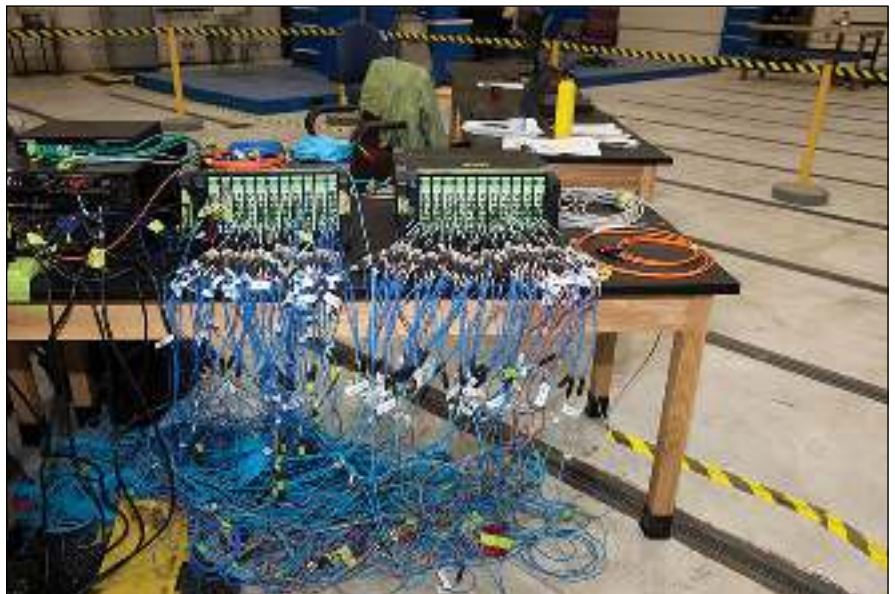
the airplane nose, tail, and wingtips to allow the struts to settle at equilibrium prior to testing.

Gearing Up

For the first test setup using the soft support system, also called the free-free setup, the team installed accelerometers at 127 different locations, which allowed them to measure 318 degrees of freedom (DOF). They distributed the accelerometers along both sides of the airplane fuselage, wing spars, control surfaces, motors and

soft-support frames (located at the main landing gear and the fuselage nose) using the global coordinate system of the airplane.

For the on-tires setup, they removed the accelerometers from the 14 locations on the soft-support system, leaving them with a total of 113 accelerometer locations, measuring 276 degrees of freedom. For both setups, they used both uniaxial and triaxial accelerometers, but the majority of the accelerometer locations were set up to measure two degrees of freedom. At these loca-



LAN-XI Mainframe #3 & #4 (two 5-slot mainframes).



Two of the LAN-XI Mainframes in Position for Testing.



Vertical Tail Lateral Excitation Location.

tions, they installed two uniaxial accelerometers or a triaxial accelerometer.

The accelerometers around the motors were very difficult to install because of the limited access and real estate around the electric motors. In addition to the GVT external accelerometers, they acquired data from the flight accelerometers using the airplane's instrumentation system and compared this to data gathered from the nearest GVT accelerometers.

To acquire data from these accelerometers, the NASA team used a 300+-channel LAN-XI data acquisition system from HBK. The LAN-XI is a modular data acquisition system and analyzer platform capable of acquiring sound and vibration data from more than 1,000 channels, with a wide dynamic input range, used in many demanding measurement applications. The NASA AFRC LAN-XI system includ-

ed four mainframes, two LAN-XI 11-slot mainframes near the nose of the airplane, where the main GVT control station was located, and two LAN-XI 5-slot mainframes at the rear of the airplane. The mainframes were daisy-chained together via a network switch.

Key components of the GVT data acquisition system included:

- Type 3660 Mainframes. This test system used both five-slot and eleven-slot mainframes. The 3660 mainframes provide both power and connectivity, as well as protection, for LAN-XI modules.
- Type 3053 12-Channel Input Module. This module was chosen because it provided a compact and cost-efficient solution for this application.
- Type 3160 Generator Module. This module was used because this application required system excitation. It is available with either two inputs and two outputs or four inputs and two outputs. All input and output channels have a frequency range of DC to 51.2 kHz.

14 Test Configurations, 191 Test Runs

NASA performed 191 test runs using 14 different test configurations. There were 11 different configurations that used the soft-support setup, two that used the on-tires setup, and one additional configuration that excited directly on the A-Frame lifting device that was part of the nose soft support system. The last configuration was added to characterize the A-Frame and ensure there was no coupling with the airplane modes of interest. The airplane remained suspended on soft supports for this A-Frame test.

To keep track of the process, a test configuration matrix was created that included the target modes, excitation locations and directions, number of shakers, and which locking devices were used as constraints in either the cockpit or the control surfaces. Throughout the testing, the test engineers relied heavily on this configuration matrix to ensure both primary and secondary test objectives were achieved. When running these tests, they used either one or two shakers appropriately placed for the test. Shaker locations are typically determined by the FE model.



Wing Tip Trailing Edge Excitation Location.

Acquiring and Analyzing Data

To run the tests and analyze the data, NASA used HBK's BK Connect software. BK Connect is an integrated software platform that enables users to acquire data, monitor a test or a structure in real-time, perform post-processing on acquired data, and then view, analyze and produce test reports. BK Connect allowed the NASA team to analyze the data without having to export the data to another software package.

The GVT results showed many airplane modes that did not show up in the pre-test Mod II FEM modal results. These missing FEM modes identified during the GVT will assist with the post-test model updating and correlation process. For example, the test uncovered modes exhibited by coupled airplane motion, wing torsion and control surfaces. In addition, the pre-test model did not include some components, such as the nose boom. The GVT test data will allow the X-57 project team to accurately add these components to the post-test model.

Summary

The GVT results gave NASA a much better understanding of the modal characteristics of the X-57 Mod II Maxwell configuration. The test showed that the pre-test airplane analytical model did not capture all the modes that were observed during the test. Updating the model to show these modes is going to be a challenge for the X-57 project team, but they now have the necessary modal test results to do it.

This article was written by Doug Lovelace, Business Development Manager, HBK (Marlborough, MA); Jack Gracia, Regional Sales Manager, HBK; and Natalie Spivey, Aerospace Engineer, NASA Neil A. Armstrong Flight Research Center (Edwards, CA). For more information, visit www.hbkworld.com

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Hybrid Circulators for mmWave Systems

When it comes to mmWave systems, science can only progress as far as compatible hardware will allow. This portion of the electromagnetic spectrum will unlock enormous potential for design engineers with the promise of vastly superior data speeds, capacity, and quality, all at low latency. However, the lack of high-performance components in the higher mmWave bands (50 GHz – 500 GHz) is limiting the ability to take full advantage of these frequencies.

NASA, for one, has invested a lot of energy in trying to solve the issue. One

focus has been on developing a new generation of mmWave circulators suitable for use in NASA instrumentation.

Circulators are primarily used in transmit-receive systems such as point-to-point radio and radar. They allow a transmitter and receiver to share a common antenna while simultaneously isolating the transmitter and receiver from each other. Thus, a high-power signal from a transmitter does not damage a sensitive receiver. The greater the isolation, the better. However, at the higher mmWave frequencies, the state-of-the-art Y-junction circulator is effective only within a very narrow bandwidth.

Using a Y-junction circulator can place a severe bandwidth limitation on the entire system.

In response to this challenge, Small Business Innovation Research (SBIR) Phase I and Phase II contracts were recently awarded by NASA to spur the development of a circulator with significantly higher bandwidth. This effort is paying dividends as a new circulator technology has recently been developed. This new type of circulator, dubbed the “hybrid circulator,” can theoretically cover entire waveguide bands with relatively low insertion loss and more than 20 dB of isolation. The



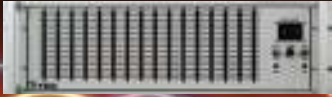
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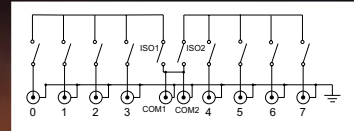
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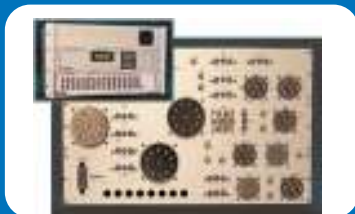
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NASA has invested a lot of energy trying to spur the development of high-performance components in the higher mmWave bands (50 GHz – 500 GHz), and recently awarded SBIR Phase I and II contracts to Micro Harmonics Corporation to develop a new hybrid circulator.

hybrid circulator will enable designers to push greater volumes of data through systems operating in the upper regions of the mmWave spectrum.

Stretching the Limits

The hybrid circulator is being developed by Micro Harmonics Corporation of Fincastle, VA. Their initial prototypes were designed to cover the 150 – 190 GHz band in WR-5 and were assembled and tested in early 2021. The measured insertion loss was less than 2.2 dB and the isolation was greater than 20 dB across the entire 150 – 190 GHz band.

For comparison, a state-of-the-art Y-junction circulator operating at 160 GHz has a 20 dB bandwidth near 3 GHz and a slightly higher insertion loss than the hybrid. The bandwidth of the hybrid circulator is thus an order of magnitude greater than that of the Y-junction.

The new hybrid circulator gives microwave engineers the option of specifying one component that can operate over multiple bands, making instrument architecture much easier. The hybrid circulators are quickly finding application. NASA's Cloud Radar System group — based at the Jet Propulsion Laboratory (JPL) in California — is currently exploring their use in weather radars. JPL utilizes circulators in their high-altitude aircraft and high-throughput satellite communication systems for measuring cloud properties and upper atmospheric constituents. Some of these systems operate in the G-band (167 – 175 GHz) with development also planned at frequencies near 240 GHz and beyond. Y-junction circulators are not manufactured at these frequencies due to the extreme sensitivity of the center frequency to small variations in the dimensions of the ferrite core. But

the hybrid circulator can easily reach the WR-2.8 band 260 – 400 GHz and possibly beyond.

Many industries have a need for wideband circulators at other mmWave frequencies: airport radar, telecommunications satellites, and high-speed point-to-point data links. Defense applications include bio-agent detection, battlefield radar, and wother IoT applications.

In radar applications, larger bandwidth makes it easier to discern a target in a given sweep. But for any application, wider bandwidths allow for more data that can be supported since the data rate is directly proportional to the amount of bandwidth around the carrier frequency.

Another problem facing system designers is that few vendors offer standard stock circulators operating in mmWave frequencies. This forces microwave designers to seek custom solutions with narrow bandwidths and long lead times. However, the development of the hybrid circulator will alter the landscape and open up new possibilities. In its partnership with NASA, Micro Harmonics plans to develop a full line of hybrid circulators operating in every standard waveguide band from 50 – 250 GHz over the course of the next two years. Beyond that, they plan to extend coverage to 400 GHz. These will not be custom solutions but rather off-the-shelf components. This is a case where science is driven by hardware availability.

Overcoming Bandwidth Limitations

The Y-junction has been the dominant circulator technology for more than 50 years. The Y-junction circulator comprises a magnetically biased ferrite core located at the convergence of three waveguides. But the hybrid circulator achieves the circulator function in an entirely different way that overcomes the inherent bandwidth limitations in the Y-junction.

Micro Harmonics' patent-pending design combines an orthomode transducer (OMT) with a Faraday rotator. Both the OMT and Faraday rotator are inherently broadband devices. When properly configured, these compo-



The hybrid circulators are quickly finding applications. NASA's Cloud Radar System group – based at the Jet Propulsion Laboratory (JPL) in California – is currently exploring their use in weather radars.



JPL utilizes circulators in their high-altitude aircraft and high-throughput satellite communication systems for measuring cloud properties and upper atmospheric constituents. Some of these systems operate between 167 - 175 GHz with development near 240 GHz and beyond. This is where hybrid circulators will be deployed.



New “hybrid circulators” can theoretically cover entire waveguide bands with relatively low insertion loss and more than 20 dB of isolation. The hybrid circulator will enable designers to push greater volumes of data through systems operating in the upper regions of the mmWave spectrum.

nents interact to create the circulator function over full rectangular waveguide bandwidths.

The Final Frontier

While opening up mmWave bands for terrestrial applications, hybrid circulators also possess characteristics that qualify them for deep space. Improve-

ments in amplifier technology are allowing higher and higher transmit power levels. But when high-power signals are used in a vacuum, such as seen in space, the problem of “multipaction” can arise.

Multipaction is a phenomenon where charged particles are accelerated by high-power RF signals and strike a

conducting surface with high kinetic energy. At low energies, the charged particles are absorbed on the surface. But if the energy is sufficient, additional charged particles are liberated from the surface and an avalanche in the number of particles can occur. Multiple high-energy impacts can damage the conductor surfaces and can cause permanent damage to the system.

The designers at Micro Harmonics are using sophisticated simulation tools to determine the power levels at which multipaction may become an issue in the hybrid circulator. To date, the simulations indicate that the multipaction phenomenon may occur in the WR-5 hybrid circulator at power levels exceeding 30 kW. This is far more power than is currently available from sources in the WR-5 band including high-power TWT amplifiers.

As industry obtains greater access to discrete components like hybrid circulators that can perform in the higher mmWave bands, design opportunities arise for microwave applications approaching the Terahertz range. The sky is becoming the limit.

This article was written by Greg Rankin, Freelance Technical Writer. For more information, visit <https://www.microharmonics.com>.



Transforming Battlespace Communications

On the other side of the U.S. Army's milestone multi-orbit antenna trials, the government's modernization initiative took a timely big step toward unprecedented network resiliency just as adversarial threats reach a fever pitch. The Russian invasion in Ukraine has certainly raised the security stakes and

intensified the need for simultaneous communications streams over a single platform, to keep connectivity flowing in the event of intentional jamming, cyberattacks, kinetic attacks, interference, and outages.

Isotropic Systems has just completed a series of situational communications

tests over its new multi-link terminal that consistently prove the ability to either run redundant or complementary communications links concurrently over GEO, MEO and LEO orbits. NATO forces can deliver mission-critical HD video surveillance of targets over LEO-based satellite links, for example, while intelligence data is distributed over the same antenna at the same time over high-speed GEO and MEO links to warfighters on the frontlines. If communications is cut off to one satellite for any reason, the user can instantly route traffic over one of the other established links, even if they are in a completely different orbit, using a single antenna.

Here's the simplest way to think about it. One multi-link antenna acts like multiple physical terminals by creating concurrent full performance links to multiple satellites. U.S. Government agencies and military forces currently use one antenna to point to one satellite and unfortunately require a second, third and fourth antenna to provide redundant links. They can now use one antenna that meets DoD JADC2 (Joint All-Domain Command & Control) and the U.S. Army's CS25 and CS27 requirements, utilizing new deep tech called transformational optics to provide concurrent full-performance links to multiple satellites in multiple orbits for a new level of powerful, secure communications.



Isotropic Systems' multi-link terminal has successfully linked with multiple satellites in multiple orbits.



On the Heels of Breakthrough Trials

Isotropic Systems' multi-link antenna enabled voice, video, and data transmissions over concurrent two-way connections to SES satellites in geosynchronous (GEO) and medium Earth (MEO) orbits during military-grade trials at the U.S. Army's proving grounds in Aberdeen, Maryland. The terminal has also opened the door to all-orbit connectivity following successful tests that delivered bi-directional traffic over Telesat's phase 1 low Earth orbit (LEO) satellite while concurrently transporting communications over a GEO satellite.

The links coming from this single terminal use patented optics lens technology to simultaneously point to different satellites over different frequencies across commercial, government and military networks — all without compromising performance. These trials will lead to the commercial rollout of the first military-grade, multi-link mobility Ka-band antenna later this year. The GM2000 terminal unlocks highly anticipated communications capabilities not only for defense initiatives but ultimately across a wide range of sectors including maritime, enterprise, government, and land mobility markets.

How it Works

Commercial and government engineers have tried to develop full-performance multi-link antennas for years. When Isotropic Systems initiated the development of their platform, they took a unique approach by pioneering a new deep tech sector called transformational optics.

They started by determining the exact behavior they wanted from RF energy, radio waves. That resulted in a series of equations that defined what needs to happen within a specified shape to get that desired behavior. Once they solved those equations, however, what they ended up with is material that actually doesn't exist in nature. That's a problem if you want to make a real antenna from it!

Some workarounds to this challenge included using metamaterials, but they come with the significant drawbacks of being lossy and narrowband. One way

to solve those equations was by using broadband, low-loss, isotropic (hence the name) materials. Ultimately, they ended up with a unique optimal beam former design that is at the core of all their multi-link antenna products.

In essence Isotropic Solutions is enabling what the satellite industry forgot to do a long time ago — mesh satellite networks together to allow for empowering levels of interoperability. Can you imagine carrying five cell



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phones in your pocket for every time you move from one cell network to another? That's exactly how the satellite networks work today — in proprietary silos.

Interoperability across satellite systems is more important than ever, especially for government and defense networks who need to access the plethora of new satellites and constellations coming online in GEO, MEO and LEO orbits to realize the flexibility and resiliency they must have in today's adversarial environment. The ability to provide multiple full-performance links also means the military can multiply the throughput to the terminal and dramatically increase the bandwidth that every front-line warfighter has at their fingertips. Once this mission-critical multi-link platform is running, there's an endless combination of possibilities for leverag-



An Isotropic Systems-connected military Humvee in action

ing multiple links and services in support of NATO forces — especially with the growing number of sensors across the battlefield.

Resiliency and flexibility across a military comms network will offer a competitive edge and save lives. If a unit outfits

all its Humvees with a terminal that can only connect to a specific network, enemy forces can easily take down communications capabilities across that fleet. A multi-layered, fully integrated terminal makes an adversary's decision matrix inherently far more complex and extremely tough to knock out your comms-on-the-move and comms-on-the-pause.

As the government's modernization initiative takes shape, multi-linked antennas capable of delivering a new age of multi-layered, multi-orbit connectivity will be at the core of the military's competitive edge in the very near future.

This article was written by Brian Billman, Chief Marketing Officer, Isotropic Systems (Washington, DC). For more information, visit <https://www.isotropicsystems.com>

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Tech Briefs

Pulsed Exposure Toxicity Testing: Method Development and Initial Evaluation for Stormwater Compliance

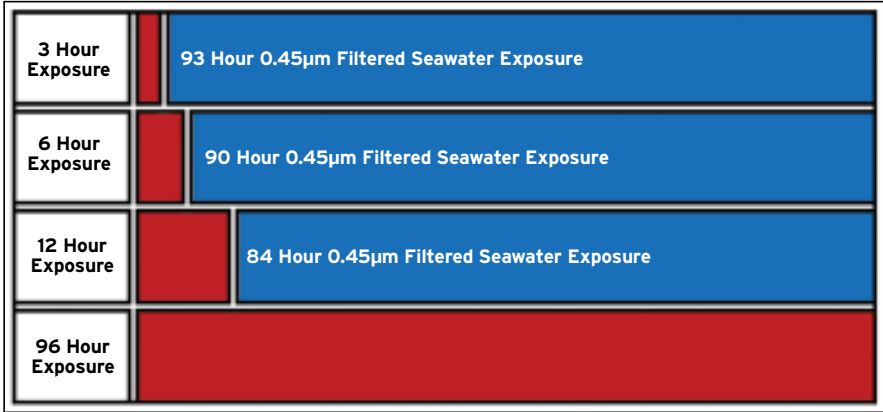
Preliminary research into modifying whole effluent toxicity (WET) testing protocols designed for continuous flow discharges as applied to episodic and/or ephemeral discharges such as those associated with storm water runoff.

Naval Information Warfare Center Pacific, San Diego, California

This report describes a preliminary research effort to modify whole effluent toxicity (WET) testing protocols designed for continuous flow discharges for application to episodic and/or ephemeral discharges such as those associated with storm water runoff. The effort was undertaken in response to a Naval Base San Diego industrial stormwater National Pollutant Discharge Elimination System (NPDES) permit (R9-2013-0064) condition that allows the Navy to assess and propose alternative testing parameters. This research (at the time it was conducted) was done for Naval Base San Diego by environmental toxicologists at the Navy's Space and Naval Warfare Systems Center Pacific (SSC Pacific).

The technical approach taken was to modify the WET testing method to simulate a range of exposure conditions found at the end-of-pipe. The test conditions matrix included: acute and chronic endpoints with commonly used test organisms; copper, zinc, and a combination of the two toxicants at various concentrations found to cause toxicity under standard WET testing; and short-term exposure conditions representing the 50th, 75th, and 95th percentile historical rainfall durations observed in San Diego over the past 55 years. The initial testing culminated in its application to multiple stormwater samples collected from Naval Base San Diego outfalls during a single rain event in March 2016. All testing was conducted concurrently with standard test method durations for comparison.

Chronic toxicity tests with purple sea urchin (*Strongylocentrotus purpuratus*) embryos and acute toxicity tests with the mysid shrimp (*Americamysis bahia*) were performed using standard Environmental Protection Agency (EPA)



Pulsed exposure experimental design.

96-hr continuous exposures alongside pulsed exposures of 3, 6 and 12-hr toxicant exposures, followed by transfer to uncontaminated seawater for the remainder of the 96 hr. Copper, zinc and a combination of the two were tested at concentrations ranging from 5.8 to 3,200 µg/L and 20 to 20,880 µg/L for copper and zinc, respectively. Copper and zinc were selected as these are commonly elevated constituents and often the cause of toxicity in stormwater at San Diego Naval Bases and other non-Navy stormwater discharges. Additionally, stormwater samples collected from Naval Base San Diego were tested in a similar manner using the standard and modified EPA methods.

Toxicity tests with single and mixed metals, and stormwater samples, resulted in progressively lower toxicity with reduced contact time to the sample when compared to standard static 96-hr exposures. The effect was more pronounced for zinc than copper for both test species. Median effective concentrations (EC50) ranged from a factor of 2 to 186 higher (less toxic) under the pulsed conditions relative to the standard 96-hr exposure. Stormwater

samples collected from NBSD consisted of a wide range of copper and zinc concentrations. As with the copper and zinc tests, the stormwater results also showed a consistent progressively lower toxicity with reduced contact time to the sample.

The results of this study showed that modifying standard WET test methods is a feasible approach to accurately access short-term exposure conditions. The tests, which were conducted over a range of realistic conditions for both a chronic and acute endpoint presented consistent results lending confidence in their application. All the tests displayed a significant progressive reduction in toxicity with decreasing exposure time. The toxicity determined with standard 96-hr static tests overestimated that of short-term exposures over a wide range (<1 to 2 orders of magnitude) depending on the exposure duration, toxicant, and endpoint evaluated. The implication is that exposure duration is as critical a testing condition as the exposure concentration when evaluating toxicity.

Although the test procedures focused on exposure conditions likely to occur



at the end-of-pipe, those conditions are still conservative in comparison to actual exposures that occur once the stormwater is discharged to, and mixes with, receiving waters.

This work was performed by Gunther Rosen, Molly Colvin, Chuck Katz, Jacob Munson-Decker, and Nicholas Hayman for the Naval Information Warfare Center Pacific (NIWC Pacific). For more

information, download the Technical Support Package (free white paper) at mobilityengineeringtech.com/tsp under the Test & Measurement category. NUWC-0012

Upgrade Transonic Compressor Test Rig Data Acquisition System

New software programming using commercial off-the-shelf software for acquiring data, processing data, displaying results, and generating reports is implemented to improve the performance of a legacy system.

Naval Postgraduate School, Monterey, California

The Naval Postgraduate School (NPS) has frequently used the transonic compressor test rig (TCR) to test new axial transonic compressor rotors and casings for design and performance improvements. Technology has improved the ability to create more detailed designs and has led to an increase in testing at NPS. While the rotors and casings produced are becoming more advanced, the data acquisition system (DAS) used to measure the performance of these products became slow and outdated in comparison to currently available DAS products.

Consequently, this work involves the procurement, design, and implementation of upgrades to the current DAS.

The TCR diagram in Figure 1 consists of a transonic axial rotor mounted on a single shaft with two opposed rotor, single stage air-operated drive turbines. The turbines are powered by supply air from an Allis Chalmers compressor. Atmospheric air is drawn into the inlet plenum and throttled via an electrically actuated butterfly valve; it then passes through the settling chamber, flow rate nozzle and finally to the transonic axial rotor where it is expelled back to the atmosphere.

Mass flow is measured by a flow rate nozzle placed just aft of the settling chamber depicted in Figure 1. Inlet stagnation pressure and stagnation temperature are measured with two combination-probes. A static pressure port measures inlet static pressure. Outlet stagnation pressure is measured with eleven Kiel pressure probes and nine combination-probes. Outlet stagnation

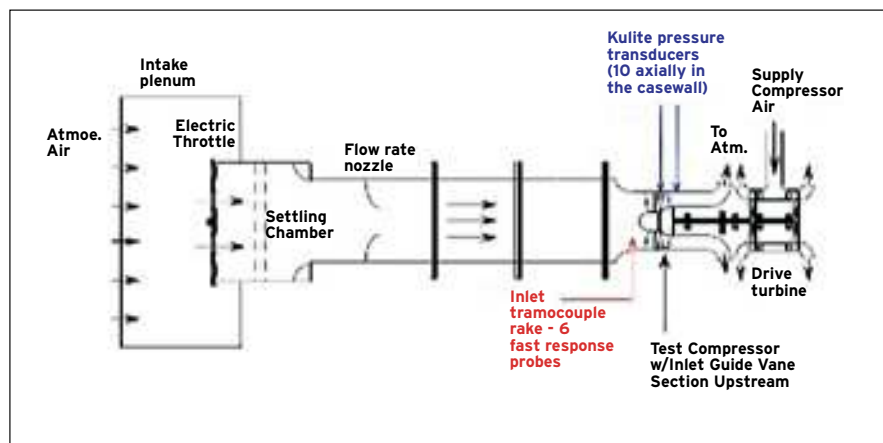


Figure 1. Transonic Compressor Test Rig Design.

temperature is measured by the nine combination probes. Static pressure is measured with four static pressure ports in the hub, and two static pressure ports in the casing. Inlet measurements are taken at AS1 and outlet measurements are taken at AS3, as shown in Figure 2.

Throughflow analysis of the TCR utilizes the stream-tube method. Probes measure streamlines of the stream-tube at stations AS1 and AS3. The probes are placed at various radial placements to create inlet and outlet pressure profiles. The stage or rotor performance is calculated using the mass flow rate and circumferentially mass averaged pressures and temperatures. The throughflow analysis provides the stagnation pressure ratio, isentropic efficiency, and power. The experimental results were compared to the isentropic, or idealized, results as a useful measure of the compressor's performance.

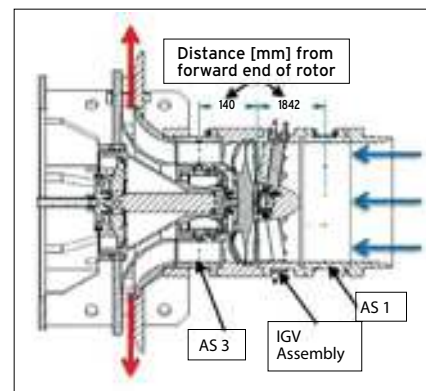


Figure 2. Probe Positions of the Test Section.

This work was done by Thomas D. Belna for the Naval Postgraduate School. For more information, download the Technical Support Package (free white paper) at mobilityengineeringtech.com/tsp under the Test & Measurement category. NPS-0025



Electrokinetics Models for Micro- and Nano-Fluidic Impedance Sensors

Microfluidics- and nanofluidics-based impedance sensors play an important role in the identification of toxic industrial chemicals and pathogens in the biodefense and biodefense arena, but their efficient modeling and design continues to be a challenge.

Army Research, Development and Engineering Command, Redstone Arsenal, Alabama

Exposure to toxic industrial chemicals (TICs) and pathogens has been acknowledged to pose a significant risk to mission capability and warfighter health. Due to their salient fieldability, microfluidics- and nanofluidics-based impedance sensors are increasingly finding favor in the biodefense and biodefense arena. However, their efficient modeling and design continues to be a challenge.

Analytical models describe the electric field distribution around the sense electrodes without consideration of the electrokinetic transport. Traditional

equivalent circuit models, constructed by sets of primitive Differential-Algebraic Equations (DAEs), used to process and interpret the experimentally measured electrical impedance data are less useful for sensor design, in particular for nanofluidic sensors that can feature overlapped electric double layers (EDLs). Numerical analysis approaches (e.g., finite element and finite difference) have also been utilized for high-fidelity analysis, design, and interpretation of impedance sensors with the focus on a single suspension cell.

In this context, high-fidelity models were used to resolve the electrokinetic transport process at the micro- and nanoscale and to interrogate the sensor performance subject to the variations in design parameters (such as medium concentration and conductivity, microchannel feature sizes, and fluidic manipulation). The models were verified by experimental data and can be used for fast, accurate analysis and design of micro- and nano-impedance sensors. The modeling framework presented here can be utilized to guide sensor design and protocol develop-



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ment of biodetection technologies, and also to interpret the experimental data/observations for technological refinement.

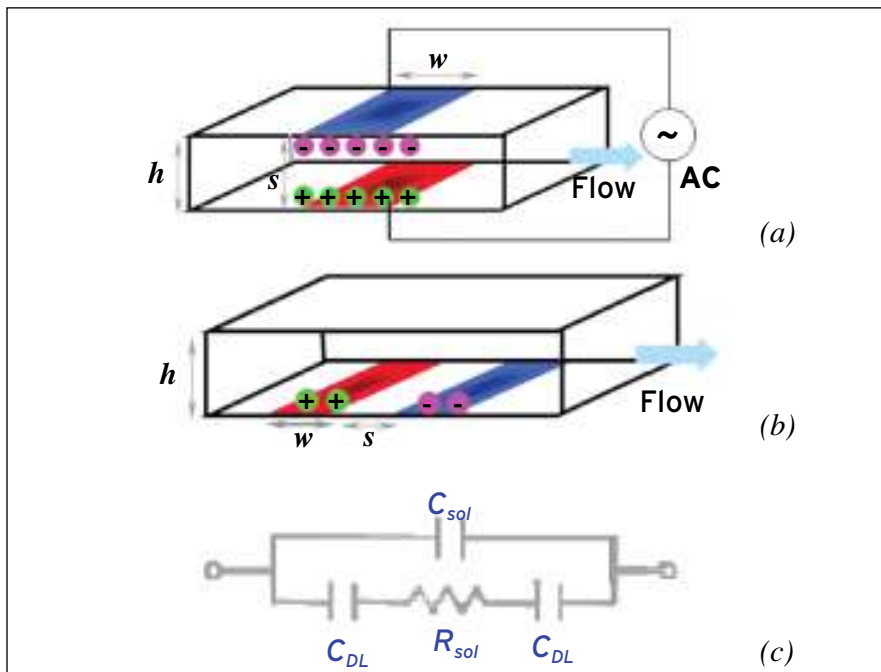
The accompanying figure illustrates the principle of impedance-based molecular detection. The solution containing the analytes of interest is introduced into a microfluidic or nanofluidic environment (a). A pair of electrodes is energized with an AC field (characterized by a voltage and

frequency). The induced current is related to the applied voltage and impedance of the system, which in turn is dependent on the composition of the solution (presence or absence of target agents).

In an analogy to electrical circuit theory, we can consider impedance in the solution as a combination of resistance and capacitance, with the solution acting as a resistor (R_{sol}), while the Electric

Double Layer (E_{DL}) at the electrode surface and the solution in the channel act as capacitors (C_{DL} and C_{sol}). The equivalent electrical circuit and resistor-capacity connection is illustrated in Figure (c). The concentrations of analytes and electrolytes impact the impedance in two ways: (1) Resistivity (or resistance) of the solution is a function of its electrical conductivity and, hence, depends on electrolyte and analyte concentrations; (2) E_{DL} capacitance is a function of double layer thickness (which in turn is a function of electrolyte concentration) and surface charges at the electrode. Therefore, when a sample with different ionic compositions is flowed through the system, it changes both the E_{DL} capacitance and the solution resistance. The changes are reflected in the form of a disturbance (called “differential current”) to the induced base current.

This work was done by Yi Wang, Hongjun Song, Ketan Bhatt, and Kapil Pant of CFD Research Corporation; Monserrate C. Roman of NASA Marshall Space Flight Center; and Eric Webster, William Diffey, and Paul Ashley for the Army Research, Development and Engineering Command. **For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the DAQ, Testing & Sensors category.** ARDEC-0008



Principle of micro- and nano-impedance-based chemical sensors (a) Microstrip design (b) Coplanar design (c) Equivalent circuit model

Evaluation and Test Requirements for Liquid Rocket Engines

This Standard establishes test and evaluation requirements related to the development, qualification (or certification), and acceptance (flight production unit) of liquid propellant rocket engines and associated propulsion systems.

Air Force Space Command, El Segundo, California

The primary objective of any test program is to maximize the probability, within programmatic constraints, that the flight design will function properly and successfully when used in actual service for the intended application. Flight risks are mitigated via prudent and effective analysis and testing. While analysis can sometimes be used in place of test, proper analytical techniques uti-

lize test data as the basis for model correlations. The combination of analysis and test verification is used for both qualification of the LRE design as well as workmanship verification of each LRE flight unit.

Certain key tenets of testing have served the liquid propulsion test community well as it has tried to accomplish that objective. One particular

“tried and true” philosophy is the “Test-Like-You-Fly” (TLYF) approach. TLYF means that testing should demonstrate engine operation with flight-representative hardware and under flight-representative conditions, including expected worst-case conditions. The overall test program should encompass and explore as much of the operational flight envelope as possible



on the flight design to accomplish the ideal objective to avoid operating any particular flight hardware configuration under any particular set of conditions for the first time in flight.

Some flight environments (e.g., acceleration) cannot be replicated during ground test. Margin testing with respect to the expected flight conditions should be included to protect against known and unknown uncertainties in the flight conditions (e.g., ground-to-flight dispersions), as well as known, anticipated, and unknown hardware variations (e.g., manufacturing tolerances, non-conformances, and undetected deficiencies).

If it is impractical to test or simulate a particular flight condition on the ground, then additional margin may be appropriate. Furthermore, testing should consider and account for engine hardware experience and exposure throughout all phases of the required life cycle, including manufacturing, acceptance testing, transportation, handling, storage, vehicle integration, checkout testing, launch preparations, aborts, liftoff, and flight. Exceptions to this approach should be carefully evaluated and include a risk determination. It is prudent that LREs be deliberately designed to provide margins equal to or greater than the specified margin test requirements so as to provide high probability for test success and high reliability for flight operations.

A corollary to TLYF is the “fly-as-you-test” approach. “Fly-as-you-test” means that flight operation should remain within demonstrated ground-tested and qualified regimes, and that design and process differences between qualified test hardware and flight hardware should be minimized and ideally avoided. A successful development and qualification program will anticipate all potential flight conditions and ensure those conditions are validated by a robust test program. If an engine has multiple applications, ideally the engine should be developed and qualified to the most demanding requirements, however programmatic considerations may dictate a phased approach.

Hot-fire testing to verify that an LRE design is ready for flight typically consists of four phases of major program

activity: prototype testing, development testing, qualification testing, and integrated system testing. The first three test phases typically occur at the component level as well as the engine level. The integrated system testing phase is

performed at the propulsion system and/or vehicle level.

After an LRE design has completed the qualification program (i.e., production phase), each individual flight engine is acceptance tested by hot-fire to verify



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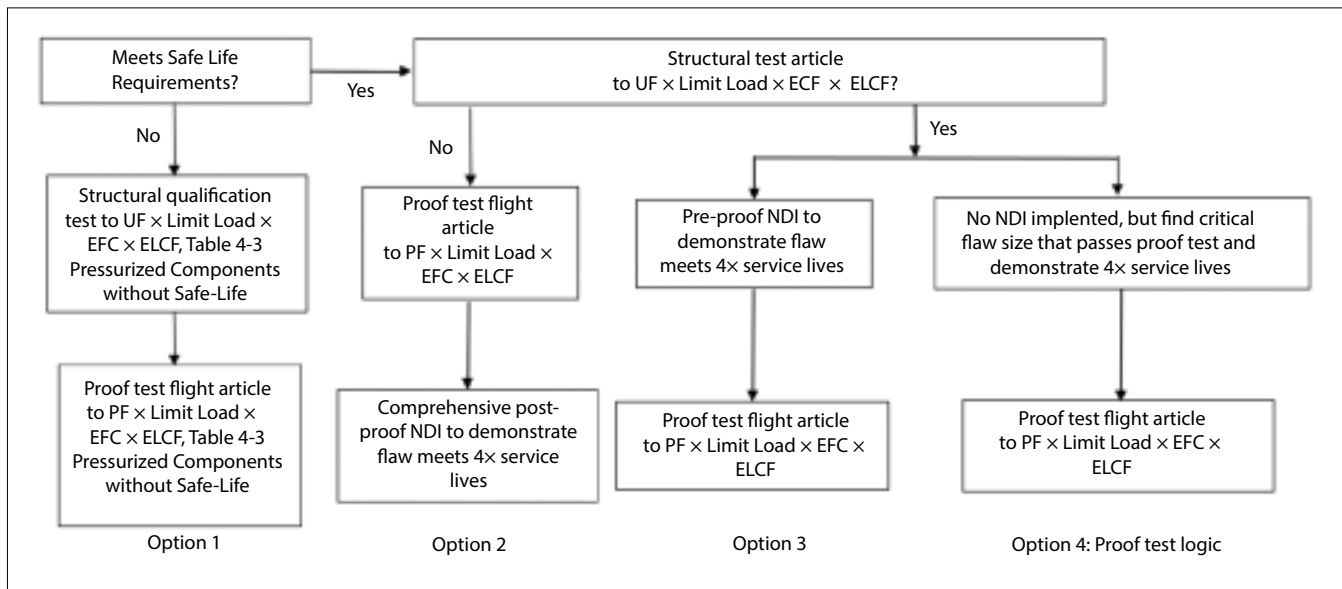
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Qualification strategies for engine elements, excepting qualification by analysis (no test option), and by similarity. (ECF - environmental correction factor; ELCF - external load correction factor; UF - Ultimate Factor; PF - Proof Factor)

that specific engine's suitability for flight. Prelaunch operational testing is performed prior to engine start and lift-off to verify readiness for launch. Finally, additional testing can be performed or additional data obtained for the system during the operational phase of a test flight or actual space launch mission.

Specific requirements are placed upon qualification, production unit acceptance testing, and integrated system testing. There is an allowance, and in

fact an expectation, that engines not meeting the full requirements of qualification will be used as a part of the overall design verification effort to increase the sample size of suitable engines. "Verification engines" include qualification engines and may also include development engines that are structurally and functionally equivalent to the qualification and flight design. Hereafter, references to the qualification requirements are meant to include test-

ing on formal qualification engines as well as development engines that are suitable as verification engines.

This work was approved by Nick Awwad, David Davis, and Thomas Fitzgerald for the Air Force Space Command. **For more information, download the Technical Support Package (free white paper) at mobilityengineeringtech.com/tsp under the Test & Measurement category.** AFSC-0001

GPS Radio Occultation and Ultraviolet Photometry-Colocated (GROUP-C) Early Orbit Testing Results

After routine flight, capture, and installation, GROUP-C underwent Early Orbit Testing to verify its performance prior to science operations.

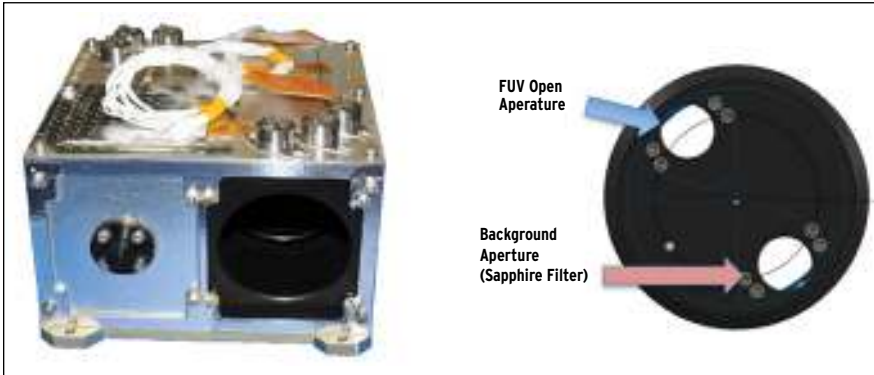
Naval Research Laboratory, Washington, DC

The GPS Radio Occultation and Ultraviolet — Colocated (GROUP-C) experiment was originally conceived in 2010 as a CubeSat mission, combining a compact GPS occultation receiver and high-sensitivity far-ultraviolet (FUV) photometer experiment to be flown as a Space Test Program experiment. The concept was to incorporate a commercial off-the-shelf GPS receiver and a

small second-generation FUV photometer to replicate the space weather portion of the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC/FORMOSAT-3) mission at lower cost. In the same time-frame, the Air Force Space and Missile System Center initiated the Space Environment NanoSatellite Experiment (SENSE) to demonstrate several CubeSat

technologies for space environment sensing, which included the Compact Tiny Ionospheric Photometer (CTIP) and the Compact Total Electron Content Sensor (CTECS).

The SENSE effort eased the urgency of demonstrating CubeSat technology using GROUP-C. When the opportunity arose in 2013 for GROUP-C to fly on Space Test Program Houston Pallet #5



(Left) The refurbished TIP for GROUP-C included optical, electrical, and surface treatment changes for the STP-H5 mission. (Right) The GROUP-C TIP filter wheel is larger in diameter, printed from black Ultem® plastic, and includes both an open aperture and a sapphire filter for red-leak monitoring. The outline of the original, smaller filter wheel is in blue.

aboard the International Space Station (ISS) with the volume, power, and weight constraints removed, the experiment more narrowly focused upon demonstrating second-generation space environment sensors.

Space experiments have relied on 135.6 nm emission to characterize the F-region nighttime ion density for decades, operating on the principle of spectrally isolating the useful 135.6 nm recombination emission from unwanted

nightglow. Nearly twenty years ago, NRL introduced the concept for a new class of compact, high-sensitivity ionospheric 135.6 nm sensors designed for the COSMIC mission. The COSMIC retrievals of ionospheric density and height from occultation data typically assume ionospheric spherical symmetry with no horizontal gradients in the vicinity of the occultation. The presence of horizontal ionospheric gradients can introduce errors into the inversion and lead to inaccurate retrieval results. However, these ionospheric gradients can be characterized using horizontal photometry and supplement GPS occultation results, but the sensor sensitivity should be at least 100 counts $s^{-1} R^{-1}$ to have sufficient signal-to-noise to impact and improve the GPS retrievals. The COSMIC TIP sensors fulfilled their role as pathfinders for nighttime ionospheric photometry; however, these low-cost, first-generation instru-

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ments exhibited some shortcomings of the sensor design and its performance on the COSMIC microsattellites.

The first problem revealed during pre-flight tests was red leak, which refers to weak residual sensitivity of the 135.6 nm FUV photometer to detect unwanted longer wavelengths, including visible light ("redder" than ultraviolet). On-orbit, the flaw manifested itself as observations of city lights and moonlit clouds that contaminated nighttime ionospheric signals. The second problem involved scattered light, both external to the TIP sensor assembly and within the TIP optical train. Aboard the crowded, compact satellite bus, TIP viewed the nadir through a jagged port-hole, and an antenna from another experiment was close to the field-of-view. Inside the instrument several components included stainless steel and iridized aluminum surfaces, which have

poor FUV reflectivity, but significant reflectivity in the visible. The impact of this visible scattered light was that the photometer could not operate near the twilight, and the scattered light potentially increased red-leak sensitivity.

The GROUP-C experiment included an upgraded, second-generation TIP module, a refurbished qualification unit from the COSMIC program. Several modifications were made to the TIP optical train to mitigate the scattered light and red-leak problems identified during the COSMIC mission (Figure Left). First, a larger, visibly black filter wheel and black anodizing of the detector housing was implemented to reduce visible scattering and red-leak. A filter overlay was generated using 3D printing of vacuum-rated black Ultem® polyetherimide plastic with only two filter apertures: one aperture open to collect FUV signal, and the other a sapphire window for monitoring red-leak contamina-

tion (Figure Right). Sapphire passes radiation longward of 145 nm, which allows monitoring the contamination alone, without the 135.6 nm ionospheric signal. By differencing the measurements through the open aperture (135.6 nm + red leak) and the sapphire filter (red leak only), the FUV ionospheric signal can be determined. Finally, aboard the STP-H5 pallet TIP did not view through a jagged hole nor have a dipole antenna near the field-of-view.

This work was done by Scott A. Budzien, Andrew W. Stephan, Todd E. Humphreys, Steven P. Powell, Brady W. O'Hanlon, and Rebecca L. Bishop, for the Naval Research Laboratory. For more information, download the Technical Support Package (free white paper) at mobilityengineeringtech.com/tsp under the Test & Measurement category. NRL-0081

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Tuesday, August 23, 2022 at 2:00 pm U.S. EDT

Integration of modeling and simulation in a common platform enables rapid evaluation of airframe design changes. This 60-minute Webinar will discuss how an airframe that is subject to design modification can be evaluated for structural performance.

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Webinars on Demand!

The Impact of SOSA on Military Computing

The Sensor Open Systems Architecture (SOSA) is a relatively new standard being driven by the Air Force, Army, Navy, and various government agencies to develop a unified, technical, open systems architecture standard for complex systems such as radar, EO/IR, SIGINT, electronic warfare, and communications. SOSA has gained incredible traction in just a couple of years, with many defense contractors having already demonstrated working hardware and software.

This 60-minute Webinar from the editors of *Aerospace & Defense Technology* highlights some of the most recent technical advances driving SOSA forward.

Speakers:



Bob Collopy
Technical Marketing Manager,
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Rodger Hosking
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Mark Littlefield
Senior Manager,
Embedded Computing Projects
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Vice President of Technology,
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Full-Scale Micro-Launcher Rocket

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Orbex has unveiled the first full-scale prototype of the Prime orbital space rocket on its dedicated launch pad publicly for the first time.

The unveiling of the first of a new generation of European launch vehicles — designed to launch a new category of very small satellites to orbit — represents a major step forward for the British rocket company as it prepares for the first ever vertical rocket launch to orbit from UK soil. Orbex's Prime rocket is the first 'micro-launcher' developed in Europe to reach this stage of technical readiness.

With the first full integration of the Orbex rocket on a launch pad now complete, the company is able to enter a period of integrated testing, allowing dress rehearsals of rocket launches and the development and optimization of launch procedures. Orbex recently revealed their first test launch platform at a new test facility in Kinloss, a few miles from the company's headquarters at Forres in Moray, Scotland.

Prime is a 19-meter long, two-stage rocket powered by seven engines that is being designed and manufactured in the UK and Denmark. The six rocket engines on the first stage of the rocket will propel the vehicle through the atmosphere to an altitude of around 80 km. The single engine on the second stage of the rocket will complete the journey to Low Earth Orbit (LEO), allowing the release of its payload of small, commercial satellites into Earth's orbit.

Uniquely, Orbex Prime is powered by a renewable bio-fuel, bio-propane, supplied by Calor UK. This fuel allows the rocket to reduce carbon emissions significantly compared to other similarly sized rockets being developed elsewhere around the world. A study by the University of Exeter showed that a single launch of the Orbex Prime rocket will produce 96 percent lower carbon emissions than comparable space launch systems using fossil fuels. Prime is also a reusable rocket that has been engineered to leave zero debris on Earth and in orbit.

Orbex Prime will launch from Space Hub Sutherland, a new spaceport being constructed on the North Coast of Scotland. Space Hub Sutherland was the first vertical spaceport to receive planning permission in the UK and will be the first European spaceport brought into operation later in 2022. It is also the first and only spaceport worldwide that has committed to being carbon-neutral, both in its construction and operation.

"We are on the cusp of an historic moment, with Orbex playing a leading role in generating a brand new launch capability in the UK, while creating opportunities for people and businesses across the country," said Ian Annett, Deputy CEO of the UK Space Agency. "I can't wait to see Prime lift off from Space Hub Sutherland."



The market for small satellites is increasing rapidly, as a wide range of new small satellite constellations are developed and deployed. Micro-launchers such as Orbex Prime give satellite manufacturers a dedicated launch service, in contrast to larger, 'rideshare' launchers, where small satellites are often a secondary payload, and frequently face significant delays.

Orbex is a UK-based spaceflight company with headquarters, production and testing facilities in Scotland, and design and testing facilities in Denmark. Orbex staff members have professional backgrounds with NASA, ESA, Ariane and several commercial spaceflight organizations. The company is now funded by two of the UK's largest and most active venture capital funds, BGF and Octopus Ventures, who join two of Europe's largest venture capital funds, Heartcore Capital and the High-Tech Gründerfonds, as well as strategic investor Elecnor, parent company of Deimos Space, the UK Space Agency (UKSA), the European Space Agency (ESA) and the European Commission Horizon 2020 program.

For More Info Visit <http://www.orbex.space>



Cryogenic Thermal Subsystem

**Space Dynamics Laboratory
Utah State University
North Logan, UT
435-713-3400
www.sdl.usu.edu**

Utah State University's Space Dynamics Laboratory announced recently that it has delivered a critical subsystem to NASA's Jet Propulsion Laboratory for integration onto the Nancy Grace Roman Space Telescope. The Cryogenic Thermal Subsystem for the Roman Coronagraph Instrument was delivered to JPL at SDL's facilities on USU's Innovation Campus.

SDL designed, built, tested, and delivered the Cryogenic Thermal Subsystem, which includes two space-qualified radiators, two thermal straps, and support structures that will reject heat generated by the detectors of Roman's sensitive Coronagraph Instrument. One of two instruments on the Roman Space Telescope, the Roman Coronagraph Instrument will demonstrate technology to enable future missions to discover and characterize planets that could sustain life within their star's habitable zones. Plan-



ets within a habitable zone are those within the range of a star where water could exist on the planet's surface.

Since the 1970s, SDL has been at the forefront of developing thermal technologies for space applications. Early in its history, SDL understood the need for cryogenically cooled instruments to

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obtain accurate space-based measurements in the infrared and other wavelengths. Now a signature SDL capability, the thermal subsystems SDL designs and manufactures enable exceptionally sensitive instruments, which in turn provide scientists with information to better understand the universe and our place in it.

The Cryogenic Thermal Subsystem's most critical function is to provide cooling to maintain the detectors in two of the Roman Coronagraph Instrument's cameras at sufficiently low temperatures, approximately minus 161 degrees Fahrenheit, which will allow them to function with the required sensitivity. The first-stage radiator shields the second-stage radiator from the heat radiated by the Roman Coronagraph Instrument and other parts of the spacecraft.

Matt Felt, head of SDL's thermal technologies, explained, "Two thermal straps conduct heat from the cameras to the

second-stage radiator, radiating that heat into deep space. Size and weight are premium commodities on any spacecraft, and SDL's new Pyrolytic Graphite Sheet thermal strap technology allows the Cryogenic Thermal Subsystem's mass to be significantly lower than previously possible with metallic straps."

The Roman Space Telescope is slated to launch no later than May 2027. With an estimated mass of 4,059 kilograms, the spacecraft will operate at the second Earth-Sun Lagrange point, where the gravities of the Earth and Sun balance each other, to answer fundamental questions about dark energy, exoplanets, and infrared astrophysics. It will measure the history of cosmic acceleration in addition to searching for worlds beyond our solar system.

For More Info Visit <http://www.sdl.usu.edu>

Multi-Mission UAS (MMU) Systems

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XTEND, a company that specializes in human-guided autonomous drone operating systems for military forces and law enforcement agencies, will supply hundreds of its advanced Wolverine drone systems to the U.S. Department of Defense (DoD). The systems are being developed under the joint leadership of the DoD and the Israel Ministry of Defense (IMoD) for deployment to protect U.S. military forces in the field.

The contract follows a joint research & development program led by the Directorate of Defense Research and Development (DDR&D) at Israel's Ministry of Defense, together with XTEND, and the Irregular Warfare Technical Support Directorate (IWTSD, previously CTTSO) of the DoD.

Made in the U.S., the small, lightweight, and rugged Wolverine is affordable, versatile, and has low power consumption. Easy to use, it enables operators — even those with no flight experience — to perform extremely precise remote tasks, maneuvers, and actions in complex environments (indoor or outdoor), with minimal training and maintenance.

Powered by XTEND's unique human-centric machine interface technology, this new human extension platform facilitates complete sensory awareness, using the most advanced virtual and augmented reality technologies, coupled with advanced machine learning flight algorithms.

Using a wearable lightweight system and a natural hand gesture-recognition controller, operators immerse themselves in the remote environment, without physical risk. Employing multi-use payloads and effectors (Modular Add-On Extensions) they may perform complex tasks in support of tactical missions, including surveying enemy territory at ground level or inside dangerous and/or hard to reach indoor environments, explosive ordnance disposal, placement of payloads at desired points of interest and more, without setting foot inside the relevant area.



Enabling combat forces to be everywhere, get real-time visuals and perform surgical precision pick-and-drop tasks, Wolverine extends their operational reach in critical situations where precision and versatility are paramount, giving them battlefield dominance in terms of both operator experience and mission planning.

"The Wolverine system was developed in direct response to the need of forces to conduct complex field and outdoor missions, while maintaining force protection, and without making contact with the enemy," says Gadi Bar-Ner, Chief Business Officer of XTEND. "For the first time, any user can operate a drone intuitively and without any prior training, giving forces complete autonomy in the field. XTEND systems are combat-proven and used with great success by the IDF in defending borders and forces."

XTEND's patented operating system fuses human intelligence and machine autonomy to enhance the operator's abilities and simultaneously reduce the need for physical confrontation, thus minimizing casualties and injuries. Hundreds of XTEND's systems are already operationally deployed worldwide and the company is continuously developing its operating system and platforms to deliver the future of man-machine teaming to defense, HLS, and security professionals throughout the world.

For More Info Visit <http://www.xtend.me>

Loitering Munition

Rafael Advanced Defense Systems
Haifa, Israel
972-73-3324710
www.rafael.co.il

Rafael Advanced Defense Systems and its US subsidiary RSGS demonstrated the SPIKE FIRELFY loitering munition at the Army Expeditionary Warrior Experiment 2022 (also known as AEWE). AEWE 2022 is a collaborative venue under the Maneuver Battle Lab of the Maneuver Center of Excellence at Fort Benning. It is the Army's primary venue for small unit modernization, providing capability developers, Cross Functional Teams (CFTs), PEO's, the Army Science and Technology (S&T) community, and industry a repeatable, credible, rigorous operational experiment supporting both concept and materiel development. This year the assessment included, in addition to US Army, soldiers from the Netherlands Army and the United Kingdom Army.

SPIKE FIRELFY is part of the SPIKE Family of precision guided electrooptical missile systems, a portable vertical takeoff and landing (VTOL) miniature tactical loitering munition designed for ground organic precision strike for close combat forces in any environment. The FIRELFY munition includes an advanced multispectral seeker with both uncooled IR sensor, high-definition CMOS day sensor, as well as a proximity sensor, allowing the system to detect, identify, track and home in on very agile targets. In addition to the seeker the munition includes an encrypted data link and a lethal blast fragmentation warhead.

During the assessment over a two-day period, seven infantry squads were qualified in operation of the weapon system using inert rounds and an embedded trainer (simulation of operation as part of the FIRELFY control unit). Following the training, the squads participated in force-on-force exercises within an urban area, deploying the FIRELFY munitions in different tactical scenarios to support infantry squad maneuver while enhancing both survivability, situational awareness, and lethality.

The SPIKE FIRELFY was found to be a disruptive product that allows the infan-



try platoon a beyond line-of-sight engagement capability, engaging the enemy behind cover with no warning while allowing the platoon leader to close its own sensor-to-shooter cycles with no need for external call for fire. The SPIKE FIRELFY's unique feature of full return-

ability up to arming of the munition allowed the squads to send the munition as a frontal robotic point-man, scanning the streets and detecting/removing threats from the path of the maneuvering squads while calling the munition back to the operator for another mission if targets were not detected or engaged.

As part of the assessment, the operators fired a live inert FIRELFY munition intercepting an enemy sniper position in an upper floor of a structure, simulating a scenario in which the whole platoon is under suppressive fire with the need to detect and engage the threat while the force is taking cover. The SPIKE FIRELFY provided the soldiers with the capability to engage a high-value target with pinpoint accuracy while reducing risk to the force and collateral damage.

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Blighter Surveillance Systems, the British designer and manufacturer of electronic-scanning military radars and surveillance solutions, was recently awarded a contract to supply vehicle-mounted tactical radars on an unmanned ground vehicle (UGV) for a Northern European NATO customer who plans to use it for border security applications.

For this program, Blighter will be supplying its B422 180-degree ground surveillance e-scanning radar in a vehicle-mounted configuration to be fitted to a six-wheeled UGV, driven by the need for flexible and rapidly deployable threat detection for perimeter and border security. The radars will be augmented by electro-optical systems provided by a systems integrator for the program to provide the UGV with a full-spectrum approach to threat detection.



At this stage, the full complement of systems will be delivered and installed by the latter half of 2022. The B400 series of tactical radars are designed to provide long-range ground surveillance to detect moving vehicles and individuals up to 32 km from a fixed, mobile or portable position. The B400 series benefits from a very wide vertical elevation beam, allowing for simultaneous detection of targets both nearby and at great distance, with a very high level of ground clutter cancellation, resulting in a low false alarm rate.

This is not the first instance of Blighter providing its B400 tactical radars to mobile platforms. Last year the company was selected to supply advanced integrated target acquisition radars to a fleet of armored fighting vehicles. Blighter radars are deployed in more than 35 countries across the world, delivering round-the-clock all-weather security protection along borders, for coastal facilities, military bases and critical national infrastructure.

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New Products

Half Rack Server

Galleon Embedded Computing (Katy, TX) has introduced the XSR Half Rack Server. This robust system has been designed specifically for deployed C5ISR applications where high performance and extreme ruggedness are essential requirements. With its 3U half-width 19" form factor and innovative cooling architecture, the XSR Half Rack Server boasts six-core Intel Xeon E3 CPUs with up to 96 GB SDRAM supporting ECC. Its flexible I/O architecture allows for easy integration with existing infrastructure and can serve as a solution for deployed Network Attached Storage (NAS) applications.

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Portable Engine Balancing System

MTI Instruments (Albany, NY) introduced the PBS eXpress aircraft engine vibration analysis and balancing system. The PBS eXpress is designed to optimize small-frame turbofan and turboprop engines, commonly utilized in regional jet, business jet and general aviation.

The PBS eXpress runs advanced algorithms to record vibration and speed and generate a one-shot balancing solution. The portable system features intuitive setup and operation as well as powerful visualization tools like vibration surveys, exportable data and PDF reporting. Supported propulsion systems include the most popular small-frame engines and APUs from major OEMs such as Honeywell, Rolls-Royce, PWC and Williams.

For Free Info Visit <http://info.hotims.com/82324-471>



Miniature RF Filters

RLC Electronics (Mt. Kisco, NY) has introduced its "Weightless Filter" series. Founded on high-Q cavities and engineered to provide premium RF performance, these new miniaturized filters boast low insertion loss (typically 0.6dB max over operating temperature) and excellent power-handling capabilities, up to 60 Watts CW. The filter pictured measures 0.8" x 0.46" x 0.46", utilizing GPO connectors to save space and eliminate the need for cables at the system level. This filter is used in a family of antennas that is part of a radar system.

For Free Info Visit <http://info.hotims.com/82324-472>



12-Slot, 3U Development Platform

Elma Electronic Inc. (Fremont, CA) has released a 12-slot, 3U Development Platform aligned to SOSA 1.0 and CMOSS. The new platform features high-speed RF and optical I/O connectivity on a number of key SOSA profiles and supports both IO-intensive and compute-intensive processor slots, two switch slots and

one PNT slot as part of the test solution. In addition to the 12 payload slots, the new platform also provides two VITA 62 power slots. The unit is built on an Elma Type 39 84HP-wide E-Frame chassis that provides open access for testing and troubleshooting. Dual high-wattage VITA 62 3U VPX pluggable power supply modules, a network timing card with radial support for IEEE 1588 precision timing and synchronization and a 4590a 1/10/40GigE Ethernet switch with copper and fiber ports from Interface Concept round out the options available with the new development platform. Also featured are conduction-cooled slot inserts, front and rear fan trays with 12 VDC fans and AC operation using a power cord. The platform includes a front panel on/off switch, reset switch, voltage LEDs and test points for easy operation and status acknowledgments via visual confirmations.

For Free Info Visit <http://info.hotims.com/82324-477>



Industrial Embedded Computer

Cincoze (Taipei, Taiwan) recently added the high-performance DV-1000 rugged embedded computer series to its DIAMOND product line. The DV-1000 has a footprint of 224 x 162 x 64 mm, and is powered by a 9/8th Gen Intel® Core™ i7/i5/i3 CPU (Coffee Lake-R S series) that supports up to 128 GB of DDR4 2666 MHz memory. Storage options include 1x 2.5 SATA HDD/SSD tray, 2x mSATA slots, and 1x M.2 Key M 2280 slot for a high-speed NVMe SSD. The DV-1000 includes all the most useful I/O interfaces for industrial applications, including 2x GbE LAN, 2x COM, 3xUSB 3.2, and 3x USB 2.0 for connecting to peripheral devices such as network connectivity, equipment monitoring, and barcode scanners. Digital and analog display options are provided, with a DisplayPort interface providing a powerful modern connection option and VGA providing legacy support for older displays.

For Free Info Visit <http://info.hotims.com/82324-478>



FPGA AI Accelerator Card

Lanner Electronics (New Taipei City, Taiwan) announced its first Hailo-8™ AI-powered PCIe accelerator card, the Falcon H8. Lanner Electronics collaborated with leading AI (artificial intelligence) chipmaker Hailo

to design the Falcon H8, enabling scalable and powerful intelligent video analytics applications for multiple industries operating at the edge. With high-density AI processors, the Falcon H8 accommodates 4, 5, or 6 Hailo-8™ AI processors. Through a standard PCIe interface, the Falcon H8 AI Accelerator Card enables legacy devices such as NVRs, edge AI boxes, industrial PCs and robots to run video-intensive, mission-critical edge AI applications. The Falcon H8 delivers unprecedented inference processing of over 15,000 frames per second (FPS) for MobileNet-v2 and 8,000 FPS for ResNet-50.

For Free Info Visit <http://info.hotims.com/82324-486>

High-Power UAS Radio System

Triad RF Systems (East Brunswick, NJ) offers the THPR1039, a new, DTC-based, high-power radio system designed for use in Group 2 UAS. The THPR1039 is a 10 W (5 W per channel), L-Band, dual MIMO radio that is used for long-distance UAS video and C2 links, which achieves RF link ranges in excess of 50 km when used in both the ground and air radio segments. This unit is an expansion of Triad's High-Power Radio System (THPR) product line. It combines a DTC Solo8 MIMO radio, high-power amplification, and custom filtering into a single, easy-to-integrate package. THPR1039's housing is made from magnesium alloy instead of the aluminum alloys traditionally used for housing RF systems, resulting in a final weight of 32 oz (908 g).

For Free Info Visit <http://info.hotims.com/82324-481>



Programmable Electric Linear Actuator

Electromate (Greenville, DE) now offers the new LDL Programmable Electric Linear Actuator from SMAC. The LDL series actuator features several innovative cost reduction elements including: stroke of 10 - 100 mm; Peak Force [N] : 90 (48 VDC); encoder resolution [µm] : 5 standard, 1 optional; fully programmable in force, position and velocity; and SMAC's patented 'Soft-Land' technology. SMAC moving coil actuators are unique in that force, position, and speed are totally programmable. SMAC electric actuators are designed to perform at exceptionally high speeds or very low speeds and with sub-micron accuracy and repeatability.

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40 GHz Bandwidth Socket

Ironwood Electronics (Eagan, MN) introduced a new high-performance elastomer socket for 0.5 mm pitch BGA package. The CG25-BGA-2002 socket is designed for a 6 mm × 6 mm package size and operates at bandwidths up to 40 GHz with less than 1dB of insertion loss (GSSG configuration). The contact resistance is typically 20 milliohms per pin. Network analyzer reflection measurements for the G-S-S-G case were taken with all except the pins under consideration terminated into 50 Ohms. The socket is mounted using supplied hardware on the target PCB with no soldering. The CG25-BGA-2002 sockets are constructed with high performance and low inductance elastomer contactor. The temperature range is -35° C to +125° C. The pin self-inductance is 0.06 nH and mutual inductance of 0.019 nH. Capacitance to ground is 0.129 pF and mutual capacitance is 0.017 pF. Current capacity is 2 amps per pin.

For Free Info Visit <http://info.hotims.com/82324-496>



DIY Cold Plates



Advanced Thermal Solutions, Inc. (ATS) (Norwood, MA) is now providing DIY (do it yourself) cold plates for engineers to custom fit onto devices whose electronics need to be thermally managed for proper performance. Manufactured in the USA, ATS cold plates provide localized cooling by transferring heat from a hot device to a liquid that flows to a remote heat exchanger and dissipates into either the ambient or to another liquid in a secondary cooling system. Each cold plate's internal, mini-channel fin structure enhances the surface area to maximize heat transfer with low pressure drop characteristics and provides uniform cold plate surface temperature. Engineers can safely drill holes in a mounting pattern that matches the specific connection points of hot devices that need cooling, such as IGBTs, MOSFETs, or other power electronics. Each cold plate includes an etched, no-drill zone to provide a visual exclusion guide.

For Free Info Visit <http://info.hotims.com/82324-474>

Lightweight Head-Up Display

BAE Systems (Rochester, UK) has unveiled a new lightweight, compact Head-Up Display (HUD) for use in commercial and military aircraft. LiteWave is a laptop sized HUD mounted above the pilot's head which presents critical information, such as direction, altitude and speed, directly in their line of sight. Being 70% smaller and lighter than a traditional HUD, LiteWave can be fitted in aircraft with even the most limited cockpit space. It's also up to 80% faster to install and its simple design makes maintenance quicker and cheaper. Powered by BAE Systems' patented waveguide technology, LiteWave can be easily adjusted to suit any individual flying position and allows the pilot to maintain situational awareness, even during poor weather or at night.

For Free Info Visit <http://info.hotims.com/82324-475>



SOSA Aligned Mission Computer



Mercury Systems, Inc. (Andover, MA) announced a new Avionics Modular Mission Platform (AMMP), the industry's first and only SOSA aligned, DAL-certifiable, 3U OpenVPX™ mission computer. Featuring the latest Intel® Core™ i7 safety-certifiable processors, AMMP delivers up to 40x more performance than current-generation avionics computers while drawing 50% less power. Fully configurable, independent 3U boards can run multiple, mixed safety workloads, while a range of avionics I/O including ARINC-429 can capture and distribute HD video. Green Hills, Lynx, and Linux board support packages achieve FAA CAST-32A objectives, and Mercury can also integrate a display, mapping system, cockpit management system and sensors with AMMP to maximize interoperability, optimize display performance and save customer integration time.

For Free Info Visit <http://info.hotims.com/82324-476>

Boxed IP65 Solution

SECO (Arezzo, Italy) has enhanced its family of fanless embedded computers with CHAMALEON, a boxed IP65 solution providing a balance between computing and graphics performance, together with low power consumption. This new product, which features an Intel® Atom® x5-E3930 Dual Core processor @1.3 GHz (Burst 1.8 GHz, 2MB L2 Cache, 6.5W TDP), comes with both commercial temperature (0° C to 60° C) and industrial temperature range from -40° C to +60° C. Several connectivity options are available through two Gigabit Ethernet ports and a microSIM slot soldered on-board for the Modem. Able to provide high-quality video resolution up to 4096 × 2160, this boxed solution mounts an integrated Intel® HD Graphics 500 series controller and can decode and encode 4K HW of several video compression standards.

For Free Info Visit <http://info.hotims.com/82324-479>



32-bit Arm Cortex-M Microcontrollers



Renesas Electronics Corporation (Tokyo, Japan) announced that the security engine of its RA Family of 32-bit Arm® Cortex®-M microcontrollers (MCUs) has been certified by the National Institute of Standards and Technology (NIST) Cryptographic Algorithm Verification Program (CAVP). The drivers to utilize the certified SCE9 Protected Mode are included in the RA Family Flexible Software Package (FSP) v3.6.0 and later. The Renesas RA6M4, RA6M5, RA4M2, and RA4M3 MCU Groups all received NIST CAVP certification of a comprehensive suite of cryptographic algorithms, including multiple modes of Advanced Encryption Standard (AES), hashing, Rivest Shamir Adleman (RSA) and Elliptic Curve Cryptography (ECC) key generation and authentication, Key Agreement Schemes, and Deterministic Random Bit Generator (DRBG).

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New Products

Universal Debug Engine

With its Universal Debug Engine version UDE 2022, PLS (Programmierbare Logik & Systeme) (Lauta, Germany) now also supports the latest automotive MCUs from STMicroelectronics' Stellar E family. Optimized for software-defined electric vehicles and with its functions for fast execution of control loops, the Stellar E family is primarily intended for use in power electronics applications such as onboard chargers or DC/DC converters. It is based on two Arm® Cortex®-M7 cores, each clocked at 300 MHz, which can be operated either in a dual-core configuration or, for the highest demands on functional security, as a single core with lockstep. For applications with increased security requirements, the integrated Hardware Security Module (HSM) offers, among other things, functions for accelerating cryptographic tasks. The MCUs are equipped with up to 2 MB on-chip flash. Split into two banks the code flash allows software updates Over-The-Air (OTA).



For Free Info Visit <http://info.hotims.com/82324-482>



Spectrum Analyzer Software

Signatec (Lockport, IL) recently announced five significant feature additions to its SpectraScopeRT Windows-based spectrum analyzer application software. Multiple RF systems, with multiple receivers and digitizers, can now be defined and added for operations within a single running instance of SpectraScopeRT. SpectraScopeRT supports a physically receiverless system with the use of a virtual receiver setup panel. Multiple systems running the new SpectraScopeRT Server Edition can be accessed and operated as remote nodes with a single user interface over an Ethernet network. Save/Restore Display Plot Configurations enable saving targeted display plots, including customized defined color schemes and layouts, along with configuration files. And digitizers that are part of the RF system can now be clocked from an external frequency source.

For Free Info Visit <http://info.hotims.com/82324-483>

External Magnetometer

uAvionix (Bigfork, MT) today announced AV-Mag, the high-precision 3-axis external magnetometer for AV-30 panel displays. AV-Mag, when paired with an AV-30, will provide consistent and accurate magnetic heading information. With its ability to precisely measure the Earth's magnetic field and aid the AV-30 directional heading measurement, AV-Mag offers a long-term, high-accuracy Directional Gyro (DG) solution. Optimal performance of AV-Mag is achieved by innovative calibration and measurement techniques, including precise integration of attitude and magnetic field data in all orientations, and the use of the World Magnetic Model (WMM) to aid in calibration. Added features like Wind Direction and Speed are planned for an upcoming release.



For Free Info Visit <http://info.hotims.com/82324-484>



Universal Development Board

MikroElektronika (MIKROE) (Belgrade, Serbia) has released UNI-DS v8, a universal development board suitable for rapid prototyping. The UNI-DS v8 development board includes a SiBRAIN socket that enables designers to try out different MCUs in a prototype system without having to invest in other expensive hardware or learn new tools. SiBRAIN is the open standard for sockets and add-on boards and currently supports 3300+ different microcontrollers from different families including STM32, Kinetis, TIVA, CEC, MSP, PIC, dsPIC, PIC32, and AVR. 100+ SiBRAIN add-on boards are currently available. UNI-DS v8 has five mikroBUS™ sockets, where you can place any of the 1200+ different Click boards™.

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Quantic Evans' rugged hermetically sealed capacitors are the most power dense in the industry. From undersea to deep space and everything in between, these capacitors help designers solve their toughest SWaP challenges in a compact hi-rel package.

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- Radar (T/R Module)
- Filtering
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COMSOL Multiphysics® is a software environment for creating

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New Products

Handheld Oscilloscopes

Saelig Company, Inc. (Fairport, NY) has introduced the Siglent SHS-X Handheld Two-channel Digital Oscilloscopes, which are available in 100 MHz and 200 MHz analog bandwidths and isolated or non-isolated versions, with 1GSa/s sample rate and 12 Mpts memory depth. The SHS800X versions have two non-isolated scope channels and one isolated multimeter channel, while the SHS1000X models feature full isolation: between the two oscilloscope channels, the multimeter channel, the power adapter, and the USB host/device port. The maximum analog voltage input for the isolated SHS1000X channels is CATIII 600 Vrms, CATIII 1000 Vrms. For all SHS-X models the maximum input for the multimeter channel is CATIII 600 Vrms, CATII 1000 Vrms. The new -X series adds increased memory depth, a faster waveform capture rate of 100,000 wfms/s, timebase down to 1ns/div, enhanced triggering choices (Edge, Slope, Pulse Width, Window, Runt, Interval, Dropout, Pattern, Video), serial trigger decoding (I2C, SPI, UART, CAN, LIN), improved FFT precision, and waveform recording of up to 50 MB internal or 2 GB external.

For Free Info Visit <http://info.hotims.com/82324-488>



Coaxial Video Cable

W. L. Gore & Associates (Gore) (Newark, DE) announced the expansion of its coaxial cables line for defense land system applications. The new product is smaller and lighter than previous offerings, yet capable of transmitting ultra-high-definition (UHD) 4K video with excellent shielding from radio frequency interference. The cable meets a variety of internationally recognized civil and military specifications, including the latest

Society of Motion Picture and Television Engineers (SMPTE) 12G-SDI standard. Published in March 2015, 12G-SDI defines a 12 gigabit per second transmission of uncompressed, latency-free UHD 4K video at 60 frames per second on a single wire. Operating temperatures range from -55 to 200 degrees Celsius. Designed for use with remote-controlled turret cameras, local situation awareness, and other video-generating sensor systems, GORE Coaxial Cables are engineered with a specialized fluoropolymer insulation. This provides superior resistance to weather, abrasion and other hazards associated with extreme weather, rough usage and confined routing space.

For Free Info Visit <http://info.hotims.com/82324-495>

FPGA Development Module

Opal Kelly (Portland, OR) announced the XEM8310-AU25P development module for the Xilinx Artix® UltraScale+™ FPGA. The module features Opal Kelly's FrontPanel® SDK for programming high-performance, software-connected FPGA applications. The XEM8310-AU25P features the Xilinx Artix UltraScale+ XCAU25P-2FFVB676E FPGA and USB 3.0 Type C SuperSpeed interface. The module also includes 12 high-speed gigabit transceiver lanes via Artix UltraScale+ transceivers. Artix UltraScale+ GTY transceivers support serial standards such as 10 GbE, JESD-204B, DisplayPort, PCI Express, SATA, HD-SDI, XAUI, and Aurora up to 16.375 Gbps. The XEM8310 includes the FPGA, USB Type C SuperSpeed connector, 2 GiB DDR4 memory, 32-MiB serial flash, two low-jitter fixed-frequency clock oscillators, and is self-powered by a single DC supply (+7.5 to +15 VDC). The new module is delivered in a compact 100 mm × 70 mm (3.94" × 2.76") form factor with three Samtec mezzanine connectors to mate with a customer's logic board.

For Free Info Visit <http://info.hotims.com/82324-473>



Rugged Small Form Factor Computer

Curtiss-Wright's Defense Solutions division (Ashburn, VA) announced that its Parvus DuraCOR AGX-Xavier rugged modular mission supercomputer will now integrate the newly introduced NVIDIA® Jetson AGX Xavier™ Industrial System on Module (SoM). Use of the new industrial GPU-accelerated module will enable extended temperature operation, enhanced security, long lifecycle support, and up to 30 TOPS (INT8) of performance for artificial intelligence (AI), machine learning (ML), and deep learning (DL) applications. The high FLOPS-per-watt DuraCOR AGX-Xavier combines the powerful Xavier SoC that contains an NVIDIA Volta GPU (with 512 NVIDIA CUDA® cores and 64 Tensor cores), and an 8-core Arm CPU with the benefits of modular open system approach (MOSA) scalability via add-on I/O cards and storage. Fully complemented to adapt to a wide range of C5ISR sensors, the DuraCOR AGX-Xavier delivers high-speed network connectivity with 1G BaseT plus 10G optical interfaces.

For Free Info Visit <http://info.hotims.com/82324-493>

AirBorn

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About Our Company

Founded in 1958, AirBorn began manufacturing electronic connectors for the military and aerospace industries. Over the years, our customer base expanded to include commercial applications in fields such as medical technology and commercial aviation.

Today, AirBorn is a 100% employee owned company whose core business is engineering & manufacturing specialized connectors and electronic components for Original Equipment Manufacturers (OEMs) across industries including: Aerospace, Energy, Geophysical, Industrial, Instrumentation, Marine, Medical, Mil-Aero, & Space Exploration.

Employee "pride-of-ownership" means each and every employee has a direct stake in making AirBorn a best-in-class operation. From unmatched customer service to delivering a product that exceeds customer expectations, our teams work hard to deliver on our quality promise each and every time.



Target Markets

AirBorn provides electronic components and services to leading companies in industries including Military/Defense, Commercial Air, Medical, Industrial, and Space Exploration.

Products/Services Offered

AirBorn is known worldwide for high-quality interconnects – offering thousands of specialized models to fit virtually any design requirement. We provide standard catalog products and design-to-order, build-to-order, and test-to-order solutions to meet our customers' unique specifications.

While connectors are at our core, AirBorn is much more than a connector company. We proudly manufacture cable (including active optical & fiber optics), flexible circuit, and printed circuit board assemblies. We also fabricate complete chassis/box builds, power supplies, wiring harnesses and offer engineering and lab services.



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Headquartered in Cary, IL, Coilcraft has been a leader in the design, manufacture and distribution of high-performance magnetic components - including RF chip inductors, power magnetics and filters - since 1945. In addition to the industry's largest selection of standard, off-the-shelf components, we also design and build custom magnetics to meet your precise requirements.

With manufacturing, distribution and engineering facilities across North America, Asia, and Europe, Coilcraft provides fast service, shipping, and response times, regardless of where you are in the world. Our global footprint allows us to produce components in multiple locations to support customers around the world and dramatically outperform industry-average lead times.

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- Military/Defense



- Coilcraft offers a broad range of high-performance magnetic components including power inductors, RF inductors, transformers and EMI chokes.
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- Coilcraft leads the industry in the design and manufacture of wirewound RF and microwave frequency inductors, including ceramic and ferrite core chip inductors, air core inductors, conical & broadband inductors, RFID and NFC transponder coils, and tunable RF inductors.
- We also offer a wide selection of transformers for power conversion, capacitor charging, gate drive, PoE, current sensing, ultrasonic sensing and data line isolation applications.
- Coilcraft common mode chokes and wirewound ferrite beads cancel EMI in power supplies and DM data lines, including automotive grade filters for USB, CAN bus, PoC, ADAS, xEV, and Class D audio amplifiers.



Aerospace & Defense Technology, August 2022

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About Our Company

COMSOL provides innovative multiphysics simulation software for R&D in industry and academia. Its platform product, the COMSOL Multiphysics® software, is an integrated environment for developing physics-based numerical models. Add-on modules are available with specialized functionality for analyzing chemical, mechanical, fluid, and electrical phenomena, and interfacing products allow the integration of COMSOL® simulations with major CAD tools. The Application Builder in COMSOL Multiphysics® enables models to be transformed into intuitive simulation applications that can be distributed to colleagues and customers using COMSOL Server™ or COMSOL Compiler™.



Multiphysics simulation of microspeaker acoustics taking into consideration the nonlinear thermoviscous acoustics effect

Target Markets

Technical enterprises, research labs, and universities.

Products/Services Offered

The core COMSOL Multiphysics® product is used for modeling designs, devices, and processes. A particular advantage of this platform is its ability to account for multiphysics phenomena in an integrated environment. Optional add-on modules are available for analyzing a variety of physical phenomena, as well as interfacing products that synchronize simulations between COMSOL Multiphysics® and other CAD software.

COMSOL Multiphysics® includes the Application Builder, which can be used to turn models into applications for use by other design teams, manufacturing departments, test labs, customers, and more. Applications are distributed through the COMSOL Compiler™ and COMSOL Server® products. Simulation applications offer a more efficient and integrated approach to product development and design, marking a revolutionary step forward in R&D.



This simulation app is deployed using COMSOL Server and allows users to optimize the design of an electronic enclosure

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At DEWESoft, we pride ourselves in our reliability and service to our customers. Our staff is comprised of physicists, engineers, technicians and other professionals who have lived and understand your challenges, timelines, and the importance of customer relationships and feedback crucial to project success. If you have not already, we challenge you to put our brand to the test. Trust the Best. DEWESoft.



Products/Services Offered

DEWESoft's KRYPTON data acquisition systems are rugged and distributed EtherCAT data acquisition systems for field measurement in extreme and harsh environments. KRYPTON DAQ systems offer IP67 degree of protection and can operate in the extreme temperature range from -40 to +85°C and offer high shock protection.



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About Our Company

Opal Kelly, founded in 2004, offers an array of powerful FPGA development modules- fortified by the easy-to-use FrontPanel SDK software interface and robust API. These FPGA-based solutions provide the essential device-to-computer interconnect for efficient and rapid product prototyping, testing, development, and OEM integration for engineers, researchers, and educators worldwide. Opal Kelly products shorten development time, fill expertise gaps, and dramatically accelerate time-to-market within most budgets.



The XEM8350 is based on the Xilinx Kintex UltraScale FPGA and includes dual SuperSpeed USB 3.0 interfaces, on-board DDR4 memory, and over 330 user I/O.



The XEM8320 Development Platform (and companion XEM8310 Production Module; not pictured) join a full range of FPGA development products for Intel and Xilinx FPGAs.

Target Markets

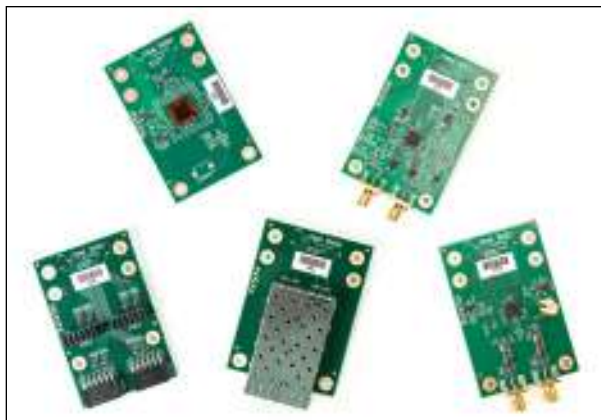
Ultra high-end data acquisition; test and measurement; instrumentation; machine vision; machine learning; scientific and industrial research; communications and software-defined radio; RADAR and LIDAR; remote sensing.

Products/Services Offered

Opal Kelly offers a range of powerful, off-the-shelf, lifecycle-managed Intel and Xilinx FPGA development boards that include the indispensable FrontPanel SDK, a powerful collection of firmware, software, and programmable hardware blocks connecting an engineer's software application and FPGA firmware. The FrontPanel SDK dramatically reduces development time and risk and accelerates time to market.

The multi-platform, multi-language FrontPanel programmer's interface (API) accommodates most development environments and provides a consistent, easy-to-use architecture supporting Opal Kelly's USB 2.0 and USB 3.0 devices. The FrontPanel SDK has over a decade of demonstrated success, proven and refined in thousands of customer deployments worldwide, across diverse applications and industries.

Opal Kelly solutions have nearly two decades of demonstrated success, and are proven and refined in thousands of customer deployments worldwide, across diverse applications and industries. ISO 9001:2015 certified, Opal Kelly is committed to delivering high-quality, production-ready FPGA modules to engineers around the world.



A variety of off-the-shelf SYZYGY peripherals make the XEM8320 Xilinx Artix UltraScale+ Development Platform an expandable and adaptable system for prototype development. Visit <https://syzygyfpga.io/> to learn more.

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About Our Company

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Target Markets

Where designs demand reliability, and size/weight constraints are a factor, Pico Electronics' products are the solution. Including industries such as Military & Defense, Commercial/Military Aerospace, Manufacturing, and anywhere else miniature, high-quality converters, transformers, inductors, or power supplies are required.

Products/Services Offered



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About Our Company

RAD Torque Systems is a leading manufacturer of pneumatic, battery-powered, and electronic pistol grip torque wrenches. RAD Torque tools are known around the world for their durability, precision, accuracy, quality, and performance.

Over a decade ago, RAD Torque pioneered and patented the first programmable digital torque technology, enabling effortless data collection and highly precise torque accuracy. The company also has more than 25 years of gearbox engineering.

RAD products have proven to be successful all over the world in such industries as aerospace, oil & gas, petrochemical, mining, power generation, and manufacturing.



Target Markets

We work with aircraft manufacturers, mechanics and aerospace engineers to develop custom solutions that ensure aircraft safety by providing accurate and reliable torque tools.

Products/Services Offered

When it comes to aerospace, there is no room for error. That's why many of the largest aerospace companies rely on RAD Torque Systems heavy duty torque tools to hold aircrafts together.

Aerospace mechanics don't need to worry about whether each bolt is fastened using the right torque, because RAD's multipliers provide accurate data - so they can rest assured that components are correctly installed to withstand extreme forces placed on them in flight.

RAD Torque Systems has a variety of high-powered torque wrenches for industrial applications, which includes the following well-known products:

- Pneumatic series torque wrench: Precise air power for controlled bolting
- E-RAD BLU series: Accurate electronic torque for complex bolting
- B-RAD series: Portable and powerful battery-operated torque wrench
- V-RAD: Electric torque wrench with quick-adjust torque settings
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For more information on RAD Torque wrenches, visit the website.



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About Our Company

In 1987, we changed aerospace assembly technology by developing adhesive-bonded fasteners that require no installation holes, weigh less, and install easily almost anywhere.



Today, Click Bond is leading the way again with Extended Reality (XR), the next game changer in assembly technology. We continue to expand the possible. Click-Bond.com/AD26.

Target Markets

Aerospace, unmanned vehicles, AAM, defense, commercial jets, space programs

Products/Services Offered

Click Bond designs and manufactures adhesive-bonded fasteners for the aerospace industry. These fasteners require no installation holes, preserve structural integrity, and prevent galvanic corrosion. Because they require no installation holes, your design is not limited by pre-existing hole-placement requirements. Without the need for a drill, they are easy to install in tight places. Click Bond's products include rivetless nutplates, sleeves, brackets, cable-tie mounts, studs, standoffs, the Click Patch®, and LoMas® Screws, which offer up to 48% in weight savings. Our new gimbaled stud's 30-degree angular spherical rotation allows for easy placement on a curved surface.



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About Our Company

CS Hyde Company is a woman-owned converter and distributor of high-performance adhesive tapes, polymer films, fabrics, silicone sheeting, threads, and beading. Premier manufacturer relationships, a stock inventory warehouse, and on-site converting machinery enable us to provide quality custom converted products in the shortest timeframe possible.

**Target Markets**

Aerospace, Military, Industrial, Manufacturing, Packaging, Battery Tech., Medical Device

Products/Services Offered

CS Hyde Company is your source for high-performance adhesive tapes, polymer films, PTFE coated and non-coated fabrics, Kevlar® products, silicone sheeting, PTFE beading, threads, and 3M™ adhesives. Common substrates we work with include PTFE® made with Teflon Fluoroplastics, FEP, PFA, Mylar®, Kapton®, PEEK®, ULTEM, Halar®, TPX®, ABS, Nylon, and many more. Our converting capabilities include slitting, die cutting, adhesive lamination, sheeting, rapid prototyping, and belting. Common specialty products include customer tolerance die cut parts, washers, gaskets, and seals. Ideal source for specialty film tapes consisting of polymer films with adhesive backing system. Full resource converter for substrate to fabricate applications.



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About Our Company

Del-Tron Precision, Inc. was founded in 1974 when we began supplying OEMs with the world's first commercially available sub miniature ball slide. An ISO 2001:2015/AS9100D certified company, we offer one of the broadest product ranges in the industry of high quality, reasonably priced anti-friction linear bearings to automated equipment manufacturers.



Target Markets

Aerospace & Defense, Medical Diagnostic Equipment, Semiconductor, 3D Printing, Assembly Systems, Scientific Instrumentation, OEM Manufacturers.

Products/Services Offered

Defense & Aerospace industries are continually developing and designing new cutting-edge technologies, some of which require linear motion products with very specific design needs. We have the experience to assist, design, and produce linear motion products that will meet your exact needs. We manufacture standard and custom slides and products for use in aircraft interiors, imaging systems, missile systems, pilot helmets, and surveillance systems just to name a few. Del-Tron Precision, Inc. is a US based company making us a domestic source manufacturer for linear motion projects that require materials and manufacturing to be sourced within the United States.



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About Our Company

Fluid Line Products is an ISO 9001 Certified, full-service supplier dedicated to the design, manufacturing and testing of fluid power/transfer components. For over 45 years, we have combined innovative design and the latest manufacturing technology to produce products that truly define value added components and immediate cost savings.

Target Markets

Agricultural, Bus & Truck, Climate Control, Chemical Processing, Construction, Emissions Control, Energy Exploration, Engine Manufacturing, Fuel Cell, Machinery, Marine, Material Handling, Medical, Military, Mining, Power Generation, Utility Vehicles

Products/Services Offered

Design Engineering – Using your specifications, our engineering department will develop a product that will optimize system performance. **Manufacturing** – Components are manufactured reflecting the highest standards in the industry. ISO 9001 Certification attests to our commitment to excellence. Customer designs are precisely crafted to include every detail and specification. All elbow and tee bodies feature one-piece construction for greater reliability. As a further benefit, a portion of our production facility has been devoted to building prototypes and to expedited delivery. **Precise Testing** – Strict test standards are the foundation of our reputation for reliability to match ISO 9001 and SAE J2337.



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About Our Company

GAGE BILT – located in Michigan has offered a full range of Commercial and Aerospace blind rivet and lockbolt tools since 1956. A complete fastener installation product line that is interchangeable and equivalent to the competition including – tools, nose assemblies, power units, accessories, and spare parts.



GAGE BILT is committed to providing innovative and robust standard and custom products. Our technical support and customer service teams will fit you to the best products for your needs.

Products/Services Offered

GAGE BILT's continued dedication to create innovative designs focused on safety, productivity, ergonomic, and FOD control has led to a wide range of products. GAGE BILT invented a lockbolt collar feeder that has changed the way lockbolt collars are installed. The collar feeder provides the operator with a FOD controlled device, which is a quick and easy way to load the collars without fumbling and dropping them. It saves collar installation time by over 50% and saves operators from fine motor handling and potential carpal tunnel syndrome. These and many other innovative products have proven invaluable to our customers.



www.gagebilt.com



Great River Technology

Great River Technology

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www.greatrivertech.com

About Our Company

Great River Technology is the global leader in ARINC 818 and HOTLink II™ products. We've helped design more than 100 mission-critical ARINC 818 capable systems and offer the only comprehensive product suite for the entire lifecycle of your ARINC 818 enabled equipment.



Target Markets

Great River Technology (GRT) is the global leader in high-performance ARINC 818 digital video systems and development tools for the mil/aero industry.

Products/Services Offered

GRT focuses on products that simplify the design and implementation of mission-critical systems for cockpit displays, graphics generators, infrared sensors, optical cameras, and flight simulators. Our products are found in design and research labs, production, and maintenance facilities, and flight-test and production aircraft. The company's portfolio includes products that support ARINC 818 and HOTLink II™ applications. Today, we are the world leader in implementation of ARINC 818, offering a complete suite of test equipment for development, production and flight test, flyable convertors and switches, and ARINC818 IP to support ARINC 818 systems.



www.greatrivertech.com/



Highland Technology, Inc.

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About Our Company

Founded in 1984, Highland Technology designs and manufactures standard and custom electronics. Highland provides innovative high-precision analog measurement and signal generation, data acquisition and control instrumentation, pulse and picosecond timing delay generation, fiberoptic/photonics, and mixed technology products. Engineering, manufacturing, and corporate management are headquartered in San Francisco, CA.



Target Markets

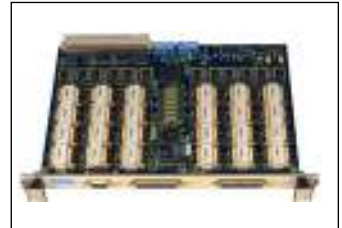
Highland products serve demanding aerospace and defense, scientific, and industrial applications. Highland specializes in

rapidly adapting its core technologies into solutions for challenging customer applications.

Products/Services Offered

Highland specializes in high quality precision instrumentation and control applications that include: precision analog measurement and control; capture of high speed transient phenomena; high speed, high resolution timing instruments; electrical and thermal energy metering; precision thermocouple and RTD temperature measurement; general purpose process inputs and outputs; cryogenic temperature instrumentation; and custom "smart" instrumentation applications.

Highland emphasizes thorough understanding of customer applications, direct engineering support, and long-term availability of products. The company's engineering expertise enables it to quickly adapt its products and technology into new designs of custom and embedded electronics. Highland welcomes the opportunity to collaborate about unusual instrumentation and control problems.



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A division of Heilind Electronics, North America's largest interconnect distributor, Interstate Connecting Components (ICC) is an AS9100D-certified value-added distributor for the entire spectrum of military and aerospace connectors, backshells, tools, identification solutions, contacts and sensors. ICC's extensive inventory includes products from over 150 manufacturers.



Target Markets

ICC supplies leading defense contractors and commercial manufacturers worldwide, serving first-, second-, and third-tier OEMs in a variety of industries – including aerospace, shipbuilding, avionics, telecommunications, and broadcast.

Products/Services Offered

ICC specializes in the military-aerospace market and offers value-added assembly on 26482, 26500, 5015, D38999, M28840, M83513 and many other MIL-SPEC connector lines. Our broad product portfolio includes:

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- Backshells
- Tools
- Identification Solutions
- Contacts
- Sensors



www.connecticc.com



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John Evans' - a trusted supplier of standard & custom designed springs to the military and aerospace industries. From sub-launched Tomahawk cruise missiles to drone (UAV) launch & recovery equipment to the Mars Rover Curiosity & Perseverance, John Evans' Sons, Inc. is a leading manufacturer for demanding aircraft & aerospace applications.

Target Markets

Applications include aircraft cockpits, interior furnishings and controls as well as ground support equipment. ISO 9001 & AS9100 certified. Engineering and design assistance always available!

Products/Services Offered



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New Wave Design & Verification

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www.newwavedv.com

About Our Company

The New Wave Design and Verification team is made up of passionate professionals who have extensive skill designing, building, testing, and delivering electronic systems for aerospace and defense systems. New Wave DV is focused on your high bandwidth, ultra-low latency, and specialized networking applications. We uphold our reputation for industry-leading products and services through persistent dedication backed by decades of experience. By providing off-the-shelf solutions and custom engineering resources, New Wave DV confidently serves you to meet your cost, schedule, and technical requirements.



Products/Services Offered

New Wave Design and Verification provides programmable network interface hardware, FPGA IP cores, and system level products for high-speed serial interfaces used in embedded and test systems. Protocols supported include Ethernet, Fibre Channel, Mii1394 (1394b AS5643), sFPDP, ARINC-818, HSDB, and custom protocols.



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Target Markets

Electronics, consumer electronics, transportation, aerospace, defense, and medical devices

Products/Services Offered

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TRICOR Systems Inc.

TRICOR Systems

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About Our Company

TRICOR Systems, Inc. is a small business that has been providing contract electronic manufacturing to the aerospace, military, and medical sectors since 1976. TRICOR is a seven-time Boeing Gold Performance Excellence Award winner offering a wide variety of manufacturing services ranging from short-run prototypes to production of cables, harnesses, circuit card assemblies (SMT, Through-Hole) and build-to-print specification of custom equipment. TRICOR is ITAR registered, AS9100D, ISO9001:2015 and ISO13485:2016 certified.



Target Markets

TRICOR's target markets include Aerospace, Avionics, Commercial, and Defense. As well as Electronic Manufacturing, Industrial, and Medical. Military and Test Equipment targets are also a target market.

Products/Services Offered

Electronic contract manufacturing of simple to complex finished products/assemblies, cables, harnesses and CCA's. Value added services include: an engineering staff to support development of electro-mechanical & electro-optical equipment from concept to production, hardware and software design, and PCB layout. Past manufacturing/developments include simulators, radar jammers, and ground support equipment (GSE).



www.tricor-systems.com



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AirBorn Inc.....	Cover 2, 15, 51.....	airborn.com
AlphaCoin.....	49.....	alphacoillc.com
Ametek - Vision Research	4, 5.....	phantomhighspeed.com
Click Bond, Inc.	9, 58.....	clickbond.com
Coilcraft, Inc.....	17, 52.....	coilcraft.com
COMSOL, Inc.....	50, 53, Cover 4.....	comsol.com
CS Hyde Company.....	43, 58.....	cshyde.com
Cytec Corporation.....	27.....	cytec-ate.com
Del-tron Precision, Inc.....	32, 59.....	deltron.com
Dewesoft, USA.....	13, 54.....	dewesoft.com
Fluid Line Products, Inc.....	45, 59.....	fluidlineproducts.com
GAGE BILT Inc.....	21, 60.....	gagebilt.com
Great River Technology.....	2, 60.....	greatrivertech.com
Highland Technology, Inc.....	39, 61.....	highlandtechnology.com
Interstate Connecting Components.....	31, 61.....	connecticc.com
John Evans' Sons, Incorporated	25, 62.....	springcompany.com
Master Bond Inc.....	50.....	masterbond.com
MPL AG Switzerland.....	48.....	mpl.ch
New Wave Design & Verification	40, 62.....	newwavedv.com
Opal Kelly Incorporated	3, 55.....	opalkelly.com
Photon Engineering	46.....	photonengr.com
Pico Electronics.....	56, Cover 3.....	picoelectronics.com
Quantic™ Evans	49.....	quanticdevans.com
RAD Torque Systems.....	1, 57.....	radtorque.com
Specialty Coating Systems.....	37, 63.....	scscoatings.com
TRICOR Systems.....	35, 63.....	tricolor-systems.com

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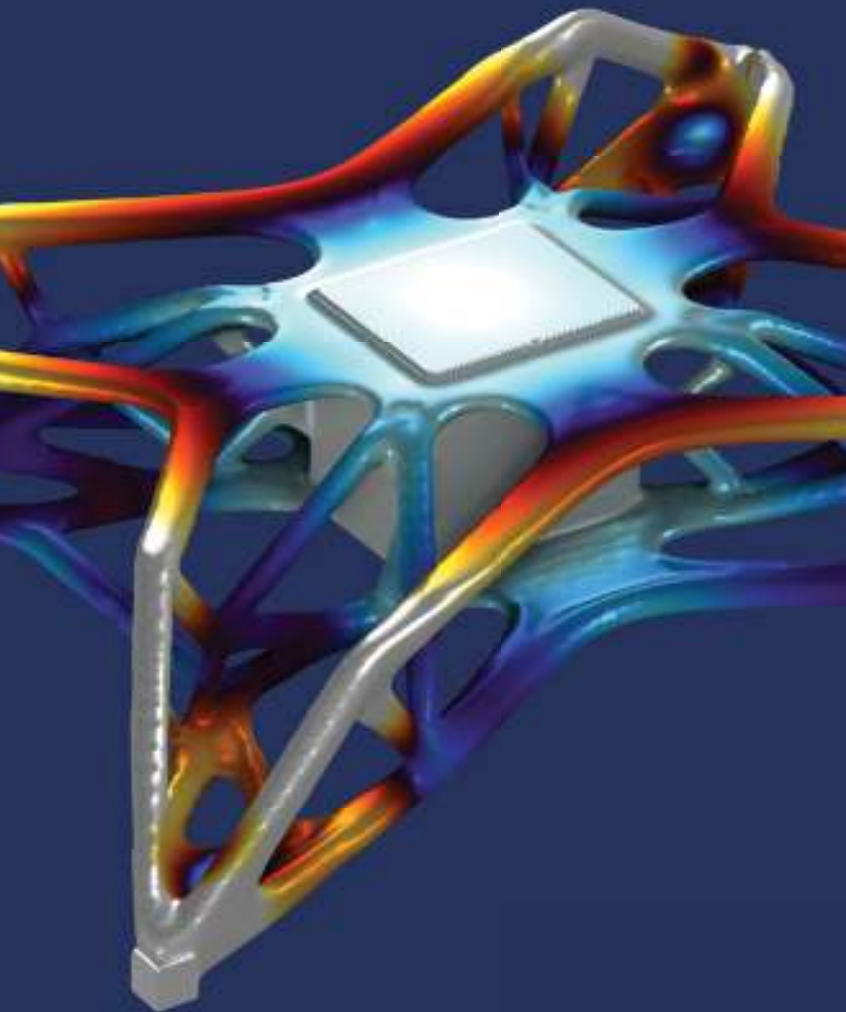
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