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The Engineer's Guide to Design & Manufacturing Advances

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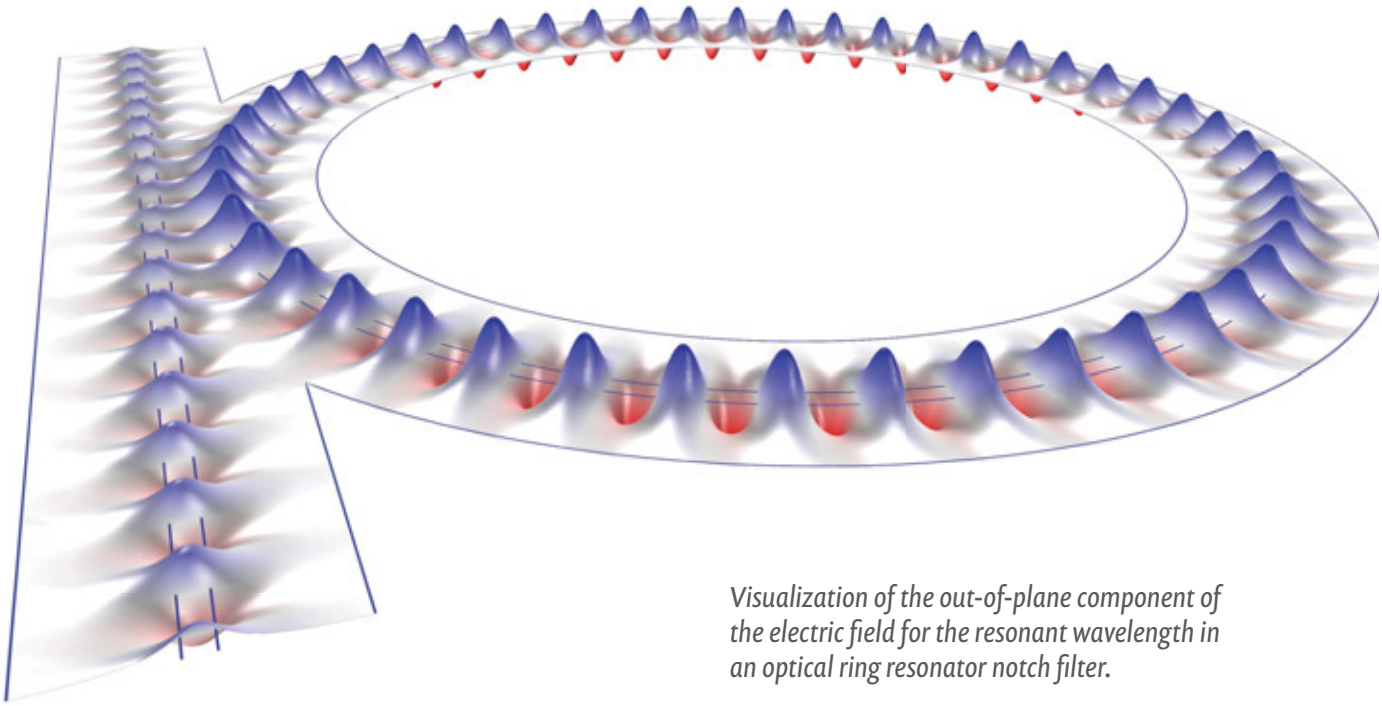
It all started with two buckets of water...



Visualization of the out-of-plane component of the electric field for the resonant wavelength in an optical ring resonator notch filter.

In 1870, a scientist named John Tyndall tried to control light using two buckets of water, illustrating total internal reflection to a fascinated audience. Today, researchers have more advanced tools at their disposal. When fabricating and analyzing optical waveguide prototypes, modern-day engineers can use numerical simulation software to speed up the design process.

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September 2020

AEROSPACE & DEFENSE™ TECHNOLOGY

The Engineer's Guide to Design & Manufacturing Advances

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Thermal Management for Directed Energy Weapons

Radiation-Tolerant FPGAs Solve Spacecraft Design Challenges

New Diamond Super-Material Enhances Aircraft Survivability

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Conceptual rendering of a directed energy weapon being used on a submarine. Directed energy weapons (DEWs) utilize concentrated electromagnetic energy focused on a target to cause damage, versus conventional kinetic energy weapons which hit the target with a solid projectile. Thermal management is a critical component of DEW systems. To learn more, read the feature article on page 10.

(*Illustration courtesy of Advanced Cooling Technologies, Inc.*)

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INSIDE STORY

Advanced Cooling Technologies, Inc. (ACT) is a premier thermal management solutions company, providing performance and cost-optimized thermal management technologies and solutions at all points along the product lifecycle.

***A&DT:* What is a heat pipe and how are they used for thermal management in space?**

Peter Dussinger: Heat Pipes have been used for decades to remove heat from electronics systems and their benefits include passive operation and long life with no maintenance. They use a combination of evaporation and condensation of a working fluid, taking advantage of the high heat transfer coefficients of these two-phase processes. Thermal conductivities can approach 10,000 to 100,000 W/m-K for long heat pipes, in comparison with ~400 W/m-K for copper.

In space, heat generating devices must be coupled to the radiator panels by conduction. The radiator panels ultimately radiate the thermal energy to deep space. Conduction coupling with high thermal conductivity materials like aluminum (200 W/m-K) or copper (400 W/m-K) is possible if the payload components are mounted to the backside of the radiator panel. However, this limits the freedom of design and distance relative to the radiator panel. Heat pipes, with superior effective conductivities, become excellent choices for thermal coupling between faraway payload components and radiator panels.

***A&DT:* Have heat pipes been used in space?**

Dussinger: Aluminum/ammonia heat pipes have been used in space for decades to enhance the conductivity of the radiator panels and to transfer waste heat from the payloads to the radiator panels. Ammonia is one of the best working fluids, having favorable thermophysical properties and being chemically compatible with aluminum, a standard material used in spacecraft. Ammonia works across a wide range of temperatures (-60°C to +70°C) typical of space environments.

***A&DT:* Why do satellite developers want Space Copper Water Heat Pipes (SCWHPs)?**

Dussinger: Satellites have traditionally been performing data collection, transmitting and receiving roles only, leaving the data processing/computing to ground stations. As the data volume continues to increase, in-situ computing is increasingly required, to minimize latency and maximize reaction speed. However, adding computing onboard satellites creates new thermal management challenges.

Copper/water heat pipes are the standard for electronics cooling on Earth. SCWHPs operate in a slightly higher temperature range than ammonia, therefore water can handle the higher heat fluxes coming off electronics chips much better than ammonia. Additionally, water is non-toxic, which is a benefit for ground testing and shipping concerns. In summary, copper/water heat pipes can transport more power, delivered at much higher power densities, at higher temperatures than current options.

***A&DT:* What are the unique challenges for SCWHPs?**

Dussinger: The biggest issue with SCWHPs is the unique phenomena that water exhibits when freezing, as its volume expands by nearly 10%. While an excess fluid charge can lead to heat pipe wick and envelope damage/breaching during freezing, an inadequate fluid charge may mean the heat transfer requirements are impossible to meet. There is a tight range of acceptable fluid charges for a specific heat pipe design to meet these opposing constraints. The space satellite environment is one where freezing can be expected under standby and other conditions, creating conditions not seen by terrestrial heat pipes. Therefore, depending on the application, space copper/water heat pipes are required to be tested for a significant number of freeze/thaw cycles under the most stressful conditions ever applied to copper/water heat pipes.

***A&DT:* How do ACT's SCWHPs address these challenges?**

Dussinger: ACT has developed complex manufacturing and testing techniques to produce space copper/water heat pipes that can meet the most stringent heat transfer, thermal cycling and structural integrity requirements. Each lot of SCWHPs is built to precise specifications and goes through a battery of acceptance and qualification tests (application specific). Various non-destructive testing techniques are used to assess the heat pipe wick and envelope integrity during the manufacturing and testing process.

***A&DT:* Have SCWHPs flown in space?**

Dussinger: ACT gained flight heritage when SCWHPs were tested on the International Space Station (ISS). Since then, they have been flown on several commercial satellites and are operating as designed. ACT has also delivered SCWHPs that are currently in orbit on developmental satellites.

***A&DT:* What does the future of SCWHPs look like?**

Dussinger: As the desire for real time, in-situ computing increases, so will the demand for SCWHPs to assist with the thermal management of the cards and chassis used to construct these space-based computers. SCWHPs will continue their rapid adoption following in the footsteps of their successful aluminum/ammonia heat pipe predecessors. ACT will continue to work with top space industry partners to develop and qualify manufacturing improvements to further increase the robustness of SCWHPs.

Visit Advanced Cooling Technologies, Inc. at
https://www.1-act.com/

Radiation-Tolerant FPGAs Solve Spacecraft Design Challenges

Satellite and spacecraft system designers have a few different options when selecting field programmable gate arrays (FPGA) semiconductors. One FPGA option is commercial off-the-shelf (COTS) components that reduce component unit cost and lead time, but they are generally not reliable enough, must be up-screened (which increases cost and engineering resources), and require soft and hard Triple Modular Redundancy (TMR) to mitigate radiation effects in space.

In missions where failure is not an option, designers typically choose higher-cost FPGAs that are radiation-hardened by design (RHBD). These are already screened and qualified to Qualified Manufacturers List (QML) Class Q and V standards. QML Class V is the highest qualification standard for space semiconductors. Manned and safety-critical missions rely on QML-V components, to mitigate the risk of failure.

Designers whose systems must meet the increasing need for a challenging combination of higher performance and greater on-board data processing and high-speed communications capabilities in space also rely on these radiation-tolerant RT FPGAs to provide a solution that is radiation tolerant by design, backed by its manufacturer's space flight heritage and expertise, and undergo QML Class V testing. This article will look at the different FPGA technologies that are available for space applications, and the process for developing the components.

Radiation Effects in Space

RT FPGAs are needed because COTS components are not immune to the various radiation effects in space and that can degrade the performance of an integrated circuit or cause it to fail. One of these radiation effects is total ionizing dose (TID), which is caused by radiation due to charged particles and gamma rays in space. This

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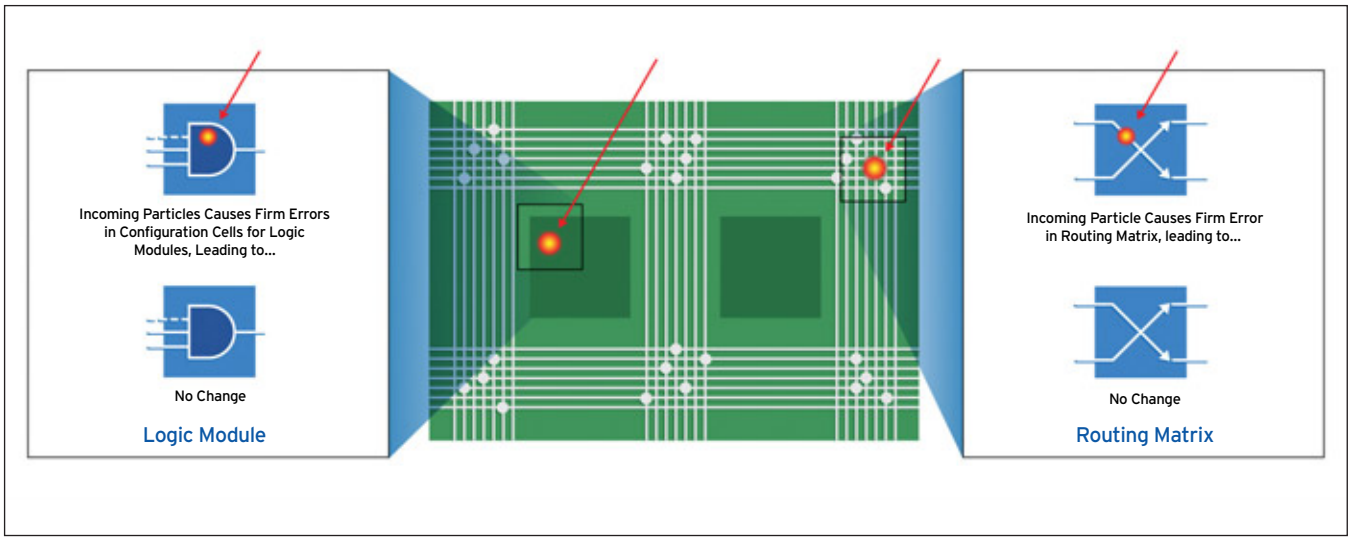

Flash and SONOS-based FPGAs are immune to SEUs in the configuration memory.

radiation deposits energy by causing ionization in the material. The ionization can change the charge excitation, charge transport, bonding, and decomposition properties of the material. This negatively affects the device parameters.

TID is the cumulative ionizing radiation that an electronic device receives over a specified period, usually the mission time. The damage is dependent on the amount of radiation and is expressed in radiation absorbed dose (RAD). Depending on the radiation tolerance for TID, a device may experience functional or parametric failures. Among the common parameters affected by TID radiation in FPGAs is an increase in propagation delay which decreases device performance. Another failure mechanism is increased leakage current after a high TID exposure.

The other type of radiation effect is single-event effects (SEEs). These are instantaneous upsets, transients, or permanent damage due to particle radiation such as protons, heavy ions, and alpha particles that can strike sensitive regions of the transistor, causing various failures. SEEs come in different forms including Single Event Upsets (SEUs), which occur when high-energy ionizing particles such as heavy ions, alpha particles or protons irradiate a circuit or pass through an integrated circuit. This results in a disruption in the system logic.

Also troublesome is a Single Event Latch-Up (SEL), which is a condition that causes loss of device functionality due to a single-event-induced high current state. An SEL may or may not be destructive. In a destructive latch-up event the current will not recover to the nominal value. In a non-destructive latch-up event the high-level current will return to the nominal value after power-cycling the FPGA.

Comparing FPGA Technologies

There are four basic types of FPGAs:

SRAM-based FPGAs

SRAM-based FPGAs store logic cells configuration data in the static memory. SRAM is volatile and can't retain the device configuration without power. Instead, the FPGAs must be programmed upon power-up. SRAM-based technology tends to consume more power and be more sensitive to radiation.

Flash-based FPGAs

Reprogrammable flash-based FPGAs use flash as a primary resource for configuration memory. Flash technology is immune to SEU, eliminating the threat of radiation-induced upsets in the configuration memory of the FPGA. RTG4 Flash-based FPGAs use up to 50 percent less power compared to SRAM-based FPGAs. Flash technology simplifies the design in multiple ways, as there is no need for external memory, redundancy, or continuous configuration monitoring. It also eliminates the need for a heat sink, reducing the size and weight of the designs while reducing power consumption, which can be especially important if an electronic module is powered with solar panels.

SONOS-based FPGAs

An example is the Microchip RT PolarFire FPGA, which offers radiation performance with characterized radiation data, low power, SEU configuration immunity, and high-reliability components with a path to QML-V qualification. These FPGAs are developed on a silicon-oxide-nitride-oxide-silicon (SONOS) non-volatile (NV) technology on a 28nm technology node.

The performance of 28nm and earlier 65nm technologies has been compared by measuring the propagation delay of an inverter. These tests show that 28nm SONOS technology offers 2.5 times higher performance than 65nm flash-technology. These SONOS-Based FPGAs also have outstanding radiation performance and SEU immunity, while offering a low-power solution. With a path to QML-V qualification, SONOS-based FPGAs are ideal in applications that require high-speed signal processing.

The accompanying figure shows how flash and SONOS-based FPGAs are architected to provide SEU immunity.

Antifuse-based FPGAs

Antifuse-based FPGAs are programmed once, which limits a key re-programmability advantage as compared to Flash and SONOS-based FPGAs. Antifuses do not conduct current initially but are burned to conduct current (the antifuse behavior is the opposite to the behavior of a fuse). Antifuse technology is very robust against radiation effects.

How RT FPGAs are Developed

RT FPGAs are developed on process technologies that have excellent radiation TID performance. They can be RHBD, with flip-flops that have built-in TMR at the circuit level. TMR deployed in software, also known as soft TMR, can be implemented if the TMR has not already been implemented at the silicon level. After the silicon is developed, RT FPGAs go through a stringent qualification.

For devices to be qualified to the highest standard, they must adhere to the MIL-PRF-38535 standard that was released by the Department of Defense, which created consistent qualification, testing, and reliability standards for military and space ICs. MIL-PRF-38535 defines requirements for IC manufacturers if they wish to be listed on the QML by the Defense Logistics Agency (DLA).

Another aspect of product development is characterizing SEE performance, which does not change from wafer lot to wafer lot if the silicon design is the same. After freezing the design, FPGA manufacturers can start the SEE characterization process. Once the device is in production, no additional SEE performance testing is needed as long as there have been no changes to the design and the component has been fully characterized.

Some process technologies may have TID performance that varies across wafers from lot to lot. As a result, TID performance testing must be performed in production, on a wafer lot basis, to guarantee a device will meet its target TID level specification (25 krad, 100 krad, 300 krad).

RT FPGAs' Impact on Spacecraft Design

The latest RT FPGAs offer numerous advantages that create opportunities for simplifying these designs while significantly improving the capability for on-board data processing. To meet these needs, RT FPGA technology nodes are shrinking to offer higher performance and higher-speed signal processing with more memory and DSP capabilities.

RT FPGAs also offer other key advantages including re-programmability and faster development time compared to an ASIC. Typically, FPGAs are not reprogrammed once they are flying in space, but this is an option as designs become more complicated, assuming that system designers follow guidelines and carefully evaluate the success rate and risks associated with on-orbit reprogramming.

This article was written by Julian Di Matteo, Senior Product Marketing Engineer, Space and Aviation, Microchip Technology (Chandler, AZ). For more information, visit ***http://info.hotims.com/76507-500****.*

Thermal Management for *Directed Energy Weapons*

Directed Energy Weapons (DEWs) utilize concentrated electromagnetic energy focused on a target to cause damage, versus conventional kinetic energy weapons which hit the target with a solid projectile. Lasers, microwaves, and particle beams are examples of DEWs. While DEWs are not a new concept, they are gaining increasing interest as the technologies to concentrate energy to damaging levels, to track the targets accurately, and to manage the massive amounts of waste energy produced are reaching higher levels of maturity. At the same time, the price tag for conventional ammunition and conventional weapons continues to climb, placing increasing funding burdens on the government.

Compared to conventional weapons, the advantages of DEWs include: (1) speed of light target engagement; (2) low cost per shot; and (3) deep magazine capability, limited only by the available power and thermal management capacity.

Thermally Managing Directed Energy Weapons

Thermal management is a critical component of DEW systems. Without robust cooling solutions, the massive amount of waste heat generated per high-powered shot will damage the weapon, and support systems, and likely cause acute failure. This is the case with any high-powered electronic device. The higher the power, the more waste heat these devices generate. Additionally, the temperature of the waste heat is relatively low, which makes it more difficult to manage with conventional methods.

The primary challenge is how to efficiently remove substantial amounts of low-grade waste heat, owed to the

Figure 1. Conceptual rendering of a Directed Energy Weapon on a submarine.

inefficiency of these devices (i.e., high energy lasers, microwave emitters, etc.) while simultaneously maintaining relatively tight thermal stability. For example, lasers are highly temperature dependent to achieve high efficiency and stable optical wavelength. If the heat rejection and temperature stability are not adequately managed, laser DEW performance degrades from the beginning of the shot to the end. Therefore, the ultimate thermal management systems must be compact, lightweight, and low power.

Cooling solutions are platform dependent (ground-based, airborne, shipboard) taking into consideration availability of resources and the ultimate heat sink (air, water, etc). For both ground-based and airborne DEW, Advanced Cooling Technologies (ACT), together with DoD partners have developed, prototyped, and tested several low size, weight, and power (SWaP) cooling systems. An integrated, fully functional thermal management prototype was delivered to the Navy in 2018 to support the Ground Based Air Defense (GBAD) program.

Thermal Storage Using Phase Change Material

Most thermal solutions are developed to handle the maximum heat load at the time of generation. In other words, a 5 kW load requires a 5 kW solution. While this is true for electronics operating in a steady state mode, it is not necessarily the case for pulsed technology such as DEW. In a DEW application, the heat load may only be "on" for a period of time and then "off" for a recovery, recharge, regenerate period of time. In these applications, the thermal management solution has additional time to dissipate the waste heat generated during the "on" period. The thermal solution can be smaller than the load generated during the "on" period. A 5 kW "on" load, that is on for one out of every five time periods, can use a 1 kW solution over the five time periods.

To accomplish this without overheating during the "on" period, thermal storage, phase change materials (PCM) can be utilized. Typically, the phase change is from solid to liquid and back. The material is selected such that it melts close to, but not in excess of, the maximum allowable temperature of the electronics being cooled. During the high power "on" portion of the shot, some of the waste heat is dissipated by the cooling system, while the balance of the waste heat melts the PCM from a solid to a liquid. During the "off" period, the traditional cooling system continues to dissipate the stored energy in the PCM, freezing it back to a solid, so that it is ready to absorb another pulse of energy when the weapon is fired again. One other benefit of the PCM is that it will provide a relatively high level of survivability should the smaller steady state cooling solution become incapacitated.

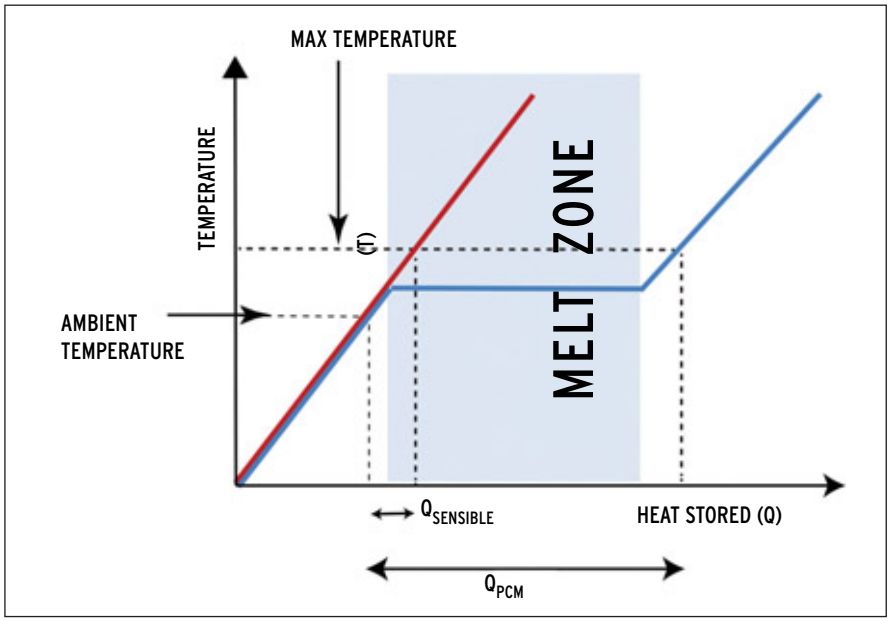

Figure 2. Visual representation of the standard operation of the PCM heat sink.

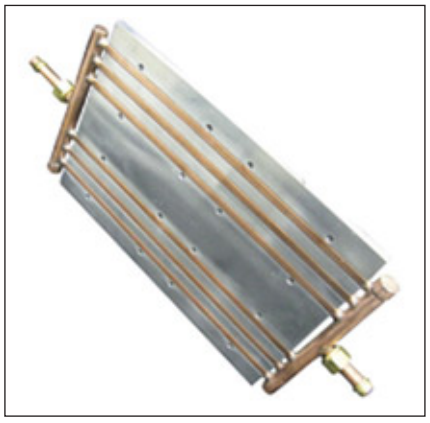
Figure 3a. Manifold Cold Plate Design. Heat from the source is transferred to a single-phase liquid coolant circulating through internal channels of the plate and subsequently rejected downstream to a radiator.


Fgure 3b. Mini Channel Cold Plate

Thermal storage is an effective way to absorb and store the waste heat until engagement is again necessary. Thermal storage works by storing thermal energy in a phase change material (PCM). The phase change from a solid to liquid occurs through energy absorption. The latent heat from melting or freezing is at least 1 to 2 orders of magnitude higher than the energy stored by the specific heat.

ACT has conducted an abundance of research, development, and prototyping

of PCM assisted cooling solutions. Efficiently delivering and extracting heat energy from the PCM reservoir is the key to a well-designed system. ACT's thermal experience with enhanced surfaces (fins), high conductivity (Hi-K™) components, heat pipes, pumped loops, etc. allows us to design and develop PCM systems that are small, lightweight, and low power. As a reference, systems sized for the peak heat load typically weigh 40-60% more than those with thermal storage, although this is highly dependent on the duty cycle.

Pumped Single-Phase Cooling

Single-phase cooling is another option for managing waste heat produced by DEW. At a minimum, single-phase cooling requires a reservoir, or fluid source at the prescribed temperature, and a pump. This method of cooling traditionally involves cold plates with pumped water or water/glycol mixtures running through channels to absorb the waste heat. This thermal solution is typically used in systems with low to moderate heat fluxes.

ACT has also shown that single-phase systems can be used for heat spreading, and to remove very high heat fluxes over small areas. Researchers at ACT have removed heat fluxes of over 10,000W/cm^2 over several square centimeters. The disadvantages of this technology for DEW are size issues. Many DEW thermal solutions will require a very small footprint and will not have space for a large pump and cold plate.

Pumped Two-Phase Cooling

In contrast, pumped two-phase (P2P) cooling systems use a non-corrosive, non-electrically conductive (dielectric) fluid, which vaporizes during the absorption of the waste heat. A much smaller amount of coolant, relative to pumped single-phase, is pumped into the cold plate, where the coolant changes phase from liquid to vapor. Because the latent heat of vaporization is many times the specific heat of the coolant, the coolant flow rate can be significantly reduced, resulting in smaller pumps and lower power usage.

High heat flux applications often use sintered wick materials in the cold plate channels to provide ample and uniform nucleation sites for boiling. These nucleation sites prevent flow maldistribution during transients and help to provide lower evaporator thermal resistances. P2P systems offer an attractive way to reduce SWaP, since they take advantage of the latent heat of vaporization of the coolant; they also allow for a much higher degree of temperature uniformity for electronic components and laser diodes that reach heat fluxes of up to 500 W/cm^2.

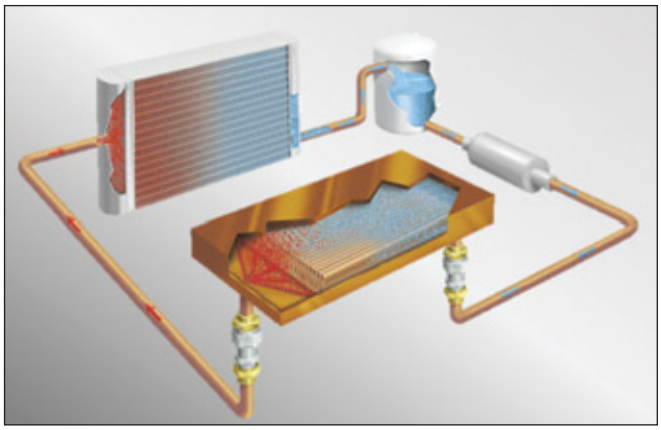

Figure 4. ACT's Pumped Two-Phase Cooling System

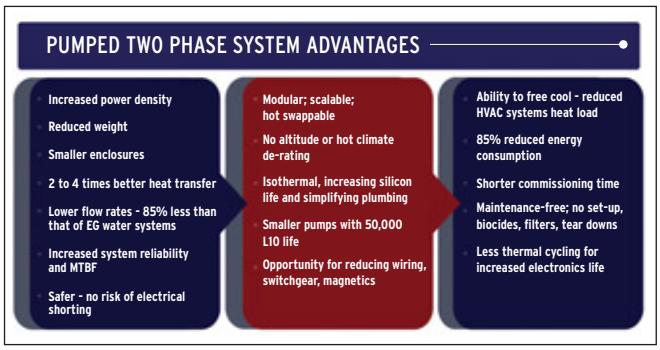

Figure 5. Pumped Two-Phase Cooling Benefits

By combining a non-conductive dielectric refrigerant with the science of heat dissipation through vaporization, ACT has found that well-designed pumped two-phase cooling products can manage power densities more than 2x over traditional water / glycol systems for high-power electronics, while eliminating the dangerous consequences of a fluid leak. Although the systems are leak-tight, should an accidental leak occur, the non-conductive fluid is inherently safe even when in direct contact with sensitive electronics.

ACT has developed reliable P2P systems for thermal control of optoelectronics and other applications that need both low SWaP, high power removal, and tight temperature uniformity. Key components in these systems have also been scaled, prototyped and tested for large-scale DEW implementations.

Thermal Management is Key

Advanced thermal management is one of the keys to bringing directed energy weapons online and to allow them to operate at peak performance. Both single-phase and pumped two- phase cooling systems, in conjunction with thermal storage, have demonstrated significant SWaP benefits. These technologies are mature and ready for field test implementation. They can also be rapidly deployed for acquisition programs.

This article was written by Pete Dussinger, Chief Engineer, Products, Advanced Cooling Technologies, Inc., (Lancaster, PA). For more information, visit ***http://info.hotims.com/76507-501****.*

New Diamond Super-Material *Enhances* Aircraft Survivability

As the U.S. military continues to seek out and develop technology that will enhance survivability of manned and unmanned military aircraft systems, a new, diamond-based coating offers an effective countermeasure to state-of-the-art directed energy weapons, including electromagnetic and high-energy laser weapons. Whether it's reconnaissance drones, air force jet fighters or spacecraft for the newly formed Space Force, every branch of the military is seeking out technological advancements that keep our soldiers and the systems they operate safe. Existing coatings, such as infrared antireflective and diamond-like-carbon, when applied to sensitive control systems and cockpit areas, are susceptible to deficiencies like delamination, degradation and fluctuating optical transmissivity.

This new "super-material," however, is a product of advanced chemistry and comprised of two materials that have not been able to be demonstrated together, until now. Thanks to advancements and breakthroughs in chemistry, physics and manufacturing, we're now able to fabricate composite diamond coated with Fluorinated Graphene Oxide (FGO), a feat never before accomplished until now. This new super-material opens up a world of new capabilities across a number of industries, especially defense, where it can be applied to countermeasure weaponry, specifically optical sensing, detecting and transmission – which are all extremely crucial to our military's efforts.

Historically, FGO is a costly and time-consuming material to fabricate (with chemical exfoliation alone taking over 12 hours), and it has failed to demonstrate the ability to adhere well with most materials, absent metals such as lithium and a few others. Today, however, thanks to innovations in advanced materials, we are able to fabricate an FGO and diamond composite that is the ultimate optics and semicon-

Processing AKHAN Semiconductor's Miraj Diamond® Glass.

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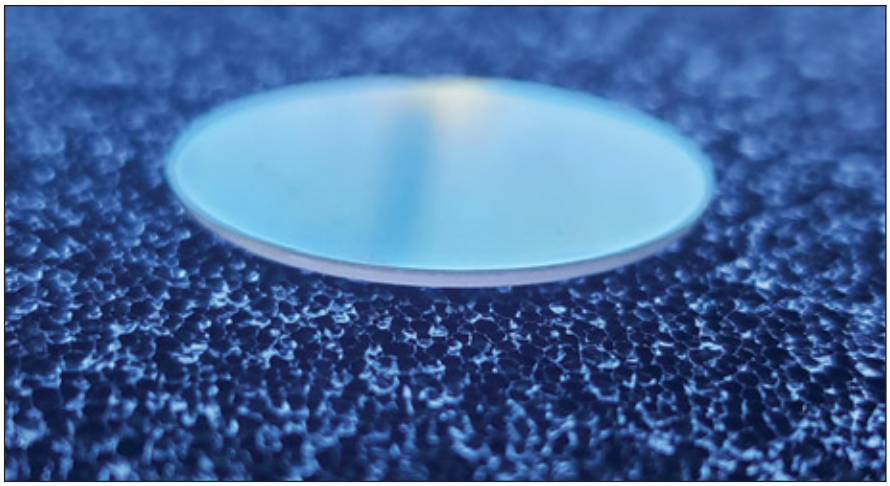


Miraj Diamond® Glass utilizes lab grown, thin-film diamond specially tuned for optical application.

A cleanroom technician holds a sample of composite diamond coated with FGO.

ducting super-material and apply it to sensitive military aircraft systems.

The Process

The process starts by using a combination of methane gas and plasma as source material. Through a state-of-the-art manufacturing process, the methane and plasma react to create the perfect, low-cost diamond wafer. In order to scale, chemical vapor deposition (CVD) reactors are used to form diamond nanocrystals below 400°C, allowing for the first-time integration with currently utilized materials in optics and electronics. The final product is a diamond composite that can be utilized in everything from complementary metal oxide semiconductor (CMOS) devices and commercial electronics to multilayer optics and display glass, and in this case, manned and unmanned aircraft systems.

The diamond coating protects these aircraft from two weapon systems rapidly being developed by adversaries: high energy lasers and electromagnetic (EM) weapons. Without the proper countermeasures, these weapon systems provide enemies with the ability to bring down jets and helicopters without explosives and negate drone swarms. Some of their other capabilities include:

High-Energy Lasers: Initially introduced during President Regan's administration, the originally dubbed 'Star Wars Defense Initiative' was matured through the 1990's and began making significant progress on high-energy laser systems in the early 2000s. Today's laser systems, with much higher beam efficiencies, and far more dense optical structures, are already proliferating worldwide. With sufficient power supply, high-energy laser weapons can represent a significant threat. With a nearly unlimited 'magazine', ranged precision attacks can hit multiple potential targets such as craft weapons, communications, support electronics, and pilots/operators. As laser systems continue to improve power efficiencies, and power supply densities, the deployment of these systems is envisioned to be widespread, ranging from craft to armed personnel.

Electromagnetic Weapons: Utilizing focused microwave energies, today's electromagnetic weapons systems are mainly utilized against UAV systems. With the ability to currently negate drone swarms, the next level of capability (requiring higher energy densities) will be able to affect larger areas and systems, ranging from carrier craft to communications. With Russia and China rapidly advancing their high-power electromagnetic weapons systems programs, the near-term threat of such systems is widely understood.

Multilayer anti-reflective coating systems, like the diamond-coated FGO super material, are critical to military aerospace concerns because the technology further allows development of optical components with ultra-hardness, scratch-resistance, high thermal conductivity, hydrophobicity, chemical and biological inertness, and with high transmittance at a variety of critical angles. The diamond-coated FGO, with its high crystalline quality, high power handling capability, high current density, low threshold voltage, and ohmic contact, under room temperature operation, was previously undemonstrated across all diamond material types.

Today, thanks to the advancements mentioned above, we are able to fabricate diamond-coated FGO, which, when it comes to man and unmanned aircraft, particularly addresses the following:

Optical Sensing: Optical sensors respond to the quantity of input by making a functionally associated optical output. Currently utilized materials such as Boron Cubic Nitride (BCN) and Diamond-Like-Carbon (DLC) lack the hardness, strength, and thermal shock protection needed for optical sensing applications in defense. Protection of optical components against directed energy, oxidation, and debris without adding significant system weight and without significant optical loss (due to

the atomically thin FGO layering) of the received signals, is for the 1st time, enabled by nanocrystalline diamond.

Optical Detecting: An optical detector picks up information of interest controlled in a modulated wave. With similarly utilized materials for the current market detector systems, the case is the same as in sensing, where detecting requires optical transmission and now modulation. Typically utilized substrate materials such as fused silica and sapphire lack sufficient strength and thermal shock resistance to meet current defense application requirements. Only nano diamond can bring the hardness, strength, high optical transmissivity, and thermal performance required to enable the next generation of detector systems.

Craft Electronics: Perhaps the most vulnerable to electromagnetic weaponry, craft electronics perform critical functions from supporting flight to enabling reconnaissance. Protecting these non-optical components from directed energy and electromagnetic weaponry is no trivial task, as any material integrated cannot interfere with the electronics operations. Here diamond is uniquely positioned to address the problem set. In addition to the above integration capabilities, unlike the status quo heat transfer material copper, diamond can be directly integrated with craft electronics to keep devices operating within thermal budget (diamond transfers heat 5x more efficiently than copper) and without adding extra weight. Through direct integration with craft electronics materials (such as silicon) and craft body (such as metals and glass) the FGO/Diamond composite also enables 1st time EM and Directed Energy protection.

As adversaries continue to develop advanced weapons systems like high-energy lasers and EM weapons, the need for diamond-coated FGO becomes even more critical. Right now, we're focused on the material's aerospace applications, but there are nearly unlimited use cases for industries like telecommunications, virtual and augmented reality, electric vehicles, and especially in the defense sector - from submarines to missiles and even spaceships. Defense companies like Lockheed Martin are already testing diamond-based coatings as defense countermeasures, and that's just the tip of the iceberg. The U.S. Military is constantly in search of new, innovative ways to keep the brave men and women who defend this country safe, and diamond-coated FGO demonstrates that ability beyond any existing material.

This article was written by Adam Khan, CEO and Founder of AKHAN Semiconductor (Gurnee, IL). For more information, visit ***http://info.hotims.com/76507-502****.*

Development of a **Secure Private Neural Network Capability**

Machine Learning (ML) tools like Deep Neural Networks (DNNs) have gained widespread popularity due to their ability to quickly and accurately perform discriminative tasks, such as object detection and classification. However, current implementations of this concept have several drawbacks. First, traditional DNNs require access to unprotected (unencrypted) data. Even if the data is secured and the ML tool is made compatible for use with encrypted data, the resulting operational performance is slowed to the point that it renders the approach intractable. Second, recent research has shown many DNNs are susceptible to white box (full access to the machine learning tool and operations) and black box (only access to system input and output) attacks, allowing adversaries to maliciously manipulate the ML tool's output.

In its short history, this concept has been successfully applied to a broad spectrum of problems: speech and image recognition, medical imagery diagnostics, drug discovery, customer relationship management, fraud detection, and military applications, among many others. In many of these applications, a critical factor has been the need to access large volumes of data, which created privacy concerns and opened the potential for insights that might have inappropriate or unwanted implications. Those factors were most obvious in applications involving patient data and in military applications. Although these problem domains could greatly benefit from the capabilities of an ML tool, these critical security concerns thwart their use.

These challenges have resulted in the development of a Secure Private Neural Network, which is a set of fully computationally tractable DNNs that preserve the privacy of core data sets via end-to-end homomorphic encryption, while providing additional defense against black box adversarial attacks through intelligent network stochasticity and training set confounding. The full implementation of the Secure Private Neural Network enables maintainers and users of ML tools to provide security and privacy, achieving a balance between data security and providing advanced modeling over the data in sensitive databases.

SPNN is a secure neural network that protects sensitive information

In developing the Secure Private Neural Network (SPNN) capability, there were two major challenges that had to be addressed. First, because the data to be used is often sensitive, it must be protected through encryption. However, performing arithmetic operations via traditional means renders the overall

Background photo: Peshkova/Shutterstock.com

process intractably slow. Therefore, it was necessary to develop a framework offering accelerated computational processes on encrypted data in a way that met security needs without compromising these processes. Second, traditional DNNs are vulnerable to a variety of attacks. Some of these involve manipulating data sets in a way that leads to incorrect conclusions and output. In so called "Trojan attacks," attackers can submit "trojans" into typical training sets that sculpt the performance of ML tools in a way that can be later exploited. Other attacks allow the attacker to gain insights about what has been learned, enabling their own counterstrategy development. Either problem can be significant, regardless of whether the attacker is a "nuisance" or a true adversary.

The approach to solving these challenges is reflected in the diagram below, showing how the multi-stage approach of the Secure Private Neural Network uses a combination of non-sensitive data in a "pretraining" phase, followed by subsequent training and classification phases, in which the data employed and the analytic results are secure from attack.

In the initialization phase, the DNN Builder converts the original structure into a homomorphic encryption-compliant structure and functions. It also adds extensions to the DNN to support resiliency to black box attacks. In the pretraining phase, the Pretrainer performs initial training of the unencrypted DNN with non-sensitive data, so the DNN begins to converge to its final state without revealing any sensitive data. The semi-trained parameters are then sent to the Trainer, which finalizes the DNN parameters in the training phase with encrypted non-sensitive and sensitive training data. Finally, in the classification phase, the Classifier Interface accepts input data from the client, selects DNN parameters from a set of DNN variants, and calculates a classification confidence that is only fully decrypted at the client.

Although homomorphic encryption is most efficient with binary data (ones and zeros), procedures can be used to perform arithmetic on more flexible

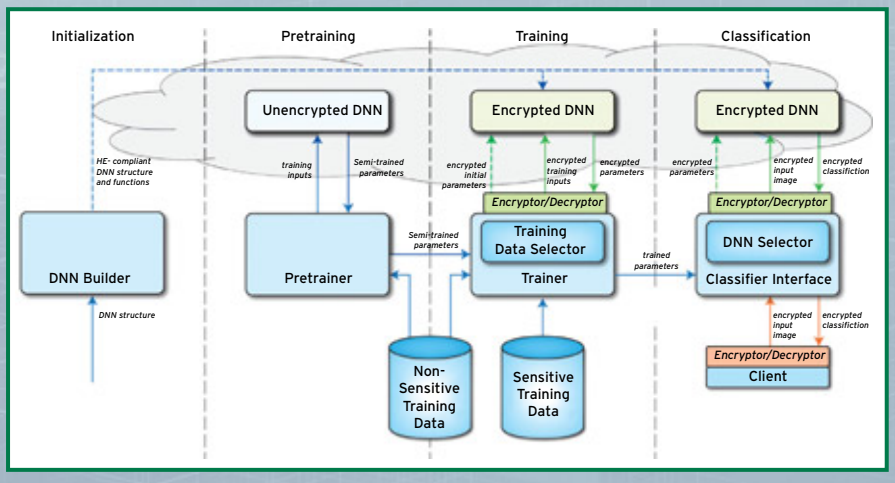
SPNN is a secure neural network that protects sensitive information

data, such as floating point numbers (allowing images to be processed). Given the need for data security, the ability to operate on encrypted floating point numbers is extremely beneficial. However, simply encrypting data can potentially leave an adversary with exploitable information, by using so called adversarial attacks. At their core, adversarial attacks exploit underlying trends in how DNNs operate, allowing the adversary to, for example, expose a DNN to imagery with subtle (non-human perceptible) changes which dramatically change its output. Obfuscation defenses work by adding network stochasticity, which masks the underlying trends of the DNNs, rendering attacks that leverage these trends ineffective.

To speed performance, the DNN can take advantage of the massively parallel computational capabilities of a GPU. GPUs are commonplace in the ML community due to the large number of processing streams they support; converting an ML algorithm to benefit from GPUs or Tensor Processing Units (TPUs) can result in nearly two orders of magnitude speed-ups. Tractable computation times is a primary concern for our Secure Private Neural Network, but encrypted calculations are not typically easy to parallelize. In our Secure Private Neural Network, encrypted operations on the encrypted DNN are parallelizable, and GPUs effectively speed up the computation proportionally to the number of available cores.

Real-time computer vision is one example application of the Secure Private Neural Network technology. Specific applications include robotic navigation; security screening; video analytics; and intelligence, surveillance, and reconnaissance (ISR). The accelerated pace of recent advances has made computer vision technology appealing to numerous products in a variety of commercial markets. One application, involving concealed weapon detection capabilities, clearly showcases the need to address the privacy and security concerns that motivated this approach.

This article was written by Curt Wu, Chief Software Engineer, and Jeff Druce, Senior Scientist, Charles River Analytics. (Cambridge, MA). For more information, visit ***http://info.hotims.com/76507-503****.*



From DC to Daylight

How Innovations in Microwave Absorbers Shield the Warfighter

The evolution of military electronics is marked by an endless series of measures and countermeasures. The enemy meets an enhancement in U.S. fighter jet technology with an improvement in its missile-guidance capabilities, forcing additional innovations from the U.S. The never-ending effort to enhance the effectiveness of military technology and protect the warfighter on the battlefield propels forward innovation in the industry.

Today, there's a battle underway that is dramatically expanding the frequency ranges used by the military for communications — soldier-to-soldier, soldier-to-satellite, aircraft-to-ground, missile-to-target, and more. Whereas military electronics used to operate in a narrow band of frequencies, today, military design engineers must protect equipment from damaging signal interference and enemy detection at a wider range of frequencies than ever before including radar at frequencies as low as 100 MHz and as high as 95 GHz.

This challenge is a complex one and addressing it requires a mix of materials science ingenuity, particle science innovation, and measurement and modeling sophistication. The solution? Changes in the makeup of a passive material called the microwave absorber.

The Crucial Role of Absorbers in Military Electronics

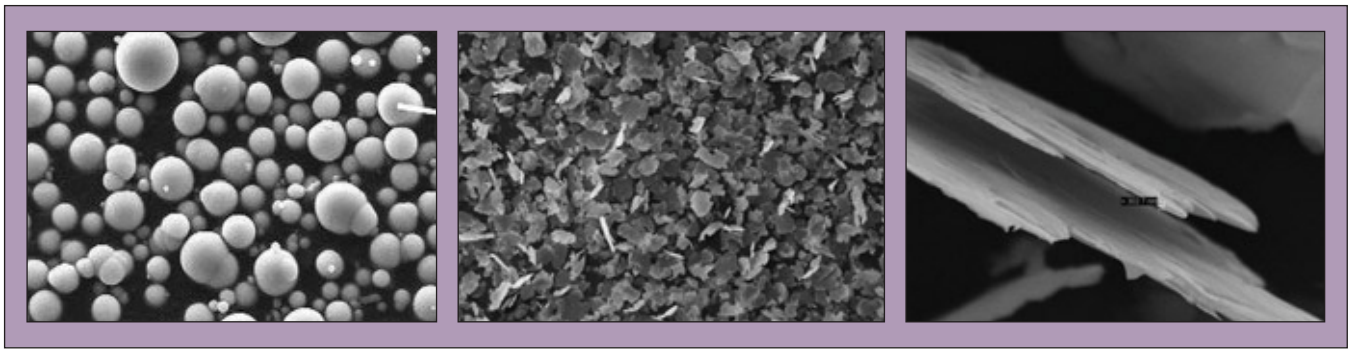
When effective, microwave absorbers:

- Eliminate stray or unwanted radiation that could interfere with a system's operation.
- Reduce the reflection of electromagnetic energy from or transmission to an object.
- Minimize oscillations caused by cavity resonance.

Absorbers can take many different physical forms including flexible elastomers, foam, or rigid epoxy plastics. In the military, absorbers play a key role in enhancing:

- Survivability – Absorbers can eliminate the "return energy" from an object, which keeps it hidden from radar detection.
- Antenna patterns – Absorbers reduce side lobes and backscatter and improve the isolation of an antenna, thereby keeping communications clear.

Absorbers consist of a filler material inside a material matrix. The external coating protects the absorber from its environment. The use of resilient fluorosilicone, instead of traditional silicone, can protect an absorber



An absorber's internal filler has magnetic and dielectric properties that enable signal attenuation. The size and shape of filler particles affects an absorber's performance at different frequency ranges.

Fluorosilicone microwave absorbers can withstand exposure to harsh substances such as jet fuel and deicing fluid.

from harsh substances, such as jet fuel and deicing fluid, improving its reliability and longevity.

An absorber's internal filler material has magnetic and dielectric properties that enable signal attenuation. To understand the effect of any material on electromagnetic energy, an engineer must first understand the material's conductivity, the electric permittivity, and the magnetic permeability.

Conductivity is a measure of the current that flows when a voltage is applied. For absorber material, the conductivity must be very low to enable absorption of electromagnetic energy. If a material has high conductivity, the electromagnetic energy will reflect at the surface and the material won't be able to absorb it.

The permittivity is a measure of a material's response to an electric field. A material's permittivity arises from polarization within the material. When subject to an electric field, charge carriers will align themselves in a direction that opposes the field. The greater this polarization field, the greater the permittivity.

Analogous to the electric permittivity is the magnetic permeability. The permeability is a measure of the material's response to a magnetic field. Materials with high permeability will concentrate magnetic field lines and increase magnetic energy density.

Knowing these parameters helps engineers develop absorbers that minimize reflection of electromagnetic energy and maximize its absorption.

Expansion in Frequencies Drives Innovation in Absorbers

Historically, military design engineers needed absorbers that were effective within a narrow range of 2-18 GHz. Magnetic absorbers for this frequency range are typically filled with standard magnetic powder. Today, however, this range has greatly expanded. As enemy radar capabilities improve, absorbers must prevent return energy at low frequencies. On the other end of the spectrum, as data transfer requirements grow, absorbers must enable clear and effective communications at high frequencies including 5G communications in the millimeter wave range.

Expanding the frequency range for absorbers involves using or designing filler materials with high absorption properties in the required frequency ranges. Maximizing the loss component of either the permittivity or permeability (or both) is very important. Also, increasing the permittivity and permeability will increase the attenuation per unit distance (or volume) due to the reduction of the wavelength inside the material.

Material absorption is significantly lower at lower frequencies due to the longer wavelengths. In these frequency ranges, engineers must increase permittivity and permeability to maximize wavelength compression and attenuation. With spherical particles, there are limits on permittivity and permeability; however, using shaped particles aligned in thin layers can greatly increase particle interaction and permittivity and permeability. So, in low frequency ranges, engineers must use metallurgical work to change a particle's size and shape (or morphology).

The picture changes as we move into the millimeter wave range, where wavelength compression is less important. Magnetically active fillers become less effective as we move into the higher fre-

quency realm and dielectric materials alone can often effectively attenuate electromagnetic energy in these frequency ranges. But the challenge in these higher frequencies is to get the energy into the absorbing material. As a result, the shape of the absorber takes on greater importance than it does in low frequency ranges. The creative use of multilayers and pyramidal shapes, for example, can enhance the effectiveness of absorbers in these high frequency ranges. Further, nanostructure materials can boost performance while allowing engineers to control the weight and viscosity of the absorber, which provides them flexibility as they shape and design the absorber.

A Key Enabler of Innovation: Modeling and Measurement

None of this innovation in absorbers is possible without sophisticated measurement and modeling capabilities. Design engineers must understand the electromagnetic properties of the various materials that comprise their absorbers. Then, they must be able to see how the absorber — made up of these materials — performs under various conditions.

The key parameters for absorbers are the complex electric permittivity and magnetic permeability. These values will vary with frequency. The most common method for measuring and characterizing absorber parameters is to measure complex reflection and transmission values from a sample of a known thickness in a closed waveguiding system. Within a material property database, a design engineer can perform multilayer performance prediction in stacks and run iterations. This database allows the military and aerospace industries to accurately and efficiently identify the proper mix of absorber materials for a specific application.

From there, a design engineer can deploy sophisticated electromagnetic modeling to essentially create a "map" of the electromagnetic behavior of an absorber. Engineers can use modeling software to calculate the form of electromagnetic fields within a volume, based on stimulus and configuration. They can use boundary conditions to complete the model and assign values. Electromagnetic modeling can help design engineers devise solutions in applications with multiple energy sources and constraints. At the same time, it helps them anticipate potential future problems and reduce the number of iterations required during the design phase of a project.

Winning on Today's Battlefield of Innovation

While the flashiest innovations in the military and aerospace industries — everything from new weapons capabilities to new fighter jets — attract the most attention, advancements in RF/microwave absorbers are crucial enablers of these larger innovations. As design engineers seek to stay ahead in the non-stop battle of measures and countermeasures with adversaries around the world, they can take comfort in knowing that the innovations taking place in the absorber space will help them improve survivability capabilities, strengthen communications and in the end, shield the warfighter.

This article was written by Paul Dixon, staff scientist, and Rick Johnson, aerospace and defense director, at Laird Performance Materials. For more information, visit ***http://info.hotims.com/76507-509.***

Army Advances Materials for New Low-Profile Antenna

Army scientists have developed a first-of-its-kind antenna that could change how ground vehicles and airborne systems communicate, transmit, and receive radio frequency communications.

The Army matured a manufacturing process using a special class of engineered materials known as metaferrites to make an ultra-thin wideband antenna. The antenna conforms to curved surfaces, making it ideal to integrate in unmanned aircraft systems, rotary wing aircraft, and ground vehicles.

Said Dr. Philip Perconti, Deputy Assistant Secretary of the Army for Research and Technology and Chief Scientist for the Army, "Our technical experts used their knowledge in material properties, modeling, and test and evaluation to further advance these materials."

In addition, the Army also invested in the development of the manufacturing processes in collaboration with coalition and industrial partners to advance from a prototype material to one that could be mass-produced.

More than 10 years ago, the Army recognized that metaferrites have special properties that could potentially be used to create RF antennas performing to standards impossible at that time. When metaferrites are sandwiched in pancake-thin antenna structures, good performance is achieved over a wide frequency range, with the antenna having a broad hemispherical antenna pattern.

Metaferrite antenna prototypes have been integrated into land platforms, as well as onto a Black Hawk helicopter. Data from lab and field testing verified the antenna is a suitable replacement for antennas with higher profiles, including X-wing and eggbeater antennas.

The metaferrite antenna has a wider frequency, which enables it to operate in both legacy satellite systems and with the Mobile User Objective System (MUOS). The MUOS provides a beyond-line-of-sight capability that allows soldiers to maintain connectivity anywhere in battle. The antenna's wide, hemispherical reach enables more reliable contact with satellites. In addition, it is self-contained and does not need to be grounded to a metal surface like commercial antennas.

The project supports the Army's Network/C3I, Future Vertical Lift, and Next Generation Combat Vehicle modernization priorities by providing a low-profile antenna for satellite-on-the-move communications. The antenna also eliminates drag for rotary-wing and other aircraft. With reduced drag, metaferrite antenna solutions could provide a path forward to integrate satellite communications capabilities previously too size, weight, and power (SWAP)-heavy for smaller unmanned aerial systems (UAS).

ARL worked with its defense, industry, and international partners to mature the technology before establishing the ManTech RF MetaFerrite Devices Program in 2017. The ManTech program advanced the project and transitioned manufacturing from a foreign source to a domestic supplier, while also increasing manufacturing from 500 antennas per year to more than 1,000. ManTech also improved performance of the antenna using 50 percent less material.

The ManTech program enabled the Army to understand the unique characteristics of the technology in order to develop a consistent manufacturing process to create the metaferrites. As a result, antenna developers have a new capability to design low-profile conforming antennas for warfighter applications.

For more information, visit the Army Research Laboratory at ***www.arl.army.mil****.*

A new metaferrite antenna (center) replaces the X-wing antenna (left) and the eggbeater antenna (right). (U.S. Army)

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Brigadier General Pantelis Arapis, Assistant Chief Of Staff ACOS J6 Cyberspace, **NATO SHAPE**

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Directed-Energy System to Defeat Small Unmanned Aircraft System Swarms

New weapons technology is needed to combat the proliferation of small unmanned aircraft systems (sUAS), miniaturization of sensor technology, and advancement of UAS swarm logic that will enable swarms of sUAS to threaten US airbases by the 2025 timeframe.

Air Command and Staff College, Montgomery, Alabama

The proliferation of small unmanned aircraft systems (sUAS), miniaturization of sensor technology, and advancement of UAS swarm logic foretell that swarms of sUAS will threaten US airbases by the 2025 timeframe. Currently fielded base defense systems are not well-suited to combat this emerging threat. Current directed energy (DE) developmental systems indicate this class of weapons is the best solution.

Three indicators necessitate US Air Force preparation for an imminent sUAS swarm threat: 1) the proliferation of sUAS, 2) the miniaturization of sensor technology, and 3) the advancement of UAS swarm logic. The first indicator necessitating US Air Force defenses against sUAS swarms is the proliferation of these systems. According to FAA estimates, the number of hobbyist sUAS in the US will increase from 1.1 million in 2016 to 3.5 million in 2021. These estimates only account for UAS weighing 55 pounds or less purchased in the US for personal use. The FAA further estimates the number of sUAS conducting commercial activities in US airspace to increase from 42,000 in 2016 to 420,000 in 2021.

The second indicator necessitating defenses against sUAS swarms is the miniaturization of sensor technology. Hyperspectral imaging technology is one example of sensor miniaturization. The Nano-Hyperspec sensor system from Headwall Photonics is only 3 inches × 3 inches × 5.1 inches, weighs just 1.32 pounds, and includes 480 GB of on-board storage capacity (approximately 130 minutes of processed hyperspectral imagery at 100 frames per second).

The third indicator necessitating defenses against sUAS swarms is the advancement of UAS swarm logic. One recent example of military swarm logic

The MIT-developed Perdix UAS

advancement was three US Navy F/A-18 Super Hornets releasing 103 sUAS during a Pentagon Strategic Capabilities Office exercise at China Lake, California. During this exercise, the Perdix UAS, developed by the Massachusetts Institute of Technology (MIT), demonstrated "collective decision-making, adaptive formation flying, and self-healing" swarm behaviors. Interestingly, MIT constructed the Perdix UAS by snapping readily available engines onto 3-D printed frames, indicating the threat may arrive sooner rather than later.

One of the few technologies capable of defending against UAS swarms is DE. There are two types of DE pertinent to military operations: lasers and microwaves. Although lasers and microwaves are both manifestations of electromagnetic energy, they are characterized by different wavelengths and, therefore, different frequencies. The relationship between wavelength and frequency is inverse, with wavelength (measured in meters) decreasing from left to right along the electromagnetic spectrum and frequency (measured in hertz) increasing.

Lasers and microwaves can be further categorized as either continuous wave or pulsed based upon how energy is emitted from their source. Whether a form of DE is continuously beamed or pulsed can fundamentally change the way the energy interacts with targets. For example, continuous wave lasers (CWL) affect targets by depositing energy, which typically results in a build-up of heat at the point of impact. Depending on the material, this heat buildup can result in burning through material layers until structural/component failure occurs. Several types of lasers are capable of producing continuous beams including chemical lasers like the YAL-1 Airborne Laser (ABL), and electric lasers such as diode-pumped or fiber lasers.

Pulsed lasers affect targets differently. The very high energy of a short pulse tends to cause ablation (stripping away molecules and atoms) at the point of impact, more than heating. These molecules can take on very high-energy states, creating plasmas at or near the point of impact, which, with proper timing, can be ignited to produce shock waves. Depending on the frequency with which a laser is pulsed, internal electronic effects are also possible. For both continuous wave and pulsed lasers, atmospheric attenuation limits the effective range and aiming precision.

Continuous wave microwaves also heat. However, microwaves heat by exciting water molecules. The Active Denial continuous wave microwave system is at a much higher frequency than a typical microwave oven, and therefore only penetrates a small distance into the skin, targeting the skin layer's pain receptors. In contrast, pulsed microwaves affect targets not by heating, but by creating an electromagnetic field that can induce currents in electrical wires. These currents can upset or destroy electronic components/systems. Unlike lasers, atmospheric attenuation, clouds, and moisture do not affect microwaves.

This work was done by David F. Pina for the Air Command and Staff College. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Optics, Photonics, & Lasers category.*** *AFRL-0295*

WIAMan Technology Demonstrator Sensor Codes Conforming to International Organization for Standardization/Technical Standard (ISO/TS) 13499

The Warrior Injury Assessment Manikin (WIAMan) Project is in the process of developing anthropomorphic test devices specific to the underbody blast environment and requires ISO Channel Codes specific to this test dummy.

Army Research Laboratory, Aberdeen Proving Ground, Maryland

The International Organization for Standardization (ISO)-Multimedia Exchange task force is responsible for maintaining the specification for the multimedia data exchange format for impact tests outlined in ISO/Technical Standard (ISO/TS) 13499.1 This specification includes what is informally known as an ISO Channel Code that encodes the test object, location, physical dimension, and other information related to a physical measurement in a 16-character, machine-readable format.

There exists a standardized and published list of ISO Channel Codes for measurements taken with existing anthropomorphic test devices (ATDs). The Warrior Injury Assessment Manikin (WIAMan) Project is in the process of developing an ATD specific to the underbody blast environment and requires ISO Channel Codes specific to this dummy. The ISO Channel Code is a string of 16 alphanumeric characters that are a composition of 9 position-specific substrings that encode details of a measurement. Each substring has an associated list of valid values.

The WIAMan ATD is a modern, high-channel count dummy that shares many attributes with other, newer dummies. It also breaks new ground in terms of volume of possible quasi-static measurements due to its embedded and distributed data acquisition system. In general, established position code selection has been used to create an unambiguous code string wherever possible. There are some cases, however, where this coding style breaks tradition in favor of more recent coding styles such as those used with the WorldSID.

Traditionally, many dummies have encoded certain anatomical locations associated with the MAIN LOCATION based on an informal descriptor, for example, the neck rather than the more formal cervical spine. If a formal code exists that describes the anatomical location it will be used in lieu of the less formal one.

Many areas within the WIAMan dummy have a concentrated number of uni- and bi-lateral measurement channels, such as the pelvis. Ideally, an anatomically specific code would be available to explicitly and unambiguously describe the anatomical location. In some cases, this level of granularity is already supported within the available codes, for example, the acetabulum or ACTB. Unfortunately, many anatomical channel positions needed by the WIAMan dummy are not included.

One possibility is that new codes be added to reflect the needed positions. Although 4 alphanumeric characters (26 letters plus 10 digits) can, in theory represent well over 1.6 million different locations, maintaining such an extensive dictionary represents administrative challenges. Fortunately, all measurement channels can be unambiguously identified using spacial qualifiers and therefore no new MAIN LOCATION codes are necessary. Recall that the ISO Channel Codes are primarily intended to be processed by a machine; thus, multiple spacial qualifiers are not expected to cause any additional burden in practice.

Similar to the Main Location substring, many dummies have used an informal descriptor in the Fine Location 1 position. For example, the UP in the code NECKUP represents the upper neck location in the Hybrid III Male dummy. Other dummies have used a numeric qualifier to add additional precision to the location. For exam-

ple, THSP04 represents the anatomical equivalent to the 4th vertebra of the thoracic spine in the WorldSID dummy. For the Channel Codes used with the WIAMan dummy, the more precise, numeric qualifier is used.

The Fine Location 3 substring is associated with the test object (i.e., dummy). This is a 2-digit code which, because of the size, limits the ability for the code to be self-descriptive in the general case. As the Channel Code is intended to be primarily machine-readable, the inability to concisely embed all adjectives associated with the WIAMan dummy or any potential WIAMan family does not pose a significant issue.

Although the code WM would seem a straightforward choice, the codes WS and WF are already taken to represent the WorldSID Dummy and the WorldSID Small Adult Female Dummy, respectively. The selected FINE LOCATION 3 code for the WIAMan dummy is DM representing the US Department of Defense average Army male. The D prefix is unused within the existing FINE LOCATION 3 codes and can therefore support a future WIAMan dummy family if needed.

This work was done by Michael Tegtmeyer for the Army Research Laboratory. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Daq, Testing & Sensors category.*** *ARL-0228*

Beam Propagation Model Selection for Millimeter-Wave Directed Energy Weapons

Comparing the relatively simple Fraunhofer or "far field" (FF) approximation commonly used in radar and high-powered microwave systems with the more complex near field (NF) propagation model based on the field equivalence principle demonstrates which approach achieves reasonable modeling fidelity with minimal compute power.

Institute for Defense Analyses, Alexandria, Virginia

Modeling and Simulation (M&S) can be used to explore the design trade space of directed energy weapons. M&S can be particularly helpful when that trade space is influenced by a large number of parameters and when acquiring field data to explore those parameters requires a large amount of resources. One example involves the Active Denial Technology (ADT) system, a non-lethal, counter-personnel, directed energy weapon that outputs high-powered, millimeter wave electromagnetic energy for crowd control, patrol/convoy protection, and perimeter security. The accompanying figure shows a photograph of a current ADT demonstrator (left) and a conceptual drawing of a future iteration of ADT (right).

A photo of an ADT demonstrator (left) and a conceptual drawing of a future iteration of ADT under development (right).

The ADT system subjects a targeted individual to short-duration pulses of a focused beam of directed energy operating at a frequency of approximately 95 GHz (3.2 millimeters in wavelength). At this frequency, and within a known range of doses, the energy diffuses approximately 1/64th inch (400 microns) into the skin of the targeted individual, producing no skin damage. Yet the targeted individual perceives an intense burning sensation, potentially strong enough to repel—that is, to compel the targeted individual to immediately flee the beam.

ADT systems that are currently under development can be placed into one of two broad categories: fixed- and variable-focus systems. A fixed-focus system combines a high-power source with a fixed-focus reflector to achieve operational power densities and spot sizes at relatively long ranges (500 – 1000 m). Variable-focus systems are phased arrays of relatively low power emitters with electronic phase control, allowing for dynamic beam-steering and focusing (e.g. the focal point can be varied). Such systems are expected to deliver an active denial capability in smaller form factors.

Like all weapon technologies, the effectiveness of ADT is dependent on both the system design parameters and the target properties. System design parameters include the ADT frequency and output power, among others. Target properties include the targeted individual's skin reflectivity, thermal conductivity, specific heat capacity, density of heat-sensitive neural endings, pain perception thresholds, and motivation, to name a few.

Simultaneous exploration of all of these parameters via M&S requires sev-

eral different model components—some to model the ADT system's output energy, and others to model the targeted individual's physiology, cognition, and behavior. Together, these components can be used to rapidly test hypotheses about how changes to the ADT system design will ultimately lead to changes in the ADT system effectiveness. However, running such a large model can be computationally expensive and therefore each individual component must be as low-intensive as possible. This research focuses on only the first component—that which simulates the propagation of the ADT beam through the environment to the targeted individual.

Two different computational models are explored to determine for which situations each model has the necessary balance of fidelity versus computational intensity:

- The first model uses the simple Fraunhofer approximation, also known as the far field (FF) approximation, that is common in radar and high-powered microwave (HPM) applications. This approximation is simple and is not computationally intensive. However, operational ranges for high-powered, millimeter wave systems like ADT often fall well within the Fresnel region where we cannot assume that the electromagnetic fields are purely diffractive—thus this approximation may not provide the necessary fidelity for all situations.
- The second model is a near field (NF) extension of the FF approximation where the system is approximated by a discrete array of radiators. This approximation is slightly more complex, meaning it is more computationally intensive but may provide improved fidelity for some situations.

The outputs of the two computational models are compared for both a fixed- and variable-focus millimeter wave system to see in which situations they differ. The models are also validated by comparing their outputs to experimental measurements taken with the variable-focus system.

This work was done by John Biddle and Shelley Cazares for the Institute for Defense Analyses. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Optics, Photonics, & Lasers category.*** *IDA-0001*

Experimental Design of a UCAV-Based High-Energy Laser Weapon

Until now, unmanned combat aerial vehicles (UCAV) have used only conventional missiles (i.e., Hellfire), but the rapid growth of laser weapon technology suggests that the day of the first deployable UCAV armed with a high-energy laser (HEL) weapon is not far away.

Naval Postgraduate School, Monterey, California

The deployment of an airborne platform armed with a High Energy Laser (HEL) weapon has been a major challenge for several decades. Attempts in the past included mounting a HEL weapon in large aircraft like a Boeing 747, mainly for strategic missions like defense against tactical ballistic missiles. Despite being very promising in their initial phases, these trial configurations presented various technical and economic issues that resulted in their cancellation.

Recently, the focus has shifted from strategic missions to tactical missions. That means that HEL weapons of lower power and, consequently, decreased size and weight would be sufficient for these missions while also being more suitable for airborne applications. Additionally, the improvements in laser weapon technology in terms of size, weight, and power (SWaP) promise that soon a HEL weapon could be deployable from an unmanned aerial vehicle (UAV).

The purpose of this research was to model a UAV-based HEL weapon by applying a model-based system engineering (MBSE) approach and simulate its performance. Two alternative HEL design configurations were selected, and their corresponding weight requirements were estimated. Finally, the endurance of the UAV for these different configurations was calculated.

Utilizing Vitech CORE software, the architecture of the UAV-HEL system was modeled, starting from the system capabilities required for a Close Air Support (CAS) mission execution along with the operational system requirements. Next came the functional and physical architecture, showing the functions that each physical component is to accomplish. Finally, the UAV's endurance and the HEL's lethality were identified as the technical performance measures of the overall system.

The first phase of the simulation experiment focused on exploring how the different operational tactics and HEL design configurations affect the lethality of the system as measured by the irradiance delivered to the target and the power accumulated in a bucket on the target's surface, with a radius of 5 cm and thickness of 3 mm. Exploring these parameters at the same time, rather than one factor at a time, called for application of the Design of Experiments (DOE), a well-structured mathematical process that allows for the determination of the significance of each factor and potential interactions among them by analyzing the simulation's experiment results. The selected parameters in this simulation are the HEL's power; the beam director size; and the UAV altitude, speed, and direction. Having defined the mission of the UAV, the target damage criteria was determined by calculating the required irradiance and power in bucket (PIB) for differ-

ent dwell times. Specifically, it was found that for an aluminum surface target, an irradiance of 11 MJ/m^2 and PIB of 85 kW for a dwell time of 6 seconds would be sufficient to melt the target.

The simulation results clearly showed the importance that the operating altitude of the UAV has on the HEL's lethality. The results showed that operating altitude has the greatest effect on both irradiance and PIB. Following altitude in importance is the beam director size and then output power. Speed and direction of UAV show no significant effect. Another important simulation result showed that under certain circumstances a 150 kW HEL deployed by a UAV flying at altitudes higher than 3000m could have the same performance as a 250 kW HEL operated from lower than 500m of altitude.

The UCAV-HEL Concept (Source: General Atomics Aeronautical Systems Inc.)

Having determined those two power levels as possible alternatives and measured their performance, the corresponding weight and power requirements were estimated for each alternative. These estimations, which were based on commercially developed systems and provided a nominal approximation, showed that a 150 kW HEL would weigh approximately 1670 kg whereas a 250 kW HEL would weigh 2635 kg. Therefore, both alternatives could be mounted and supported by a UAV similar in size and capability to the Predator B.

By consulting a subject matter expert on UAVs, it was determined that a simple mathematical relationship existed between the endurance of the UAV and its payload weight. Using this relationship, it was determined that the lower power HEL would allow an endurance of around 25.5 hours, whereas the bigger one would allow only for 23 hours, or a 10 percent decrease in endurance.

This work was done by Antonios Lionis for the Naval Postgraduate School. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Optics, Photonics, & Lasers category.*** *NPS-00012*

Application Briefs

Remotely Piloted Aircraft

General Atomics Aeronautical Systems, Inc.
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General Atomics Aeronautical Systems, Inc. (GA–ASI) recently flew its SkyGuardian Remotely Piloted Aircraft (RPA) in the skies above Southern California as part of a joint flight demonstration with NASA. GA-ASI was selected to participate in NASA's Systems Integration and Operationalization (SIO) activity, which includes multiple flight demonstrations focusing on different types of Unmanned Aircraft Systems (UAS) and their respective flight environments. GA-ASI and NASA have worked collaboratively since 2014 to prove the safety of flying large UAS in the National Airspace System (NAS).

GA-ASI demonstrated ways in which SkyGuardian can be used for a variety of commercial and public services applications, using its onboard sensors. Services featured in the demo included inspections of hundreds of miles of rail, power line, communication and canal infrastructure, agriculture monitoring and topological surveys, as well as wildfire and flood monitoring.

After taking off from GA-ASI's Gray Butte Flight Operations Facility near Palmdale, Calif., SkyGuardian flew through the NAS in Southern California towards Yuma, Ariz. while being operated by a remote pilot based at Gray Butte. The pilot used the GA-ASI-developed Detect and Avoid System (DAAS) to provide situational awareness of air traffic near the UAS.

The DAAS includes a Traffic Alert and Collision Avoidance System (TCAS II) used in manned aircraft that fly in civil airspace. It also has an air-to-air, "Due Regard" radar to provide detection and tracking capability of any nearby aircraft which may not have active transponders. Using the DAAS, the remote pilot was able to "see" and navigate around airborne traffic just like an airborne pilot.

"NASA's goal to help accelerate routine UAS operations into the national airspace has moved one step closer with this successful flight demo," said Mauricio Rivas, UAS integration in the NAS project manager at NASA's Armstrong Flight Research Center. "Our efforts with General Atomics and our other SIO industry partners will help commercial UAS move closer towards certification."

General Atomics Aeronautical Systems, Inc. (GA-ASI), an affiliate of General Atomics, is a leading designer and manufacturer of proven, reliable Remotely Piloted Aircraft (RPA) systems, radars, and electro-optic and related mission systems, including the Predator® RPA series and the Lynx® multi-mode radar. GA-ASI's technology partners for the demonstration include Honeywell (supplied the TCAS II for the DAAS), and Collins Aerospace for the Command and Non-Payload Communications (CNPC) datalink radios, which is part of the Command and Control datalinks system.

For Free Info ***Visit http://info.hotims.com/76507-460***

Operating System Software

Green Hills Software
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www.ghs.com

Green Hills Software, a company that specializes in high-assurance operating systems, announced this year that its INTEGRITY®-178 Time-Variant Unified Multi-Processing (tuMP™) RTOS for the Xilinx® UltraScale+™ FPGA has been selected by Collins Aerospace for the U.S. Navy's Tactical Combat Training System Increment II (TCTS Inc. II) program. Key factors in the selection of INTEGRITY-178 tuMP were its Multiple Independent Levels of Security (MILS) architecture, its ability to host Multi-Level Security (MLS) applications such as Cross Domain Solutions (CDS), its ability to host a guest OS and legacy applications in a secure virtualized partition, and its conformance to the Future Airborne Capability Environment (FACE™) 3.0 Technical Standard.

Collins Aerospace's TCTS Inc. II solution enables the rapid adaptation of new missions and threats into training as well as joint and coalition interoperability with fourth- and fifth-gen-

eration aircraft platforms. The ability for the Navy and Marine Corps to rapidly advance future technology insertions is due to Collins Aerospace's open architecture design and use of industry standards, including alignment with the FACE™ Technical Standard.

The INTEGRITY-178 tuMP high-assurance RTOS is a critical part of a CDS solution with an unequalled security-critical pedigree. The INTEGRITY-178 RTOS is the only commercial operating system ever certified to the Separation Kernel Protection Profile (SKPP) published by the Information Assurance Directorate of the U.S. National Security Agency (NSA). That certification was done by the National Information Assurance Partnership (NIAP) to Common Criteria EAL 6+ "High Robustness."

The INTEGRITY-178 tuMP RTOS was also the first operating system certified conformant to the latest revision of the FACE Technical Standard, edition 3.0, and it is still the only operating system that meets all of the multicore requirements defined in the FACE 3.0 Technical Standard.

For Free Info ***Visit http://info.hotims.com/76507-464***

Rocket Engine Technology

Invocon, Inc.
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The team of Invocon, Inc., KT Engineering Corporation, and Troy 7, Inc. has been awarded a Prototype Project Award by the U.S. Air Force Space and Missile Systems Center (SMC) for the Aerospike Rocket Integration and Suborbital Experiment (ARISE). Awarded through the Space Enterprise Consortium® (SpEC) and managed by the Air Force Research Labs (AFRL) Rocket Lab at Edwards AFB, California, the project will demonstrate flight in a sub-orbital flight test of a launch vehicle utilizing a single rocket engine with an annular aerospike nozzle, modular thrust cells, and modular turbomachinery.

The primary objective of the flight test is obtaining flight performance data for the modular aerospike engine over a range of operation representative of a launch vehicle trajectory, including open wake regime, wake transition, and closed wake regime. To achieve this objective, the team will produce a highly instrumented modular aerospike engine and launch vehicle and perform integration activities, execute range coordination, and conduct launch operations on a sub-orbital flight, the first of which is scheduled for 2022.

This effort will also mark the first representative flight of an aerospike engine after many decades of research and abandoned flight efforts. Aerospike nozzles operate in three modes (open wake, wake transition, and closed wake) at specific altitudes depending on the engine design, flight trajectory, and ambient atmospheric conditions. ARISE will fly a launch-to-orbit trajectory to ensure the aerospike nozzle operates in all three regimes and gathers applicable data for future launch vehicles.

The benefits of this structure include improved performance, better facilitation of integration schemes between vehicle and engine, and improved adaptability between different derivative engine and vehicle. Until now, uncertainties related to design and performance presented barriers to engine modularity and aerospike nozzles in launch vehicles. Since ARISE will demonstrate relevant behavior in flight and gather large amounts of data that can anchor models, this initiative will significantly decrease the risks and costs associated with developing future rocket engines that incorporate this technology.

KT Engineering (KTE) is a small business specializing in the research, design, analysis and testing of aerospace systems, subsystems and components. KTE has demonstrated expertise in the research and development of low-cost chemical rocket engines, high-performance pressurization systems, and lightweight metallic tanks and structures, and 18 years of experience in the design, analysis and testing of aerospike and plug cluster rocket engines.

Troy7 is a woman-owned small business with core competencies in guidance and control, telemetry, vehicle design, and launch operations. Troy7 is a highly technical small business with a legacy of support to more than 350 DoD and NASA flight test missions. Troy7 currently supports MDA, the National Aeronautics and Space Administration (NASA), PEO Missiles and Space, the US Army Space and Missile Defense Command (SMDC), and commercial companies.

Invocon is a veteran-owned small business that provides turnkey instrumentation and control solutions for demanding applications in extreme environments for the sensing and data acquisition communities. For the ARISE project, Invocon is responsible for engine instrumentation, PCM telemetry encoders and transmitters, vehicle battery power and control, and flight termination system. As a SpEC Consortium member, Invocon will serve as prime contractor for the project.

For Free Info Visit ***http://info.hotims.com/76507-465***

CAM Software

OPEN MIND Technologies USA, Inc.
Needham, MA
888-516-1232
www.openmind-tech.com

OPEN MIND Technologies, a worlwide developer of CAD/CAM software solutions, announced that Ramco Machine, LLC (Rowley, MA) is helping to impact the future of space exploration by using hyperMILL® CAM software and 5-axis machining to make parts for an advanced NASA satellite mission. The mission, named Transiting Exoplanet Survey Satellite (TESS), is credited with discovering its first circumbinary planet - a world orbiting two stars.

In 2017, Ramco was contracted by MIT Lincoln Laboratory (Lincoln, MA) to fabricate the critical camera mount brackets for an important NASA TESS satellite mission. NASA's TESS mission is designed to explore and survey nearby bright stars to analyze planets, both smaller and larger than earth, as the planets circle their host stars and the earth orbits the sun.

In 2018, a solar powered in-space satellite equipped with four ultrasensitive cameras was launched aboard a two-stage SpaceX Falcon 9 rocket on its way beyond earth's solar system to outer space. The four-camera system developed at the MIT Lincoln Laboratory monitors the brightness of more than 200,000 stars and searches for minute drops in brightness as the planets transit in front of each star.

Making the mounting brackets required machining Invar, a nickel-iron alloy with a low thermal expansion coefficient, allowing it to meet the rigors of launch and enabling it to compensate for the extreme temperature swings of outer space. The mounting bracket has exceedingly tight tolerances. The central rib's thickness is .050" +/- .001", perpendicularity between surfaces is held to .001" and the bracket's two opposing surfaces must be in-line with each other to within .001".

To cut Invar and achieve the required tolerances, Ramco used a hyperMILL® generated 5-axis profile finish tool path. By doing this, an accurate finish across each part was achieved, keeping them within these very tight tolerances.

Headquartered in Germany, OPEN MIND is a leading developer of powerful CAD/CAM solutions for machine and controller-independent programming. The company develops optimized CAD/CAM solutions that include many features unavailable elsewhere, to deliver significantly higher performance in both programming and machining. Strategies such as 2.5D, 3D, as well as 5-axis milling, mill/turning, and machining operations such as HSC and HPC, are designed into the hyperMILL® CAM system, providing maximum user benefit and compatibility with all current CAD solutions and programming automation.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland. Astronomers predict that TESS will discover dozens of Earth-sized planets and up to 500 planets less than twice the size of Earth. In addition to Earth-sized planets, TESS is expected to find some 20,000 exoplanets in its two-year prime mission. TESS will find upwards of 17,000 planets larger than Neptune.

For Free Info Visit ***http://info.hotims.com/76507-463***

Rear Fuselage Packer

Kaman UK
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Aerospace manufacturer, Kaman UK, successfully delivered its 80,000th rear fuselage packer to BAE Systems for its F-35 manufacturing program. Kaman UK has been supplying these parts since 2003. To date, the rear fuselage packers, and 1,000 plenum ducts, have been used in the manufacture of over 500 aircraft.

According to a company spokesperson, this is part of a long-term partnership between both companies for the manufacture and supply for multiple aircraft platforms such as Typhoon, Hawk, Tornado and Harrier AV-8B for a wide range of metallics, composites and ground support equipment. These include plenum ducts, chemical treatments, landing gear doors, rudders, over-wing panels, ailerons, blanking plugs, canopy removal tools, and various other complex assemblies for wing and fuselage.

Kaman UK – trading as Brookhouse Patterns – first began working with BAE Systems in 1951 under its predecessor company, English Electric Company. This covers a wide range of ongoing and legacy programs such as Javelin, Buccaneer, Harrier and Tornado and today the Hawk and its variants, Typhoon and the F-35 (latter since 2003). Kaman manufactures and provides spare parts on these programs via BAE Systems for air forces around the world.

Packers are frequently used in the assembly of large, complex aircraft components such as sections of the fuselage. It is important to ensure during assembly that a tight fit is maintained to ensure the proper transfer of loads and aerodynamic performance and to mitigate tolerance build-up. Typical tolerances that could impact performance include length, width, thickness, angles, and profiles. These tolerances are all analyzed during the design phase and acceptable limits are established.

A packer is then inserted between the two components during assembly to ensure that these tolerances are not exceeded. In the case of the F-35's rear fuselage, for example, the packer and the fuselage components to be joined would have mating part-spherical surfaces. After inserting the packer into one part of the fuselage, the second part of the fuselage can be moved into place via the packer and joined to the first part without negatively impacting assembly tolerances.

Kaman UK has a 70-year history of providing technical breakthroughs and innovation that global aerospace clients use to deliver high-performance component parts into the aerospace supply chain.

For Free Info Visit ***http://info.hotims.com/76507-461***

Solar-Powered Structures

Pvilion
Brooklyn, NY
718-852-2528
www.pvilion.com

Pvilion, a solar-powered fabric provider, was recently awarded a Phase II Small Business Innovation Research (SBIR) contract by the United State Air Force (USAF) to continue its development of rapidly deployable, solar-powered structures. Through a competitive awards-based program, the Small Business Innovation Research (SBIR) Program enables small businesses to explore their technological potential and provides the incentive to profit from its commercialization.

The USAF's Rapid Sustainment Office (RSO) and AFWERX have partnered to streamline the Small Business Innovation Research process in an attempt to speed up the experience, broaden the pool of potential applicants and decrease bureaucratic overhead. The RSO's goal is to increase mission readiness by rapidly identifying, applying, and scaling technology essential to the operation and sustainment of the United States Air Force.

In moments of crisis, the USAF needs to be able to deploy structures in forward areas to support personnel, equipment and operation centers. These structures need to be agile in that they must be easy to set up quickly and be independently powered. Additionally, the structures need to provide climate control. The USAF favorably evaluated the products Pvilion presented for cost, complexity, sustainability, and required

manual labor, as well as for energy independence, all with the goal of maximizing mission-objective readiness.

Pvilion's solar technology is significantly lighter, more adaptable than traditional solar options, and can be integrated entirely into a system already being installed; e.g., a tent, shade canopy, hangar, etc. With fully integrated photovoltaic fabric panels, Pvilion's structures allow for the multi-capability use by providing power, shelter, lighting, and climate control. Pvilion's commercial customers typically use its solar fabric technology in structures used for events such as music festivals, in temporary industrial worksites and in structures found in parks, municipalities, universities, and corporate campuses. These solar fabric products have been commercially available for eight years.

Pvilion has also successfully developed ways to modify framing systems and fabric to be built lighter in weight with highly insulated walls. Pvilion's high-efficiency structures are integrated with solar cells for a turnkey solution that includes climate control, improved thermal performance, and increased equipment performance and they are well suited for on-site additive manufacturing. The integrated technologies reduce cooling power requirements while simultaneously generating the power needed.

This is reported to be the first product of its kind to properly align solar, energy storage, cooling and heating for a fully off-generator expeditionary system capable of operating in most climate conditions. The lighter technology and increased thermal performance specified by the Air Force will have applications in the commercial market, as well. Pvilion's product will both reduce the manpower required to set up renewable energy and shelter solutions, while also reducing the dependency on costly, loud, and environmentally dirty diesel generators.

For Free Info ***Visit http://info.hotims.com/76507-466***

Mars Rover Electric Motors

maxon precision motors, inc.
Taunton, MA
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www.maxongroup.com

NASA recently sent its fifth rover to Mars. Its main mission is to collect soil samples that will be analyzed on Earth at a later time. The rover will also carry a helicopter that will perform the first flights on the Red Planet. maxon precision motors, inc. revealed that a number of its precision DC and BLDC motors were designed into the Perseverance rover to allow it to accomplish a variety of mission-critical tasks.

This isn't the first time maxon's motors have been to Mars. Their drives have been used in virtually every successful robotic mission over the last three decades, meaning there are now more than 100 of them on the Red Planet.

An Atlas V rocket launched the new Perseverance rover on its way to Mars, where it will be searching for signs of previous life on the planet. Its most important job is to take multiple soil samples, seal them in containers and deposit them on the surface of Mars so that a future mission can return them to Earth. Several maxon motors will be used to handle the samples inside the rover. For example, maxon DC motors are installed in the robotic arm, which moves the samples from station to station. Maxon motors will also be used for sealing and depositing the sample containers.

NASA's Jet Propulsion Laboratory (JPL), charged with carrying out the mission, asked maxon to produce 10 drives for the rover. As with almost all previous Mars missions, these drives are based on standard products from maxon's catalog with modifications. For the first time, NASA is using brushless DC motors, including: nine EC 32 flat and one EC 20 flat in combination with a GP 22 UP planetary gearhead. Working closely with JPL specialists, maxon engineers developed the drives over several years and tested them thoroughly to achieve the necessary standards of quality.

Space missions place the highest demands on drive systems. This includes vibrations during the rocket launch, vacuum during the journey, impacts on landing, and the harsh conditions on the surface of Mars, where temperatures fluctuate between -125 and +20 degrees Celsius and dust penetrates everywhere.

The Perseverance rover was expected to land on Mars sometime in February 2021 – but it won't be alone. A drone helicopter called Ingenuity will be attached to the underside of the rover. It weighs 1.8 kilograms, is solar powered and will perform several short flights, as well as take aerial images. The main goal of this experiment is to test the concept for further drones of this kind. maxon has six brushed DCX motors with a diameter of 10 millimeters controlling the tilt of the rotor blades and the direction of flight. The drives are very light, dynamic and highly energy-efficient.

These properties are crucial, because every gram counts on the Mars helicopter. Flying on Mars is not easy. The atmosphere is extremely thin, roughly comparable to the conditions on Earth at an altitude of 30 kilometers. The drone helicopter has flown in a simulated test environment in the JPL laboratory, but whether it will lift off on Mars remains to be seen.

For Free Info Visit ***http://info.hotims.com/76507-462***

Damage & Repair Tracker

tlmNexus
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Since May 2020, the UK's fleet of Merlin Mark 2 helicopters has been testing the tlmNexus' Damage & Repair Tracker (DaRT) application in conjunction with multinational aerospace company Leonardo. In 2019, Brighton-based tlmNexus launched the service with the UK Defence Equipment & Support (DE&S) to provide MOD Typhoon multirole fighter jets with the DaRT system. The new contract with Leonardo is further recognition of the benefits that DaRT offers. The application is relevant to both defence and civilian operations. DaRT enables an entire system's damage and repair to be recorded and tracked in a single location by multiple users. The Leonardo contract permits the application to be used by both the RN aircrew who fly the helicopter and also the civilian and military maintainers who keep it in the air. Using the application in this 'end-to-end' manner, the intention is to ensure that all damage and subsequent repairs are recorded in one place, throughout the system's lifetime, providing crucial information for making decisions today – as well as into the future.

DaRT is configurable to suit the different platform systems and processes used by various operators. Users are able accurately to record damage and repair on pictorial views and can include a variety of related data. DaRT is also able to support the progression of the repair process. For Merlin the tlmNexus team have included existing forms used by the helicopter crew and support team to request technical assistance into the DaRT application, helping to further improve the efficiency of the damage and repair process.

tlmNexus Ltd is a UK technology company with a headquarters located in Brighton, a city rapidly building a reputation as a tech hub, with team members stationed across the country. Two of its three founders served together as military engineers. The idea of through-life management was emerging as a force for good but was frequently paper-based and disjointed. Both men recognized that to improve the availability of front-line fleets, the management of various processes needed to change dramatically to ensure the efficient delivery of defense capability. Upon completion of their service, they set out on a new journey determined to maximize the benefits from through-life thinking.

Then known as TLM Solutions, they joined forces with a leading technology company in 2007, Nexus Internet Solutions, a company pioneering the early benefits of using web-based applications to increase business performances, and so formed tlmNexus. Today, the company is working alongside the defense sector bringing services and technologies together to solve complex information problems and transform the way organizations work and deliver.

For Free Info Visit ***http://info.hotims.com/76507-467***

New Products

Satellite Phone Docking Station

Blue Sky Network (San Diego, CA) has released the 9575A Docking Station, the first and only secure docking station for the Iridium 9575A satellite phone. The Iridium 9575A satellite phone is the only commercial handset capable of Type I encryption accredited by the U.S. National Security Agency for Top Secret voice communications and is replacing the now-obsolete Iridium 9505A satellite phone. Blue Sky Network's 9575A Docking Station, the successor to the ASE-MC03-DOD dock for the 9505A, is the only commercially available docking station that supports the 9575A satellite phone handset. The 9575A Docking Station supports General Dynamics' DOD security module 2 and Enhanced Mobile Satellite Services (EMSS) for global voice, data, and paging capabilities.

The Iridium Security Module 2 (ISM2) is a sleek, small form factor encryption module that provides NSA Certified protection of classified voice and data communications. The module is covert, fits completely inside the Iridium 9575A handset, and provides end-to-end security for information classified Top Secret and below.

For Free Info Visit http://info.hotims.com/76507-470

3U OpenVPX SBC Module

Sundance Multiprocessor Technology Ltd. (Chesham, UK) launched the VF370, an Intel-based 3U OpenVPX single board computer (SBC) module designed for reduced Size, Weight and Power (SWaP) requirements. Available in standard air-cooled and rugged conduction-cooled versions, the VF370 utilizes the Intel Atom E3900 Series of embedded processors combined with Intel's well-established Cyclone FPGA technology. The VF370 features a single, dual or quad core Intel Atom processor operating at up to 2 GHz for running post-processing software. An onboard SATA SSD provides fast booting and reliable storage, while associated onboard peripherals include 4 GB of associated DDR memory, a real-time clock (RTC), elapsed time indicator (ETI), EEPROM and Flash for user configuration data and logs.

The Intel Cyclone FPGA, with scalable logic and variable-precision DSP resources facilitates the implementation of IP cores and/or custom logic. Combined with 2 GB of DDR3 memory, it supports algorithms with large memory size and bandwidth requirements. The high pin-count FMC connector connects to the FPGA through four high-speed serial interface (HSSI) lanes and 58 differential LVDS/LVTTL signals while an optional FMC I/O connector routes 32 differential pairs to the P2 VPX connector for backplane or rear I/O functionality.

For Free Info Visit http://info.hotims.com/76507-482

Single Pair Ethernet Aircraft Wiring

TE Connectivity (TE) (Harrisburg, PA) unveiled its new Mini-ETH single pair ethernet system for commercial aircraft that offers weight savings, more bandwidth and simpler installation and maintenance by using proven technologies from other markets. TE's new Mini-ETH system offers them up to 73% weight savings in cables and up to 41% weight savings in connectors compared to standard eight-wire cables and rectangular connectors.

Using ethernet over single pair protocols derived from the automotive market, the Mini-ETH system delivers its weight savings by employing a two-wire cable design, which was recently standardized under the ARINC 854 cabin equipment network bus standard. Two-wire cables and corresponding 369 connectors help reduce termination time by up to 50% compared to standard quadrax connectors. The package is qualified to 100Mb/s with the ability to support up to 1Gb/s in future applications. The Mini-ETH system is currently designed for use in In-Flight Entertainment (IFE) systems, seat power and lighting controls.

For Free Info Visit http://info.hotims.com/76507-471

Drilling and Tapping Centers

With rapid traverse speeds up to 2,362 ipm (60 m/min) in all axes and acceleration of 1.2 g, the Tongtai VTX series of drilling and tapping centers are now available from Absolute Machine Tools, Inc. (Lorain, OH). The machine's compact 87" × 63" (2,210 mm × 1,600 mm) footprint conserves shop floor space, and a fixed column/moving table type design with Meehanite cast-iron frames and roller-type linear slideways provides rigidity and fast, precise movement.

Two types of high-speed ATC systems are available. The 21-tool turret-type ATC on VTX-5 and VTX-7 models offers tool change time of 1.4 seconds tool-to-tool and 1.9 seconds chip-to-chip. VTX-5A and 7A versions have a 20-tool arm-type ATC system that reduces tool change time to 0.8 seconds tool-to-tool and 1.3 seconds chip-to-chip.

The standard 7.5 hp, 12,000 rpm direct-drive spindle provides rigid tap speeds up to 6,000 rpm. An optional 24,000 rpm direct-drive spindle delivers high speeds for machining aluminum and magnesium parts and is suitable for processing graphite. A BBT-30 (Big Plus dual contact) taper is standard for rigid milling.

For Free Info Visit http://info.hotims.com/76507-472

Spectrum Analyzer Platform

RIGOL Technologies (Beaverton, OR) announces the new RSA3000N and RSA5000N Spectrum Analyzer, which extends the flexibility and capability of the UltraReal platform with a new Vector Network Analyzer measurement mode. The RSA5000N and the RSA3000N deliver the same performance specifications and feature set as the current RSA models but adds the VNA capability as a standard feature. With integrated Smith Charts, Polar Charts, Reflection Coefficient, Impedance, Insertion Loss, Frequency Response and a host of other measurements the RIGOL UltraReal Spectrum Analyzer becomes a fully functional Vector Network Analyzer.

Supporting S11, S21 and Distance to Fault Analysis, the RSA5000N and RSA3000N can be used to tune antenna sets, search for communication and cable faults, or fully characterize their active or passive RF components. There are 5 models of Vector Network Analyzer. The RSA3000N supports frequency ranges of 1.5 GHz, 3.0 GHz and 4.5 GHz. The RSA5000N ranges from 3.2 GHz to 6.5 GHz.

For Free Info Visit http://info.hotims.com/76507-476

Multi-Spindle Automatic Lathe

INDEX (Noblesville, IN) has launched its next generation MS32-6 multi-spindle automatic lathe. Accommodating up to 32 mm bar stock, the MS32-6 easily handles a wide variety of complex parts, as the machine is equipped with twelve cross slides, with two v-shaped cross slides equipped with X and Z axes located at each spindle position. C and Y axes, together with live tools, can also be implemented to allow for off-center drilling, threading, contouring, hobbing and polygonal turning.

Each cross slide in the MS32-6 now incorporates INDEX's patented W-serration locating system that provides µm-accurate alignment of the tool holder. Coupled with the company's newly developed quick-clamping device, tools can be set up off of the machine and then quickly installed, reducing tool change times by 50%. Additionally, the machine incorporates the same W-serration system on its live units for drilling, milling and polygonal turning. The machine's fluid-cooled spindle drum features six spindles with speeds that are independently controlled to a maximum of 8,000 rpm. The machine can also be equipped with one or two synchronous spindles, each of which can apply up to six tools for machining the rear end of parts.

For Free Info Visit http://info.hotims.com/76507-477

Micrometers

Mahr, Inc. (Providence, RI) has introduced five new micrometers for specialized measuring tasks, including:

- 40-EWR-R/40-EWRi-R micrometers with spherical and flat anvils for measuring wall thickness;
- 40-EWR-S/40-EWRi-S micrometers with non-rotating blade anvils for measuring grooves and slots;
- 40-EWR-B/40-EWRi-B micrometers with 3mm diameter measuring faces for recesses and spline shafts;
- 40-EWR-K/40-EWRi-K micrometers with blade and point contact for measuring wire crimps;
- 40-EWR-V/40-EWRi-V universal micrometer kits with interchangeable contacts for measuring diameters over balls, threads and many other special lengths.

All Micromar 40 EWR/40-EWRi micrometers incorporate a large 10 mm digit high contrast display; tolerance limits to qualify the part; a built-in reference system for setting zero position only once; and a "hold" function (digital lock) that allows measured values to be "frozen" so they can be easily read. All are IP65 rated so users can have confidence they will work in some of the harshest manufacturing conditions.

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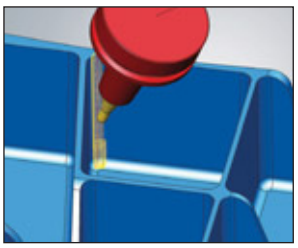
CAD/CAM Software



OPEN MIND Technologies AG (Needham, MA) has introduced hyperMILL® 2020.1, a new version of its advanced, comprehensive CAD/CAM software suite. In addition to powerful 3D and 5-Axis machining enhancements for complex part manufacture, the new version increases ease-of-use and overall programming performance and includes new automation and additive manufacturing strategies.

hyperMILL® 2020.1 offers new Corner Rest Machining strategies for 3D and 5-axis techniques that benefit complex machining applications including mold and die. Enabled by a simple instruction, corners can be machined largely by vertical stroking motions. Then traditional z-level steps can be used to blend with the vertical section and the lower floor area. The top section has an automatic surface extension to enable the production of sharp edges.

Programming is simplified within the Mill-Turn module by a new Automatic Contour Feature Splitting capability, enabling hyperMILL® to automatically determine the area to be machined based on the turning contour. The grooving job will automatically recognize if a contour is a groove, making it faster and easier to program certain areas.

For Free Info Visit http://info.hotims.com/76507-484

Bargraph Meter

A form, fit and function drop-in replacement for popular analog meters such as the GE/Yokogawa 180, Weschler VX252/252, Dixson BB101, Sigma 1151 and many others, OTEK's (Tucson, AZ) NTM-9 digital panel meter is a vertical 6-inch bargraph meter able to accommodate up to 2 channels. The NTM-9 carries an industry-standard housing of 2.16" W × 6" H × 3" D and is available in either plastic or metal.

The NTM-9 offers a full automatic tricolor bargraph with intensity control and 4 digits at 0.3" measuring at 0.1% accuracy. The bar direction is also configurable with navigational options of up/down/center zero. In addition to isolated O.C.T/SPDT relays and isolated analog outputs, the NTM-9 also features an input signal failure alarm with run time stamp to alert the operator in the event of an interrupted or lost signal, which also includes self-diagnostics. The meter boasts isolated serial I/O with USB/RS485, math functions including polynomials, operational requirements of less than 50 mW of power, and over 30 available input signals.

For Free Info Visit http://info.hotims.com/76507-475

Inertial Measurement Unit

Silicon Sensing Systems' (Devon, UK) high-performance DMU30 micro electro-mechanical systems (MEMS) inertial measurement unit (IMU) has been selected by the Institute for Q-shu Pioneers of Space, Inc. (iQPS) of Fukuoka, Japan, for the control system of Japan's first X-band synthetic aperture radar (SAR) small satellite. This is a 1m resolution, high-performance, X-band SAR-satellite weighing only 100 Kg.

The DMU30, Silicon Sensing's highest performing IMU, is an ITAR (International Traffic in Arms Regulations)-free product that matches the performance of a FOG unit but is far more rugged, ideal for operating over extended periods in the harsh space environment. This formidable, high-integrity IMU is calibrated to deliver precision performance over the full rated temperature range. It is also much smaller, weighs less and is less costly than a comparable FOG device, freeing up capacity on the satellite for other technologies.

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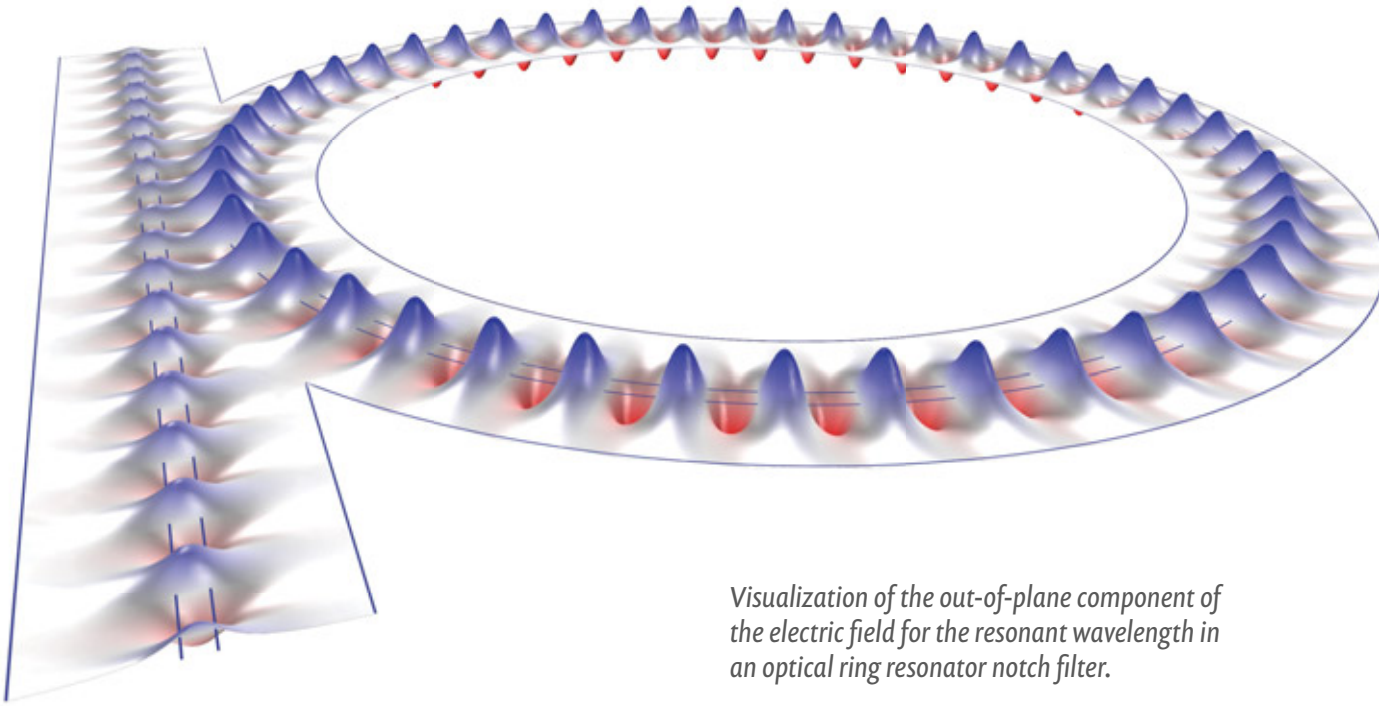
September 2020, Volume 5, Number 6

It all started with two buckets of water...



Visualization of the out-of-plane component of the electric field for the resonant wavelength in an optical ring resonator notch filter.

In 1870, a scientist named John Tyndall tried to control light using two buckets of water, illustrating total internal reflection to a fascinated audience. Today, researchers have more advanced tools at their disposal. When fabricating and analyzing optical waveguide prototypes, modern-day engineers can use numerical simulation software to speed up the design process.

The COMSOL Multiphysics® software is used for simulating designs, devices, and processes in all fields of engineering, manufacturing, and scientific research. See how you can apply it to designing silicon waveguides.

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