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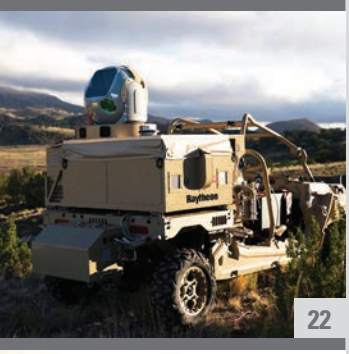

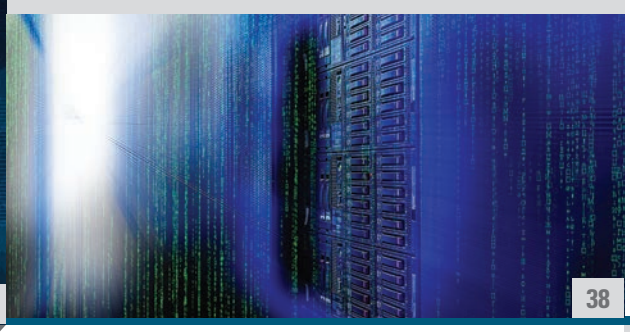


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**ON THE COVER:**

**Top image:** Raytheon's high-energy laser weapon system (HEL WS) has already shown that it can knock down more than 40 UAS targets coming at it. Photo courtesy of Raytheon.

**Bottom image:** U.S. Army soldiers assigned to the 10th Special Forces Group, Unmanned Aerial Systems Det., Fort Carson, Colo., break down an RQ-7B Shadow unmanned aerial vehicle (UAV). Photo courtesy U.S. Air Force/photo by SSgt Andy M. Kin.

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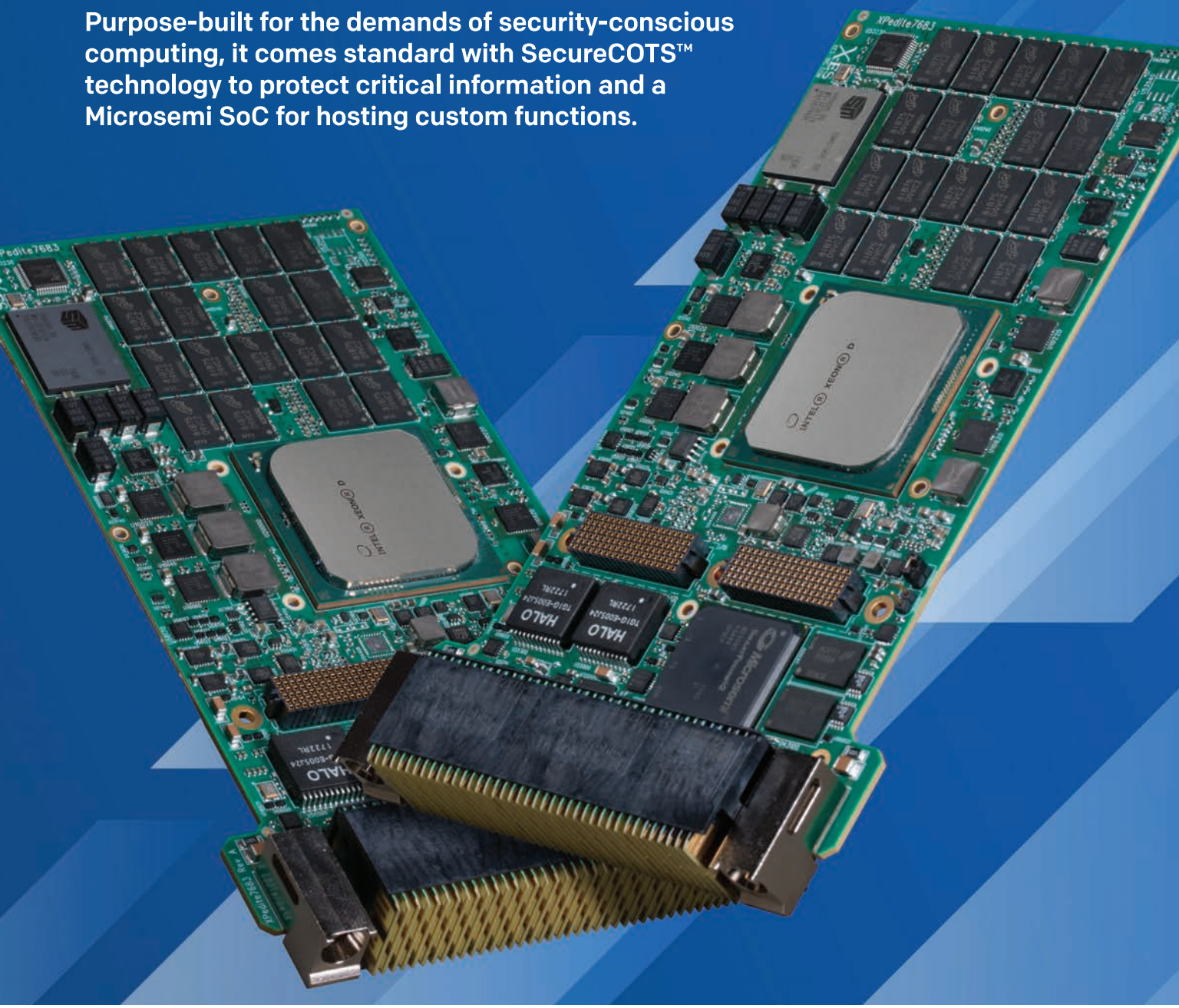


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# Unmanned systems trends

*By John McHale, Editorial Director*

Welcome to our annual Unmanned Systems issue, our yearly look at the embedded computing trends in military unmanned platforms – air, ground, and sea. We bring the Unmanned Systems issue to you every year prior to the Association for Unmanned Vehicle Systems International (AUVSI) Xponential show, as this magazine and its editorial staff attend the conference sessions and roam the exhibition floor during the show, which is held this year in Chicago.

While the show is more commercially oriented – to meet the demands of the growing commercial market for unmanned systems – military applications still play a major role, with embedded computing driving many of the solutions from intelligence, surveillance, and reconnaissance [ISR] payloads to one of the hottest areas in the unmanned systems market – counter-UAS solutions.

"Hundreds of millions of dollars are being spent on counter-drone systems today – ranging from military drone mitigation to small drones," says Mike Blades, vice president, Americas, Aerospace, Defense, and Security for Frost & Sullivan, in our Special Report on counter-UAS technology on page 22. "Most of the efforts center on small drones because that's proliferating the fastest."

Tech for "countering the counter" is also developing fast: "There's a sort of little arms race going on now – so many counter-drone systems and approaches are available," Blades says in the article. "Drone makers are asking, 'How do we counter that counter?' and 'What can we put on our drones so they can't see or hear us?'"

Embedded computing plus RF and microwave components from companies such as MACOM are enabling many of these applications.

"The rise of UAV and counter-UAV technology is pushing UAV developers to ask some much-needed questions," says Doug Carlson, senior vice president and general manager, RF & Microwave business unit, MACOM (Lowell, Massachusetts) in our MIL TECH TRENDS feature on page 26. "Detecting UAVs effectively at a distance in order to give the user time to react is turning into a very hot topic in the field of radar and RF." How much RF and how much sensing is going into this counter-UAV problem? "UAVs are now a weapon system, both in defense and civil airspace, or civil domains, such that we have to come up with cost-effective and very reliable solutions to counter malicious attacks," Carlson says.

The DoD also continues to invest in unmanned systems technology. For example, the Department of Defense (DoD)'s Fiscal Year (FY) 2020 request is funding the U.S. Air Force MQ-9 Reaper UAS program in the amount of $1.025 billion, up from $741 million spent on the program in FY 2019. The base request includes the procurement of three MQ-9 aircraft, twelve ground-control stations, and continued modification of MQ-9s to the extended-range configuration.

A new program seeing an increase in funding in the FY 2020 request is the U.S. Navy MQ-25 Stingray Unmanned Carrier Aviation program, which is rapidly developing an unmanned capability to embark as part of the Carrier Air Wing (CVW) to conduct aerial refueling and provide ISR capability, according to the DoD. The program is expected to enter initial operational capability by FY 2024. The FY 2020 program funds production development, procures three demonstration aircraft, conducts engineering analysis, and initiates assembly of four developmental vehicles. Total FY 2020 funding requested is $671 million, up from $519 million spent in FY 2019.

According to the DoD's FY 2020 budget release, $3.7 billion is requested for "Unmanned/Autonomous projects to enhance freedom of maneuver and lethality in contested environments." In that arena, $927 million was requested to fund "artificial intelligence/machine learning investments to expand military advantage through the Joint Artificial Intelligence Center (JAIC) and advanced image recognition."

For more on the FY 2020 DoD budget requests for unmanned systems and other platforms, please turn to page 18.

Much of the funding for new unmanned solutions and other platform upgrades such as avionics, radar, electronic warfare, and the like, will also be leveraging open architectures.

Along those lines, we have Part 2 of our 3-part article series on the tri-service convergence on a common open architecture through programs such as the Sensor Open Systems Architecture (SOSA). The article – titled "Development of the next-generation OpenVPX-based embedded system standard: A tri-service convergence of approaches: Part 2 of 3" – can be found on page 36. The authors are Mike Hackert of the U.S. Navy's Naval Air Systems Command (NAVAIR), the Navy lead for SOSA; and his fellow leads at the Air Force (Dr. Ilya Lipkin, Air Force Life Cycle Management Center [AFLMC]) and the Army (Ben Peddicord, Communications-Electronics Research, Development and Engineering Center [CERDEC]).

We hope to see you at Xponential in Chicago: Please visit us at the Military Embedded Systems booth (#4739).

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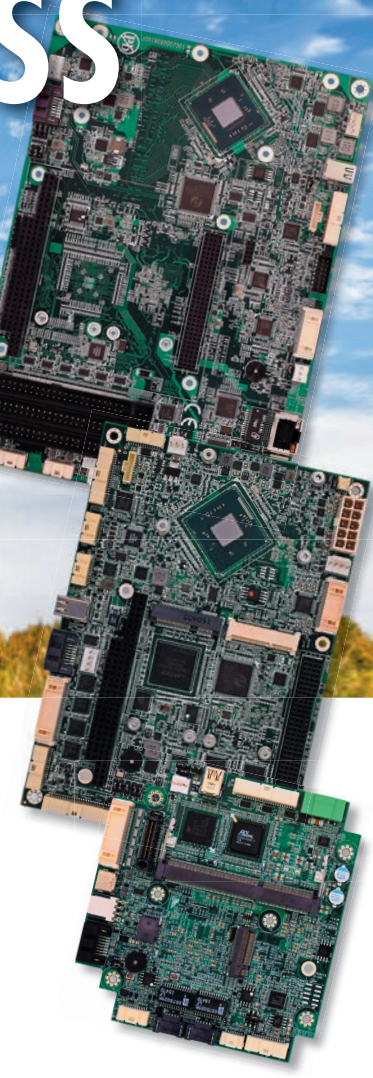

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# U.S. Army preps for future of AI on the battlefield

*By Sally Cole, Senior Editor*

As the U.S. Army launches a project to bring artificial intelligence (AI) to the battlefield, other researchers have developed tests to determine whether systems are using "explainable artificial intelligence," which can play a crucial role in preventing undesirable decision-making.

The Army project, a $72 million AI fundamental research effort, will run for five years in a search for capabilities that can help enhance mission effectiveness that will augment soldiers, optimize operations, increase readiness, and reduce casualties.

Military use of AI isn't a remotely new concept; in fact, the U.S. Department of Defense (DoD) began training computers to mimic basic human reasoning back in the 1960s.

Today, AI and machine learning algorithms are already integral parts of our daily lives, from enabling digital speech assistants to autonomous driving or drones.

But the big challenge is that we don't know exactly how AI systems reach their conclusions: Exactly how "smart" are they? It's often unclear whether the decisions made by AI are truly intelligent.

A group of researchers in Germany and Singapore – unrelated to the Army project – recently tackled this problem of a lack of "explainable AI," enabling a glimpse of the diverse "intelligence" spectrum observed in current AI systems. These projects analyzed AI systems with novel technology that enables automated analysis and quantification.

"Explainable AI" is one of the most important steps toward a practical application of AI, according to Klaus-Robert Müller, professor of machine learning at TU Berlin in Germany. Researchers from TU Berlin, Fraunhofer Heinrich Hertz Institute, and Singapore University of Technology and Design developed algorithms to put any existing AI systems to a test and to derive quantitative information about them: A whole spectrum starting from naïve problem-solved behavior to cheating strategies up to highly elaborate "intelligent" strategic solutions can be observed.

This group discovered that an AI system, which won several international image-classification competitions a few years ago, pursued a strategy that can be considered naïve from a human point of view, classifying images mainly on the basis of context. Images were assigned to the category "ship" when there was a lot of water in the picture, with others classified as "train" if rails were present. Still other pictures were assigned to a category by their copyright watermark. The real task to detect the concept of ships or trains wasn't solved by this AI system – even though it indeed classified the majority of images correctly.

They also discovered the types of faulty problem-solving strategies in state-of-the-art AI algorithms – deep neural networks – that were considered immune from such lapses. Surprisingly, these networks based their classification decision in part on artifacts that were created during the preparation of images and have nothing to do with the actual image content.

"Our automated technology is open source and available to all scientists," Müller says. "Our work is an important first step in making AI systems more robust, explainable, and secure in the future, and more will have to follow. This is an essential prerequisite for general use of AI."

"Explainable AI" will be crucial when applying AI to military applications. As part of the Army project, Carnegie Mellon University is leading a consortium of universities to collaborate with the Army Research Laboratory (ARL) to speed research and development of advanced algorithms, autonomy, and AI to enhance national security and defense.

The Army's ultimate goal is to accelerate the impact of battlefield AI. "Tackling difficult science and technology challenges is rarely done alone, and there is no greater challenge or opportunity facing the Army than AI," says Dr. Philip Perconti, director of the Army's corporate laboratory.

The project will focus on developing robust operational AI solutions to enable autonomous processing, exploitation, and dissemination of intelligence and other critical, operational, decision-support activities. It also aims to support human-machine teaming using AI.

In support of multidomain operations, "AI is a crucial technology to enhance situational awareness and accelerate the realization of timely and actionable information that can save lives," says Andrew Ladas, who leads ARL's Army Artificial Innovation Institute.

Adversaries with AI capabilities will pose new threats to military platforms, including human-in-the-loop platforms, and autonomous platforms. "The changing complexity of future conflict will present never-seen-before situations wrought with noisy, incomplete, and deceptive tactics designed to defeat AI algorithms," Ladas says. "Success in this battlefield intelligence race will be achieved by increasing AI capabilities as well as uncovering unique and effective ways to merge AI with soldier knowledge and intelligence."

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# Small businesses reshaping future Army tech

*By Mariana Iriarte, Technology Editor*

The U.S. Army is aggressively seeking next-generation technologies by reaching out to the heart of the American economy: Small businesses. To that end, officials kicked off the second Expeditionary Technology Search 2.0 (XTechSearch 2.0) at the beginning of 2019; the program aims to be a catalyst in changing the way the Department of Defense (DoD) acquisition process occurs in the small-business sector.

XTechSearch 2.0 enables companies not as familiar to the defense procurement process to get past the traditional barriers of entry to compete for contract wins by getting in front of DoD. Entering the second year of the competition, officials are seeking solutions in the areas of Long-Range Precision Fires, Next Generation Combat Vehicle (NGCV), Future Vertical Lift (FVL), the Army Network, Air and Missile Defense, Increasing Soldier Lethality, Medical Technologies, and Military Engineering Technologies.

"xTechSearch was designed as a vehicle to deliberately engage with non-traditional companies that typically look at the government as a customer and see red tape and a limited return on investment," explains Matt Willis, Director for Laboratory Management, Office of the Deputy Assistant Secretary of the Army, Research and Technology, ASA(ALT). "Our goal is to get the innovation community cognizant about Army research and development problems and apply their unique technologies to modernize the Army."

The competition's format echoes entrepreneurial pitch competitions, Army officials report. During the first phase, white papers were submitted, then Army subject-matter experts chose the winning entries based on the potential for impact and scientific engineering viability.

Phase II selectees were asked to appear in Boston, Massachusetts; Playa Vista, California; Chicago, Illinois; and Austin, Texas – all are Army Research Laboratory (ARL) regional locations – communities that live and breathe technology innovation. These regional sites are just part of the Army's Open Campus Business Model, which builds partnerships with the tech community to drive cutting-edge technologies to the warfighter.

At each of these locations, Phase II selectees pitched their ideas in hopes to enter the next phase of the competition. In Playa Vista, California, five companies were selected out of 11 to move on to Phase III of the competition, where xTechSearch finalists had the opportunity to exhibit alongside the U.S. Army at the 2019 Association of the United States Army (AUSA) Global Force Symposium & Exposition (held in March in Huntsville, Alabama).

California selectees include: Cogitari, NAVSYS Corp., SIGINT Systems, NOVI, and Vidrovr, Inc. "It was great to see the dialogue between Army subject-matter experts and these innovative companies trying to reshape the world as we know it," says Joshua Israel, the xTechSearch lead for Playa Vista.

*The XTechSearch 2.0 program aims to be a catalyst in changing the way the DoD acquisition process occurs in the small-business sector.*

The Armaments Research Co. (ARC), AUV Flight Services, LLC, Lumineye, and Spark Thermionics, Inc., were chosen out of the Boston ARL location. In the Chicago group were four selectees – Advanced Hydrogen Technologies, Great Lakes Sound and Vibration, MELD Manufacturing, and Sphere Brake Defense, LLC – that will address the NGCV technology focus.

The Texas group had the largest number of submissions, with 60 companies pitching. Out of the 60 from the Texas ARL, Army officials selected the following eight companies – which came from around the nation – as finalists: AKHAN Semiconductor; Ghostwave, Inc.; Invisible Interdiction; NOVAA Ltd.; Response Technologies; United Aircraft Technologies; Valley Tech Systems; and Vita Inclinata Technologies.

This type of competition opens up a conversation about how private industry and the small-business sector can collaborate to really make a difference in military technology development.

"Our Army of the future must be ready to deploy, fight, and win decisively against any adversary, anytime and anywhere, in a joint, multidomain, high-intensity conflict, while simultaneously deterring others and maintaining the ability to conduct irregular warfare," says Dr. Bruce D. Jette, Assistant Secretary of the Army (Acquisition, Logistics and Technology); his office launched the nationwide competitions. "The next generation of enabling technologies required to achieve these goals may not currently exist or they may not be apparent to the Army so we must proactively and aggressively engage with innovators to see what new ideas, concepts, systems, and subsystem components they can bring to the table."

The final phase – the xTechSearch Capstone Demonstration – will see DoD leadership and Army subject-matter experts pick the Phase IV winner, the team that successfully demonstrates a proof-of-concept solution at the AUSA Annual Meeting in October 2019.

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*By Andrew McCoubrey*
*An industry perspective from Curtiss-Wright Defense Solutions*

Designers of rugged military and aerospace systems continue to look to the commercial world for networking technology – leveraging available Ethernet switch chips to connect between processing modules and PHY devices to link systems over fiber-optic or copper cables. However, using the latest high-performance networking technology in deployed systems based on modular commercial off-the-shelf (COTS) standards isn't always practical. While the latest commercial devices support IEEE standards for 100G Ethernet and beyond, based on 25G and 50G SerDes technology, OpenVPX systems using the standard MultiGig-RT2 connector have so far been limited to 10G SerDes signals.

Designers using high-performance and feature-rich commercial Ethernet technology to connect their embedded systems can deploy a growing range of techniques for managing traffic flows on their networks. Faster networks can carry more traffic, from more sensors and applications, on a single link, but care must be taken to ensure critical data isn't delayed or dropped. These trends – performance and convergence – are two of the most significant factors influencing today's COTS networking designs.

**Performance for the most demanding systems**

In the past, meeting the performance needs for defense electronic applications often necessitated the use of custom hardware and FPGAs. Today, the technical challenge faced by many designers is how to implement high-speed interfaces in board-and-backplane modular systems.

Modular systems based on VPX backplanes have been proven and deployed using 10G and 40G Ethernet, but moving to 100G Ethernet and beyond will require the use of 25 Gbps or faster SerDes technology. The use of Ethernet at 10 Gbps and above has also driven a growing need for optical interconnect solutions. A wide array of commercial products is available for implementing optical links. However, no single approach has emerged as the de facto standard for rugged systems. As a result, few COTS products integrate optical interfaces, leaving integrators to convert from electrical to optical in their systems.

**Convergence of networks**

Faster Ethernet links also mean it's now practical to use a single network to carry data from multiple different systems over a single cable. Ethernet in aerospace and defense systems can now carry a mix of voice, video, and data from various sensors and applications. This "converged" network can replace multiple single-purpose cables, providing substantial SWaP benefits and increased flexibility when adding new capabilities to a platform.

As network designers seek to transmit multiple sources over the same data pipe, a major concern is the potential for interference or contention that delay real-time traffic. For time-sensitive or safety-critical applications, deterministic performance may be essential. Faster networks don't necessarily deliver lower latency for critical messages if less-critical traffic leads to network congestion.

One solution for getting closer to real-time networking is to implement policies that ensure critical data has the highest priority. Another approach is to divide the network into fixed time slices where each application or host is given exclusive access to the network during its assigned slice. These methods can help provide service guarantees along with bounded end-to-end latency, including on networks that use standards-based Ethernet.

In recent years, a range of IEEE standards have been ratified to enable "time-sensitive networking" (TSN). TSN mechanisms being implemented in new switches have emerged to address the need for real-time scheduling, including:

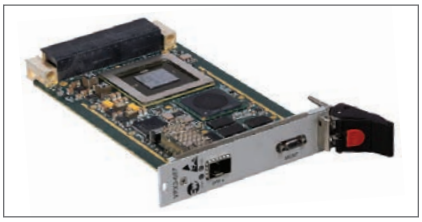

**Figure 1** | The VPX3-687 is designed to connect the next generation of 3U OpenVPX systems.

- 802.1Qbv: Enhancements for Scheduled Traffic – enables time slicing
- 802.1Qch: Cyclic Queueing and Forwarding – reduces jitter
- 802.1Qcc: Stream Reservation Protocol – allocates capacity to avoid congestion

Whether they implement the latest TSN standards or vendor-specific QoS mechanisms, today's embedded switches can enable traffic from a variety of sources, combining mission-critical and latency-sensitive real-time data on converged platform wide networks.

Curtiss-Wright's VPX3-687 10 Gigabit Ethernet Switch – with support for gigabit, 10 Gbps, and 40 Gbps Ethernet – is an example of a high-performance Ethernet switch designed to connect the next generation of 3U OpenVPX systems. (Figure 1.) It provides switching throughput of up to 320 Gbps and full line-rate forwarding of up to 32 by 10 GbE or 8 by 40 GbE interfaces. Its nonblocking architecture is suitable for low-latency control plane and high-throughput data plane applications.

***Andrew McCoubrey*** *is the product marketing manager, switching and routing solutions, for Curtiss-Wright Defense Solutions.*

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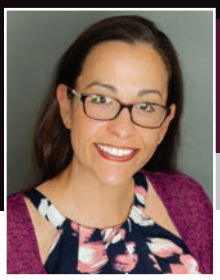

# DEFENSE TECH WIRE

NEWS | TRENDS | DOD SPENDS | CONTRACTS | TECHNOLOGY UPDATES

*By Mariana Iriarte, Technology Editor*

NEWS

## NASA taps orgs for final phase UAS traffic-management system

The Nevada Institute for Autonomous Systems in Las Vegas and the Lone Star UAS Center for Excellence & Innovation in Corpus Christi, Texas will host the final phase of NASA's four-year series of technical demonstrations involving small unmanned aircraft systems (UASs).

The two organizations will host demonstrations to confirm that NASA's UAS Traffic Management (UTM) system can safely and effectively manage drone traffic in an urban area.

Key technologies to be demonstrated include the Airspace Regulator Flight Information Management System, the UAS Service Supplier interface for multiple independent UAS traffic-management service providers and the interface with vehicle integrated detect-and-avoid capabilities, vehicle-to-vehicle communication and collision avoidance, and automated safe landing technologies.

**Figure 1** | This illustration depicts multiple small UASs flying in an urban environment, the last in a series of NASA demonstrations of a system to safely manage drone flight. Image courtesy of NASA.

## S-70M Black Hawk helicopter receives FAA type certification in the Restricted Category

Federal Aviation Administration (FAA) officials granted Sikorsky's S-70M Black Hawk helicopter the FAA's type certification in the Restricted Category.

The type certificate will enable Sikorsky to request authorization from the FAA to produce S-70M aircraft for the following special-purpose operations increasingly requested by the growing civil helicopter market: external cargo, agriculture operations, and forest and wildlife conservation.

For example, within the forest and wildlife conservation special-purpose category, Restricted Category aircraft may drop water as part of an aerial firefighting operation. The S-70M is based on the UH-60M utility helicopter that Sikorsky built for the U.S. Army.

## Air Force awards funding to 51 companies at Pitch Day

U.S. Air Force officials awarded 51 companies at the recently held inaugural Air Force Pitch Day event, releasing an initial award of up to $158,000 to each company, for a total of $8.75 million.

Air Force Pitch Day was conceived to focus on rapidly awarding Phase I Small Business Innovation Research (SBIR) contracts to companies based on a simpler streamlined evaluation of white papers and in-person presentations.

During the process, Air Force contracting officials reviewed 417 submissions received during the 30-day application period and then invited 59 businesses to pitch their proposals in person. The average amount of time to award contracts and pay companies via government credit card following a successful pitch at Air Force Pitch Day was 15 minutes.

## National Guard RC-26B ISR aircraft to get avionics refresh

M7 Aerospace LLC, a subsidiary of Elbit Systems of America, will provide avionics refresh for the U.S. Air National Guard's RC-26B fixed-wing aircraft used for intelligence, surveillance, and reconnaissance (ISR) operations.

The subcontract from Support Systems Associates, Inc. (SSAI) is valued to as much as $22 million, with an initial $5 million in funds already released for the first order. The contract includes avionics engineering, design, integration, modification, test, and maintenance for the aircraft.

M7 Aerospace, through type certificate ownership, is the original equipment manufacturer of the RC-26B aircraft, officials report. The program will be completed by 2021, with engineers working from San Antonio, Texas.

**Figure 2** | The U.S. Air National Guard's RC-26B fixed-wing aircraft. Photo courtesy of the U.S Army/Staff Sgt. Marvin Cornell.

## Mine-hunting sonar system completes developmental testing

U.S. Navy officials announced that the AN/AQS-20C mine-hunting sonar system has completed development testing at the Naval Surface Warfare Center, Panama City (Florida) Division.

During testing, the Raytheon-developed towed sonar sensor conducted 12 underway missions in various operational modes and at different depths at four separate NSWC PCD test ranges. The missions were conducted aboard the test vessel M/V Patriot. Developmental testing verified that a system's design meets all technical specifications, and that all contract requirements have been met. Test results will now undergo scoring and performance assessment leading up to a final developmental testing report that is expected to be completed sometime during spring 2019. Findings from this report will be used for future performance improvements of the system.

The AQS-20C is the next generation of the AN/AQS-20 system designed to be incorporated into the Littoral Combat Ship (LCS) Mine Countermeasures Mission Package. The system consists of four sonar arrays: two side-looking arrays; a gap-filler sonar array; and a forward-looking sonar array providing simultaneous detection, localization, and classification of bottom mines, close-tethered moored mines, and volume-moored mines.

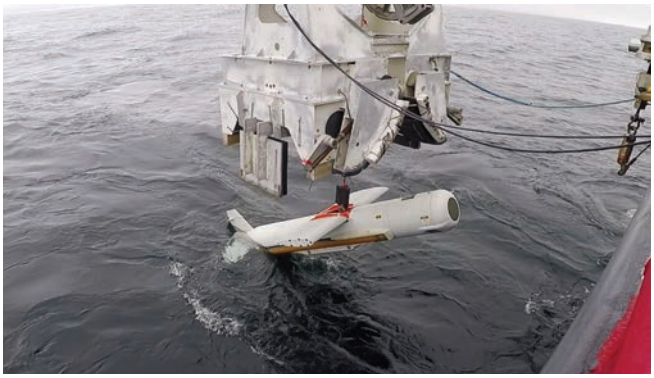

**Figure 3** | The AN/AQS-20C towed mine-hunting sonar is streamed into Gulf of Mexico waters of the Naval Surface Warfare Center Panama City Division, Florida. Photo courtesy of the U.S. Navy by Eddie Green.

## Raytheon nabs $63.3 million contract for hypersonic weapons program

Raytheon has signed a $63.3 million contract with the Defense Advanced Research Projects Agency (DARPA) to continue to develop a "tactical boost glide" (TBG) hypersonic weapons program. According to information from DARPA, for a tactical-range boost glide weapon to achieve hypersonic speeds – that is, velocities greater than Mach 5 – "a rocket accelerates its payload to high speeds. The payload then separates from the rocket and glides unpowered to its destination."

Raytheon officials say that hypersonic weapons will enable the U.S. military to engage from longer ranges with shorter response times and enhanced effectiveness compared to current weapon systems. The joint DARPA/U.S. Air Force effort includes a critical design review, a key step in bringing the technology to fruition.

## DARPA modernizes SBIR/STTR program to increase award opportunities

The Defense Advanced Research Projects Agency (DARPA) is planning on releasing Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) opportunities on an out-of-cycle basis, separate from the three predetermined announcements traditionally issued directly through the Department of Defense (DoD). The change is expected to reduce the overall time from opportunity announcement to contract award.

Under the terms of the pilot program, DARPA will institute time-saving measures to speed program integration, such as Direct to Phase II authority, which enables the agency to bypass Phase I research requirements once performers provide satisfactory documentation of feasibility, and/or proof of scientific merit, technical merit, and commercialization potential.

DARPA will also seek to identify SBIR/STTR Phase II awardees with a compelling go-to-market strategy for participation in a newly created commercialization accelerator. The DARPA accelerator will provide additional funding to employ one entrepreneur-in-residence or business development lead who will offer the awardee direct support for activities including, but not limited to, customer engagement planning, market analysis and mapping, competitive analysis, techno-economic analysis, IP securement strategy development, and financial plan creation.

## USAF XQ-58 Valkyrie UAV completes first flight

The U.S. Air Force XQ-58A Valkyrie demonstrator recently completed its maiden flight – lasting approximately 76 minutes – at the Yuma Proving Ground in Arizona.

The XQ-58A Valkyrie is a long-range, high subsonic unmanned aerial vehicle (UAV) developed by the Air Force Research Laboratory (AFRL) in partnership with Kratos Unmanned Aerial Systems under the Air Force Research Laboratory's Low Cost Attritable Aircraft Technology (LCAAT) portfolio.

The time to first flight took a little more than 2.5 years from contract award, officials report. The XQ-58A has a total of five planned test flights in two phases with objectives that include evaluating system functionality, aerodynamic performance, and launch and recovery systems.

**Figure 4** | The XQ-58A Valkyrie demonstrator, a long-range, high subsonic unmanned aerial vehicle. Photo courtesy of the U.S. Air Force.

# Procurement, modernization highlights from DoD FY 2020 budget request

By John McHale, Editorial Director

An Army UH-60 Black Hawk helicopter transports troops across Afghanistan. Photo by Army Capt. Roxana Thompson.

*WASHINGTON. Funding requested for Department of Defense (DoD) Major Defense Acquisition Programs (MDAPs) for Fiscal Year (FY) 2020 totals $89.3 billion, accounting for about 34 percent of the Trump administration's Procurement and Research, Development, Test, and Evaluation (RDT&E) funding request for the Department of Defense (DoD) of $247.3 billion. Included below are updates on programs such as the Joint Light Tactical Vehicle (JLTV), the Apache helicopter, the F-35, cyberspace programs, the B-21 Raider, the Unmanned Surface Vehicle, and more.*

The president's Fiscal Year (FY) 2020 budget request for modernization in the RDT&E and procurement titles encompasses 106 Major Defense Acquisition Programs (MDAPs) that spell out 2,487 Program, Project, and Activity (PPA) line items. This funding request is covered in the DoD's "Program Acquisition Cost by Weapons System" booklet, which lists funding for programs that have been designated as MDAPs. To read the entire booklet, visit https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2020/fy2020_Weapons.pdf.

**Aircraft and related systems**

The F-35 Joint Strike Fighter (JSF) is a fifth-generation strike fighter for the Navy, Marine Corps, Air Force, and U.S. allies. The F-35 consists of three variants: the F-35A Conventional Take-Off and Landing (CTOL), the F-35B Short Take-Off and Vertical Landing (STOVL), and the F-35C Carrier variant (CV). The FY 2020 program procures 78 aircraft in FY 2020: 48 CTOL for the Air Force, 10 STOVL for the Marine Corps, and 20 CV for the Navy. The program also accelerates an organic depot maintenance capability to reduce depot repair cycle times to improve air-vehicle availability rates. Total FY 2020 funding requested is $11.211 billion, down slightly from the $11.580 billion spent in FY 2019.

The F-15C/D is a twin-engine (F-15C single seat/F-15D dual seat), supersonic, all-weather, day/night, air-superiority fighter aircraft. The F-15E is a twin-engine, dual-seat, supersonic dual-role, day/night, all-weather, deep-interdiction fighter with multirole air-to-air/air-to-ground capabilities. The FY 2020 program initiates a new program to procure the F-15EX, which will initially refresh the F-15C/D fleet with a planned buy of 144 aircraft, with the potential to refresh the remainder of the F-15C/D fleet and the F-15E fleet. The program continues the F-15E Radar Modernization Program to replace the legacy radar. The F-15C/D radar upgrade program will extend through FY 2021 to replace the mechanically scanned antenna on F-15C/D aircraft with an active electronically scanned array (AESA). Technology maturation efforts for the Eagle Passive/Active Warning Survivability System are ongoing. Total FY 2020 funding requested is $2.055 billion, up from $1.004 billion spent in FY 2019.

THE NAVY'S MQ-25 STINGRAY UNMANNED CARRIER AVIATION PROGRAM IS RAPIDLY DEVELOPING AN UNMANNED CAPABILITY TO EMBARK AS PART OF THE CARRIER AIR WING TO CONDUCT AERIAL REFUELING AND PROVIDE ISR CAPABILITY.

The P-8A Poseidon is a multimission platform designed to replace the P-3C Orion propeller-driven aircraft. The FY 2020 program procures six P-8A aircraft, support equipment, spares, and repair parts. It also continues research and development on the aircraft systems that will be delivered and installed incrementally. Total FY 2020 funding requested is $1.513 billion, down from $2.245 billion spent in FY 2019.

The B-21 Raider, previously referred to as the Long Range Strike-Bomber (LRS-B), is a new high-tech long-range bomber that will eventually replace a portion of the Air Force's bomber fleet. The B-21 initial capability will be fielded in the mid-2020s. The Air Force plans to procure a minimum of 100 aircraft. The FY 2020 program continues engineering and manufacturing development of the B-21. Total FY 2020 funding requested is $3.004 billion, up from $2.279 billion spent in FY 2019.

The AH-64E Apache program is a parallel new-build and remanufacture effort, integrating a mast-mounted fire-control radar into an upgraded and enhanced AH-64 airframe, resulting in a zero-time Longbow Apache, which restarts its service life and upgrades the aircraft with updated technologies and performance enhancements. The AH-64E has entirely new open architecture computer systems, including an all-digital cockpit flight control. The FY 2020 program funds the remanufacture of 48 AH-64D aircraft to the AH-64E configuration in the fourth year of a five-year multiyear procurement contract (FY 2017 – FY 2021) and continued upgrades. Total FY 2020 funding requested is $1.003 billion, down from $1.463 billion spent in FY 2019.

The UH-60 Black Hawk is a twin-engine, single-rotor, four-bladed utility helicopter and comes in many variants; one modification is the UH-60M, which features a digital networked platform with greater range and lift. The FY 2020 program funds procurement of 73 UH-60M aircraft, in the fourth year of a follow-on five-year multiyear procurement contract (FY 2017- FY 2021). It also funds procurement of 25 cockpit kit upgrades of UH-60L helicopters to UH-60V. Total FY 2020 funding requested is $1.673 billion, up from $1.448 billion spent in FY 2019.

The U.S. Air Force MQ-9 Reaper UAS program is comprised of an aircraft segment consisting of aircraft configured with an array of sensors to include day/night full-motion video, signals intelligence, and synthetic aperture radar sensor payloads, avionics, data links, and weapons. The FY 2020 program funds the continued development, transformation, and fielding of Reaper aircraft and ground stations. The base request includes the procurement of three MQ-9 aircraft, arranges for twelve ground-control stations, and continues the modification of MQ-9s to the extended-range configuration. The Overseas Contingency Operations (OCO) request includes the procurement of nine additional MQ-9 aircraft for the USAF and three MQ-9 aircraft for the USMC. Total FY 2020 funding requested is $1.025 billion, up from $741 million spent in FY 2019.

The U.S. Navy MQ-25 Stingray Unmanned Carrier Aviation program is rapidly developing an unmanned capability to embark as part of the Carrier Air Wing (CVW) to conduct aerial refueling and provide intelligence, surveillance, and reconnaissance (ISR) capability. The program is expected to enter initial operational capability by FY 2024. The FY 2020 program funds production development, procures three demonstration

aircraft, conducts engineering analysis, and initiates assembly of four developmental vehicles. Total FY 2020 funding requested is $671 million, up from $519 million spent in FY 2019.

**Command, control, communications, computers, and intelligence (C4I) systems**
The Handheld, Manpack, and Small Form Fit (HMS) program procures radios that are software-reprogrammable, networkable, multimode systems capable of simultaneous voice and data communications. The HMS program encompasses the single-channel Rifleman Radio (RR), two-channel Leader Radio (LR), Manpack Radio (MP), and Small Form Fit (SFF) radio. The FY 2020 program funds the full and open competition contract strategy for the LR and MP radios and provides for testing of the LR and MP candidate products to demonstrate compliance with program requirements. It also supports safety, spectrum supportability, and certifications necessary for fielding and procures as many as four Brigade Combat Team (BCT) LR and MP radios. Total FY 2020 funding requested is $504 million, up from $302 million spent in FY 2019.

The DoD released a new cyber strategy in September 2018 that articulates how the department will implement priorities of the National Defense Strategy in and through cyberspace. The FY 2020 program funds cybersecurity capabilities in the following focus areas: endpoint management; identity, credential, and access management; insider-threat security; secure application development; cross-domain security to include mission partner networks; supply chain risk management; encryption; and other critical infrastructure. The program also increases cyberspace warfighting capabilities and continues development of the Unified Platform while supporting weapon-system and critical-infrastructure vulnerability assessments and mitigation efforts. Total FY 2020 funding requested is $2.845 billion, up from $2.593 billion spent in FY 2019.

**Ground systems**
The Joint Light Tactical Vehicle (JLTV) is a joint program currently in development for the Army and Marine Corps, with the JLTV intended to replace the High Mobility Multipurpose Wheeled Vehicle (HMMWV, colloquially called the Humvee). The FY 2020 program procures more than 4,000 JLTVs of various configurations to fill multiple mission roles and minimize ownership costs for the Light Tactical Vehicle fleet. Total FY 2020 funding requested is $1.642 billion, down from $1.928 billion spent in FY 2019.

Stryker is a 19-ton wheeled armored vehicle family consisting of 24 different vehicles. The FY 2020 program completes funding for Engineering Change Proposal (ECP) 1, embarks on ECP 2 lethality engineering development, and continues support of the application of multiple fleet-wide modifications. Modifications address training devices; obsolescence, reliability, capability, and performance degradation; safety; and operational-related issues. Total FY 2020 funding requested is $755 million, up from $443 million spent in FY 2019. (Figure 1.)

**Figure 1** | An Army Stryker mobile gun system fires on targets at the Grafenwoehr Training Area in Germany. Photo by Army Sgt. Timothy Hamlin.

The Amphibious Combat Vehicle (ACV) will replace the aging Amphibious Assault Vehicle. The Approved Acquisition Objective (AAO) is 204 vehicles. ACV Increment 1.2 will deliver additional ACV 1.1 Personnel Variants (currently in production) as well as Command and Control (ACV-C), Recovery (ACV-R), and 30-mm (ACV30) Mission Role Variants (MRVs). The FY 2020 program funds the ACV 1.1 full rate production Lot 3 of 56 vehicles, plus procurement of related items. Total FY 2020 funding requested is $395 million, up from $233 million spent in FY 2019.

**Missile defeat and defense programs**
The Terminal High Altitude Area Defense (THAAD) is an element of the Ballistic Missile Defense System (BMDS). The FY 2020 program supports the procurement of 37 THAAD interceptors, obsolescence mitigation, production and training support, and tooling and equipment for the THAAD stockpile reliability and recertification program. It funds THAAD software upgrades and provides for improved capability to engage short-range, medium-range, and limited intermediate-range ballistic missile threats. Total FY 2020 funding requested is $754 million, down from $1.463 billion spent in FY 2019.

The Aegis Ballistic Missile Defense (BMD) is the naval element of the BMDS and provides BMD capability on Aegis cruisers, on destroyers, and ashore. The FY 2020 program procures approximately 30 SM-3 Block IB missiles and seven SM-3 Block IIA missiles, integrates SM-3 Block IIA into the BMD Weapon Systems, continues development of the Aegis BMD 5.1 and Aegis BMD 6 Weapon Systems, and supports procurement of 12 inline/back fit shipsets, five weapons system upgrades, and 19 installs of the BMD 4.x/5.x equipment. Total FY 2020 funding requested is $1.720 billion, up from $1.631 billion spent in FY 2019.

The Army's Patriot system is a long-range air defense guided missile system that provides protection for ground combat forces and high-value assets. The FY 2020 program continues improvements in software for improved combat identification, improved communications, interoperability, supportability, and electronic warfare capabilities; it also supports transition to the Integrated Air and Missile Defense architecture. Total FY 2020 funding requested is $804 million, up from $488 million spent in FY 2019.

**Shipbuilding and maritime systems**

The Columbia class Ballistic Missile Submarine is designed to replace the current Ohio class of Fleet Ballistic Missile Submarine (SSBN). Construction begins in FY 2021 for FY 2028 delivery when the first Ohio-class ships begin decommissioning. The FY 2020 program funds advance procurement for long-lead items, detail design, and research and development of nuclear technologies and ship systems such as the propulsion system, combat systems technology, and the common missile compartment. Total FY 2020 funding requested is $2.232 billion, down from $3.906 billion spent in FY 2019.

The Virginia-class submarine is a multimission nuclear-powered attack submarine. The FY 2020 program funds three ships, advance procurement for four ships in future years, and outfitting and support equipment. It also continues funding the development of the Virginia Payload Module, technology, prototype components, and systems engineering required for design and construction. Total FY 2020 funding requested is $10.218 billion, up from $7.428 billion spent in FY 2019.

The Unmanned Surface Vehicle (USV) is a reconfigurable, multimission vessel designed to provide low-cost, high-endurance, reconfigurable ships able to accommodate various payloads for unmanned missions and augment the Navy's manned surface force. Future missions and payloads will be informed as the concept of operations is developed. The FY 2020 program funds continued development, testing, and procurement of two Large USVs and continued research and development of payload systems. Total FY 2020 funding requested is $447 million, up from $49 million spent in FY 2019.

**Space-based systems**

The Global Positioning System (GPS) provides worldwide, 24-hour, all-weather 3D positioning, navigation, and precise timing information for military and civilian users. The FY 2020 program funds launch campaign and on-orbit checkout for GPS III Space Vehicles (SVs) 03 and 04 and procures independent, technical, systems engineering, and integration support critical to managing the production of SVs 05 through 10. It funds continued development of the GPS III Follow-on satellites (SV 11+) and funds the first of 20 production satellites (SV-13). Total FY 2020 funding requested is $1.752 billion, up from $1.425 billion spent in FY 2019. **MES**

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# Counter-drone technologies are evolving to "counter" countermeasures

By Sally Cole, Senior Editor

*Counter-unmanned aircraft system (UAS) technologies are focusing on a multilayered defense. They're also being tasked with providing a "counter" to countermeasures.*

Raytheon's high-energy laser weapon system (HEL WS) has already shown that it can knock down more than 40 UAS targets coming at it. Photo courtesy of Raytheon.

Drone technologies are evolving rapidly and, not surprisingly, counter-drone technologies are as well. The U.S. military is currently embracing multilayered counter-drone approaches to deal with the threat drones pose, but no silver bullet approach exists yet that can detect and mitigate every threat.

"Hundreds of millions of dollars are being spent on counter-drone systems today – ranging from military drone mitigation to small drones," says Mike Blades, vice president, Americas, Aerospace, Defense, and Security for Frost & Sullivan (New York, New York). "Most of the efforts center on small drones because that's proliferating the fastest."

Raytheon's defense customers are "likening drones to the improvised explosive device (IED) situation 20 years ago, when we saw an adversary take a readily available technology and weaponize it in a low-cost way," says Todd Probert, vice president of Raytheon Intelligence, Information, and Services (Dulles, Virginia). "This is a similar situation in which the cost of the technology has come down so rapidly that the influx of this capability on the marketplace has given adversaries the ability to do nefarious things with them."

Threats from drones have become "much more prevalent with the proliferation of inexpensive drones," says Dave Bessey, assistant vice president of business development for SRC (North Syracuse, New York). "For example, the disruption of air travel or small unmanned aircraft systems being used in insurgent operations for surveillance or to deliver deadly payloads. This threat is also becoming autonomous – with a lack of communication signals – and is undetectable by RF, which means that other layers of defense are now required."

Right now, SRC is actively developing on-the-move sensor suites for multifunction electronic attack and surveillance, as well as advanced cameras and optical tracking.

"To enhance all of our technology, we're investing in artificial intelligence (AI) and machine learning," Bessey adds.

**Detection of targets**

When it comes to counter-drones, "you need the capabilities to detect, track, and positively identify a target before you can engage," explains Don Sullivan, chief technologist of directed energy for Raytheon's Missile Systems (Tucson, Arizona). "So you need what we refer to as 'full skydom' coverage: it has to be 360 degrees in azimuth, and then from below the horizon to straight up zenith in the sky. If you don't have that capability, then you have a vulnerable path to the target not being covered and it can become a major issue."

Another consideration is that your response should be commensurate with the cost of the target. "Sending an interceptor that's going to cost you tens of thousands of dollars to take down a $200 or $500 drone isn't a good approach," Sullivan says. "It may be necessary against some high-value assets that you're trying to protect, but it certainly isn't an economical way of countering the threat. For that reason, both electronic warfare and cyber and directed energy are good approaches because you're engaging targets for as few dollars per engagement as possible – if you take into account maintenance and operation costs. So the military is looking at non-kinetic solutions vs. kinetic solutions for most counter-unmanned aircraft system (UAS) capabilities."

Blades says he expects the military to continue to invest in more advanced capabilities like AI to help with detection. "They want to be able to detect drones really far out, so they need radar that can detect small things flying low and fast," he notes. "EO/IR is good too, because it allows you to do payload detection. Once you have this thing on your radar you can point a camera over that way to see if it's carrying something bad and, if it is, hopefully you have some sort of AI able to detect that automatically so you won't need to have a person sitting there looking at every drone detected."

**Mitigation can focus on directed energy**

On the mitigation side, expect to see a continued focus on directed energy such as laser and microwave counter-drone technologies. "Microwave technology isn't as destructive as lasers," points out Blades. "You'll usually want to be able to do forensics on something that you shoot out of the sky to determine who sent it and why. The microwave will simply fry the electronics so that it can't operate; it won't destroy the aircraft and burn it up like a laser would."

Raytheon offers both laser and microwave counter-UAS systems. Their high-energy laser weapon system (HEL WS) has already shown that it can knock down more than 40 UAS targets coming at it. "The Air Force and Army are mostly interested in Class I and II UASs, which are the smaller systems that you normally see like the small quadcopters and fixed-wing UASs being used by terrorist groups overseas for attacks," Sullivan explains. HEL's main advantages are that "it has a fairly long range within the 3- to 5-km range, on the order of a 10kW laser, and can take out individual UASs fairly rapidly. They can go after ISR [intelligence, surveillance, and reconnaissance] UASs that are there to search for and locate potential targets for the adversary."

Raytheon's high-power microwave (HPM), called Phaser, is primarily custom-built and has advantages that are complementary to HEL. "It doesn't have as long a range (which is classified) as HEL, but because its beam is more akin to a searchlight than a laser beam it can take down UASs simultaneously within its beam," Sullivan says. "We've demonstrated Phaser several times. Because of the complementary nature and the advantages of engaging targets at the speed of light and being able to specifically with the Phaser take out swarms of UASs simultaneously, the Air Force wants additional demonstrations of both of these systems." (Figure 1.)

**Multilayered counter-drone approaches**

Many counter-drone approaches focus on radio frequency (RF) because most drones use some sort of RF command and control link, but now it's being combined with electro-optical/infrared sensors, radar, or acoustics for a more complete multi-sensor detection capability.

"Companies are forming partnerships with others who specialize in areas they don't. Sensor makers are partnering with companies that make jamming guns or net guns, or directed energy and lasers on the defense side," Blades says.

Counter-UAS solutions "are expanding to include fixed, transportable, and mobile configurations," Bessey says. "Military customers will ask for more autonomous systems because they want systems that are open to integrate with other sensors, such as acoustics, depending on the environment."

What do you do once you gain lots of situational awareness from all these sensors? To help make it more useful, Raytheon has created a command and control mode called Windshear, a counter-UAS system, which is a platform to plug in other sensors – think radars and optical systems – to help get a better picture of what's going on within your airspace.

"Windshear is plugged into large-scale air traffic control radars, but it's purpose-built to go to that small space as well to look at that 100- to 1000-foot range to understand what's going on within that environment," Probert says. "Then we marry it up with effectors. So if you have an intrusion, in the case of a UAV entering an airport's airspace, maybe the first phase of the effectors would be lights and sirens to make the operator aware that it's a restricted space and give them the option to move out of it."

**Figure 1** | Raytheon's high-power microwave (HPM), called Phaser, is primarily custom-built and has a beam that is more akin to a searchlight than a laser beam so it can take down UASs simultaneously within its beam.

A layered defense beyond that would also be preferred, and Raytheon has RF techniques that allow it to jam the communications systems of a large class of these unmanned systems, which might be the second layer of defense. "Beyond that, we've got GPS jamming capabilities and cyber effects that can take out the GPS these systems use to navigate, or the operator can take positive command and control of those systems to ensure a safe landing or steerage out of a public venue," Probert adds.

Windshear has been demonstrated with battlespace effectors and Raytheon's high-energy laser; it's also been part of demonstrations where a kinetic effector like a missile might be used as well.

Raytheon is dealing with all of the military services, and they're all looking at a multilayered defense. "Think of a set of range rings around the point you're trying to defend – whether it's a fixed point or a convoy in motion," Sullivan says. "You'd like to be able to do that within these rings."

For example, one UAS system Raytheon has developed for the Army is called the Coyote. It has a very small kinetic warhead, but a very advanced seeker that gives you the ability to attack individual drones. "It can go out for quite a long range and inside it you'd have something like Windshear and a high-energy weapons system, which provides a ring 360 degrees around and full-sky coverage that allows you to take out UASs within that secondary ring," Sullivan adds. "Then, when you want to take out large swarms simultaneously, you'd use the HPM Phaser to defend the point within the closest range ring."

**The problem of swarms**

Swarm technology – with numerous drones working cooperatively together on a mission – doesn't need to be very advanced to pose a serious threat.

Swarms are becoming an increasing issue, and "if you watched the Olympics in South Korea you saw the demonstration of many UASs flying in formation," Sullivan says. "And the Chinese had a

demonstration of 1,374 drones, the world record, which shows that you can have a very large number of these types of systems. Both military and civilian authorities are quite concerned about the potential of swarms attacking targets."

What is likely to become a target? "In general, the U.S. worries about large groups of people at big events, in stadiums, parades, and on main operating bases where high-value assets in terms of aircraft and other defense systems are located," Sullivan adds. "Of course, forward operating bases are an issue, where the concern is mostly about surveillance, but there's a potential for swarming attacks as well."

"Even if a bad actor launches 50 drones at the same time, not working together, it's bad because it's an asymmetric threat," Blades says. "You can buy 50 drones for $50,000 and inflict millions of dollars of damage. Drones have very unsophisticated launching mechanisms, and bad actors can select waypoints and let them fly and drop on targets. Even if it isn't a swarm, with small ammunition like grenades or 40-mm shells, if 20 or 30 drones are coming at you, it could get real bad fast."

A bunch of drones coming at you poses a threat, but a swarm coming at you is much worse because they will be able to change to adapt to whatever you do to counter them. "The idea behind swarms is to coordinate and cooperate to make the attack more lethal," Blades notes. "So the military needs to be able to take out multiple drones simultaneously."

Hostile swarms will likely "become a reality, because there are reports of countries already testing swarm capabilities," Bessey says. "SRC's technologies, including Silent Archer and SkyChaser, are engineered to detect, track, and mitigate a single drone or a swarm. Many of the existing technologies such as netting or jamming drone guns aren't capable of mitigating a swarm. The more sophisticated the swarm technology is, the more difficult it is to neutralize them." (Figure 2.)

**Countering the countermeasures**

Once it becomes possible to counter UASs, the next step is to find a way to counter the countermeasures.

**Figure 2** | SRC's counter-UAS technology shown conceptually on a military Stryker combat vehicle. Image courtesy of SRC.

"There's a sort of little arms race going on now – so many counter-drone systems and approaches are available," Blades says. "Drone makers are asking, 'How do we counter that counter?' and 'What can we put on our drones so they can't see or hear us?'"

A small industry is already emerging to make drones more difficult to detect, Blades notes, using everything from antispoofable GPS antennas to new ways to reduce the acoustic signature of drone propellers so you won't hear that classic high-pitched drone noise until it's much closer or you won't hear it at all.

This is just the beginning. **MES**

# Military UAVs tackle performance issues under SWaP-driven designs

By Mariana Iriarte, Technology Editor

U.S. Army soldiers assigned to the 10th Special Forces Group, Unmanned Aerial Systems Det., Fort Carson, Colo., break down an RQ-7B Shadow unmanned aerial vehicle (UAV). Photo courtesy U.S. Air Force/photo by SSgt Andy M. Kin.

*The U.S. Department of Defense (DoD) is seeking high-performing unmanned aerial vehicles (UAVs) designed to meet stringent size, weight, and power (SWaP) constraints. One solution is to pack the vehicles with components. The problem? The lower the SWaP and the smaller the UAV gets, the more performance suffers.*

Unmanned aerial vehicle (UAV) designs are increasing the number of onboard RF [radio frequency] and microwave components to address performance issues and tackle technical challenges ranging from counter-UAV tech to power consumption. To address these challenges, UAV developers are integrating different technologies to deliver a high-performing UAV in a design constrained by size, weight, and power (SWaP) concerns.

UAVs in particular are "incredibly challenging because the radar cross-section is fairly low. The only thing they really reflect are the little engines on the rotors," says Doug Carlson, senior vice president and general manager, RF & Microwave business unit, MACOM (Lowell, Massachusetts). "Detecting UAVs effectively at a distance in order to give the user time to react is turning into a very hot topic in the field of radar and RF."

The rise of UAV and counter-UAV technology is pushing UAV developers to ask some much-needed questions, Carlson says: "How much RF and how much sensing is going into this counter-UAV problem? UAVs are now a weapon system, both in defense and civil airspace, or civil domains, such that we have to come up with cost-effective and very reliable solutions to counter malicious attacks. We are suddenly seeing the flip side – we've done a great job making UAVs and now UAVs are a problem."

Unmanned systems developers still have quite a few technical challenges to still address aside from counter-UAV problems. For one, "unmanned systems are becoming more and more autonomous," Carlson adds. "As they become more and more autonomous that means that the sensor capabilities are going to have to go up. The sensor capabilities are going to have to be able to work in all environmental conditions. That tends to lend itself towards RF solutions. I think you'll see even more RF ending up on unmanned vehicles."

As unmanned systems become more and more autonomous, and with RF components increasing and at the same time the overall size of the UAV shrinks, users "want more performance (sensitivity, dynamic range, bandwidth, channel count, processing power) for less SWaP. Whatever the current state of the art can deliver is never quite enough to satisfy," says Jeff Hassannia, senior vice president of Business Development, Strategy,

and Technology for Cobham Advanced Electronic Solutions (Crystal City, Virginia). "This is a very big challenge, especially as missions are expected to get bigger and require more performance and new features such as jamming resistance, radiation interferers, the ability to execute multiple missions with single payloads, and more."

Designing a UAV under the SWaP umbrella is a major – if not the biggest – challenge for design engineers to ensure that this system is stable and powerful enough to complete a mission. "One the biggest technical challenges that we see our customers already trying to tackle is that as you get smaller and smaller you have so much gain; the real challenge is keeping the whole architecture stable," says Gavin Smith, product marketing manager at NXP Semiconductors (Phoenix, Arizona).

Moreover, UAVs come in various sizes. With "the larger UAVs, the challenge is not whether there is enough power

**Figure 1** | Cobham waveguides. Photo courtesy of Cobham.

available, but rather heat dissipation," Smith says. "Sometimes they want to make a very small package for a full module. The higher efficiency, the less heat that's dissipated and the smaller the product can be. As you probably can appreciate, size is very important because of how much is being crammed into a very small vehicle including communication components, and in some cases there's data recording, a video component, and UAV controls. All of that stuff requires higher efficiency."

The drive for higher efficiencies is not new but it is a key factor to delivering a complete solution to the end user. Smith adds, "We also consider battery consumption. Some of the smaller UAVs, pretty much the handheld UAVs, run off battery, so the efficiency is very, very important, as well as the weight."

In addition to delivering an efficient system, getting some actionable intelligence back from it is a challenge because "High-definition video is becoming more prominent," Smith explains. "That means higher data bandwidths, which requires more signal bandwidth, which also makes it more challenging for us [to build]."

"In general, in the entire field we're also seeing a trend towards a higher degree of digitization," Carlson adds. "What do I mean by that? The information that users get from the air platform, we're not going to receive it or broadcast it, but I'm very quickly going to digitize that signal onboard and turn that signal from raw data to information. That way, I'm broadcasting information back to the command center rather than just raw data. The design is driven by the fact that there is so much data flowing into these vehicles, so we've been able to condense it down and take advantage of the bandwidth pipe."

Companies are positioning themselves to handle current and future technical challenges. For example, Cobham's "Waveguides will remain an important element of RF communications and ISR [intelligence, surveillance, and reconnaissance] applications for the future, as waveguide efficiency still makes it the best choice for many applications. In future UAV systems, reduction of system size and weight will be crucially important," Hassannia says.

Traditional manufacturing techniques have constrained the design of waveguide assemblies of filters, diplexers, duplexers, and antennas resulting in extended assemblies of numerous waveguide elements, he continues. "Cobham is working with additive manufacturing technology that will be a game changer for the packaging of complex waveguide architectures. By removing fabrication constraints and allowing the creation of complex architectures that 'fold back on itself,' system volume can be reduced, and the waveguide assembly more easily customized to the host vehicle." (Figure 1).

**Integrating tech to achieve max results**

Integrating different types of technologies to deliver a high-performance system will be key for the warfighter. Of course, it doesn't negate the fact that as unmanned systems become more integrated with all the additional RF components to meet high data demands, there is still the DoD's SWaP directive.

OF COURSE, IT DOESN'T NEGATE THE FACT THAT AS UNMANNED SYSTEMS BECOME MORE INTEGRATED WITH ALL THE ADDITIONAL RF COMPONENTS TO MEET HIGH DATA DEMANDS, THERE IS STILL THE DOD'S SWAP DIRECTIVE.

Without a doubt, UAV design trends toward integration, Hassannia says. "What was once a box is now a board, and someday it will be a chip. Today's highly integrated solutions are made possible by high-performance direct digital back-end solutions based on system-on-chip FPGAs [field-programmable gate arrays]."

"With size, if we move to the integration phase, for example, it would be about using an IC [integrated circuit] as opposed to a multichip module," Smith says. "The size of the device along with the size of the matching network on the PCB, the printed circuit board that's required, if we do a lot of internal matching in the IC, then very little is left to be done outside, which allows our customers to shrink the overall size of the package they're housing."

Unfortunately, adhering to SWaP requirements hurts system performance. To achieve peak performance within SWaP constraints, MACOM is focusing on higher levels of integration, Carlson says. "We tend to focus on heterogenous forms of integrations, in other words bringing multiple technologies together to form a highly capable, compelling solution. Often, if I integrate in a silicon platform or something like that, I compromise certain RF functionality. Sure, I get the integration, but I degrade performance. And most of the things we're addressing, the performance is as critical a requirement as weight and cost."

"SWaP optimization is definitely a major design challenge in this space," asserts Deepak Alagh, senior director and general manager, Mercury Systems RF & Microwave group (Andover, Massachusetts.) "As we shrink high-frequency circuitry into very small spaces, accurate modeling becomes very critical and difficult. In addition to modeling and accounting for cross-coupling, the models need to capture nonlinear effects as well as the heat generated in the devices.

"Recently, we have been seeing an increase in requests for both high power density and high integration density," Alagh adds. Users are leveraging "GaN [gallium nitride]-based amplifiers to maximize the RF output power while minimizing the module size. Additionally, instead of developing multiple separate modules, our customers are asking us to integrate multiple capabilities in a single, compact housing."

For example, Mercury Systems' Mercury's "SpectrumSeries Platform combines RF, digital, and custom SiP in a small outline," Alagh says (Figure 2).

Thankfully, "the advancements in semiconductor performance and chip-scale integration have had a very dramatic impact on the receive side of the system, resulting in maybe a 10:1 reduction in size and power consumption," Hassannia says. "Improvements on the transmit side have been less dramatic, resulting in a 2:1 reduction in size and power consumption."

"On the LDMOS [laterally diffused metal-oxide semiconductor] side of the equation, we have devices that are moving toward higher level of integration," Smith says. "RFICs that offer several stages of gain and additional features such as power sense, temperature compensation; it's in a small plastic package which makes it lighter weight, has higher conductivity in the flange which helps that thermal resistance, and is less expensive than traditional ceramic packages."

NXP's entrant in this market, the avionics AFIC10275, "is a silicon LDMOS product: It is a two-stage RFIC designed for transponder applications operating from 978 to 1090 MHz. (Figure 3).

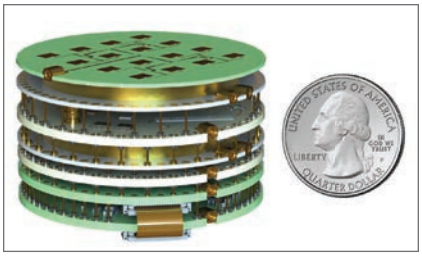

**Figure 2** | Mercury Systems' SpectrumSeries Platform. Photo courtesy of Mercury Systems.

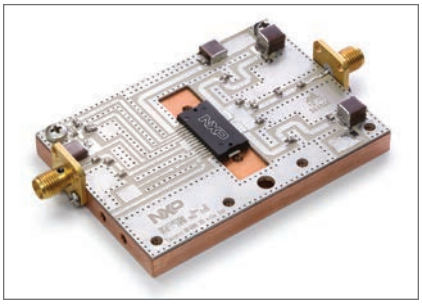

**Figure 3** | NXP's AFIC10275N. Photo courtesy of NXP.


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For UAV developers, "SWaP-C [SWaP plus cost] is still the primary guiding system," Carlson says. "For example, the communication system can't be 10 times the platform cost. Clearly whatever communication system or sensor system I put on it, I have to be very cost-conscious. [Efficient transmitter designs are critical] because you don't want to be throwing away any transmitted RF power, it's wasted heat," Carlson says.

**RF & microwave benefits communications, radar, EW**

The increase in RF and microwave components in UAVs is having a positive effect in delivering to the warfighter the systems they require for successful missions.

"It's funny, because in a sense, I think [the components] are all a little bit codependent in that a UAV has a great suite of sensors but no ability to communicate that information," Carlson states, noting that the system then becomes pretty useless if it can't deliver mission-critical information to the command center.

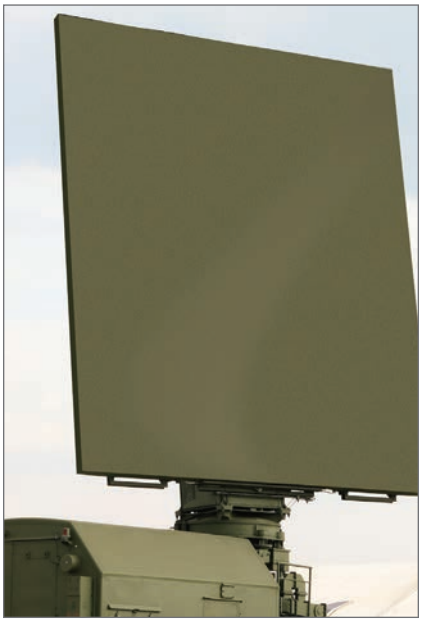

**Figure 4** | Ku-Band 8 W TRM for radar systems. Photo courtesy of MACOM.

"Communication links clearly require RF," Carlson adds. "In general, those links are going to higher and higher frequency for higher and higher bandwidths, so you can push more and more data from the UAV. In other words, there is lot of live sensor data that is not just a command-and-control type of the device, but the idea is to actually get actionable information from the UAV."

"We see the radar sensors as being an incredibly vital part of the UAVs, as well as of communication links," he continues. Precision requirements are driving demand for higher and higher frequencies for radar applications, "because as I go to a higher frequency, I can get a much more precise geolocation. Obviously, once I start detecting all this stuff, now I'm in a circular argument. I have to broadcast back so that somebody can actually do something and take action on it."

For example, MACOM "has a single-chip KU-band T/R module that's been used in a communication phased array for drones that creates a real-time video link for a military application, providing an over-the-horizon video link," Carlson explains (Figure 4). **MES**

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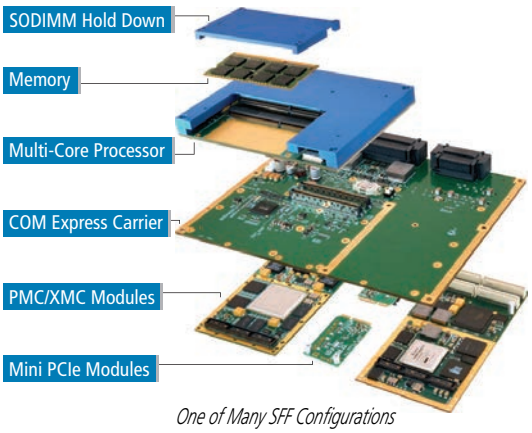


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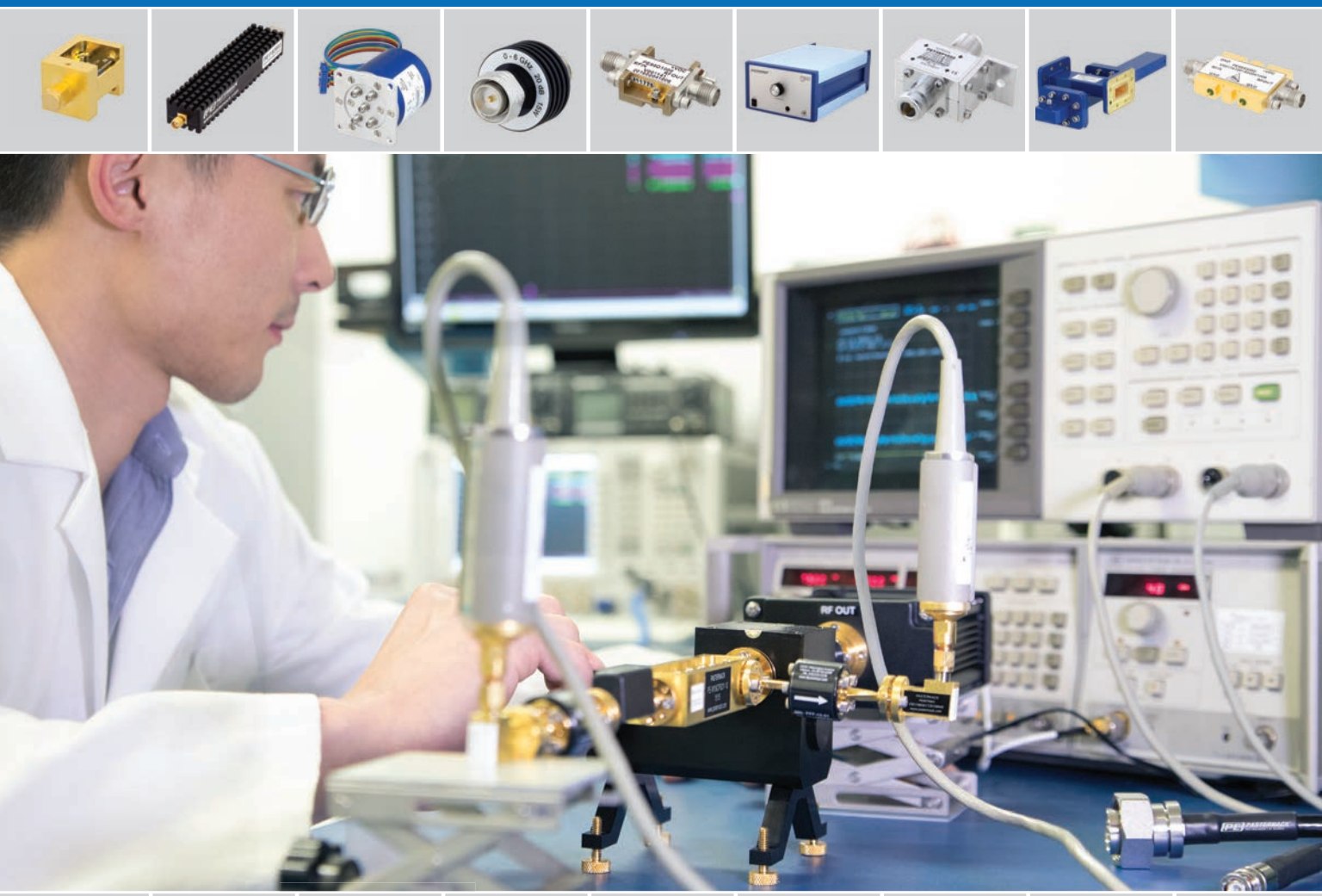

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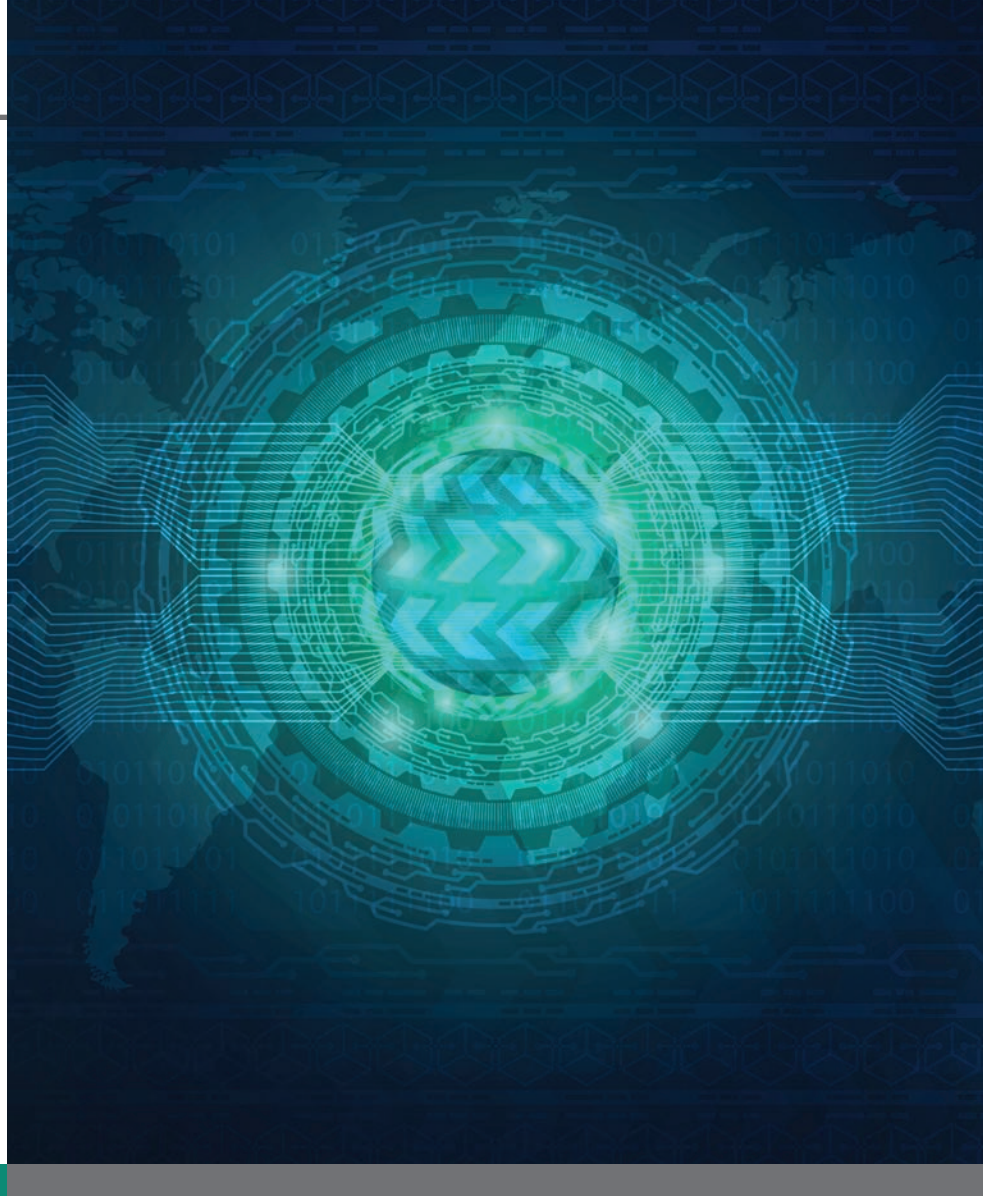

# Development of the next-generation OpenVPX-based embedded system standard – A tri-service convergence of approaches: Part 2 of 3

By Mike Hackert (NAVAIR), Ben Peddicord (CERDEC), and Dr. Ilya Lipkin (AFLCMC)

*Something exciting is happening in the service representative community. Representatives from three different programs, one from each of the U.S. Department of Defense (DoD) services, have come together with a common objective to solve their respective acquisition problems with an agreed-upon, open architecture standard. Here is Part 2 of a 3-part article covering the SOSA [Sensor Open System Architecture] Consortium's efforts. Read Part 1 in the March 2019 issue of Military Embedded Systems.*

The best way to understand the uniqueness of this tri-service convergence is to provide the historical perspective building from the development of the underlying, enabling technology from the past. The current cutting-edge embedded systems are based on the VPX connector, which began standardization around 2003 with the development of VITA 46. The VPX connector provides the state of the art for high-bandwidth, high-connectivity embedded system backplanes. It is a key enabler that allows 728 pins on an IEC-60297-3 Eurocard 6U format and 280 pins on a 3U format circuit card, with options for replacing connector segments for card-edge RF and optical connections with significantly greater bandwidth. This technology came into its own when the OpenVPX standard was approved as VITA 65 in 2010; the market has grown year by year since then, with broad adoption of OpenVPX, as the market converts from legacy VME-based chassis.

OpenVPX includes a broad range of standard options from which a system designer can choose during development. While these options enable a high degree of flexibility to support a broad range of applications, they also create the potential for dilution of the market for any one design, effectively creating a nonstandard standard through all of the allowed permutations. This, of course, is the risk any developing standard faces if it is created in advance of user adoption and broad enough application.

The stated vision of the HOST [Hardware Open Systems Technologies] hardware standard was to apply existing industry standards to effectively do for the U.S. Department of Defense (DoD) what the release of the IBM PC standard did for personal computing. Specifically, the IBM PC standard [1] provided definition of standard interfaces so that the computer industry could focus and converge on providing capabilities through a market ecosystem which could connect through

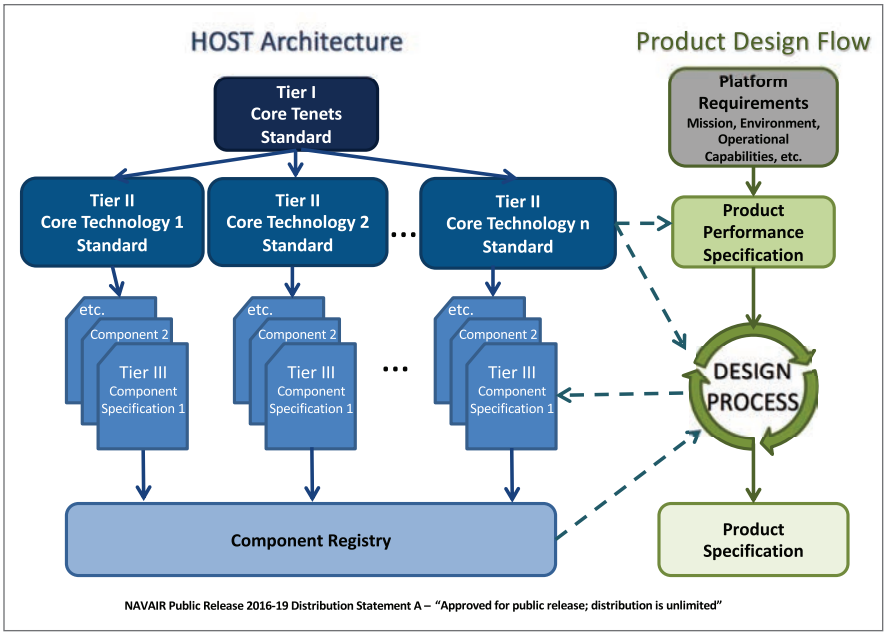


**Figure 1** | Application of HOST's tier structure.

these interfaces. This definition allowed a range of businesses small to large to develop new capabilities which could be sold at affordable prices, through hardware and software, the development of which could be afforded by the volume that then ensued. In a similar vein, the stated goal of HOST is to allow the industry to stop reengineering existing technologies for new systems (e.g., to slightly different specifications such as environments or pinouts) and refocus the DoD's and market's investment in development towards new state-of-the-art technology and value-added new capabilities. The current HOST Tier 2 standard is based on the VITA 65 OpenVPX standard, providing greater specificity as well as adding requirements for basic hardware management (e.g., via VITA 46.11 over the IPMB [intelligent platform management bus] or control-plane Ethernet). It also creates the Tier 3 specification process and requires its use to specify plug-in modules. This tiered structure can be seen in Figure 1.

The Tier 3 specification process is under development, with plans to be applied and tested during 2019 by end users of HOST (e.g., the Joint Strike Fighter program office and NAVAIR's PMA 209 supporting development of a replacement mission computer for a number of legacy platforms). A Tier 3 specification can be thought of as a module-level component specification that includes both the way in which the Tier 2 standard requirements are met as well as the additional requirements for module or payload functionality. The definition of a HOST module also allows for the specification of HOST mezzanines: By proper design and functional decomposition, base HOST plug-in modules can be reconfigured for new payload capabilities through selection of different HOST mezzanines. If properly written, a Tier 3 specification will allow an acquisition authority to create a family of products built from modules specified by Tier 3 specifications. This general acquisition authority can include anyone needing, designing, or building an embedded system (e.g., prime contractor or service platform, system designer or integrator, or contract manufacturer that builds systems to a design for a customer).

A product-line manager can then use the set of Tier 3 specifications that they have selected to satisfy customer performance needs with custom designs built upon standard plug-in modules and mezzanines. This vision can be seen in Figure 2. HOST's benefits to the customers include lower cost hardware through use of standardized modules (not requiring reengineering for each application) with higher volumes, especially if they can be shared across product lines and/or across acquisition authorities or services. Benefits to industry include higher volume for standard modules (e.g., power supplies, switches, and single-board computers) and greater consistency of their market from which to recoup their development costs.

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Moreover, by knowing the interfaces that customers are selecting, new products can be developed to interface into old systems so that upgrades to the newer model becomes simply a little integration work to create new software load and a lower-cost card swap (i.e., much simpler logistics) versus getting approval and funding for a major acquisition program. When combined with efforts such as FACE [the Future Airborne Computing Environment standard] that intend to abstract application software (that ultimately provides capabilities) from the underlying hardware, industry will know the interfaces of the existing modules and be able to use R&D to develop the next generation of technology (e.g., as new processor chips become available or the next in a family of FPGAs gets announced) in order to be able to plan for more frequent technology refreshes. Stated differently, instead of reengineering each custom card for each new application, common interfaces will allow both customers and industry to commoditize common building blocks so that shrinking development dollars can be focused on greater value-added capability creation.

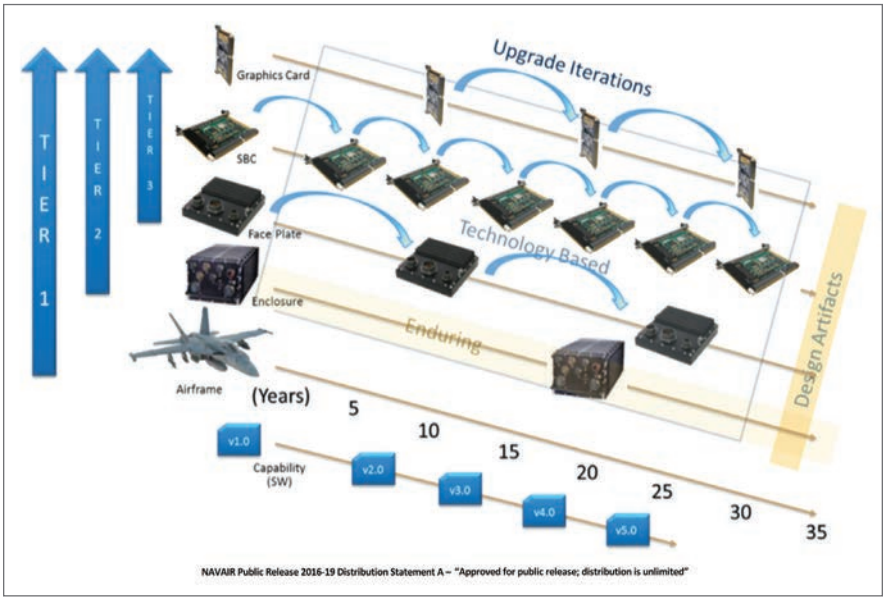


**Figure 2** | The vision for HOST.

## CMOSS and refinement of RF application standards

The Army has historically implemented C4ISR [command, control, communications, computer, intelligence, surveillance, and reconnaissance] capabilities as a multitude of separate "boxes" on individual platforms. This approach makes it difficult to upgrade capabilities or keep pace with commercial technology due to complex integration challenges, lack of competition, and proprietary interfaces. In many cases stovepiped systems consume more size, weight and power (SWaP) than is currently available, thus necessitating expensive and time-consuming vehicle redesigns.

CMOSS [C4ISR/EW Modular Open Suite of Standards] defines a Universal A-kit (or wiring harness for interconnection) that eliminates the need for platform-specific integration as capabilities can be fielded as cards in a common chassis and components that use existing cabling. The concept of a Universal A-kit is a game-changing approach as it ensures commonality across multiple platforms, while allowing for rapid insertion of the latest C4ISR capabilities. Built upon open standards, this Universal A-kit enables the soldier for the next fight while providing significant cost savings during the procurement and sustainment phases of the life cycle.

CMOSS revolutionizes sustainment as logistics tails can be smaller due to common spares, while unit costs can be reduced by greater competition and economies of scale. Sustainment organizations will no longer need to purchase enough spares to last 30+ years as they can perform modernization through spares and upgrade to the latest hardware every five to ten years or less.

CMOSS defines an open architecture that reduces the SWaP footprint of C4ISR systems by enabling sharing of hardware and software components. Well-defined components with open interfaces not only allow rapid technology insertion to keep pace with emerging needs, but they also permit capabilities that are innovative but unplanned to be quickly implemented. The open architecture consists of a suite of layered standards that are individually useful and can be combined to form a holistic converged architecture.

The CMOSS suite of standards shown in Figure 3 includes:

- Network-based interoperability using VICTORY [2] [Vehicular Integration for C4ISR/EW Interoperability] to share services such as time and position
- Hardware form factor using OpenVPX to field capabilities as cards in a common chassis
- Functional decomposition using the MORA [Modular Open Radio Frequency Architecture] to share resources such as antennas and amplifiers
- Software frameworks such as REDHAWK [3], Software Communications Architecture (SCA [4]), and FACE to enable software portability

The linkage between VICTORY and MORA can be more easily seen in Figure 4.

CERDEC is working with industry and academic partners to define and mature the CMOSS standards by developing reference implementations within the converged architecture. These activities include coordination with the Tank Automotive Research,

Development and Engineering Center (TARDEC) to integrate and demonstrate the reference implementation on a tactical vehicle.

CERDEC is leveraging CMOSS to develop capabilities within its portfolio; these activities will not only further mature the architecture, but will also facilitate technology transition to programs of record. CERDEC is actively working with the acquisition community to include CMOSS requirements in current and emerging programs.

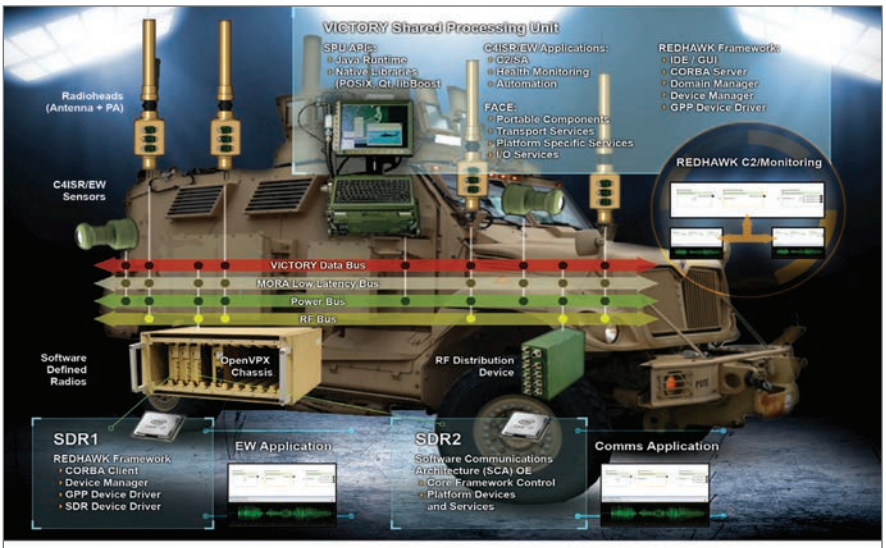


**Figure 3** | The CMOSS suite of standards.

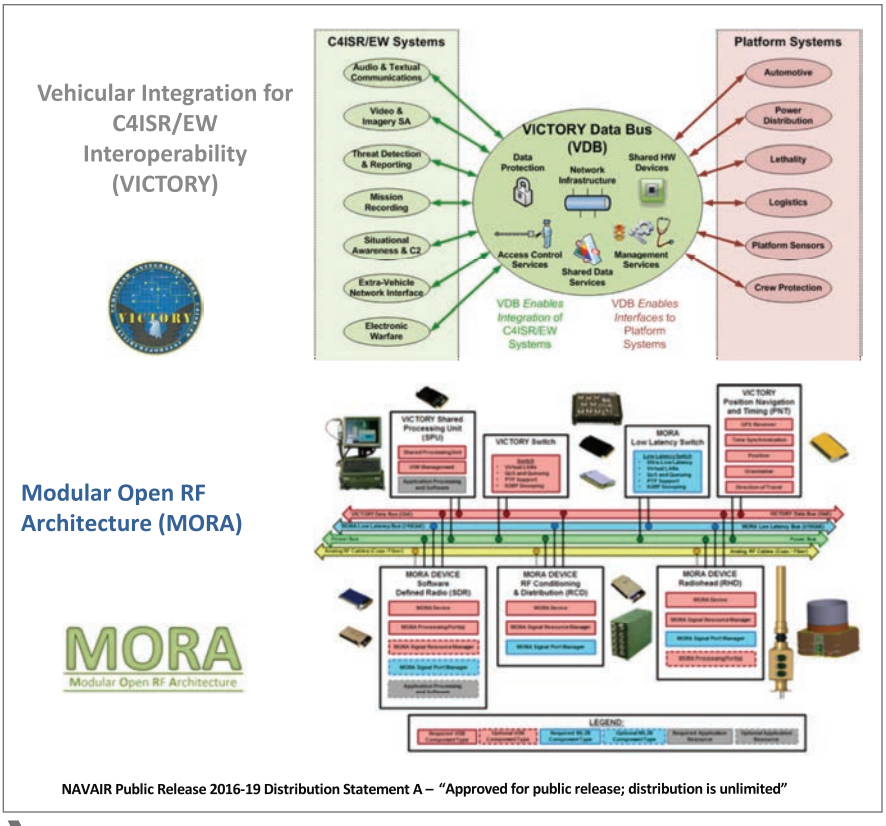


**Figure 4** | CMOSS ties VICTORY and MORA.

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Transformers &
Inductors

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1-300 Watt Modules

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A critical component to the success of any open standard is its sustainment. To that end, CERDEC is actively participating in the associated standards bodies to address emerging requirements and technology. CERDEC is also collaborating with other services to align open architecture activities and enable procurement of common hardware and capabilities: CMOSS has been included in the Air Force's Sensor Open System Architecture (SOSA) standard and has been aligned with the Navy's HOST standard.

**SOSA and convergence of end-user embedded system requirements**

As a cooperative industry forum, SOSA's stated goal is to lower the life cycle cost of technology development and deployment and reduce the time it takes to get new capabilities deployed faster than the traditional, stovepiped platform approach. This cooperation includes the underlying technology which enables and/or provides the next capability, both hardware (e.g., plug-in modules) and logic (e.g., software and firmware). These goals are similar to those for HOST and CMOSS – that is, all three efforts are effectively trying to achieve the same goals of lower cost and faster transition of capability – so consequently SOSA became a logical overarching organization upon which these two efforts could converge. As an Open Group consortium, SOSA has also benefited from what has been learned from past open architecture initiatives that have been successful, as well as learning how to avoid the mistakes of past unsuccessful standards. For example, SOSA incubated under the FACE Consortium in order to leverage lessons learned, membership structure, and develop valuable initial processes that took FACE years to develop and accumulate. Under the FACE Consortium, SOSA was able to come up with a common ecosystem between avionics and sensor domains, further improving interoperability of both efforts. **MES**

**References**

[1] https://en.wikipedia.org/wiki/IBM_Personal_Computer

[2] Reference to the public version of the VICTORY standard

[3] https://redhawksdr.github.io/Documentation

[4] http://www.public.navy.mil/jtnc



***Mike Hackert** is program sponsor at NAVAIR [Naval Air Systems Command], **Ben Peddicord** is chief of CERDEC [Combat Capabilities Development Command (CCDC) C5ISR Center/formally the Communications-Electronics RD&E Center] Intel Technology and Architecture Branch, and **Dr. Ilya Lipkin** is lead manager for SOSA at the AFLCMC [Air Force Life Cycle Management Center].*

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The PCI104-SIO4BX-256K-IC board is a four channel serial interface card which provides high speed, full-duplex, multi-protocol serial capability for PMC applications. The SIO4BX combines two multi-protocol Dual Universal Serial Controllers (USC®), 8 external FIFOs, and multi-protocol transceivers to provide four fully independent asynchronous or synchronous serial channels. Multiprotocol Transceivers support RS422 (V.11)/RS485, RS423 (V.10), RS232 (V.28), V.35, RS530, as well as other Mixed Protocol modes. These features, along with a high performance PCI interface engine, give the PMC-SIO4BX unsurpassed performance in a serial interface card.

Note: All PC/104-Plus boards are available in a PCI-104 form factor. The ISA connector is not installed for the PCI-104 board. Use the prefix PCI104- instead of PC104P to order a board without the ISA connector. PC/104+ boards can also be ordered with non-stackable PCI connectors by adding -NS to the end of the part number.

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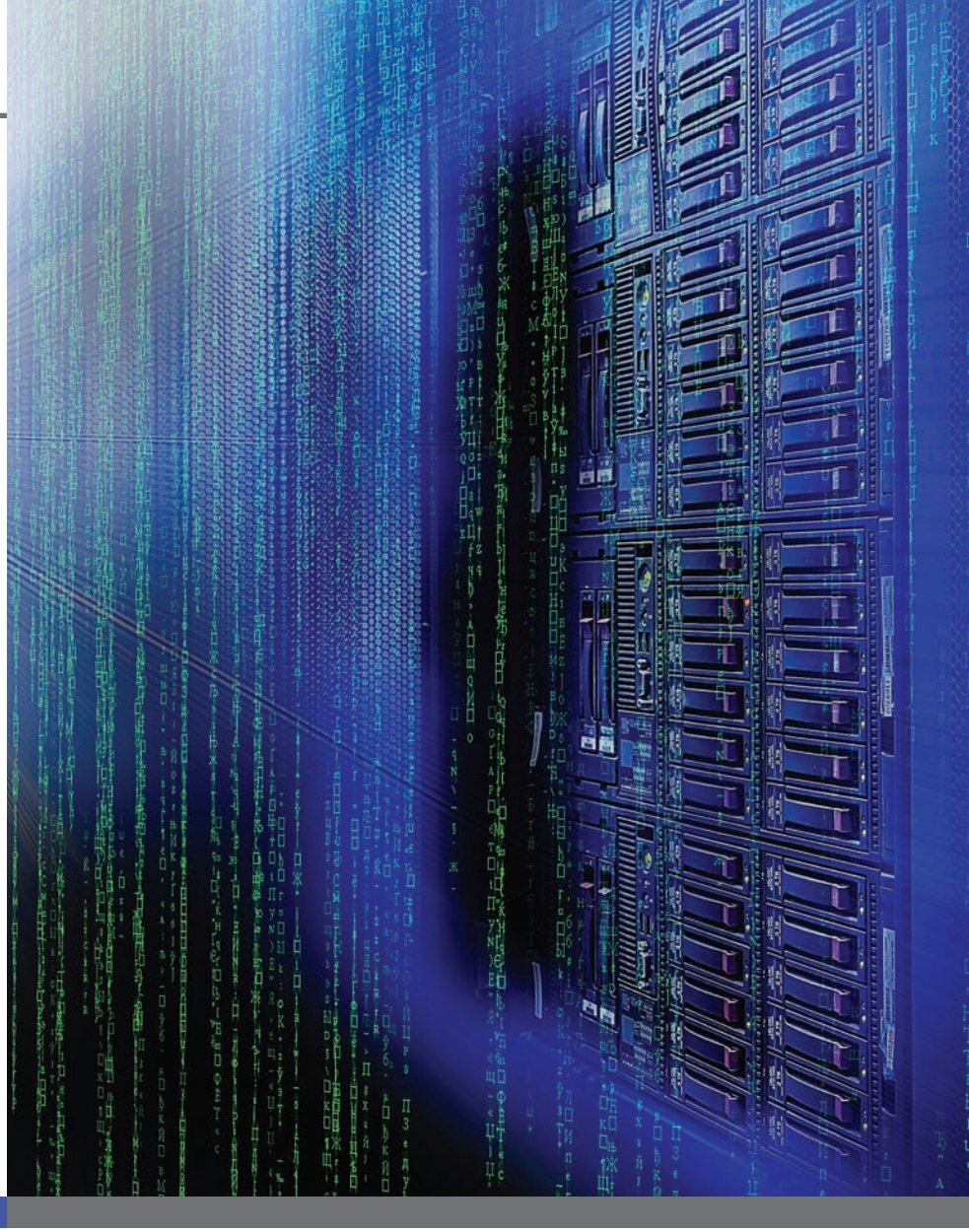


# Wideband signal and data recorders harness new technologies

By Rodger Hosking

*Wideband recorders draw upon diverse disciplines of new technology to keep pace with the explosion of the number of information traffic channels and increased bandwidth. Fortunately, many of these technologies are driven by large worldwide market forces, which feed off our planet's insatiable need for connectivity and storage. With no perceivable upper limit to speed or capacity requirements, wideband recorders will continue to serve critical roles in both deployment and development of vital military and aerospace systems.*

The inexorable race to maintain superiority of military warfighting infrastructure means increasing the complexity, quantity, and capacity of high-speed signals that flow among sensors, targets, equipment, and platforms. Yet more so than ever before, successful outcomes against the enemy depend heavily upon timely exploitation of information gleaned from intercepting these signals. Because of these two conflicting trends, new solutions and strategies are mandatory to capture, classify, decrypt, and decode this growing landscape of signals as efficiently as possible.

One essential class of tools in this effort are wideband recorders that can capture analog and digital signals and can make them available for immediate tactical action, detailed analysis and decryption, upgrading equipment to deal with new threats, and developing new equipment. Integrating advancements in components and technologies into deployable instruments that achieve maximum performance, ease of use, and operation in adverse environments requires a thorough understanding of the elements and how they interact.

**Wideband recorders at work**

Mission recorders are systems that capture live signals in a wide range of environments and operating conditions, with many different configurations. They are widely deployed in virtually all military platforms, mainly for gathering signals of interest for transmission to another platform, or for offloading data for analysis after completion of the mission.

For example, intelligence-gathering missions can use unmanned platforms to perform a spectral survey of a battlefield or hotspot. Analysis of the recordings can

provide a wealth of information about which types of radios and satellite links are being used and may identify the ground platforms. Decoding and decrypting these signals can yield valuable intelligence and patterns of communication.

Airborne recorders can also capture radar signatures illuminating the aircraft from ground, sea, and other airborne platforms. Because these signals are recorded, they can be quickly sorted into known signatures for immediate use by the pilot or forwarded to a ground station for further analysis and classification. New, unknown radars can be investigated, cataloged, and then added to the library of known signatures.

When the opponent develops new signal-encryption and anti-detection techniques that thwart extraction of information by existing equipment, new receivers must be designed. After capturing these new signals, some recorders can play them back in real time in the laboratory. By reproducing them on demand, these signals can be used iteratively for testing during the development of new or enhanced receivers or radars.

Lastly, recorded communications and radar signals can be used to design carefully crafted countermeasures such as cloaking, jamming, and spoofing. Often, these new designs can be delivered over the air to update military equipment for automated and real-time electronic countermeasures against platform-specific enemy equipment.

**Operational requirements**

For successful operation across this wide range of applications, environmental requirements for wideband recorders can be tough to meet. Temperature extremes for mission recorders can range from -40 °C for an aircraft in Alaska to +80 °C for an unmanned ground vehicle operating in the desert. Shock and vibration levels found on many platforms pose serious threats to rotating-media magnetic drives with their sensitive mechanical structures to keep the heads in contact with the platters.

To maintain operation under challenging conditions of humidity, fungus, altitude, salt spray, and sand, designers must carefully seal the recorders to protect internal structures and electronics. Electromagnetic emissions pose double-edged requirements: First, the recorder must not radiate energy that could interfere with other equipment on the platform. Secondly, the recorder must be immune to interference from external sources such as high-power radar pulses and transients on the power lines. This capability becomes more critical in crowded equipment compartments.

Some recorders must capture signals based on a hardware gate or trigger, such as a radar system recorder that may need to capture repetitive radar pulses and skip the intervals between them. Multiple recorders at different locations may need to start capturing data at the same sample clock to calculate the position of a satellite through triangulation based upon the relative phase of received signals. The best solution is often a GPS receiver in each recorder, fully integrated with the recording software and hardware. An increasing number of applications require precise time-stamping of each recording, often resolved to a specific sample clock.

In many cases, the recorder is located in an aft cabin or wing compartment and must be controlled remotely by a pilot from the cockpit, or by an operator on the other side of the world via satellite link. Perhaps the most fundamental requirement for these recorders is the bottom line: they must capture data continuously at the required rate for a specified duration under all conditions with absolutely zero loss of data.

**Solid-state drives**

Solid-state drives (SSDs) offer significant reductions in size, weight, and power (SWaP) compared to rotating-media hard drives, although their high original pricing made them economically feasible only for high-end military applications. Now, however, inspired by enormous commercial markets and after more than a decade of continuously-evolving new technology, costs are now very competitive with hard drives. At the same time, density, speed, and capacities are steadily improving. Figure 1 compares the essential attributes of typical high-end hard drives and SSDs currently available. Unlike earlier cost/capacity ratios between the two types, which differed by factors of 100 of more, now it is just over six, and dropping.

Another critical benefit of SSDs is their immunity to shock and vibration: In older systems, extreme measures of protection were required to isolate these effects from rotating drives, making systems bulky and expensive to maintain, so SSDs naturally presented an immediately attractive alternative.

High-bandwidth analog and digital inputs push recording rates far beyond the capability of a single drive, forcing the use of RAID [redundant array of independent disks] controllers to aggregate the speed of multiple drives. The latest generation of SSDs offer data read/write speeds far exceeding those of rotating drives, thus reducing the number of SSDs in a RAID array to meet a guaranteed recording rate.

**RF analog I/O**

The world must share a single radio-frequency spectrum that struggles to support ever-higher traffic, forcing the governments to stringently regulate and allocate thousands of bands for specific uses, representing a virtually unlimited number of targets for intercepting and recording critical information. Use of each precious frequency band for maximum information bandwidth, reliable performance, and adequate security mandates complex digital signal processing techniques at both ends of the signal path. Spread-spectrum techniques and the insatiable demand for data at every level of the economy can only be met with wideband modulation schemes. This demand drives the need for fast data converters to capture and generate these wideband signals to keep pace with vast markets of communications, radar, and wireless networks.

| Feature | 3.5" Rotating | 2.5" Solid State |
|---|---|---|
| Capacity (high end) | 10 TB √ | 4 TB |
| Read Rate | 220 MB/sec | 560 MB/sec √ |
| Write Rate | 220 MB/sec | 530 MB/sec √ |
| Weight | 750 gm | 64 gm √ |
| Size | 376 $mm^3$ | 89 $mm^3$ √ |
| Power | 7.2 W | 0.28 W √ |
| Operational Shock | 30 G | 1500G √ |
| Operational Temp | 5 to 60 °C | 0 to 70 °C √ |
| Cost | $400 √ | $1,000 |
| Cost / GB | $0.04 √ | $0.25 |
| MTBF | ∞ √ | 2,500,000 hrs |

**Figure 1** | SSDs offer many performance and environmental advantages over rotating drives for wideband military or aerospace recorders. Winning attributes are marked with a check.

To capture as much of the RF spectrum as possible during a mission, wideband signal recorders must digitize antenna signals at high sample rates, generally at least twice the bandwidth of the signals. Some new monolithic analog-to-digital converters (ADCs) operating at sampling rates at 6.4 GHz can digitize nearly 3 GHz of bandwidth, nicely covering most critical radio bands with the help of some RF tuners at the front end.

Some wideband recorders must capture all digitized information at the full bandwidth, so that the extraction of information from unknown signal types can be attempted later on in the lab. In this case, the recorder must be capable of continuously recording gigabytes of data each second, perhaps for hours or days. In other cases, DSP techniques can extract information from the wideband ADC digital output stream for known radio channels within the captured spectrum by using DDCs (digital downconverters), decoders, and demodulators. This technique reduces the data rate for recording and subsequent downstream processing. For playback, digital-to-analog converters (DACs) reverse these signal-processing operations to fetch recorded digital samples from disk and deliver analog outputs at the original signal frequencies.

Wideband recorder vendors usually take advantage of ADC and DAC board-level products, offering a modular solution for different analog interfaces to address diverse applications. Most of these feature FPGAs [field-programmable gate arrays] because of their configurable I/O ports for high-speed parallel LVDS and also sport gigabit serial links to match the specific requirements of each data converter. FPGAs can also implement the critical timing, triggering, gating, synchronization, and time stamping of the recorded signals. Most importantly, they provide wideband PCIe interfaces to system memory for access by the

**Figure 2** | Pentek RTX25xx ½-ATR mil-spec wideband analog or digital rugged recorder is sealed against the environment. A field-removable QuickPac array of 8 SSDs stores 30 TB of recordings at up to 4 GB/sec. An API (application programming interface) library enables Talon recorders to be controlled from a remote facility or a larger system.

RAID controllers, supporting PCIe Gen.3 links with 8 or 16 lanes.

### High-speed digital I/O

Many recorders must also store and play back high-speed digital streams arriving in a wide range of different formats and protocols. Ethernet dominates this application space due to its widespread adoption and low-cost hardware infrastructure, including optical and copper interfaces, cables, routers, host adapters, and switches. Virtually every computer system now sports one or more 1GbE ports, but higher performance systems are now migrating to 10, 40, and 100GbE ports.

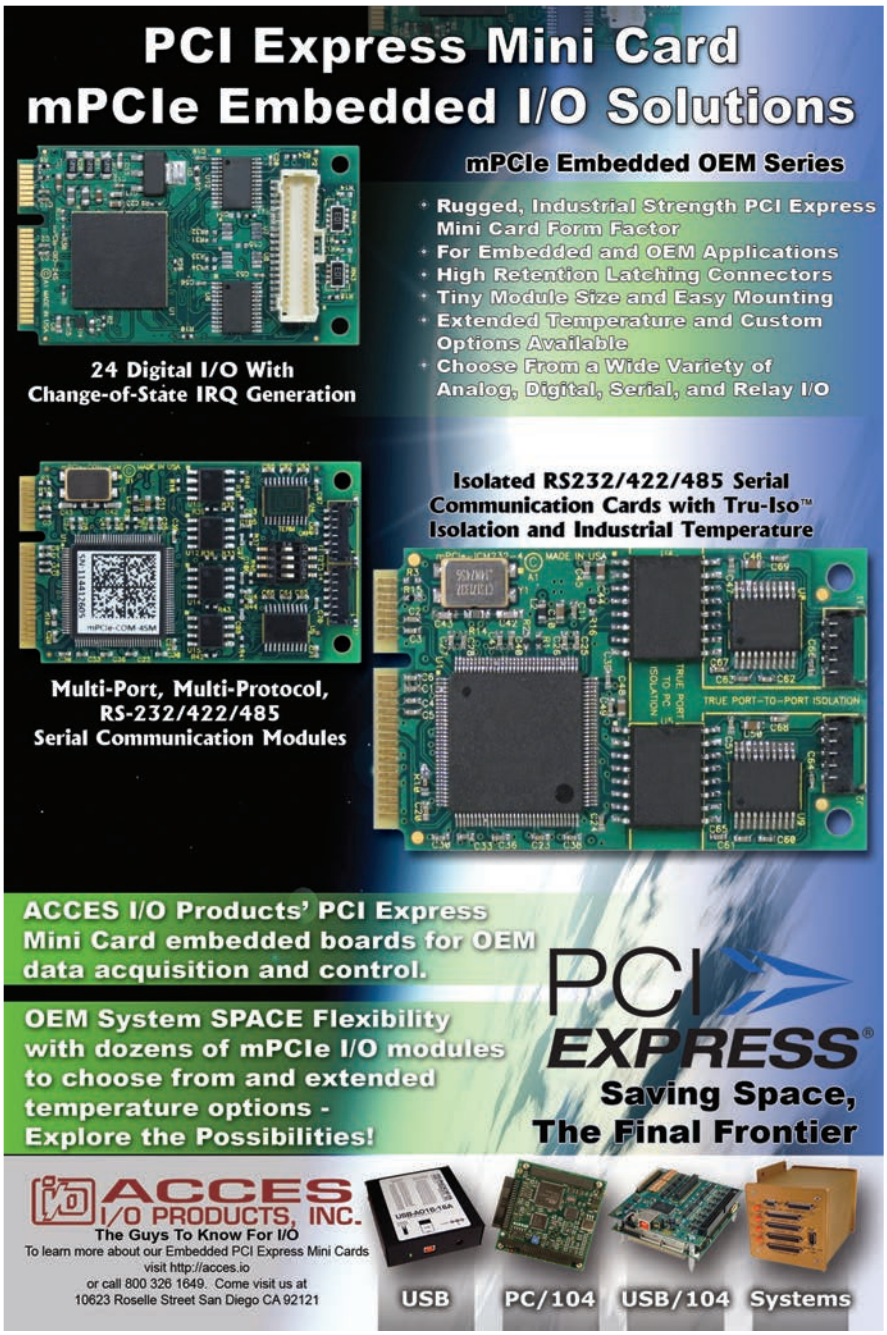
By taking advantage of commercially available Ethernet adapters, wideband recorders can support dozens of different interfaces. Optical adapters accommodate single- and multimode fiber with different wavelengths, data rates, distance spans, cable types, and optical connectors. Fortunately, most of these adapters offer PCIe interfaces with drivers for all popular operating systems.

For other digital I/O interfaces, FPGAs with flexible I/O transceivers and state machines provide configurable logic to support both serial and parallel interfaces including SerialFPDP, SerialRIO, Infiniband, LVDS, and other custom protocols. Fast PCIe interfaces deliver data to the system memory. (Figure 2.)

### Wideband recorder system components

Wideband recording systems benefit from a wealth of new technology developed for the data server market, including RAID controllers and server-class computers. RAID controllers combine multiple disk drives using SAS or SATA ports, connecting them to the system over a PCIe interface. They perform two functions vital for wideband recorders.

First, by striping reads and writes across each of the connected drives, RAID controllers aggregate the individual access speeds of each drive. With new SSDs rated for read/write rates of 500 MB/sec each, a 16-port RAID controller using a PCIe Gen 3 by 8 interface can sustain guaranteed read/write rates of 6.4 GB/sec for



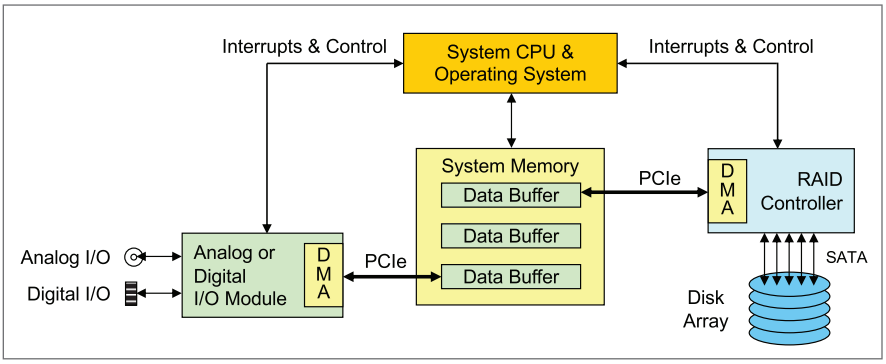



**Figure 3** | Hardware DMA engines in analog or digital interface modules and RAID controllers take advantage of fast PCIe data links to and from buffers in system memory provided by new chip sets in server-class PCs. The CPU supervises these transfers but never actually touches the data so that real-time performance is maintained.

the array. Secondly, RAID controllers also aggregate the capacity of the drives for longer recording times. In the example above using sixteen 4 TB drives, the combined capacity is more than 48 TB, providing a recording time of over two hours at a recording rate of 6.4 GB/sec.

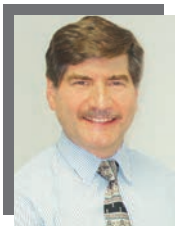
These new RAID controllers and fast data acquisition boards are useless without a powerful PCIe system environment. Server-class PCs feature chip sets that join the CPU and fast SDRAM system memory to a number of PCIe slots and peripherals. The latest chip sets support Intel Core i9 CPUs, quad-channel DDR4 SDRAMs with 3600 MHz transfer rates, and multiple PCIe Gen 3 ports with as many as 16 lanes.

### Recording software and user interfaces

Data-acquisition boards use internal DMA (direct memory access) controllers to move data across PCIe into buffers in system memory. Once initialized, these hardware engines take care of completing the transfers with no CPU overhead. Likewise, the RAID controllers fetch data from system memory across PCIe using their own DMA controllers, and then stripe the data writes across the array of disks. (Figure 3.)

Although the CPU never "touches" the data in the scheme outlined above, the system CPU must orchestrate the transfers by setting up the number and size of data buffers in system memory before the recording starts, and then monitor the progress of each DMA operation during the recording.

While simple in concept, choosing the appropriate transfer parameters is critical to achieving guaranteed real-time operation, primarily because of system latencies. Such latencies occur because of the burst transfer nature of DMA packets and the often-conflicting priority levels for myriad system processes. Each recording system requires an optimized configuration based on the number of channels, guaranteed recording rates, characteristics of the RAID array, and the architecture and chipset of the system PC. **MES**



***Rodger Hosking*** *is vice president and cofounder of Pentek. He has spent more than 30 years in the electronics industry and has authored hundreds of articles about software radio and digital signal processing. He previously served as engineering manager at Wavetek/Rockland; he also holds patents in frequency synthesis and spectrum analysis. He holds a BS degree in physics from Allegheny College in Pennsylvania and BSEE and MSEE degrees from Columbia University in New York.*

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# Rugged unmanned vehicle computers integral to mission success & safety

*By Robert Haag, Vice President of Sales & Marketing, Crystal Group Inc.*

Military organizations worldwide continue to expand their adoption of unmanned vehicles, relying on innovative platforms for myriad missions. They increasingly call upon modern UAVs, UGVs, and UUVs to perform critical functions and fulfill key, ever-expanding roles in varied and often hostile environments.

Militaries need unmanned vehicles to be highly capable and full-featured, scalable, and have a long operational life. Above all else, they must perform reliably and work when and where needed, without fail.

Unmanned vehicle complexity, as well as production and deployment, continue to grow at an exponential rate and drive the demand for Crystal Group's robust, rugged, and reliable compute, networking, and data storage devices at the edge – on land, at sea, and in air and space.

Engineers and systems integrators are choosing Crystal Group rugged compute systems, designed to deliver high reliability and high performance over a long life in the most extreme environments, for the next-generation of unmanned, automated, and autonomous systems.

Crystal Group rugged hardware is enabling complex capabilities – including sensor fusion, AI, machine learning, and neural networks – in unmanned and autonomous vehicles to help militaries fight and win, meet mission goals and achieve success, and protect public safety while keeping personnel out of harm's way.

**Unmanned SWaP-C Considerations**

Crystal Group hardware is engineered to meet the most demanding requirements for size, weight, power and thermal management, cost, and ruggedness for military unmanned and autonomous vehicle computer systems.

- **Size:** Unmanned vehicle computers must be both compact and highly capable, as platforms grow in functionality but shrink in size.
- **Weight:** Every ounce matters on unmanned platforms and can affect range and fuel economy, making strong, lightweight materials like carbon fiber a popular option for unmanned computer and electronics enclosures.
- **Power & thermal:** The use of powerful processors – CPUs, GPUs, and GPGPUs – in compact computer systems demands sophisticated power and thermal management, calling for components that do not consume a lot of power or produce a lot of heat.
- **Cost:** Commercial off-the-shelf (COTS) components enable unmanned vehicle designs to take advantage of the latest technology advances while saving money and avoiding obsolescence issues.
- **Rugged:** Unmanned vehicle computers need to work reliably and withstand harsh environments, elements, and conditions – from shock and vibration to temperature extremes, dust/dirt/sand, and rain/snow/humidity.

**Rugged intelligence**

Engineered to accelerate unmanned system development and deployment, Crystal Group RIA™ – Rugged Intelligence Appliance – combines impressive compute power, data-handling capabilities, and storage capacity in a compact, rugged solution able to withstand harsh conditions and environments likely to cause traditional systems to fail. Crystal Group RIA high-performance computers integrate the latest Intel® processors, high-capacity DDR4 memory, and sophisticated power and thermal management

stabilized in a size, weight, and power (SWaP)-optimized aluminum chassis.

Crystal Group RIA systems are built for safety and reliability, leveraging the company's 35 years of experience designing, manufacturing, and testing high-performance, fail-safe rugged hardware for hundreds of safety- and mission-critical applications.

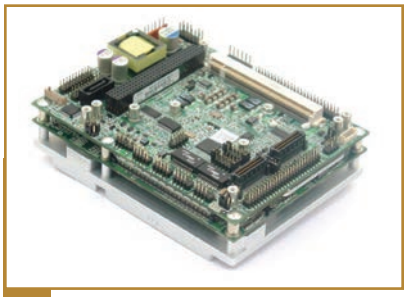
**Count on Crystal Group**

Crystal Group, like the aerospace and defense customers it serves, requires strict adherence to precise specifications and requirements. Crystal Group products meet or exceed IEEE, IEC, and military standards (MIL-STD-810, 167-1, 461, MIL-S-901); are backed by warranty (5+ year) with in-house support; and are manufactured in the company's Hiawatha, Iowa, USA, facility certified to AS9100D and ISO 9001:2015 quality management standards.

Serious about security, Crystal Group meticulously manufactures its field-tested, combat-proven products in vertically integrated NIST-compliant, U.S.-based facilities, and maintains a system for the management and control of Government property in accordance with Federal Acquisitions Regulation (FAR), 52.245-1 and the Defense Federal Acquisition Regulation Supplement (DFARS).

Engineers and systems integrators are pushing the unmanned envelope with novel new systems and applications, and partnering with Crystal Group to bring greater capabilities to the edge, extend the limits of technology, and take rugged hardware to impressive new heights.

**Crystal Group Inc.**
**www.crystalrugged.com**



## Magellan SBC that matches COM Express footprint

The Magellan single-board computer (SBC) from Diamond Systems matches the footprint of the popular COM Express computer-on-module (COM) standard. Its CPU consists of a COM Express CPU module with several power/performance choices of CPUs available. The system uses conduction cooling for improved ruggedness and reliability via a heat spreader mounted on its bottom side. This design makes room for integrated dual gigabit Ethernet LAN ports, a +7-36 V DC/DC power supply, a full set of peripheral interface header connectors, stackable PCI-104 or SUMIT card expansion, and a FeaturePak zero height expansion socket, in addition to a complete embedded PC core. The SBC is able to fit all of this within the 95 by 125 mm COM Express footprint.

Magellan runs Linux, Windows XP, Windows Embedded Standard, and Windows Embedded CE, with all OS drivers shipped with the product. Magellan is offered in a range of models that vary according to the choice of COM Express CPU module and SDRAM capacity (socketed or soldered-on). Magellan LC models come with only +12 VDC input power, but have no DC/DC power supply. Magellan is intended for use either as a highly integrated embedded component or as a platform for application development and reference designs.

**Diamond Systems | www.diamondsystems.com**

## Rugged, high-power, military-grade inverter from SynQor

SynQor, Inc.'s MINV 4000 W 115/230 AC is a fully isolated, low-weight inverter that was designed for military, field, and mobile high-reliability applications. The inverter draws power from a standard 28 Vdc power supply and delivers an isolated, well-conditioned, pure-sinusoidal AC output. Compliant with a wide range of military standards, the inverter is aimed at applications where output power, space, weight, and reliability in harsh environments are a major concern.

The MINV inverter is also flexible, supporting parallel and N+M redundant configurations of as many as 32 units for high-power and/or high-reliability requirements. Additionally, multiple MINV units can be arranged to deliver multiphase power schemes including three-phase and split-phase, which effectively doubles line-to-line output voltage and total output power. The MINV can also be combined with SynQor's 3-Phase Military Power Supply (MPS-4000) to create a three-phase to single-phase AC changer for applications that require a well-balanced three-phase input current; a well-conditioned, single-phase AC output; or a single-phase AC output with different voltage and/or frequency characteristics.

**SynQor, Inc. | www.synqor.com**

## 6U VME SBC based on 4th-gen Intel Core i7 processor

The XVME-6510 from Acromag is a high-performance 6U VME SBC based on the 4th-generation Intel Core i7 processor and uses the Intel 8-Series QM87 PCH chipset for extensive I/O support. Two ruggedized SODIMM offer up to 16 GB of high-speed DDR3L removable memory with 32 GB of flash memory. The air-cooled XVME-6510 features dual PMC/XMC sites, DVI-D display, and programmable CPU power limits for heat-sensitive applications.

The XVME-6510 SBC features a FPGA-based VME-to-PCIe bridge that addresses the end-of-life issue with the TSI148 VME interface chip. The XVME-6510 also enables increased expansion capabilities through two PMC/XMC sites on the board. In lieu of one PMC/XMC module, the optional XBRD-9060 expansion I/O carrier module may be installed. The XBRD-9060 allows for two SSD mSATA drives, as well as another gigabit Ethernet port, RS-232 port, and two USB 2.0 ports. The XVME-9640 rear transition module is also available for further storage, networking, and access to the P2 connector I/O.

**Acromag | www.acromag.com**

## Armada battery conditioner aimed at transportation issues

Lincad's Armada is a six-channel battery conditioner designed for charge management of Lithium Ion (Li-ion) and other battery types. The system features a transport mode to prepare Li-ion batteries to less than 30 percent state of charge for air transport in line with current IATA regulations, and a storage mode to prepare Li-ion batteries to 50 percent state of charge for long-term storage. The charger may be bench- or 19-inch-rack mounted and is designed to be rugged enough to operate in military environments. Each conditioner has six independent channels for automatic charging and discharging to get batteries into a suitable state of charge for immediate use, storage, or air transport.

The conditioner is compatible with IrDA and SMBus smart batteries as well as those with no communications interface. The multichannel battery conditioner is able to accept field software upgrades via a laptop computer or Android app, both to improve operational flexibility and to provide a high degree of future-proofing. Charge and discharge functions are controlled by the system software and – once initiated – are largely automatic. User control is via an uncomplicated push-button interface with LED displays providing detailed status indication during operation.

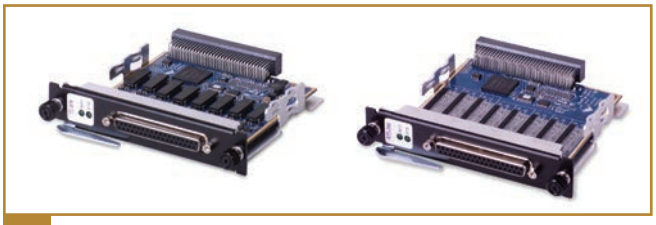
**Lincad | www.lincad.co.uk**

## DGX-1 optimized for deep learning

The NVIDIA DGX-1 system from RAVE Computer is a purpose-built system optimized for deep learning and building an artificial intelligence (AI) infrastructure, featuring fully integrated hardware and software. Its performance significantly accelerates training time, making this system, the maker says, "a deep learning supercomputer in a box."

The NVIDIA DGX-1 system is available with NVIDIA's Tesla V100 and includes next-generation NVIDIA NVLink and TensorCore architecture. The NVIDIA DGX-1 software stack includes major deep-learning frameworks, the NVIDIA Deep Learning SDK, the DIGITS GPU training system, drivers, and CUDA for rapidly designing deep neural networks. This system also includes access to cloud-management services for container creation and deployment, system updates, and an application repository. The combination of these software capabilities running on Pascal-powered Tesla GPUs enables applications to run significantly faster than with previous GPU-accelerated solutions.

**RAVE Computer | www.rave.com**



## Thermocouple and RTD simulator boards for accurate temps

United Electronic Industries (UEI) engineers developed the DNx-TC-378 8-channel thermocouple simulator board and the DNx-RTD-388 8-channel resistance temperature detector (RTD) simulator board for high-reliability measurement environments.

The DNx-TC-378 high-precision thermocouple (TC) simulator has 16-bit resolution and offers more than 0.6 °C accuracy with most thermocouple types. Each channel is fully isolated from all others and is capable of simulating the full TC range. Built-in support for J, K, T, E, N, R, and S type TC is included. The board provides cold-junction compensation, so field connections can be made wherever required. The board will simulate an open TC and includes voltage and current diagnostic readback on each channel.

The DNx-RTD-388 simulates 1000Ω RTDs and is based on actual switched resistors, precisely duplicating the behavior of actual RTDs. The board supports 2, 3, and 4-wire configurations with accuracy of 0.26 °C (1Ω). The board is aimed at simulator/software-in-the-loop applications where an on-board device expects an RTD as an input. The board also has built-in diagnostic current monitoring capability. The RTD-388 series simulates 1000Ω RTDs, while the standard DNx-RTD-388-100 simulates 100Ω RTDs.

**United Electronic Industries | www.ueidaq.com**

## GIVING BACK

### K9s for Warriors

Each issue, the editorial staff of Military Embedded Systems will highlight a different charitable organization that benefits the military, veterans, and their families. We are honored to cover the technology that protects those who protect us every day. To back that up, our parent company – OpenSystems Media – will make a donation to every group we showcase on this page.

This issue we are highlighting K9s for Warriors, a U.S. veterans' service organization that trains rescue dogs to help veterans coping with post-traumatic stress disorder (PTSD), traumatic brain injury, military sexual trauma, post-9/11 issues, and other psychological challenges associated with military service.

The organization was founded by Shari Duval, who launched the charity in 2011 following the return of her son from several tours in Iraq as a civilian K9 officer/bomb-dog handler. After several years of research on canine assistance for PTSD, Duval and her family decided to create a nonprofit organization to train and provide service canines to assist in warriors' efforts to return to civilian life with dignity and independence. The K9s for Warriors training regimen – which occurs in two locations in Florida and one being built in Texas, with the program open to recipients across the U.S. – consists of bringing the warrior to a free three-week, in-house training program. During this time they receive a trained service canine, housing, all meals, equipment, veterinary care, and 120 hours of training in a supportive atmosphere that provides essential peer-to-peer encouragement. Because the service canines are already trained when they are paired with their veterans, the three-week training period is to teach the veterans how to interact with their new service dogs and facilitate the bonding necessary for successful human/dog teaming.

The 501(c)(3) organization reports that it graduated its 500th service dog team in January 2019.

For more information on K9s for Warriors, please visit www.k9sforwarriors.org.

## WEBCAST

### Anatomy of Modern Systems: Where Safety-Critical and General-Purpose Applications Coexist

*By Wind River*

Companies seek to meet the evolving needs of end users by adopting sophisticated technology, from game-changing artificial intelligence applications to augmented reality and enhanced computer-vision capabilities. How do companies deploy these new mission-critical applications into a safety-critical environment when most of them start in the world of open source software?

In this webcast, attendees will learn how to use adaptive virtualization for embedded, C4ISR, space, and edge computing systems; navigate the development journey safely – from Linux-based prototyping to safety-critical deployment; and consolidate safety-critical and general-purpose applications onto a single secure and reliable platform that enables integration of legacy and future applications without system redesign.

View archived webcast:
http://ecast.opensystemsmedia.com/842

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http://opensystemsmedia.com/events/e-cast/schedule

## WHITE PAPER

### Advancements in Card Lok Technology to Satisfy Swap and Second Level Maintenance Requirements

*By nVent Schroff*

Military equipment – including shipboard, surveillance, mobile artillery and control stations, combat aircraft, and unmanned air vehicles – often consists of highly technological and sensitive electronics. Further, it is likely that these electronics get exposed to harsh environments, including extreme heat, dust, moisture, shock, and vibration. Within these harsh environments, Card or Wedge Loks are used for printed circuit board retention and thermal management to ensure continued reliability and performance.

This white paper will detail the ways in which newer-type Loks can maintain the same profile, common options, mounting holes, and footprint as conventional Loks, thereby enabling engineers and users to upgrade existing applications for more extreme environmental challenges without having to perform total redesigns.

Read the white paper: https://bit.ly/2U7aEdg

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