INCLUDING DEFENSE TECH WIRE

# Military EMBEDDED SYSTEMS

July/August 2013
Volume 9 | Number 5
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## Smarter sensor payloads enable UAVs to hunt targets everywhere

What's needed to ensure safety and security in UAV software
*By Mark Pitchford, LDRA*

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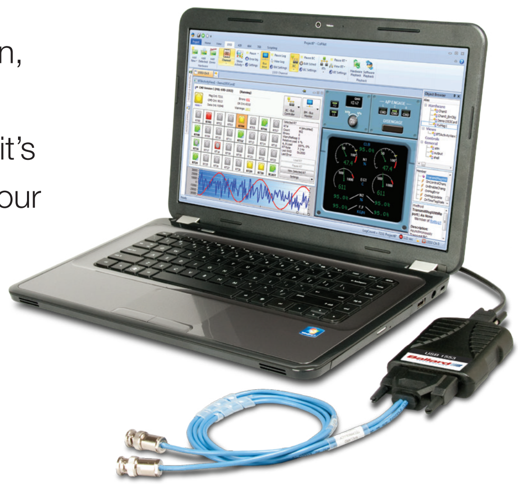

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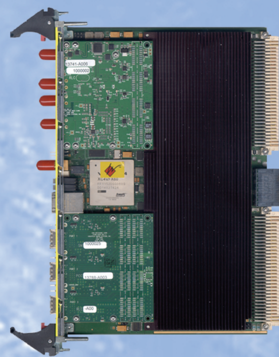

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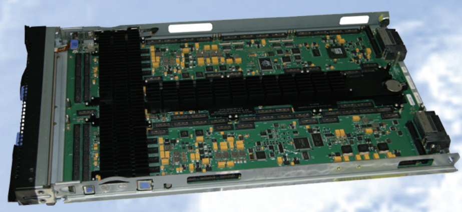

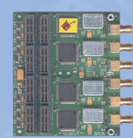

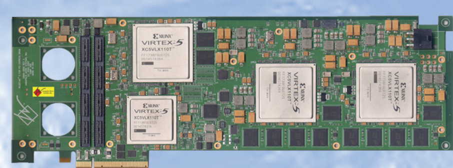

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## ON THE COVER:

**Top photo:** Enhanced ISR payloads enable platforms such as the weaponized Gray Eagle Unmanned Aerial System (UAS) to track targets in all types of environments. Photo courtesy of General Atomics-Aeronautical Systems, Inc. (GA-ASI).

**Bottom Photo:** Small UAVs such as this hand-launched Puma AE from Aerovironment rely on rugged connectors to meet their reduced Size, Weight, and Power (SWaP) requirements. Photo courtesy of Aerovironment.



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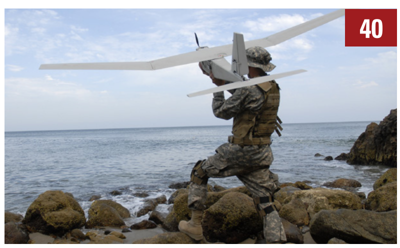



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# UAS military market evolves beyond U.S.

By John McHale, Editorial Director

Unmanned Aerial Systems (UASs) – also known as Unmanned Aerial Vehicles (UAVs), Remotely Piloted Aircraft (RPA), and drones – have been the fastest growing application in the U.S. arsenal during the past decade. They are still a key part of U.S. military strategy, but the U.S. defense market is shrinking or flat in many areas because of sequestration and large cuts to the Department of Defense's budget. UAS platforms will be an important part of the nation's future defense strategy, but with the war in Afghanistan winding down, there is uncertainty regarding military UAS requirements.

There are many UAS platforms coming home from the war such as image intelligence platforms and "we see an emphasis on repurposing them to justify their use in different environments," says Chris Michalski, Technical Director, ISR at Mercury Systems in Chelmsford, MA. "For example, the Shadow UAS has traditionally been a camera platform so repositioning its payload with new defense electronics capabilities would enable the platform to extend its life and the government would get more return on its investment."

UAS platforms and their payloads – ones with low classification levels – may also be repurposed for foreign military sales. U.S. UAS suppliers know their best bets for growth are global markets. General Atomics Aeronautical Systems, Inc. (GA-ASI) already has customers for its Predator B UAS in the United Kingdom and Italy and is working on a Predator B variant that can be sold to NATO foreign customers. In Europe the military and civilian UAS market is expected to be more than $17 million over the 2013-2021 period, according to ASD Reports.

However, the foreign market that might provide the best bet for American UAS developers over the next few years is the Middle East, as the area's constant turmoil makes every nation want its own UAS fleet. The only obstacles they might face are U.S. export regulations and the Missile Technology Control Regime (MTCR) guidelines. The main competition for U.S. UAS manufacturers worldwide is Israel, but they are unlikely to do business with Arab nations.

*"UAS platforms will be an important part of the nation's future defense strategy, but with the war in Afghanistan winding down, there is uncertainty regarding military UAS requirements."*

"The U.S. seems to understand the strategic implications of not catering to the Middle East and may be considering options to bypass MTCR or amend existing norms in order to tap the Middle East market," says Mahendran Arjunraja, Frost & Sullivan Aerospace & Defense Senior Analyst in a public release. "One way to bypass the MTCR is by providing [UAS] 'services' instead of selling the equipment. When [UAS] capability is rented, the ownership of the equipment still lies with the supplier country. The recent sale of ISR-only [UASs] – Predator drones – to UAE shows that the U.S. is willing to relax restrictions to grab market opportunities."

Nonmilitary applications such as law enforcement and first responder applications are other growth areas. The U.S. is exploring these applications too, but interest differs from state to state and the rules for civilian aircraft are still developing. Currently to fly a UAS in U.S. civilian airspace, you have to ask for Federal Aviation Administration (FAA) permission and comply with rules such as only flying less than 400 feet high and maintaining a line of sight and staying more than 5 miles from the nearest airports.

"The proliferation of UASs in civilian airspace is getting very interesting," says David Strong, VP of Marketing at FLIR Government Systems in Wilsonville, OR. "Civil use of UASs is potentially a huge market, but there [are] still not any clear rules or regulations governing them in that space. There is not a lot of clarity. Imagine all the applications that will spring forward if civilian communities were to embrace UAVs."

In the U.S., UASs are not allowed for commercial use; only the government or FAA-approved law enforcement agencies may use them, but that fact doesn't comfort everyone. In Deer Trail, CO, town officials are considering an ordinance that would allow for drone-hunting licenses, even offering $100 bounties for UASs, Amanda Kost of DenverChannel.com reports. She quotes the ordinance's author, Phillip Steel, as saying: "We do not want drones in town. They fly in town, they get shot down."

According to the story, the ordinance appears to be a reaction to government drones, but I wonder if Mr. Steel's animosity toward unmanned aircraft would extend to civilian use as well. In the United Kingdom, a Domino's franchise partnered with UAS maker AeroSight to deliver pizzas in an unmanned DomiCopter. According to a story on money.cnn.com, Domino's officials in the U.S. denied any involvement in the publicity stunt and say they have no plans to initiate pizza drone delivery in the U.S. Good thing, as it might be dangerous in Deer Trail.

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The pulse of innovation

# OpenVPX/InfiniBand: From SWaP to SWaP-C

*By Charlotte Adams*

*A GE Intelligent Platforms perspective on embedded military electronics trends*

As the search intensifies for equipment with advantages in Size, Weight, and Power (SWaP), the military services are also focusing on system cost – up front and over the life cycle. Thus, like it or not, SWaP is becoming "SWaP-C." Faced with budget cuts almost everywhere they look, service leaders are stressing affordability as never before.

One of the most attractive and cost-effective options for embedded systems is InfiniBand running on OpenVPX. The high-speed InfiniBand serial link – widely adopted in the larger commercial market (Sidebar 1) – allied with the high-bandwidth OpenVPX interconnection fabric is making waves as vendors tailor the technologies to the needs of the rugged, embedded world. Slowly but surely, as legacy bus-based architectures like VME run their course, a more powerful and affordable paradigm is ready to take their place.

**VME versus VPX: Populating the ecosystem**

The marriage of InfiniBand and OpenVPX in the embedded space was probably inevitable. The VPX point-to-point serial backplane interconnect is the migration path for widely deployed VME systems, shares form factors with VME cards, and boasts data rates at least 10 times faster than the newest incarnation of the bus technology. And, unlike VME, OpenVPX features a connector that supports high-speed serial links. InfiniBand can be configured in OpenVPX to provide a theoretically maximum throughput of 25 times the capacity of the fastest VME technology. That translates to a whopping 8 GBps data rate on the OpenVPX data plane.

OpenVPX/InfiniBand is an excellent option for image, audio, and signals intelligence applications. Moreover, it is ideally suited for radar because radar signals cannot be processed on one chip; they require multiple chips and therefore interprocessor communications. A bus-based radar subsystem would lack the throughput to keep up with more than a handful of CPUs. For anything beyond that, a switched fabric network topology – propelled by high-port-density switches – is necessary. An OpenVPX/InfiniBand solution potentially could perform more radar processing functions than a similarly sized VME system.

Vendors are speeding adoption by introducing InfiniBand-on-OpenVPX options at key niches in the embedded ecosystem, such as the switches that connect end point processors. These switches, which plug into OpenVPX backplanes, are the engines behind InfiniBand subsystems. They provide connectivity to InfiniBand-enabled processor cards, creating the VPX data plane network for interprocessor communications. One of the first rugged, 6U OpenVPX/InfiniBand switch fabric modules in the military/aerospace embedded market is GE Intelligent Platforms' IBX400, with Double Data Rate (DDR) InfiniBand pumping out bits at 400 Gbps on the data plane and with 1 Gbps Ethernet on the control plane (Figure 1).

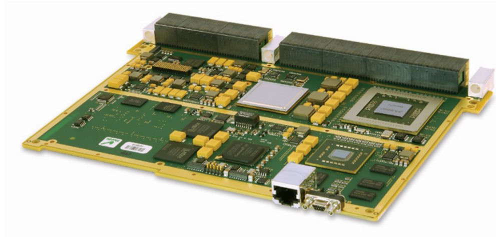

**Figure 1** | The GE Intelligent Platforms rugged IBX400 6U OpenVPX InfiniBand Switch Fabric Module is designed for High Performance Embedded Computing applications.

**Compelling case**

The combination of blazing speed, low latency, and scalability in the hardware with mainstream-tested, performance-boosting, zero-cost middleware makes InfiniBand-on-OpenVPX a compelling candidate for upgrades to VME-based systems as well as for new systems.

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**Why InfiniBand?**

## Why InfiniBand?

InfiniBand isn't new, but that's good. It proved its scalability and reliability in the demanding world of High Performance Computing (HPC), physics research facilities, huge government data centers, and high-frequency trading floor operations, where microseconds make a difference. Chip-level switches – the heart of both commercial and militarized switch modules – provide multi-terabit-level performance. They enable sites using tens of thousands of processors to crunch very large data sets very quickly. The Texas Advanced Computing Center's Ranger Cluster, for example, which operates more than 62,000 CPU cores using InfiniBand and the OpenFabrics Alliance's (OFA's) Open Fabrics Enterprise Distribution (OFED) middleware, delivers 579 teraflops performance, according to OFA. Indeed, some InfiniBand middleware, such as the OFED, is free. OFED includes, as standard features, Remote Direct Memory Access (RDMA) drivers that run out of the box. The middleware is optimized for RDMA and kernel bypass operations common to both the data center and the embedded world. Scaled down to embedded system sizes and tasks, the technology is more than adequate for the job.

A count last year by TOP500.org, which tracks the top 500 supercomputer complexes, found that InfiniBand had just surpassed Gigabit Ethernet as the most popular internal interconnect system for these mammoth computers. Such statistics imply the maturity of the technology, as well as the large community of hardware and software developers supporting it, offsetting the costs for military adopters.

**Sidebar 1** | InfiniBand, long adopted in the commercial market, is finding a niche in rugged computing.

# Trends in securing data comms for the new era of unmanned flight

*By Val Zarov*

*An industry perspective from Curtiss-Wright Controls Defense Solutions*

On January 18, 1911, the age of naval aviation was born when Eugene Ely, flying a Curtiss Pusher biplane rigged with arresting hooks on its axle, performed the first shipboard landing aboard the USS Pennsylvania in San Francisco Bay. A little more than 100 years later, on May 14, 2013, a new era of unmanned naval aviation took flight with the first successful launching of a drone, the X-47B Unmanned Combat Air System (UCAS), from the USS George H.W. Bush aircraft carrier. (Watch the U.S. Navy's video of this historic flight: www.youtube.com/watch?v=hknsbswLFwo.)

Because of their ability to provide persistent surveillance while eliminating the need to put our warfighters in harm's way, Unmanned Aerial Vehicles (UAVs) continue to grow in importance. As these platforms proliferate in number and in deployed missions around the world, various technology trends of interest to vendors of rugged embedded systems have emerged, several of which revolve around the need for security: There is increased demand for highly networked UAS infrastructures to enable any UAV to exist on the network, streaming relevant data while providing support for multiple securing enclaves for control and data transfer. On the ground segment front, the trends indicate specialization for control and gathering of highly sensitive data along with the ability to support wider variety and quantity of UAVs simultaneously. To reduce burden on downlink bandwidth, much of the image/data post-processing and relevant feature extraction will be preprogrammed by the user and only relevant end result will be streamed down for bandwidth conservation and timely reaction by the user. Still, the need for security prevails.

### Trends enable UAS security

System designers of Unmanned Aerial Systems (UASs) – the full support architecture that contains the UAV, ground segment, communication infrastructure, and data processing capability that allow full control and utilization of the technology – know that one of their biggest challenges is in the arena of secure UAV command, control, and communications. There is increasing demand for control compatibility with other UAS ground stations, the ability for the UAV to directly communicate with various ground/air support in the area of operation, regardless of whether they share the same UAS architecture. It's also important to ensure that there is sufficient bandwidth to provide secure downlinks. With an increasing number of UAVs streaming high-throughput data simultaneously, it's critical to ensure the secure, timely availability of relevant/post-processed data.

From a technology trend perspective, we are seeing significant interest in using data guard/cross-domain technology to provide information assurance while transferring data between different security domains.

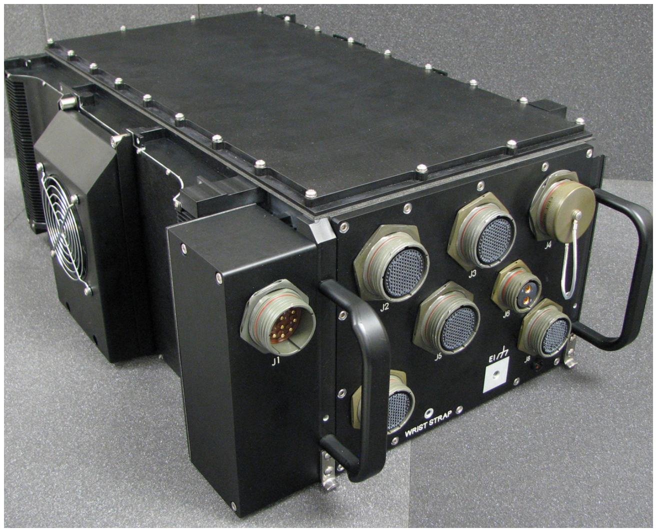

**Figure 1** | Curtiss-Wright's COTS-based Sensor/Payload Management Unit deployed on leading UAVs

The desire for greater interoperability between UASs is also increasing interest in using open architecture hardware and software (OS, BSP, drivers, and applications) to enable more generic, open source-based ground command and control stations while protecting highly sensitive/classified data from unauthorized access. Additionally, UAS systems designers are looking toward open source software and tools as a solution, as problems often arise from using applications software – which requires third party licensing, support, and availability – for critical and proprietary technologies in the ground segment of the UAS. But to take full advantage of this solution, the UAV's streaming hardware and data need to be compatible with the open source-based application being used on the receiving platform. What's more, the UAV hardware has to be able to segregate relevant and authorized sections of the data before it gets sent to an open source ground segment in order to protect classified sections of gathered data.

Starting at the rugged board level and ending with the fully integrated system, vendors including Curtiss-Wright Controls Defense Solutions are providing increased hardware-level convergence of information assurance security features to protect critical data, combined with new operating systems and BSPs that incorporate sophisticated data guard features to effectively secure data communication (Figure 1).

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# DEFENSE TECH WIRE

NEWS | TRENDS | DOD SPENDS | CONTRACTS | TECHNOLOGY UPDATES

*By Sharon Hess, Managing Editor*

## Northrop Grumman Minuteman III: Final PQA testing

The Minuteman III Intercontinental Ballistic Missile's (ICBM)'s Propulsion System Rocket Engine (PSRE) recently underwent the last Product Quality Assurance (PQA) test of its program. PQA testing was required after the PSREs were refurbished under the Life-Extension Program (LEP) program. The recent test was the final of seven and was conducted at NASA's White Sands Testing Facility located in Las Cruces, NM. "The entire ICBM team, including our Aerojet and Boeing teammates and the Air Force, celebrate the success of this program as it comes to an end with this final accomplishment," stated Tony Spehar, Northrop Grumman VP and Program Manager for the ICBM Prime Integration Contract, in a media statement. Kickstarted in 2000, the PSRE LEP program was managed by Northrop Grumman and the USAF, with the goal of extending the whole Minuteman III fleet's service life through the year 2030 (Figure 1). The program encompassed 558 PSREs.

**Figure 1** | Northrop Grumman's Minuteman III ICBM's Propulsion System Rocket Engine (PSRE) recently underwent the last Product Quality Assurance (PQA) test of its program. Minuteman III photo courtesy of the U.S. Air Force

## USAF's OMEGA contract to ease mission planning, synthesis

The USAF's mission planning process is about to become a whole lot easier, thanks to a $13 million contract recently awarded to TT Government Solutions Inc. dba Applied Communication Sciences, Basking Ridge, NJ. Under the contract, Applied Communication Sciences will provide OMEGA, covering development of technology capable of building mission plans and synthesizing them automatically into mission scripts that can then be executed. The company will also incarnate technologies capable of formal plan verification and quantification of anticipated outcomes and effects. Mission construction referenced under the contract comprises domain-specific language creation for cyber warfare and also high-level-specification-derived automated program construction and program synthesis. Contract work occurs at Basking Ridge, NJ by September 2017. The contracting activity is the Air Force Research Laboratory/RIKE, in Rome, NY.

NEWS

## Raytheon to upgrade Navy's AN/AQS-20A sonar

The U.S. Navy's AN/AQS-20A mine hunting sonar will soon be upgraded, per a recent $14 million delivery order awarded to Raytheon Integrated Defense Systems, Portsmouth, RI. The sonar's 3493-AS-780-9 configuration will be fitted with a multifunction side-looking sonar and high-frequency wideband forward-looking sonar, in addition to related components. Contract work is slated for September 2014 completion in Portsmouth, RI, and the contracting activity is the Naval Surface Warfare Center, Panama City Division, Panama City, FL. The AN/AQS-20A detects, identifies, localizes, and classifies sea mines. It can spot and classify possible mines in the water near the surface all the way down to the seafloor in only one pass. Advanced signal processing, portability, and computer processing power enable the sonar to boost search rate agility while reducing search times.

## Boeing to render more C-40A logistics support

The U.S. Navy recently awarded The Boeing Co., Wichita, KS, a $17 million contract modification for C-40A aircraft fleet logistics support services (Figure 2). Under the modification, Boeing will provide site support and commercial depot support at Naval Air Station (NAS) Oceana, VA; NAS North Island, CA; NAS Joint Reserve Base, Fort Worth, TX; and NAS Jacksonville, FL. Work is slated for completion in July 2015. The contracting activity is the Naval Air Systems Command in Patuxent River, MD. Deployed in 2001, the C-40A is a 737-700C commercial airliner variant utilized for Navy Unique Fleet Essential Airlift missions. C-40As have started to replace the Naval Air Reserve's aging C-9 aircraft fleet and can fly in a trio of configurations: 70 passengers and 3 cargo pallets, 8 cargo pallets sans any passengers, or 121 passengers only.

**Figure 2** | The Boeing Co. was recently awarded a $17 million contract mod for Navy C-40A aircraft fleet logistics support services. U.S. Navy photo by Mass Communication Specialist 2nd Class Ron Kuzlik


Wind River® is honored to be part of the Unmanned Combat Air System Carrier Demonstration (UCAS-D) industry team responsible for this groundbreaking military program and looks forward to a continued partnership and success with Northrop Grumman.

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INNOVATORS START HERE.

# UAS payloads get smarter sensors, enhanced imagery in smaller packages

By John McHale, Editorial Director

*Requirements for smart sensors that can see further and produce high-quality imagery in small, low-weight packages are driving Unmanned Aerial System (UAS) payloads development. Designers of these systems also face challenges such as balancing reduced Size, Weight, and Power (SWaP) requirements while increasing performance, uncertain Department of Defense funding priorities, and data link bandwidth limitations.*

Enhanced ISR payloads enable platforms such as the weaponized Gray Eagle Unmanned Aerial System (UAS) to track targets in all types of environments. Photo courtesy of General Atomics-Aeronautical Systems, Inc. (GA-ASI).

The advantage U.S. military forces have gained from the deployment of Unmanned Aerial Systems (UASs) is unquestioned. From the Intelligence, Surveillance, and Reconnaissance (ISR) capability of Global Hawks to the lethality delivered by armed Predator B aircraft, these platforms have been a force multiplier for the U.S. in Iraq, Afghanistan, and across the globe in the hunt for terrorists.

While these wars are winding down, the demand for the drones remains steady, but their missions are changing. In the near future – in absence of the breakout of another war – they will be repurposed for a variety of ISR, Signals Intelligence (SIGINT), and Communications Intelligence (COMINT) missions, but less for delivering weapons. However, what these missions will be and how these payload designs will be funded remains uncertain because of sequestration and other cuts in the DoD budget. What is certain is that these payload designers will produce smarter, better-performing sensors to get around low air-to-ground data links. They will also design around reduced Size, Weight, and Power (SWaP) requirements in systems they mostly develop themselves as the DoD reduces technology development spending.

"There is a drive toward flying before you buy," says Christy Doyle, VP of Business Development at Mercury Systems in Chelmsford, MA. "In the past there was a significant government investment in payload development, but today the industry must invest before the government purchases systems. The government is also involved with flight demonstration to qualify the payload for each platform. It is moving toward a commercial business model requiring that contractors stay in lockstep with customers as we develop a system. There is a significant demand for multimission ISR payloads, which can be used on multiple platforms. In this uncertain budget environment, DoD customers are evaluating priority missions, requiring contractors to stay close to the evaluation process."

## Payload requirements

"Requirements for Predator payloads are trending toward higher-resolution optical and infrared cameras for narrow field of view reconnaissance," says Chris Pehrson, Director of Strategic Development at General Atomics in San Diego. "Radars and other sensors are used for observing large-area operations, covering tens or even hundreds of square kilometers. This will be especially relevant in the Pacific maritime domain for piracy and counterterrorism applications. These missions require not just the narrow field of view for detailed observation, but also wide-area surveillance for persistent situational awareness. In the maritime domain, for example, our Lynx radar is able to detect small craft and semisubmersibles over a large area and cross-cue to a high-resolution camera for close-in observation. This can help determine if there's illicit trafficking or potential piracy activity.

"Broad area surveillance is also accomplished with sensors such as Wide Area Motion Imagery (WAMI), which can provide persistent observation of several city blocks or other large geographic areas," he continues. "Multispectral and hyper-spectral sensors, as well as Signals Intelligence (SIGINT) sensors, are capable of observing large areas. These sensors can search for unique signatures or detect radio and other emissions of potential threats or adversaries. Many of them are modular and pod-mounted so they can be installed on the MQ-9 Reaper or the new Predator C Avenger based on mission requirements.

GA-ASI also is developing LIDAR sensors, an active imaging system that uses a laser to provide full field of view targeting, geo-rectification for accurate GPS coordinates, and foliage penetration capability. This sensor can be integrated with existing electro-optical/infrared sensors to greatly enhance their performance. When LIDAR is used for foliage penetration, any geometric shape will jump out at you."

"The military sensor market is driving us toward high-definition and laser designation, but what everybody wants is to see further with less weight and in more compact systems – especially in the UAS and helicopter communities," says David Strong, VP of Marketing for FLIR Government Systems in Wilsonville, OR.

**Smaller payloads, more performance**

"There has been a dichotomy regarding payload gimbal size," Strong says. "If you want to see for long distances, you need a gimbal that is 16 or 15 inches and weighs about 100 pounds. The trade-off has been that you can't carry that much load. Standard operating procedure is to go with smaller gimbal weights of 40 or 50 pounds. That has been the choice you had to make. It's just a question of physics about how much optics you can pack into a system.

"So what we did is turn that trade-off on its head and changed the geometry in how we put together the payload – because we want to have the performance of a big gimbal but at half the weight or better in a 10-inch gimbal," he explains. "It was a question of geometry, but you have to redesign everything that goes inside. We can do that because we make all the components. The result was the Star SAFIRE HDc – the C is for compact (Figure 1). It has the performance of a big gimbal at half the weight. It is

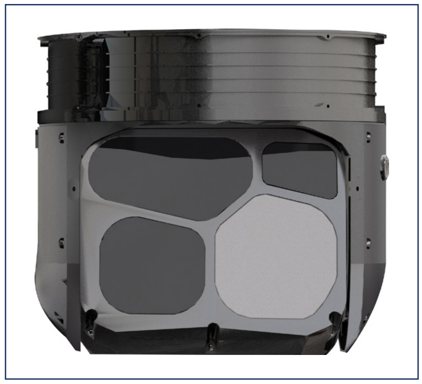


**Figure 1** | The Star SAFIRE HDc from FLIR has Short Wave Infrared (SWIR) technology and continuous zoom lenses for thermal, color, and low-light viewing.


a 15-inch diameter gimbal while the typical large gimbal has a height of between 18 and 20 or more inches. We reduced it to less than 14 inches in height. This cut the weight in half, but the package still has the same number of multiple sensors, long focal lengths, big apertures, etc."

**Managing SWaP, costs through standards, FPGAs**

Not every small system requires custom designs and many integrators will turn toward standards such as VPX for their payload designs. Larger UAS platforms such as the Predator will use 3U and 6U VPX systems, but smaller UASs do not have enough room and that's where Small Form Factor (SFF) designs fit in, says Ray Alderman, Executive Director of the VITA Standards Organization in Fountain Hills, AZ.

"There are always SWaP challenges in UAS payloads. Many use custom SFF designs to solve them, yet this can be costly not only up front, but over the lifetime of the product," says Bill Ripley, Director, Business Development at Themis Computer in Fremont, CA. "Leveraging standards such as VITA 74 SFF enables integrators to procure designs often priced 50 percent less than similar 6U products or custom designs, while maintaining military environmental specifications. We are seeing an increased desire from industry to stay with standards as opposed to custom form factors. Some custom form factors can come in with lower initial costs and initial prices, but for cost savings over the life of a program, standards-based systems are still the best choices. For conventional-sized UAS applications, Themis offers the NanoATR VITA 74 product. For larger applications, we offer 3U VPX systems.

"When we first started looking at VITA 74, the obvious market niche was UASs, and at about the same time there was a big push recapitalizing ground vehicles and building new advanced tactical ground vehicles," Ripley continues. "This heated up because the numbers associated with them were large. For a while, ground vehicles enabled development in the UAS market more than in their own sector. A lot of the development cost was spent on the hardware used in UAS platforms. The UAS market had a need but didn't have the numbers of assets at that time. Now the ground vehicle market is quieting down when the UAS market is potentially heating up."

Mercury Systems engineers leveraged FPGA technology for the signal processing functions and reduced the electronic footprint in their smaller payload designs. "Our COMINT payload is an FPGA-based system with an antenna array design and electronic system self-contained in a small pod," Doyle says (Figure 2). "This small pod was designed specifically to facilitate field retrofits, so it can be rapidly mounted under the wing or fully integrated into the fuselage."

"The use of FPGAs enabled us to provide tremendous signal processing power in the same weight and DC power footprint," says Chris Michalski, Technical Director, ISR Systems at Mercury Systems. "In previous systems most of the processing was performed

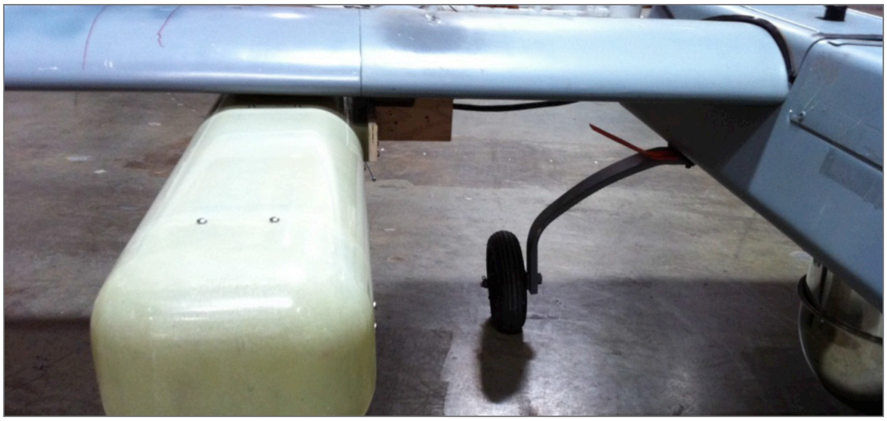


**Figure 2** | A Communications Intelligence (COMINT) payload from Mercury Systems can be rapidly mounted under the wing or fully integrated into the fuselage.

in general purpose CPUs. There were not a lot of FPGAs involved in front end processing. Today we offer systems with ruggedized embedded boards that leverage FPGAs. This enables us to offload processing onto the FPGAs at a much lower level of DC power consumption than you would get by running a standard PowerPC device. FPGAs such as the Xilinx Virtex-6 have gotten quite good not only in terms of performance but also in lowering power consumption because the feature sizes are small."

**Data link bandwidth problems**

Another reason designers are packing so much signal processing horsepower next to the sensor is to get around the bandwidth limitations of the air-to-ground data links. "They have got to move the processor closer to the sensor and preprocess the data before sending it to the ground," Alderman says. "It is similar to satellite payloads that have a video camera and use a frame grabber to send images to the ground. Well if nothing happens you are sending the same frame three or four times. The data needs to be compressed so that only images that differ from the previous image are sent. This requires large processing systems such as VPX."

"Getting the warfighter access to actionable intelligence is a challenge with the large amount of data generated onboard on a UAS platform," Doyle says. "Determining which data are truly actionable can require a long time, so if you can automate recommendations at the payload level, it frees up the warfighter to focus on other tasks."

"For small payloads, the data link bandwidth to the ground is even worse than for larger systems," Michalski says. "A lot of these platforms won't even have a link to ground or an imagery link. Sometimes the link bandwidths on the aircraft are smaller than what the SIGINT payload provider uses. It is also an asset management issue as the military doesn't want to add more assets or ground personnel to operate new payloads while still operating the older payloads." **MES**

## Multiple UASs and their payloads managed by one control station in demonstration

During a NAVAIR demonstration, Lockheed Martin engineers monitored and controlled multiple types of Unmanned Aerial Systems (UASs) – including the Unmanned Carrier Launched Airborne Surveillance and Strike System (UCLASS) – and their Intelligence, Surveillance, and Reconnaissance (ISR) payloads from one integrated Command and Control (C2) system. The Lockheed Martin system provided operators with one mission picture by integrating with other Navy C2 and ISR planning and execution systems. The demonstration was performed in support of the Navy's UCLASS and Common Control System (CCS) programs. The CCS leverages multiple architectures from different operational systems. The UCLASS – an ISR sensor system – will be the first adopter of the CCS.

"We wanted to show an existing control system that could interoperate with a UCS-compliant control system," says Marty Jenkins, Director of Business Development, Lockheed Martin C2 in Washington. [The UAS Control Segment (UCS) is the Department of Defense's (DoD's) effort to create a universal UAS control station architecture.] "We had done a launch of a mission and handed off the same system in the UCS framework, which was a big deal, but the Navy demonstration went a step further. We created a UCS-based framework that pulled in the Air Force Joint Mission Planning System (JMPS), used Ballista drone control software from DreamHammer in Santa Monica, CA., and Navy compliant software protocols to enable a single operator to manage multiple UAS platforms simultaneously – increasing his decision-making speed. The Ballista software is more of a display layer than a control layer and was built from the ground up in the UCS framework.

"We could not only control two UASs, but were able to fully integrate in parts of other systems," Jenkins continues. "We took the JMPS – generally used for manned aircraft – to strategically plan missions and take into account intelligence feeds and threat envelopes. The JMPS operator can tactically redesign the route and give an order for UCLASS to start flying a route for a new mission."

The team also used the new Navy Cloud capability via the Distributed Information Operations Services (DIOS) to demonstrate control of the ISR sensors and integrate the data into one complete mission picture, he says. "The picture was then rapidly retasked and rerouted to the UAS assets. DIOS is designed to handle shipboard sensors and national sensors and display their data in one console, enabling operators to see all sensors in an area and what platform they are on. DIOS also pulls feeds directly from those sensors then takes control of those sensors, retunes them, and reorients them to look in a different direction."

The Lockheed Martin system also manages the data link bottlenecks by doing bandwidth compression in the DIOS system to "separate the wheat from the chaff," Jenkins notes. "In other words, I'm pulling only data that makes sense. For example, if you are following a moving target rather than get five hours of video showing nothing, the sensor will only start sending when it sees specific data that I want.

"I think other companies have shown things approaching the UCS framework, but not in an architecture such as this," he says. "We are the first to show it in an actual area control system. We are also working with the Navy to help them pull applications or services from any vendor they want into the framework and be interoperable with C2 and ISR."

## Fiber Optic Gyros for UAS payloads face SWaP challenges too

"In most UAS platforms there is a requirement to reduce Size, Weight, and Power (SWaP) and that's where Fiber Optic Gyros (FOGs) come in," says Jay Napoli, VP, FOG & OEM Sales at KVH Industries in Middletown, RI. "Any kind of airborne application is driven by a balance [of] size, weight, and performance and the same thing holds true for FOGs.

"Typically in FOG designs when you go smaller in size and weight you lose accuracy and performance decreases the smaller you go," he continues. "I'm talking specifically about a single axis sensor where you measure rate in one specific orientation – 1, 2, or 3 or pitch, roll, and yaw. The number of gyros required depends on the application. Most manufacturers reduce the number of components to reduce size and weight or by trying to get away with using only two gyros."

Another trend is to use Inertial Measurement Units (IMUs) to stabilize and point the payload, Napoli says. "We tried to come up with the smallest high-performance IMU that we could and developed the 1750 IMU, which is one package with three of our DSP-1750 FOGs and three MEMS accelerometers that is about the size of a coffee cup. Some platform manufacturers prefer the IMU for this reason. The 1750 IMU can be used for antennas, cameras, laser pointing, and stabilization and has RS-422 asynchronous communication with user programmable data output rates from 10 to 1000 Hz.

"If you have an aircraft flying straight and only care about looking straight down, you could get away with only one FOG; however, aircraft don't fly straight and level," he continues. "Therefore, most of the gimbal applications that use KVH FOGs use three gyros, but some get away with using two. That's pointing and stabilization, rate measurement of each X and/or Y and/or Z orientation.

"The FOG's most critical component is the bobbin of optical fiber," he says. "The longer the length of fiber the more accurate your FOG will be. The larger diameter your bobbin is the more accurate it will be. If you make a big bobbin with kilometers of fiber you can get a really good gyro. By reducing the diameter of the fiber we can put more fiber on a small bobbin. How small can we go? Fiber is strong and rugged, operates over a wide range of shock and vibration environments, and is robust. However, you do reach a certain point

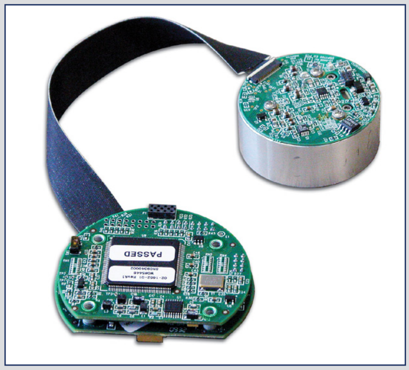
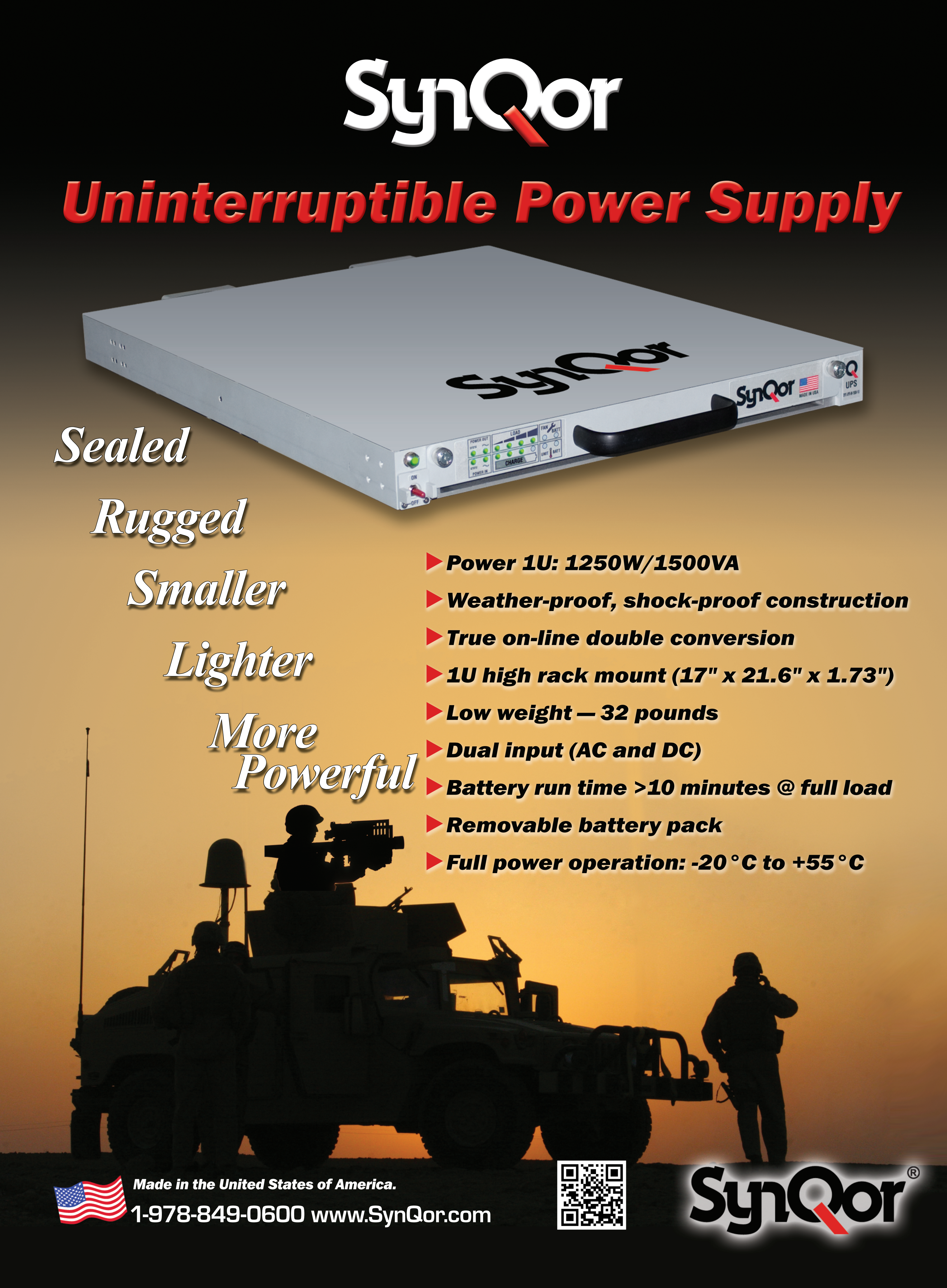


**Figure 3** | Three DSP-1750 Fiber Optic Gyros from KVH are used in the company's 1750 Inertial Measurement Unit that is about the size of a coffee cup.

at which you can only do so much with something that is made out of glass. If you exceed a certain point, it will put stresses in the glass that could fracture it. Currently we take an optical circuit that is smaller than a dime and actually wrap fiber around that component and have never had a problem with fractures or breaks around it. If we went much smaller than that we might see problems in high shock and vibration environments."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PAYLOAD DESIGNS FOR UAVs, UGVs, AND UUVs

# OpenVPX enables tightly coupled FPGA and CPU processing for unmanned EW platforms

By Eran Strod

*OpenVPX brings together high-speed parallel processing FPGAs with the software capability of CPUs to meet the most challenging sensor processing applications for unmanned platforms.*


U.S. Army photo

Today's UAVs, UGVs, and UUVs are being enhanced with an increasing amount of sensors. The huge amount of incoming data from these Electronic Warfare (EW) sensors needs to be processed as close to real-time as possible. As processing elements go, the FPGA is ideal as a sensor interface. It is great at performing a fixed algorithm on parallel data with unmatched speed and very low latency. High-end FPGAs are equipped with a large number of serial or parallel interfaces, allowing them to input large quantities of raw data that is then preprocessed.

However, the modern sensor does not exist in isolation. It lives in the context of a "system of systems" with interconnectedness to computers, tablets, and handheld devices. The software protocols that connect smart devices together over a large network run on CPUs, not FPGAs. For example, it is relatively straightforward to run an Ethernet MAC in an FPGA. One can even run TCP/IP although it is a little cumbersome. It is harder yet to run higher-level functions: for example, sockets, FTP, http, data movement middleware like MPI, or a publish/subscribe middleware like DDS. The FPGA without these enabling software components is isolated. It can collect data, and it can process that data, but it cannot easily share the data with the outside world. The unmanned platform's data must be shared to be actionable.

The connectivity functions on an unmanned platform's sensor processing system belong on a CPU that has easy access to software components, stacks, and applications. There are literally billions of lines of open source software, most of which is written for the x86 architecture. Software infrastructure running on CPUs provides the framework and the protocols for applications to connect the sensor to systems and users. The best way to interface an FPGA and CPU in an open architecture is to use OpenVPX (VITA 65) because it was built from the ground up to provide a mechanical and electrical framework for heterogeneous computing benefitting unmanned platforms' data processing.

## Wideband EW for unmanned platforms

The ideal sensor processing architecture optimized for an EW unmanned platform has a very high-speed receive function and a high-speed transmit function connected to a common FPGA. The fastest COTS ADCs on the market today contain technology that is brought to the mil/aero market from the test equipment market. Data centers, communications equipment vendors, and OEMs are on the verge of migrating to 10 Gbaud signaling in nearly every domain of computing. Test equipment vendors such as Tektronix are meeting this need with very high-speed probe technology, which at its base contains an ADC converter. The technology that is used to probe 40 GbE, InfiniBand FDR, or PCI Express 3.0 is based upon very high-speed ADCs. While there are very advanced technologies in the works, ADC technology able to acquire 12 GSps at 8 bits of resolution is now crossing the chasm and fast becoming a volume market.

This is a very powerful sampling capability when it is applied in the mil/aero unmanned platforms setting for wideband data acquisition. 12 GSps at 8 bits amounts to 12 GBps of raw data, an enormous processing and data movement challenge. The processing power needed to find signals of interest in this relentless stream of raw bits is tremendous. The latest FPGAs, such as the Virtex-7 from Xilinx, combine the processing resources required to meet this processing challenge with the high-speed signaling required to ingest tremendous amount of data. The FPGA is able to keep up with a 12 GBps input data stream, process it in real time, and yet still has enough high-speed signals to generate a waveform response. Turning to state-of-the-art DAC technology, from test equipment vendor Tektronix, one finds a 12 GSps 10-bit DAC now achieving the technical maturity required for deployment in unmanned systems.

The collocation of the ADC and DAC within the same physical FPGA device brings the latency of response to the lowest possible level. This set of emerging technologies is now able to increase wideband EW performance 2-4 times over what has been previously possible with open architecture COTS components. The 12 GSps at 8 bits ADC and 12 GSps 10-bit DAC can be achieved in COTS form by a 6U OpenVPX FPGA-based computing module. The FPGA node can support data plane interfaces using Direct Memory Access (DMA), but it has a difficult time running the specific high-level protocols and middleware that enable it to reach across the system fabric or wide-area network. This makes it difficult for an FPGA to provide the wide area connectivity that unmanned sensors require to supply data to analysts and ground forces. CPUs offer the flexibility needed for this aspect of the EW system. The FPGA and CPU blocks must be connected by a high-speed OpenVPX backplane interface to avoid bottlenecks.

**CPUs provide flexibility, connectivity**

As mentioned earlier, a CPU is best at running the middleware that connects the sensor in the UAV, UGV, or UUV to the outside world. The leading choice in this category is the Intel 4th generation Core i7 CPUs (formerly named "Haswell"). This brand new Core i7 processor for mobile computing is based on a low-power embedded implementation of Intel's 22 nm microarchitecture, and is ideal for sensor computing. The CPUs contain integrated 16-lane PCIe Gen 3 interfaces, allowing 16 GBps data movement between the FPGA and CPU memory. The resulting data rate is effectively more than the speed of the entire ADC, which serves to provide a great deal of flexibility to applications that interface to the outside world. The CPU runs an operating system, typically Linux or VxWorks, and executes a stack that interfaces to the data plane. Figure 1 shows how the FPGA and CPU are connected via this high-speed pipe.

The data plane in an embedded system is typically one of three types of fabrics: 10/40 GbE, InfiniBand, or RapidIO. The data plane fabric is used to transfer data between processing elements in the system. In the case of InfiniBand or RapidIO, there usually must be a bridge to Ethernet before data can be transmitted to the outside world.

One of the most powerful capabilities provided by a CPU is the ability to execute publish/subscribe middleware such as Data Distribution Service (DDS). Pub/sub is a message-oriented middleware that allows data sources to publish to interested parties called subscribers. The subscribers are able to tune in specifically to the data that they want and are able to set quality-of-service parameters that are specific to their needs. For example, a high-speed device may request a continuous stream of images. A slower device may request one image at a time. Some devices may only want to see an image once and might wish that it be discarded after being viewed. Others may wish to see the oldest images (FIFO or First-In-First-Out), instead of the most recent (LIFO or Last-In-First-Out). The publish/subscribe middleware allows data publishers and subscribers to share a virtual link without having to manage and be aware of the service requirements of each other and various other system publishers and subscribers.

Another powerful middleware is the Message Passing Interface (MPI). MPI is a portable, language-independent protocol used to share data among distributed processors such as CPUs. It has become a de facto standard for communication among high-performance compute clusters and is used by many of the TOP500, the most powerful computers

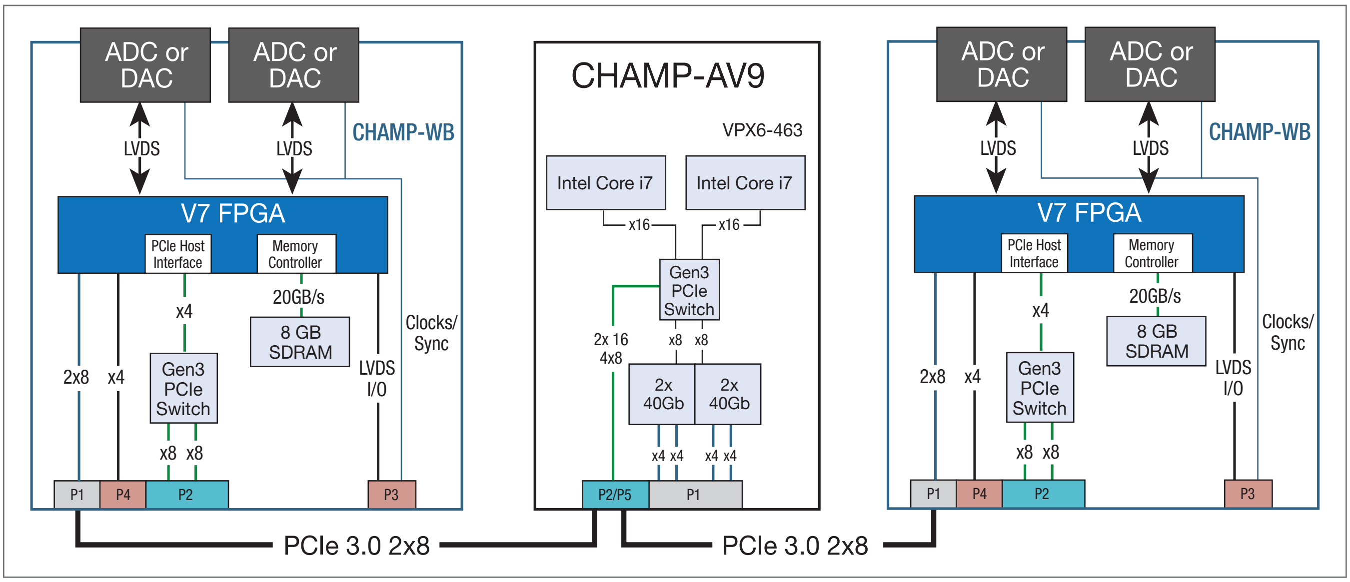


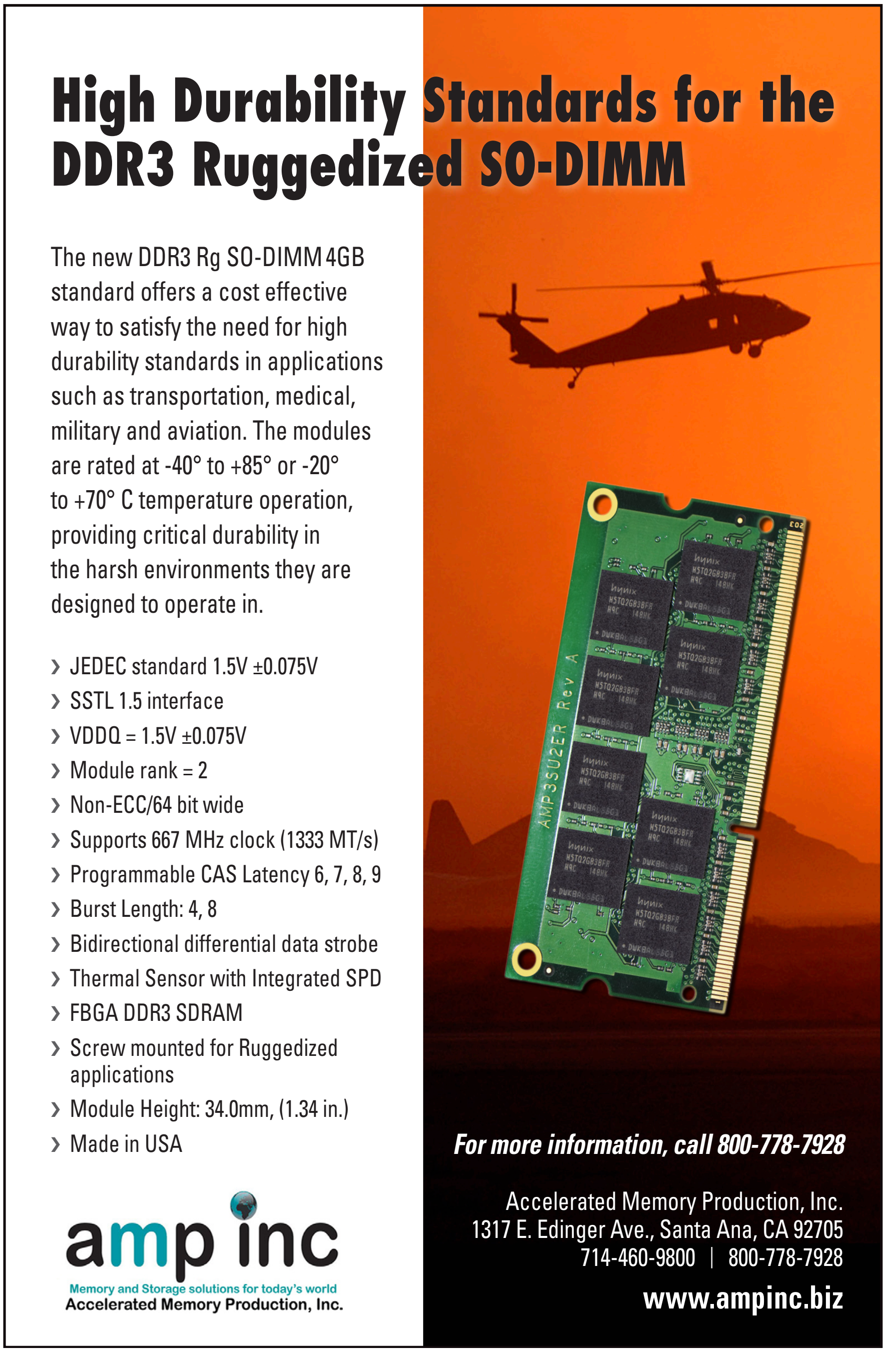

**Figure 1** | A 6U OpenVPX FPGA computing module and an OpenVPX multiprocessing DSP module bring FPGA and CPU processing together.

in the world. Middleware like MPI is an essential element in the effective scaling up of a CPU cluster to a large High Performance Embedded Computing (HPEC) system.

In addition to the ability to run sophisticated middleware, CPUs make it easy to add features that are common in PCs such as:

- **Display** – CPUs support high-resolution image rendering interfaces like embedded DisplayPort (eDP). DisplayPort is a digital communication interface that utilizes differential signaling to achieve a high-bandwidth bus interface designed to support connections between PCs and monitors, projectors, and TV displays. DisplayPort is the first display interface to rely on packetized data transmission.
- **Storage** – Serial ATA (SATA) is an interface that connects to mass storage devices such as hard disk drives and optical drives. Sensor processors on unmanned airborne platforms, land vehicles, or naval vessels are often connected to the enterprise network on a wireless or satellite link.
- **Peripherals** – These are connected via the ubiquitous Universal Serial Bus (USB), which connects to many electronic devices including keyboards, pointing devices, and other adapters.

**Figure 2** | The Curtiss-Wright dual Intel Core i7 4700EQ-based CHAMP-AV9




### OpenVPX conquers heterogenous processing

OpenVPX is an ideal platform for heterogeneous systems that perform the processing required for high-speed radar, image processing, SIGINT, and EW in unmanned vehicles. An example is Curtiss-Wright's OpenVPX-based, dual Intel Core i7-4700EQ CHAMP-AV9 DSP module (Figure 2) – including 32 lanes of PCIe 3.0 expansion plane and 16 lanes of 10 Gbaud data plane signaling on the OpenVPX backplane. The module utilizes OpenVPX to bring together the high-speed parallel processing of FPGAs with the software capability of CPUs. The result of such a paradigm: Designers are able to conquer the most challenging sensor processing application requirements for unmanned platforms. **MES**

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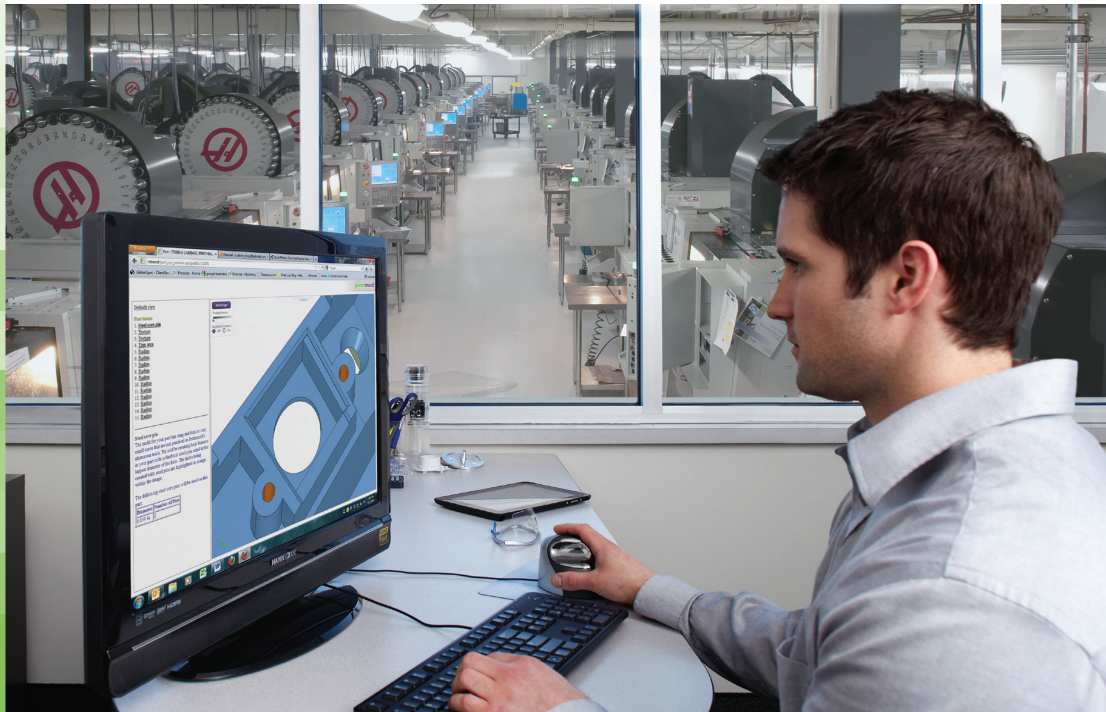


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PAYLOAD DESIGNS FOR UAVs, UGVs, AND UUVs


# VITA 75 vs. VPX: Optimizing unmanned vehicle thermal and payload efficiencies

By Mike Jones

U.S. Navy photo courtesy of Northrop Grumman by Chad Slattery

*The fast pace of UAV/UGV/UUV evolution places an ever-increasing demand on size, weight, and power, while the range of use applications – from surveillance to air defense to communications relays – and interest from national security organizations beyond military continue to grow. To accommodate increasing requirements and diminishing budgets, public contractors and private vendors are moving to Size, Weight, Power, and Cost (SWaP-C)-savvy standards-based systems design, such as by utilizing the smaller envelopes of VITA 75 small form factors to replace existing 3U and 6U VPX technologies. This allows the integration of future payload capabilities into the space available in existing mobile platforms.*

Military vehicles are getting smaller. Today's fighting forces are increasingly equipped with vehicles that are remotely teleoperated by soldiers, and also operate semi-autonomously. These unmanned vehicles operate in the air, on ground, at sea, and underwater (UAV, UGV, USV, UUV), and are rapidly comprising an increasing percentage of the U.S. fleet. These vehicles are tools used to perform the vital military task of protecting and extending the capabilities of the modern warfighter.

The absence of troops in-vehicle does not lessen the processing demand for unmanned vehicles. High-performance computer systems with greater processing capabilities, wider and higher-speed data buses, and more and higher-resolution sensors are required to enable the autonomous functions when a vehicle is unmanned. The higher data input and processing needs demand that these smaller vehicles provide the space necessary for cooling that allows for reliable, high-performance operation.

Thermal dissipation requires space, and space in these small unmanned vehicles is a scarce commodity. The operating environment of unmanned vehicles is no less demanding than that of manned vehicles. Temperatures can be just as extreme, but in these smaller vehicles, cooling computer systems becomes even more difficult.

3U and 6U VPX embedded systems have evolved to keep up with the latest bus speeds of modern CPUs while holding SWaP at bay. These relatively compact solutions are currently fulfilling modern requirements for high-performance computing in mobile military platforms. These systems provide connectivity, as well as the wide, high-speed I/O required to support visible spectrum and infrared cameras, radar, and other fast, high-definition sensors. At the heart of these systems is the processing power (CPUs, GPGPUs, FPGAs) required to process that data for object detection, classification, and tracking.

All these functions are required in smaller unmanned platforms, but these vehicles have tighter payload restrictions than their larger brethren. Every bit of weight and volume that can be removed from a system has the potential to improve the range, capabilities, or cost of a deployed unit, so engineers must consider the function of every cubic centimeter of space, and each gram of weight. This is where Small Form Factor (SFF) VITA 75-based systems excel; all unnecessary space can be squeezed from the system to reduce its size, and unnecessary mass can be eliminated. And while dissipating the thermal energy produced by these systems does require space, making the electronics portion of a system smaller leaves more space available for that thermal dissipation.

**Efficiencies and space**

One part of unmanned systems design that is often overlooked is empty space (air space), or mass. In military unmanned vehicle applications, each ounce or cubic inch of space that can be removed from a computing subsystem has the potential to improve the range, capabilities, or cost of a deployed unit. To this end, again, engineers must consider the function of every bit of cubic space and each ounce of weight. All unnecessary space should be squeezed from the system to reduce its size, and any unnecessary mass should be eliminated (see Sidebar 1). If included in the system design, the purpose of air space should be well understood. For instance, systems may include empty space because the design requires a particular internal or external surface area for convective thermal dissipation. Similarly, thermal transfer or sinking might require material mass to be designed into the unmanned vehicle system.

Consider the large and heavy thermally conductive pathways that distribute heat from critical components in VPX design. This conductive scheme distributes the energy from each board in a chassis via contact with slotted card guides, thereby facilitating the flow of internal temperatures to the external skin of the enclosure. The conductive components, as a function of their mass, also have a sinking capacity within themselves. This mass adds thermal sinking capacity, and can therefore average out peaks of the thermal demand of the processing components. Physical pressure, provided by wedge locks, maximizes the contact area between the thermal shunts on the blades and the slots. While wedge locks increase the shunt-to-slot contact area opposite the wedge lock, the wedge locks themselves, which provide pressure based on interlocking wedges, present a low (<50%) contact area. Every other wedge on the device can only contact the slot or the blade, but not both (Figure 1). The resulting effect is that the use of bladed slots actually reduces potential contact area, conductivity, and the resulting thermal efficiency of VPX.

## Breaking down SWaP-C

The increasing pressure for lower Commercial Off-the-Shelf (COTS) cost and the continuing desire to reduce size, weight, and power in unmanned systems yields SWaP-C requirements. But these requirements come without a reduction in the importance of reliability or performance, prompting cooling demands to only increase.

Size and efficiency, both power and thermal, are the root driving considerations of SWaP-C. Size reduction is achieved by finding a way to put the same functions in a smaller package, enabling weight – and to some degree the cost – to also decrease. The value of all aspects of the design must be considered, and any component of the system that can be eliminated or made smaller, without reducing performance, should be. Improvements in electrical efficiency are achieved by using the latest processors and can, for a given wattage, increase performance or reduce the power requirements per GigaFlop. Thermal efficiency increases allow for the use of higher-performance processors, or improvements in reliability from a resulting reduction in component temperatures.

**Sidebar 1** | SWaP-C's root driving considerations are size and efficiency.

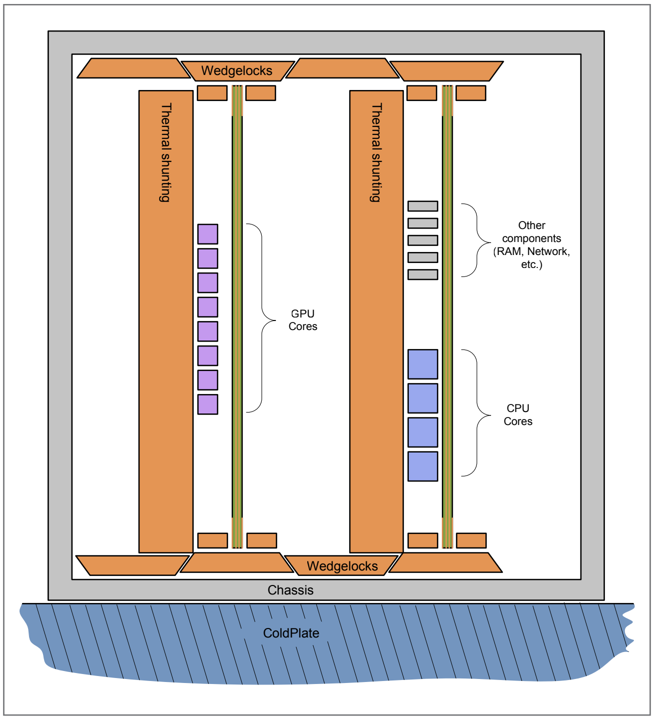



**Figure 1** | Physical pressure from wedge locks maximizes the contact area between thermal shunts; the wedge locks cannot contact both blades and slots, reducing conductivity and thermal efficiency in the bladed designs of VPX.

By contrast, within a VITA 75 form factor system such as the Extreme Rugged HPERC, critical components are positioned an absolute minimum distance from heat dissipating elements. This system integrates a high-efficiency heat spreader between these components and the external heat dissipater (Figure 2). The spreader is compact, to minimize ΔT and to increase thermal transfer to the outside of the system.

### System and component standards

Standards that define the scope of system architectures, such as VPX and VITA 75, provide uniformity and modularity at various levels of a system. These requirements put pressure on system developers, because the form factors they select can require compromises to overall SWaP design.

As previously mentioned, power or electrical efficiency is chiefly driven by the evolution of processors. However, to address thermal challenges, higher cooling efficiency has been achieved with systems based on the VITA 75 standard. An example is ADLINK's HPERC system, which uses the highest-efficiency processors, improves thermal design, and reduces system size to improve the SWaP equation and, as a result, the unmanned system's payload efficiency. These improvements come by removing or shrinking elements like wedge locks, thermal shunts, connectors, and carriers that purport to provide ease of configuration and repair, but are unnecessary for system performance.

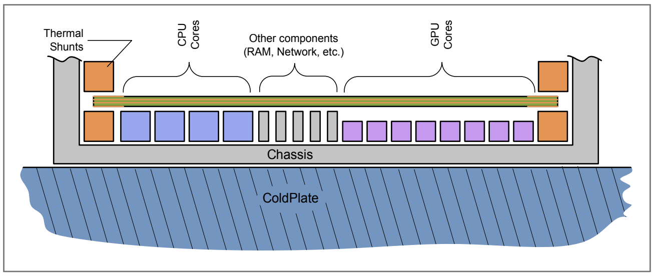



**Figure 2** | VITA 75 designs incorporate a high-efficiency, compact heat spreader to increase thermal transfer to outside the system.

Additionally, VPX specifies a robust bus scheme featuring rugged bus connector utilization and an infrastructure of bladed expansion cards. The modular bladed architecture has the ability to be easily expanded and reconfigured internally to accommodate changing requirements, but these ubiquitous components – while implementing standardization internally – add nothing to, and in fact subtract from, the performance equation. Wedge locks, for instance, are unnecessary when thermal energy is not required to traverse a sliding slot mechanism. They are a cost in size, weight, and performance.

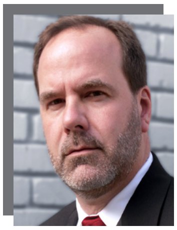
System size and weight can be reduced significantly while improving thermal efficiency when specifications, such as

VITA 75, define the box-level solution rather than define overly constrained requirements that penetrate to the interior form factor of a system. The weight of an enclosure card slot can exceed 1 lb. and, by eliminating it, the critical components can move closer to the dissipater. Some comparisons show the resultant improvement from lowered thermal resistance compared with VPX can exceed 48 percent. Clearly, the removal of thermally conductive card slots does nothing to reduce processing performance, but can shave more than 1 lb. of payload.

**VITA 75: A winning solution for unmanned systems**

When designing unmanned systems, the key to realizing the benefits from SFF computing systems lies in rethinking the aspects of the open standards that are required by the end user. VPX blades and card cages provide an easy way to configure mix-n-match modularity, which is convenient in the lab. But when a higher level of integration is required in-vehicle, modular design must be deconstructed. Careful VITA 75 design has removed some aspects of modularity in order to improve SWaP; as mentioned, it is a specification that defines an SFF, box-level standard, and is based heavily on the voice of the customer, focusing on both the size and the level of ruggedization of the operating environment (Figure 3). The result is a game-changing improvement in situational awareness that not only preserves unmanned vehicles themselves, but also provides the quality and volume of information needed for total control of battlefield technologies and unprecedented force protection. **MES**

**Figure 3** | The ADLINK HPERC is a sealed, rugged COTS computing platform incorporating VITA 75 and other industry standard technology and long-life processing architecture.




***Mike Jones,*** *product manager at ADLINK, focused on factory automation equipment, devising algorithms, optics, and mechanics for sensitive, high-speed material analysis in the harsh environments of aluminum, steel, and paper production after cutting his teeth on avionics in the U.S. Navy. He went on to develop personal computer products for the consumer market, creating forward-looking, now ubiquitous industrial designs. At ADLINK, he now directs and champions the advancement of ADLINK's Extreme Rugged system products. He can be contacted at Mike.jones@adlinktech.com.*

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# Special Report

PAYLOAD DESIGNS FOR UAVs, UGVs, AND UUVs

# Capturing, processing, and transmitting video: Opportunities and challenges

By Chris Jobling

*The proliferation of unmanned vehicle platforms – in the air, on the ground, and in the water – has provided an unparalleled opportunity to expand intelligence, surveillance, and reconnaissance operations. Choosing the optimal blend of functionality, performance, reliability, and cost is the key challenge in optimizing the use of video. Meanwhile, key considerations include sensor processing location trends, video fusion, and video compression and bandwidth, in addition to Size, Weight, and Power (SWaP).*

U.S. Navy photo by Mass Communication Specialist 2nd Class Felicito Rustique

The next wave of military evolution is being driven by the twin imperatives of the need to preserve the lives of warfighters, on the one hand, combined with the need to control operational costs on the other. These imperatives are driving substantial investment by the Air Force and Navy. Unmanned vehicles are more expendable than their manned equivalents, meaning that they can be deployed on missions that would otherwise be impossible, and they offer greater endurance.

The appearance of unmanned vehicle deployment scenarios such as cooperative missions (manned/unmanned teaming) and autonomous operations (refueling, landing/docking, sense and avoid) (Figure 1) has increased the complexity and demands of the video processing features and subsequent image data transfer. Whatever the type of unmanned vehicle – whether land-, sea- or airborne – its mission will typically comprise three key elements: data capture, data processing, and data transmission. In addition, applications such as target tracking and data fusion have a need for time sensitivity, spatial awareness, and mutual awareness to correctly understand and utilize the data. Low-latency processing and transmission are key performance metrics, particularly where there is a human operator and key decision maker situated in a location remote from the point of data gathering. An examination of key considerations – sensor processing location trends, video fusion, and video compression and bandwidth, in addition to Size, Weight, and Power (SWaP) – lends insight.

**Trends: Stay close to the sensor**

As high-definition sensors become commonplace on unmanned vehicles, their increased bandwidth demands place significant processing overhead on traditional video tracking and processing systems. This trend leads to adoption of video architectures that can process the higher pixel densities, frame rates, and multiple video feeds with minimal latency. Higher definition in turn generates an exponential increase in the volume of data with associated impact on the bandwidth requirements of download links and the need to manage this through effective capture, conversion, and compression of video streams. Figure 2 shows interface bandwidth versus raw video bandwidth.

One way to address this dichotomy is to do processing at the sensor as often


**Figure 1** | The Autonomous Airborne Refueling Demonstration (AARD) program was a DARPA-funded demonstration of in-flight refueling using an autonomous aircraft. A GE COTS image processor card provided near-flawless detection, clutter rejection, and rigorous tracking of the refueling drogue in three dimensions.

there is no time to send data to the ground for decisions, or in doing so video fidelity might be lost (Figure 3). Processing the video locally at the sensor can be beneficial in that it is possible to extract pertinent information, such as target metrics, from the original high-fidelity imagery prior to any downscaling or compression losses, and this can be done with low latency (typically less than 1 frame) for driving subsequent decision making processes. However, this comes at the potential cost of greater power consumption in the remote vehicle, which can impact range and endurance, particularly on smaller platforms with extremely tight power constraints.

## Image fusion streamlines data avalanche

The number of sensors on unmanned military vehicles is increasing rapidly, leading to a requirement for intelligent ways to present information to the operator without information overload, while reducing the power consumption, weight, and size of systems. Military and paramilitary imaging systems can include sensors sensitive to multiple wavebands including color visible, intensified visible, near infrared, thermal infrared, and terahertz imagers. To this list we can add the need to assimilate camera feeds with synthetic video such as terrain maps. Typically these systems have a single display that is only capable of showing data from one camera at a time, so the operator must choose which image to concentrate on, or must cycle through the different sensor outputs. Image fusion is a technique that allows combining complementary information from each sensor into a single, superior image that can be displayed to the operator.

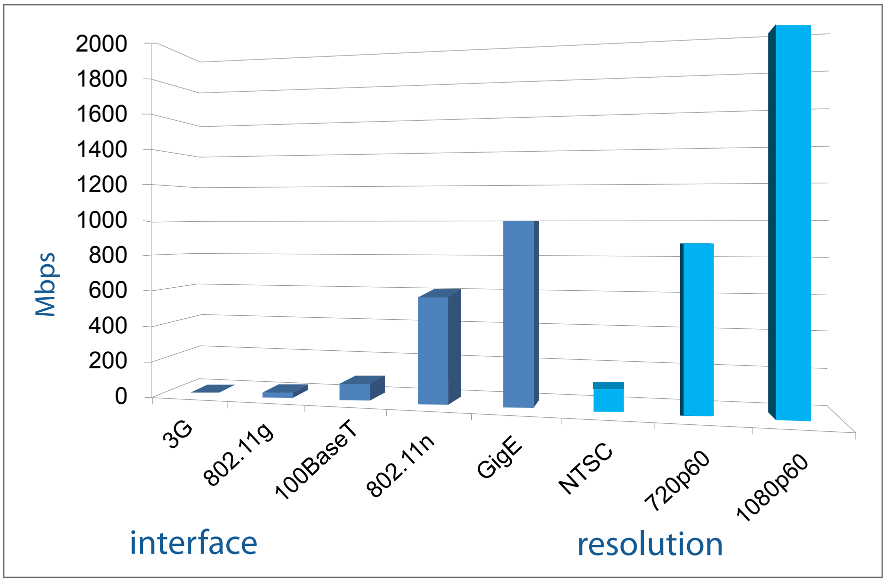



**Figure 2** | Interface bandwidth versus raw video bandwidth

Approaches to fusion include the simple additive image fusion approach, which applies a weighting to each of the input images and then linearly combines them. This has the benefits of low latency and moderate processing power, but with variable quality output, and it cannot guarantee retaining the full image contrast. In most cases, a linearly weighted fusion algorithm will produce a perfectly acceptable image that is clearly a combination of the input images and is preferable to viewing the two camera outputs side-by-side. However, in some cases the weighted average technique will result in the loss of key scene features and the fused image might not offer an enhanced view of the scene.

More advanced techniques must be employed if a higher-quality image fusion system is required. The most reliable and successful approach to fusion of two sensors uses a multiresolution technique to analyze the input images to maximize scene detail and contrast in the fused image. The added complexity of the multiresolution approach introduces an additional processing load over the linear combination technique but offers much greater scope for tailoring the algorithm to requirements and a higher-quality, more reliable fused image.

A key component of successful image fusion is input alignment to ensure that pixels in the different source images correspond to the same time and location in the real world. If this were not the case, a

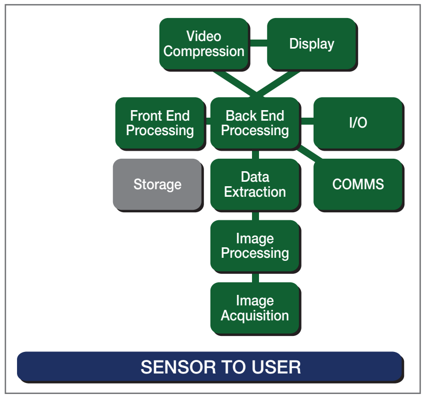



**Figure 3** | The trend is to process video, and to extract information of relevance, as close to the sensor as possible.

feature in the real world could be represented twice in the fused image, creating a confusing representation of the scene. An ideal image fusion system would contain synchronized sensors and a common optical path, but this is often not possible because of cost or other constraints.

Temporal alignment can be provided by buffering one image stream, which can compensate for unsynchronized imagers or sensors with different latencies. The process of matching one image to the other is achieved by creating a warped image. The pixel intensities of the warped image are evaluated by first calculating where in the original image the output pixel comes from and then interpolating its intensity using the values of the surrounding pixels. This can compensate for any relative rotation of the sensors, misalignment of the optical axes, or differences in the scale of the images.

Built-in warp engines can provide rotation, scale, and translation for each video source to compensate for image distortion and misalignment between the imagers, reducing the need for accurate matching of imagers with a resulting reduction in overall system cost. The systems only require a single monitor, further reducing SWaP requirements.

With the goal of fusion being to increase dynamic range and offer increased depth of field, sensor data and synthetic video (for example, terrain maps) are now being fused to provide for enhanced local situational awareness for challenging environments such as brownout.

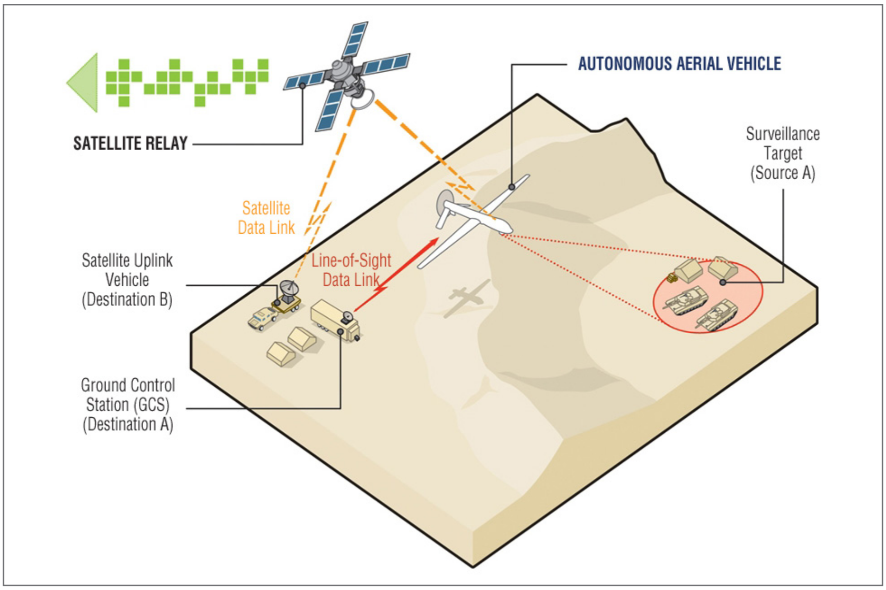
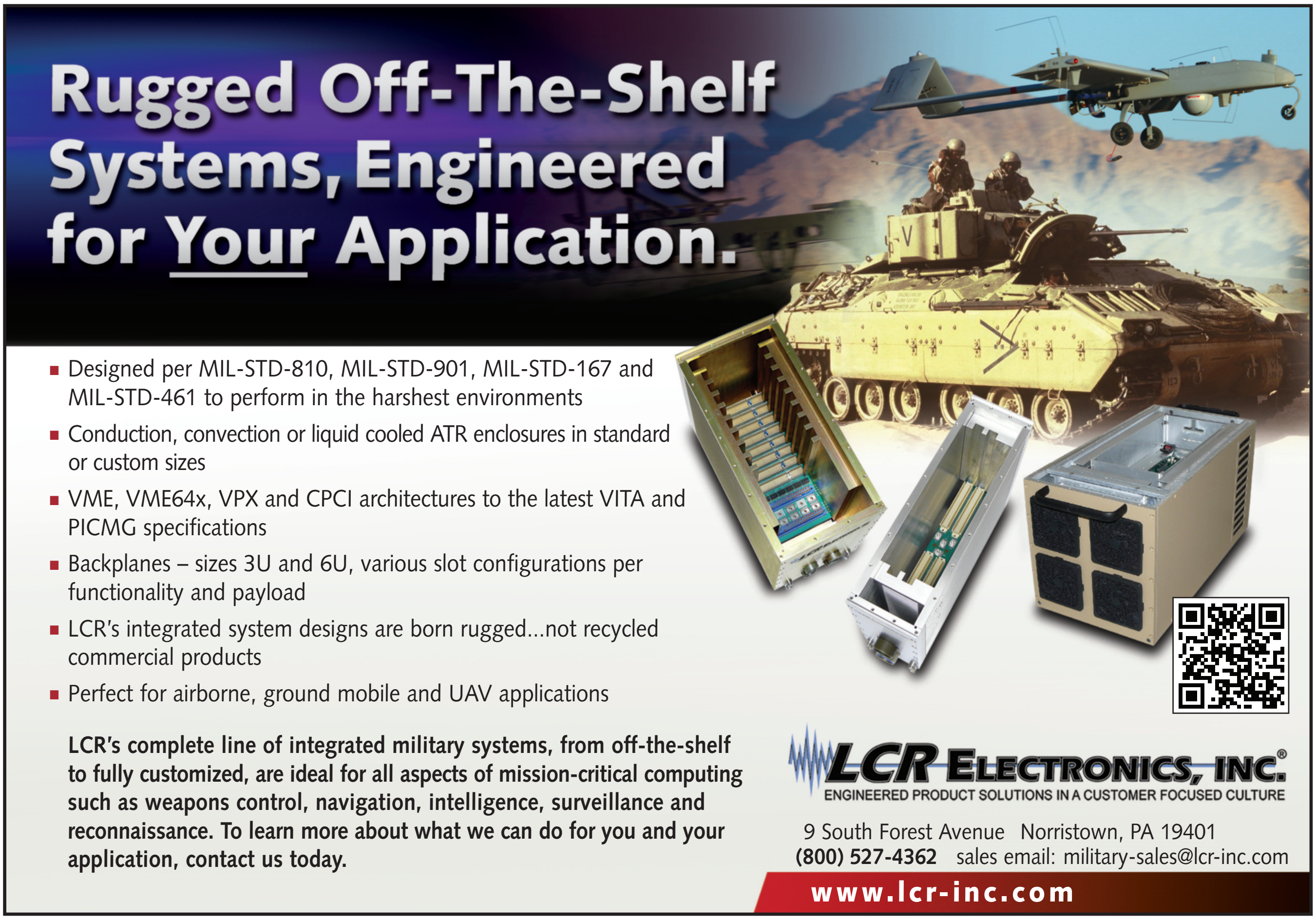



**Figure 4** | Communication of video imagery from the autonomous vehicle to a ground station presents significant challenges.

**Video compression**

Communications bandwidth is always at a premium between an unmanned vehicle and the ground station (Figure 4). Transmitting raw captured video, for example, is at best likely to result in unacceptable delays. As such, the onboard system will typically be required to undertake significant local processing in order to identify valuable information, and discard that which has no value prior to transmission. As unmanned vehicles become increasingly autonomous – no longer guided by a ground station, and capable of adapting the mission based on real-time data – such onboard processing will assume even greater significance.

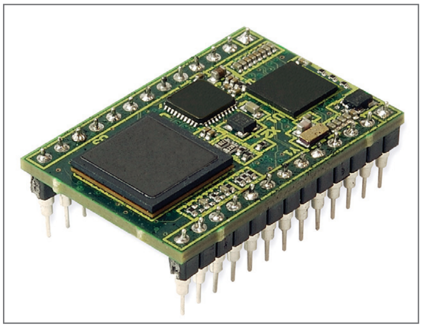


**Figure 5** | GE's ADEPT3000 system-on-module image processor is designed for highly constrained SWaP environments.

Beyond this, to reduce bandwidth consumption even further, the requirement exists to compress transmitted video, using codecs that minimize the data stream while maximizing image fidelity. The codec of choice today is H.264, also known as H.264/MPEG4, which uses around half the bit rate (or less) of previous video codecs. H.264 is popular not only because of its efficiency, but also because its applications are widespread – including in broadcast television. The implication of this is that there is a substantial infrastructure of support and expertise that can make implementing an H.264-based system both quicker and less costly for the military as well, when compared to alternatives such as JPEG2000.

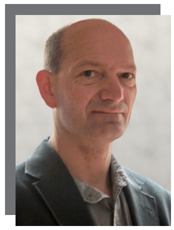
Effective video compression becomes even more critical considering that new systems are adding more video sources, and increasing the image resolution from lower quality to high definition at increased frame rates. The result is up to 12x more raw data per video stream, which requires significant data compression to enable an operator to view even one video source at a control center.

### The SWaP issue

Increasingly complex pixel processing chains (tracking and stabilization compression, for example) combined with a rise in the number of sensors used on each vehicle has led to a tenfold increase in the number of pixels being processed. Meeting skyrocketing video processing demands for unmanned systems while satisfying continually declining SWaP expectations is a daunting task. Combining processes such as tracking, moving target detection, image stabilization, image processing, and compression on a single board not only saves space but also results in a more tightly integrated system with lower overall power levels.

The rationalization of disparate processing tasks into a single unified processing platform is one approach that is useful in tackling this problem, and SWaP-optimized COTS-based image processing modules are already available that are designed to be placed on small platforms such as hand-launched UAVs or small unmanned ground vehicles (Figure 5).

Ultimately, careful planning and implementation of the video architecture are crucial to any effective solution, and the use of multifunction image processors can be an effective tool in reducing the overall SWaP footprint without sacrificing performance. **MES**



***Chris Jobling*** *is Product Manager, Applied Image Processing, at GE Intelligent Platforms. He can be contacted at christopher.jobling@ge.com.*

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# Making drone software safe and secure

**MIL EMBEDDED:**
***How do we assure the safety and security of the software deployed in drones?***

**ADACORE:** Much of the attention to Unmanned Aerial Vehicles (UAVs), or drones, has focused on privacy matters. These are obviously valid concerns, but an underlying technical issue is at least as significant: having confidence that UAVs will not cause hazards to people or property, and ensuring that UAV control is immune to both accidental and intentional interference. In short, guaranteeing safety and security.

These issues are not merely theoretical. A recently publicized video shows a German Army UAV coming dangerously close to an Afghan commercial jet over Kabul in an incident that occurred in 2004, and, although many details are still unclear, the Iranian capture of a U.S. military surveillance drone in 2011 raises serious security questions.

These issues are timely: The FAA Modernization and Reform Act of 2012 (Section 332) requires "the safe integration of civil unmanned aircraft systems into the national airspace system as soon as practicable, but not later than September 30, 2015."

Safety and security are, of course, also concerns for manned aircraft, but UAVs introduce particular challenges. Historically, since UAVs have been used primarily in either military contexts or in segregated airspace, safety has not been a major concern, and indeed the accident rate for UAVs has been much higher than for other types of aircraft. Speed of innovation has been a driving factor, which can compromise the rigor of the development and quality assurance processes.

How can we address these issues? A three-pronged approach is suggested:

› "Safety/security first" culture

Given the potential hazards and threats, developers and operators of UAV systems must consider safety and security as essential attributes of the UAV mission. This is to some extent a personnel training issue, but an underlying requirement on the software side is to ensure that appropriate processes are followed during the entire development life cycle. This includes "front end" effort such as fault analysis; effective development processes that give confidence that the system requirements have been met; and "back end" processes such as quality assurance, configuration management, and change control.

› Compliance with certification standards

One of the most successful software standards has been DO-178B (recently updated to DO-178C), which governs airborne software on commercial aircraft. It consists of guidance (objectives, activities) relating to a variety of software life-cycle processes, with the goal of providing confidence that the system correctly meets its requirements and has no unneeded functionality. Although not a safety standard per se, DO-178B complements system safety standards such as SAE ARP 4761 and can serve as the basis for UAV software certification. On the security side, relevant Security Functional Requirements from the Common Criteria can be included as system requirements for UAV software.

› Use of appropriate programming language technology

Programming languages and their supporting tools can play a key role in reducing the likelihood for errors that could lead to safety hazards or security vulnerabilities. An important factor is the ability to detect errors early in the software development life cycle. A common example is a "buffer overrun," where data is inserted past the end of a data structure; this may cause the system to crash or to be hijacked by malware. Language features such as strong typing and runtime index checking as found in Ada can prevent such errors. Ada is widely recognized as a better vehicle for creating safe and secure applications than alternative languages in common use, and new features added in Ada 2012 (such as contract-based programming) reinforce its strengths.

For the highest levels of safety or security, formal methods may be useful or necessary for demonstrating program properties such as the absence of runtime exceptions or the compliance of a program with its specification. Again, appropriate languages can help. A 2011 NIST study on Source Code Security Analysis Tool functionality showed that various vulnerabilities exist in many commonly used programming languages, but identified one language – SPARK, a variant of Ada – that was free from any of the considered vulnerabilities.

It is clear that UAVs will be playing an increasingly important role in the future. They fill a need and can help save lives, and their technology has matured to make them economically feasible. But introducing UAVs into shared airspace requires that developers adhere to the principle that the medical profession subscribes to: "First do no harm." This will require a different mindset as well as a systems and software engineering approach that takes advantage of appropriate language technology and rigorous certification standards.

***Dr. Robert Dewar** is Cofounder and President of AdaCore and Emeritus Professor of Computer Science at New York University. Contact him at dewar@adacore.com.*

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# Safe, secure, and interoperable unmanned systems

**MIL EMBEDDED:** ***What is your outlook for the unmanned systems segment of the defense market in this budget-constrained environment?***

**DOWNING:** The most obvious change occurring in the unmanned systems segment is the transition from highly proprietary systems to systems based on Commercial Off-the-Shelf (COTS) technology using standards-based hardware and software integration. The impact of this change is that more commercial avionics systems will be proven to be robust and stable, and integrate safety, security, reusability, interoperability, and autonomy requirements. This transition will help drive broad solutions for the following challenges:

- **Safety and security:** Next-generation unmanned systems will need to have a proven foundation in safety and security. The days of only flying in MOAs and war zones are over – all future growth will be in flying over the Earth to protect and enhance our security and personal lifestyle. To do this safely, we will need to build unmanned systems from the ground up that can readily achieve FAA RTCA DO-178C and EUROCAE ED-12C certification. In addition, there will need to be a secure framework built into these systems that secures not only the device, but also the entire aircraft and its complete end-to-end control environment.
- **Interoperability and reuse:** Next-generation systems will need to prove they have a systems architecture that can rapidly integrate a wide range of capabilities from a vast ecosystem of hardware and software suppliers. Static, single-source capabilities will quickly be made obsolete by platforms that can rapidly morph to meet the challenge of the hour. The excellent work by the Future Airborne Capability Environment (FACE™) and the Unmanned Control Segment (UCS) teams will drive and accelerate this platform expansion.
- **Autonomy:** Future unmanned systems need to fully capture the essence of autonomy, loading platforms with missions and having these platforms serve humans' intelligence on demand. We need to pull humans back from direct control of the platform to planning and controlling the mission, using real-time intelligence that delivers high-confidence situational awareness. The unmanned platform will recharge/refuel autonomously during periods of low activity, and be ready to serve as humans demand.

**MIL EMBEDDED:** ***What are the hot technologies for ISR payload designs in unmanned systems – hardware and software?***

**DOWNING:** There are three hot categories for ISR payload design in today's unmanned systems designs:

1. **Integrated Modular Avionics (IMA) consolidation:** Platform consolidation, compressing federated systems into IMA systems, has become an increasingly viable option with advancements in both silicon processing power and multicore architecture. Consolidation strategies, already proven in systems based on ARINC 653, greatly reduce Size, Weight, and Power (SWaP), and provide a solid foundation for future technology refreshes.
2. **Intelligent connected systems:** In order to make future platforms more capable and connect them into the C4ISR cloud, there is a move in the industry toward open architecture-based systems that drive improved system interoperability and portability. Both the FACE Technical Standard and the UCS standard are creating open platforms for rapidly deploying new payload capabilities into both legacy and next-generation systems.
3. **Information assurance:** As payloads become connected to the C4ISR system of systems, and for commercial systems the Internet, they will need to prove that their end-to-end security remains intact over the life of the system, using global standards such as Common Criteria. Information assurance will have to provide security for not only the sensor information, but transmission through public and private networks to the end users. The days of simple and/or nonexistent security of intelligent platforms are over, and these devices will be measured by the depth and robustness of their security coverage.

Global aerospace and defense avionics companies are continually challenged to deliver safe, secure, and reliable systems to satisfy complex mission-critical requirements. Today's system designers must choose technology partners that can minimize security risks over the life of a product to be successful in this critical systems marketplace.

*Chip Downing is the Senior Director for Aerospace and Defense at Wind River. He can be contacted at chip.downing@windriver.com.*

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# Unmanned systems: Present and future

**MIL EMBEDDED:** ***What is your outlook for the unmanned systems segment of the defense market in this budget-constrained environment?***

**MONTICCIOLO:** We expect the unmanned systems segment to remain strong over the next several years. The DoD and IC have gained confidence in the usage of these platforms deployed with high-performance sensor systems such as Gorgon Stare, an airborne wide-area EO/IR surveillance system, being a key example. The DoD will continue to push for open standards-based systems with plug-n-play capabilities that will support different sensor packages for different missions. Larger UASs will possibly be deployed differently than in our current theaters of operation and smaller tactical UASs will remain a priority for SOCOM-oriented missions. With the so-called Pacific Pivot, unmanned underwater systems with ISR, mine detection, and electronic warfare capabilities will become increasingly important.

**MIL EMBEDDED:** ***What are the hot technologies for ISR payload designs in unmanned systems – hardware and software?***

**MONTICCIOLO:** We expect onboard multi-INT fusion to be an important future capability. For example, tip-and-queue functionality between SIGINT and wide-area motion imagery subsystems to detect and track high-value targets is one such capability. Given advances in onboard processing and storage, we also anticipate Big Data-like capabilities including predictive analytics to be moved onto platforms as sensor data and reports can be correlated against onboard databases, which essentially moves important actionable intelligence closer to the warfighter and mitigates off-board communications link bandwidth limitations. These processing advances will also support more autonomous platform operation during missions by learning from collected sensor data. We also see security and information assurance for onboard systems becoming more important as unmanned systems operate in environments where U.S. forces do not have complete control of the battlespace. We also see the potential for multifunction payloads that integrate ISR with EW/EA capabilities that leverage AESA technology.

*Paul Monticciolo is CTO at Mercury Systems. Contact him at pmonticciolo@mrcy.com.*

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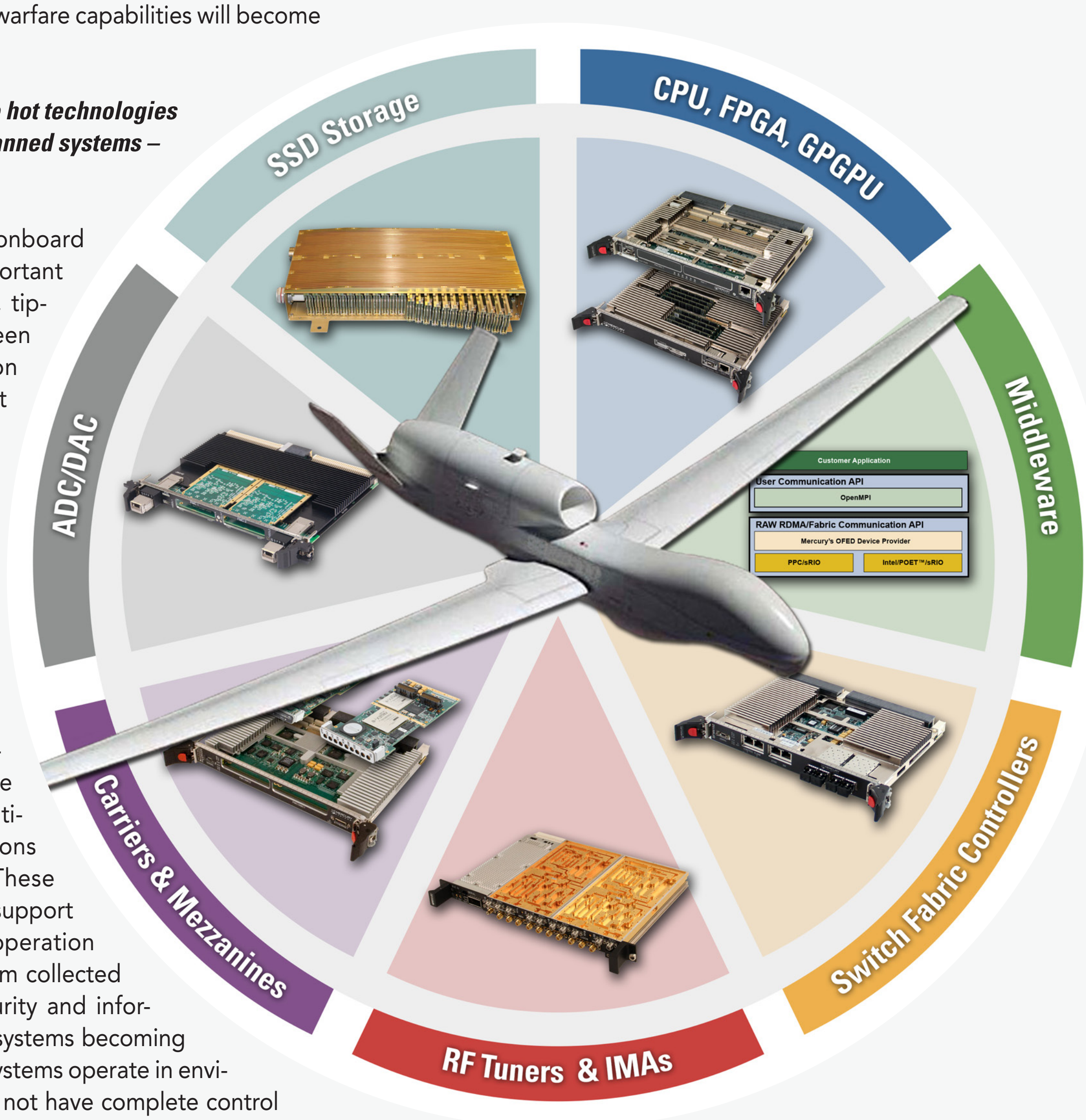

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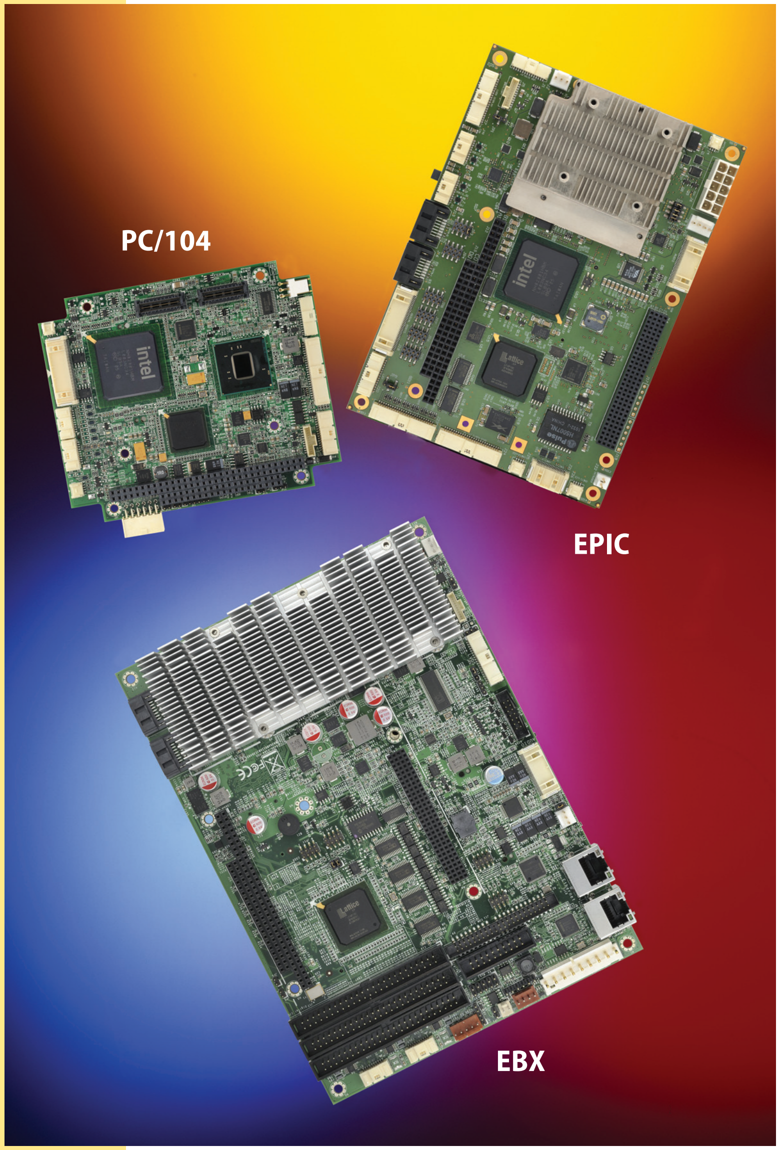


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SOFTWARE FOR UNMANNED SYSTEMS APPLICATIONS

# What's needed to ensure safety and security in UAV software

By Mark Pitchford

*UAVs are not like the remote control stunt plane you unwrapped on your 10th birthday. In their different guises they can be found in civil airspace or flying as integral players in military missions. That makes unmanned systems' safety and security very serious considerations. Accordingly, ISO 14508 and DO-178 could prove helpful in perpetuating safety and security for unmanned systems. Software tools that automate the processes required by these certification standards are easing the burden.*


U.S. Air Force photo/Rob Densmore

As a basic concept, the idea of an Unmanned Aerial Vehicle (UAV or "drone") is "childishly" simple: a miniature plane that can be piloted remotely. The major difference between UAVs and the toys of our childhood is the sophistication of the vehicles themselves and of their navigation and pilot systems. Given that these vehicles enter civil airspace and will continue to do so more and more as they begin to be used for an increasing number of civilian activities, the safety and security of UAV software has become critical. It's paramount that we raise the stakes in terms of the robustness of the code and minimize its potential vulnerability to hackers.

As early as 2004, NASA's "Civil UAV Capability Assessment" listed 30 categories of private-sector organizations with a potential interest in UAV use, including those in forestry management, crop dusting, and coastal search and rescue. The number of drones and applications has ballooned since then, and according to *The Washington Times,* as many as 30,000 UAVs could fly in U.S. airspace by the year 2020.

This expansion in UAV use challenges the FAA's goal "to provide the safest, most efficient aerospace system in the world." With no human pilot onboard, the control software is chiefly responsible for maintaining UAV safety and security. And, with no mandated standards in place to govern the safety and security of UAV systems, the proliferation of drones increases the overall risk to our safety and security.

Notably, even if FAA standards are imposed, safety might still be at risk unless security standards are mandated. The 2011 crash of a CIA drone in Iran underlines that unless a system can withstand hacking, safety remains at risk. In that incident, local authorities claimed that they had diverted the vehicle by hacking its GPS. Their claim gained credence when Professor Todd Humphreys of the University of Texas and a group of U.S. researchers hacked a UAV in front of representatives of the U.S. Department of Homeland Security. The team spoofed an onboard GPS receiver by mimicking the actual signals sent to the global positioning device to trick the UAV into following different commands.

To address such a scenario, developers at the U.S. Air Force Institute of Technology are working on a system that enables a UAV, like a human pilot, to supplement GPS navigation with visual feedback by using a camera with pattern-recognition software. Such efforts are only as secure as the security of the software deployed.

**Which safety/security standards should be in place**

There are two kinds of standards to consider for UAV safety and security:

- Process standards describe the development processes to be followed to ensure that the finished product is written in a safe manner (DO-178) or a secure manner (ISO 14508).
- Coding standards describe a high-level programming language subset that ensures the software is written as safely (MISRA C) and securely (CERT C) as possible.

Safety is clearly important in UAV development, but a UAV can only be considered safe if it cannot be controlled by a hostile intruder.

ISO 14508 (also know as the "Common Criteria" with reference to the merged documents from which it was derived) is an international process-oriented standard that defines IT security requirements. These requirements are categorized according to seven Evaluation Testing Assurance Levels (EALs), as displayed in Table 1, with EAL 7 representing the most secured system. Security functional requirements include audit, communications, cryptography, data protection, authentication, security management, privacy, and protection of Targets of Evaluation (TOEs). Professor Humphreys' spoofed GPS signals demonstrated just one resulting vulnerability when these general principles were not applied to UAV communications.

Software developed for use in UAVs falls under the guidelines of DO-178, "Software Considerations in Airborne Systems and Equipment Certification." Both DO-178B and the recently ratified DO-178C provide detailed guidelines for the production of all software for airborne systems and equipment, whether safety-critical or not. As part of these guidelines, DO-178B/C defines Design Assurance Levels (DALs) with Level A involving the most rigorous safeguard against failure. DO-178 translates these DALs into Software Levels, as shown in Table 2. Each software level has associated objectives that must be satisfied during development.

DO-178 recognizes that software safety must be addressed in a systematic way throughout the development life cycle. To help developers do this, the standard outlines needed processes such as requirements traceability, software design, coding, and the validation and verification that ensure confidence in and the correctness and control of the software. Robust software validation and verification processes enable developers to detect and correct errors introduced during software development.

With respect to software, the overlap between the two standards is considerable, especially with configuration management, software development, quality assurance, verification, and planning. However, DO-178 focuses solely on the safety of the software in the airborne system, while ISO 14508 focuses on system security.

Both DO-178 and ISO 14508 suggest the use of language subsets (or "coding standards") such as MISRA C:2012 for safety and CERT C or CWE for security. These language subsets consist primarily of lists of constructs and practices for developers to avoid in order to ensure safe or secure code. It is, for example, entirely possible to adhere to coding rules from both MISRA C:2012 and CERT C to gain acceptable levels of safety and security.

| Common Criteria Evaluation Assurance Level (EAL) | Process rigor required for development of an IT product |
|---|---|
| EAL 1 | Functionally tested |
| EAL 2 | Structurally tested |
| EAL 3 | Methodically tested and checked |
| EAL 4 | Methodically designed, tested, and reviewed |
| EAL 5 | Semiformally designed and tested |
| EAL 6 | Semiformally verified, designed, and tested |
| EAL 7 | Formally designed and tested |

**Table 1** | ISO 14508 defines a range of Evaluation Assurance Levels (EALs), which determine the process rigor associated with each software component.

| Level | Failure condition | Description |
|---|---|---|
| A | Catastrophic | Failure may cause a crash. |
| B | Hazardous | Failure has a large negative impact on safety or performance. |
| C | Major | Failure is significant, but has a lesser impact than a Hazardous failure. |
| D | Minor | Failure is noticeable, but has a lesser impact than a Major failure. |
| E | No Effect | Failure has no impact on safety of aircraft operation. |

**Table 2** | DO-178 defines a range of software levels that must be examined and determined for each software component.

Given the anticipation that UAVs will fall under both DO-178 and ISO 14508 standards, development teams should strive to fulfill the aims of both standards moving forward.

It is certainly critical to ensure that the UAV is developed to meet system requirements that ensure safety and security issues are dealt with. However, with increasing market pressure related to UAV development, improvements in time-to-market and development costs are also important. Fortunately, vendors have come a long way in providing tools that automate the processes required by these certification standards (Figure 1). For example, fundamental to both DO-178 and ISO 14508 are requirements traceability, static analysis, and dynamic analysis, and tools are available to help automate the labor-intensive aspects of all three objectives.

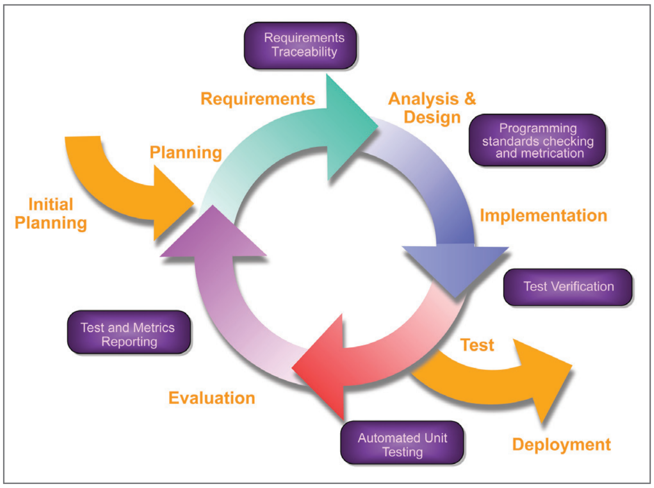


**Figure 1** | Meeting one standard is a challenge; adhering to two such as DO-178 and ISO 14508 is totally daunting. By applying appropriate automation techniques, development teams can minimize the overhead involved.

*Requirements traceability tools*

Both standards require that high-level requirements are traceable to design documents, that design documents trace to code, and code traces to test – and back up again, from tests through to requirements to gain "bidirectional requirements traceability."

If requirements could be static and fixed from the outset, then traceability would be relatively straightforward. However, that is rarely the case, and consequently the maintenance of a matrix to show traceability at any particular time becomes a very labor-intensive task.

To help manage this matrix of relationships, requirements-traceability tools link system requirements to software requirements, from the software requirements to design artifacts, and then to source code and the associated test cases. The automated bidirectional tracing of requirements ensures that the developed UAV does exactly what is specified by the final set of requirements – no more, no less, and no matter how often those requirements change (Figure 2).

*Static analysis tools*

When requirements are established and designs are in place, developing safe and secure source code demands the use of appropriate coding rules. Again, the rules designed to develop safe code are similar to those designed for secure code. For example, many C language features that are unsafe are similarly unsecure.

Notably, it is impractical to manually check for compliance to both the MISRA C and CERT C language subsets. Static analysis automates verification of coding rules. Once the rules are selected, the source code is statically analyzed to highlight the precise location of any rule violations.

Static analysis helps to fulfill other obligations too. For example, it identifies code that is unnecessarily complex and therefore more error prone. And, it confirms that the code does what it's specified to do. Developers must prove not only that the code functions correctly, but that all code is exercised to a degree appropriate to the criticality of the system.

*Dynamic analysis tools*

Dynamic analysis tools exercise code as a whole system or piecemeal, by means of unit or integration testing, to show correct functionality. Any code necessary to permit a subsystem

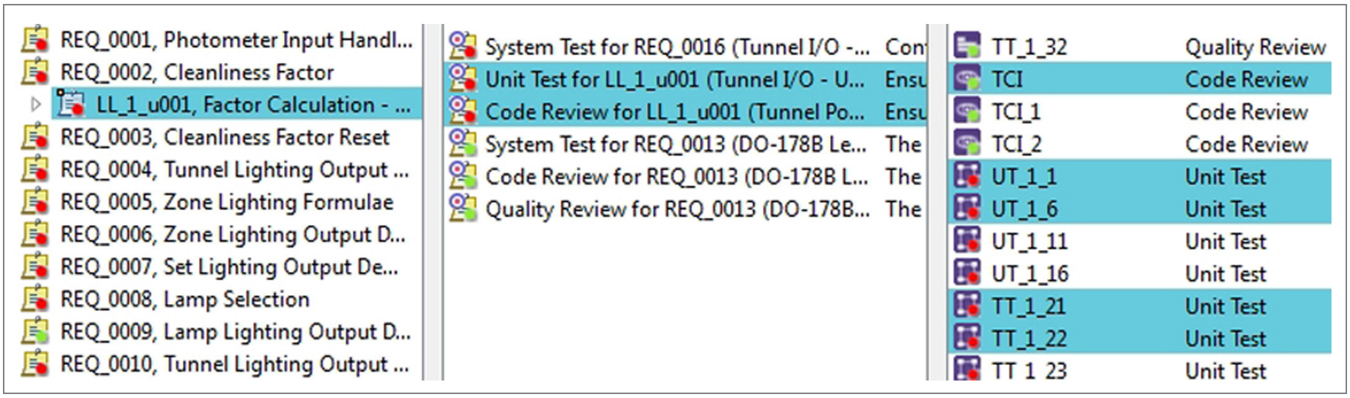


**Figure 2** | Requirements traceability is a vital factor in meeting security and safety standards. Dynamically linking high-level requirements to source code and verification tasks ensures that an up-to-date traceability matrix is always maintained.

to be built and executed is created automatically, and the exercised code is identified.

## Cost-effective safety and security

As mentioned earlier, UAV projects are obliged to meet neither DO-178 nor ISO 14508. Even if they were, those standards do not insist either on the use of automated tools or on the automation of the development process. However, the need for UAVs to be safe and secure is vital given their expanded role. Automated requirements traceability coupled with modern static- and dynamic-analysis tools make it viable to meet the exacting demands of such standards in an efficient and cost-effective manner. **MES**


***Mark Pitchford*** *has more than 25 years' experience in software development for engineering applications. He has worked on many significant industrial and commercial projects in development and management, both in the UK and internationally including extended periods in Canada and Australia. Since 2001, he has specialized in software test, and works throughout Europe and beyond as a Field Applications Engineer with LDRA. He can be contacted at Mark.Pitchford@ldra.com.*

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# The evolution of miniaturization within UAV connector technology

By Derek Hunt

*Throughout the world, military and aerospace engineers are focused on new design efforts to not only modernize existing operations, but at the same time, miniaturize these efforts and electronics to improve flexibility and portability as well as overall survivability in the field. With these changes in mind, electronics and connectors in particular are playing a vital role in terms of reducing a system's overall weight and size while maintaining yesterday's proven technology, in half the footprint.*

Small UAVs such as this hand-launched Puma AE from Aerovironment rely on rugged connectors to meet their reduced SWaP requirements.

It's no surprise that size and weight are two of the largest factors these days when it comes to interconnects. Soldiers typically haul their own weight and then some in what we deem "portable" electronics. In fact, with the amount of data transferred in and out of battlefields today, yesterday's interconnect solutions alone would have had our soldiers weighted down with heavy analog-driven technology, not to mention a variety of back-breaking batteries, all essential to power each unit and/or device. Luckily, this challenge has paved the way for new unmanned technologies to surface. UAV technology has quickly become a leading global industry in supporting existing defense systems as well as providing new ways of protecting the home front and abroad.

UAV technology, although relatively new, is already evolving. What we've known to be "standard," such as fixed wings and motorized propulsion, are becoming things of the past. Instead, researchers are now using more of a biological template, such as flapping wings to mimic a bird in an effort to achieve a level of aerial camouflage. This ability for UAVs to mimic a bird or in some instances insects gives the UAV an almost natural protection from the elements. Even in the heart of the battlefield, enemies might notice the UAV disguised as a bird, but could very well identify it as just that, a bird.

All these factors – combined with the fact that UAV systems manufacturers are requiring smaller, more innovative interconnect systems – have brought miniaturization to the forefront. What was once thought of as simply a portable military surveillance device has now branched out into applications such as agriculture, law enforcement, and border control, yet in reality, all UAVs these days are essentially demanding the same things: smaller size, lighter weight, higher performance, and more importantly, higher-reliability miniaturized connectors, and those connectors are here.

**Smaller size and weight, more ruggedness**

Nano-miniature connectors are beginning to play a vital role in a number of UAV applications. Such small and lightweight electronics and components allow for longer flight times, which is vital within this industry. In addition to

> "Nano-miniature connectors are beginning to play a vital role in a number of UAV applications. Such small and lightweight electronics and components allow for longer flight times."

size and weight considerations, these new robust interconnect designs must be ultra-rugged. These connectors must be capable of withstanding a high shock and vibration environment. For example, Omnetics BiLobe connectors can handle a shock of 100 *g* in each axis and have passed vibration testing from 10 to 2,000 to 10 Hz at 20 *g* amplitude in each axis (Figure 1) – ensuring more than enough to survive the high shock and vibration demands often associated with the UAV tendency toward aggressive landings. In addition to size characteristics and vibrational elements, other conditions such as adverse weather and high altitudes push the UAV's electrical requirements and overall performance to new heights.

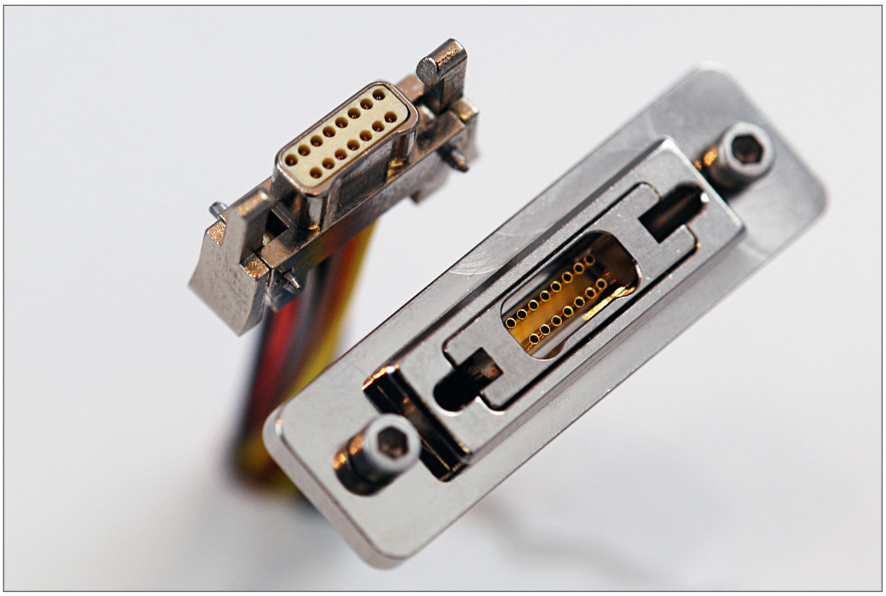


**Figure 1** | BiLobe connectors can handle a shock of 100 *g* in each axis and have passed vibration testing from 10 to 2,000 to 10 Hz at 20 *g* amplitude in each axis.

Electronics requirements in general have new ruggedized standards to be met simultaneously with the expectations of lightweight flexible cables and locking interconnect systems. These new standards have forced connector manufacturers to think "outside the box" and design specifically to meet these newfound requirements. New connector designs based at .025" on center contacts offer military-level quality and reliability, suitable for UAVs. Nano-miniature interconnects are specifically designed to meet these rugged demands, while consuming the smallest physical space possible. These nano-sized connectors exceed performance levels specified within MIL-DTL-83513, commonly referred to as the Micro D, and are also designed to fit the new requirements of MIL-DTL-32139 (Figure 2). Nano-miniature connectors as a whole are 10 times smaller in volume and about 10 percent the weight of a standard Micro D connector with the same number of positions. With cameras, weaponry, GPS modules, and other detectors now onboard many of these lightweight UAVs, there is an increased demand for high data rates as well as a high-volume capacity for video data streaming. If not handled correctly from a design standpoint, these transmission signals could cause extreme Electromagnetic Interference (EMI) conditions and extreme headaches for designers.

**Nano-miniature connector challenges**

As we've learned from past endeavors, regardless of the industry, new challenges arise with each new technological trend, and nano-miniature connectors are no different. The main reason is that old standards no longer apply. Simultaneously, "comfort" connectors such as MIL-38999 circulars and D-Subs are just too big. Some MIL-83513 Micro Ds are becoming too large in some in-stances, as connectors themselves are becoming the limiting factor in UAV-related applications.

Aside from the size and weight challenges mentioned, there are countless other factors at play today. The overall environment – and specifically environmental protection – is a major focus when developing miniature connectors. Engineers often compare this challenge to finding a needle in a haystack, and although difficult, solving this challenge is not impossible. Most cables designed for transmission of electrical power or high-voltage signals are relatively unaffected by EMI. However, nano-sized cables (generally consisting of 30 AWG wires or smaller) are rarely designed in with the intention of transmitting high power, but rather Low Voltage Data Signaling (LVDS). This issue is requiring many UAV manufacturers to physically require Electromagnetic Pulse Protection (EMP). Designing against EMP is basically the same as designing against EMI, and that generally starts with the physical cable used versus the nano-connector in question.

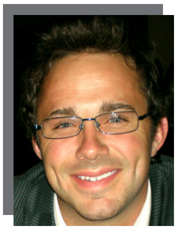

**Figure 2** | A cable harness featuring both Micro D and BiLobe technology, braided with a backshell to ensure a clean and clear signal is transmitted

The first line of defense is generally twisted pairs. Twisted pair cable is good for transferring balanced differential signals, and the process itself dates back to the early days of telegraph and radio. However, if twisted pairs aren't cutting it, the next step is to physically shield the wire bundle. Yesterday's technology had engineers believing that the best cable shields for EMI were solid materials such as conduit; however, within the UAV market where lightweight solutions are vital, metal braided shields can be used effectively to keep the size and weight down. In fact, with cabling now carrying more LVDS than ever before, proper shielding has never been more important if the integrity of the transmitted data is to be consistently maintained. The most common method of shielding nano-connectors against EMI is to physically enclose the cable in a tightly woven metal braid comprised of wire strands, which is then terminated at one or both ends of the cable depending on the assembly in question.

Best results are generally found when the metal braid can be physically terminated to a backshell. If this is indeed the preference, designers must ensure the shield has a clean metal-to-metal contact with the backshell, as continuity is an extremely important factor relating to EMP/EMI protection. Ideally, a 360-degree circumferential mechanical bond between the shield and the connector's backshell should be present; this can be achieved using a standard band-it clamp or via a soldering process. A variety of backshell configurations is available specifically for nano-miniature connectors. Designers can select from straight or angled options depending on the application.

**Nano-miniature connectors enhance military UAVs**

Nano-miniature connectors are helping the military UAV industry to overcome its ubiquitous challenges of electronics size and weight, and providing rugged protection against harsh environments and landings. Helping to prolong UAV flight times and ensure and maintain data transmission integrity in half the footprint of traditional connectors, these connectors are available with temperature ranges as wide as -55 to +200 degrees Celsius in single and dual-row configurations up to 85 contacts. Jackscrew hardware is typical; however, tool-free "latching" versions are available as well. Nano-miniature connectors are also available in environmentally sealed circular configurations as provided by Omnetics' Nano 360 series. Regardless of the shape, these nano-miniature connectors can be manufactured with flying leads, as jumper assemblies, or as custom harnesses with multiple connectors involved. **MES**



*Derek Hunt is an Application Specialist for eight years at Omnetics Connector Corporation, where he is responsible for designing and maintaining new and existing business opportunities within Omnetics Connector Corporation in the continental U.S. He graduated from the University of Minnesota, Mankato in 2002 with degrees in Speech Communication and Business Administration. He can be contacted at dhunt@Omnetics.com.*

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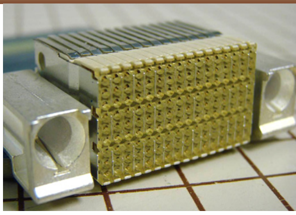

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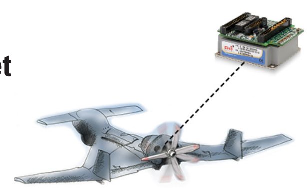

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Military EMBEDDED SYSTEMS Editor's Choice

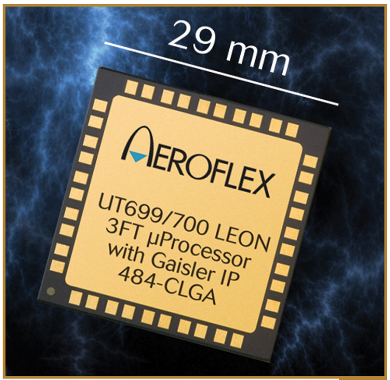
## Rugged display computer enables synthetic aperture sonar

The MAGIC1 rugged display computer from GE Intelligent Platforms in Huntsville, AL, provides processing capability for signal processing intensive applications such as radar, sonar, and image processing. Engineers at the Centre for Maritime Research and Experimentation (CMRE) used the board to demonstrate near real-time processing of synthetic aperture sonar data for adaptive track spacing and target detection on an autonomous vehicle. It was deployed on the Minehunting UUV for Shallow water Covert Littoral Expeditions (MUSCLE) Autonomous Underwater Vehicle (AUV) to create detailed images of the seafloor as part of the Autonomous Mine Search Using High-Frequency Synthetic Aperture Sonar project.

The computer provides parallel processing capability through the NVIDIA EXK107 GPU for access to GPGPU computing. For rapid application development, it uses tools such as CUDA, OpenCL, and MATLAB. Onboard storage is provided by a solid-state disk drive, which has a capacity of as much as 256 GB and sustained read performance of 250 MBps. It has three chassis configurations: base-plate cooled when a suitable coldplate is available, convection cooled with integral fins, or forced air cooled through hollow sidewall heat exchangers when no external cooling mechanism is available.

**GE Intelligent Platforms I www.defense.ge-ip.com I www.mil-embedded.com/p9914565**

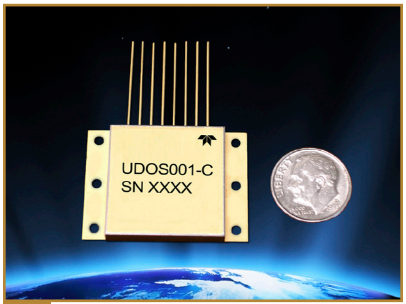
## SPARC-based microprocessors for space applications




Engineers at Aeroflex Colorado Springs improved performance in a 130 nanometer CMOS process with their new microprocessors – the UT699E and the UT700. The UT699E is an enhanced version of the company's UT699. It was migrated from .25 micron CMOS to 130 nm CMOS, resulting in a faster microprocessor with targeted speeds of 133 MHz that is also lower power. Software developed for the UT699 also will be 100 percent compatible with the UT699E. The UT700 is a derivative of the UT699E that has a more powerful EDAC scheme as well as a 1553 port to support the bus controller remote terminal function. A Reed Solomon EDAC provides fault-tolerant protection for the SDRAM.

Both devices have a seven-stage pipelined monolithic, high-performance, fault-tolerant SPARC V8/LEON 3FT processor and a compliant 2.0 AMBA bus interface that integrates the on-chip LEON 3FT, SpaceWire, Ethernet, memory controller, CPCI, CANbus, and programmable interrupt peripherals. While the UT699 and UT699E are pin-to-pin compatible, the UT700 is not. Aeroflex is adding additional I/O and improving the EDAC scheme so it has a slightly different pinout but is offered in similar packages to the other devices.

**Aeroflex Colorado Springs I www.aeroflex.com/radhard I www.mil-embedded.com/p9914566**




## Spacecraft radiation monitoring enabled by Teledyne device

The Micro Dosimeter (P/N UDOS001) from Teledyne Microelectronic Technologies in Los Angeles is a compact hybrid microcircuit that directly measures Total Ionizing Dose (TID) absorbed by an internal silicon test mass. The test mass simulates silicon die of ICs onboard a host spacecraft in mission payloads and subsystems. The device monitors spacecraft radiation doses absorbed by other electronic devices on the same vehicle by measuring the energy absorbed from electrons, protons, and gamma rays. The 20 gram device is a custom microchip in a small-footprint package that provides lower weight and power than alternative devices.

The Teledyne device can be mounted in multiple locations on a spacecraft and can operate from a variety of input voltages – 10 mA from 13 V to 40 V. The accumulated dose is presented to three DC linear outputs and one pseudo-logarithmic output providing a dose resolution of 14 uRads and a measurement range as high as 40 kiloRads. The Teledyne product provides total mission dose and dose rate data to help diagnose spacecraft anomalies caused by changes in environmental fluxes. It also correlates environmental models and ray-tracing analyses with real in-flight measurements. Commercial, Class H, and Class K options are available.

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