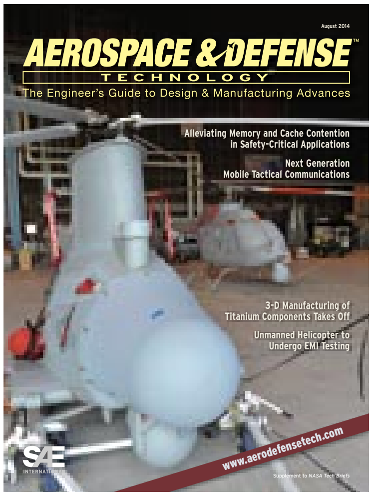
AEROSPACE & DEFENSE™
TECHNOLOGY
The Engineer's Guide to Design & Manufacturing Advances

Welcome to
your Digital Edition of
Aerospace & Defense Technology
August 2014



How to Navigate the Magazine:

At the bottom of each page, you will see a navigation bar with the following buttons:

Arrows: Click on the right or left facing arrow to turn the page forward or backward.

Intro **Introduction:** Click on this icon to quickly turn to this page.

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

ToC **Table of Contents:** Click on this icon to quickly turn to the table of contents.

Zoom In: Click on this magnifying glass icon to zoom in on the page.

Zoom Out: Click on this magnifying glass icon to zoom out on the page.

Find: Click on this icon to search the document.

You can also use the standard Acrobat Reader tools to navigate through each magazine.

August 2014

AEROSPACE & DEFENSE TECHNOLOGY™

The Engineer's Guide to Design & Manufacturing Advances

Alleviating Memory and Cache Contention in Safety-Critical Applications

Next Generation Mobile Tactical Communications

3-D Manufacturing of Titanium Components Takes Off

Unmanned Helicopter to Undergo EMI Testing

www.aerodefensetech.com

SAE INTERNATIONAL

Supplement to *NASA Tech Briefs*

Contents

FEATURES

DEPARTMENTS

ON THE COVER

Northrop Grumman's MQ-8C Fire Scout unmanned helicopter will undergo electromagnetic interference (EMI) testing in preparation for planned shipboard flights next year. The helicopter used specially designed Faraday cages to protect sensitive equipment from signal interference. To learn more, read the Application Brief on page 34.

(Image courtesy of Northrop Grumman)

Top Products

Dual-Purpose Engine Stand

Champion GSE has developed a dual-purpose stand for both the -1B and -2B GEnx engine platforms from GE. Features of the Stronghold stand were designed to increase personnel safety, usability, and function. These features include hydraulic, automated casters and shock isolation mount; onboard storage for all tools and parts; industrial nonslip material coating to replace no-skid strips; and improved rigidity. More detail at ***http://articles.sae.org/13122***.

Inline Caster

Hamilton Standard custom engineered an all-stainless inline caster for a major aerospace supplier. The aerospace company ordered two of these special casters designed for a cleanroom environment, each with a carrying capacity of 15,500 lb. The caster stands 10-1/8-in tall and 21-in long, and is equipped with two 8-in-diameter by 2.2-in-wide double flanged track wheels. Four 40-mm double sealed precision stainless steel ball bearings were press fit into each wheel with 1-1/4-in axles. More detail at ***http://articles.sae.org/12838***.

Low-Loss RF Coax Cable Assemblies

Crystek's 50-GHz low-loss RF cable assemblies feature corrosion-resistant 2.4-mm 303 stainless steel connectors and three levels of shielding for low attenuation (loss) over distance (1.44 dB/ft at 50 GHz). They are in stock in standard lengths of 24, 39.4, and 48 in, with custom lengths available. The assemblies are suited for high-frequency interconnects in mission-critical applications and microwave laboratories. More detail at ***http://articles.sae.org/13017***.

Temperature Indicator With Fixed Probes

Palmer Wahl Instrumentation Group's Wahl DST500-FM temperature indicator with fixed probes is a high-accuracy, wide-range thermometer designed for hazardous locations where accurate and reliable temperature monitoring is critical. Fixed-stem probes are available in straight or 90° back-, left-, or right-angle connection from either 304 or 316 stainless steel. More detail at ***http://articles.sae.org/13015***.

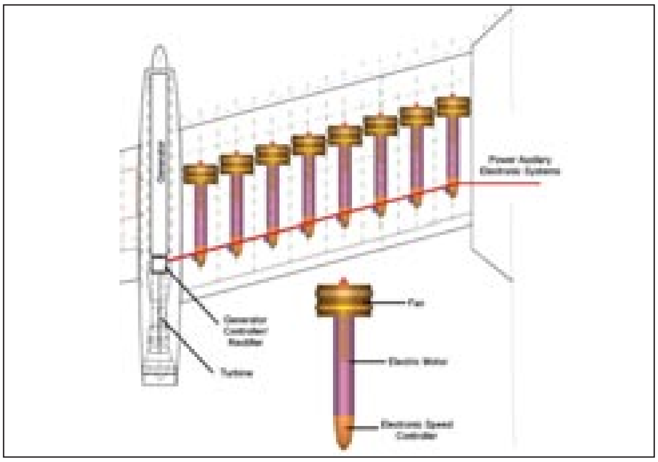
Pressure Switches

Honeywell's HP Series, HE Series, and LE Series of pressure switches provide high burst pressure ranges, a long lifecycle rating, and IP67 sealing, enhancing durability and reliability. High burst pressure and up to 2 million lifecycle ratings allow the switch to operate and survive in demanding applications and ensure long life and reliable switching. More detail at ***http://articles.sae.org/13019***.

Top Articles

Hybrid-Electric Distributed Propulsion Explored

Recent advancements in electronics, computers, and power distribution have made distributed propulsion feasible, but major challenges remain. Read more at ***http://articles.sae.org/13049***.



A generic turboelectric distributed propulsion (TeDP) system architecture featuring eight fan/motor assemblies powered by one turboshaft engine/electrical generator combination located in each wing half.

3-D Printing in Aerospace: Not Just Winging It

The demand for innovative manufacturing technology that produces lighter parts with stronger material grows each day in the competitive aerospace industry. 3-D printing, also known as "additive manufacturing," is at the center of this innovation. Read more at ***http://articles.sae.org/13170***.

Embry-Riddle to Offer Master's in Unmanned Systems

Unmanned systems coursework will examine the application, development, management, and policies of unmanned systems and address issues including regulation; systems design; policy and ethics; education and training; and human performance and machine interaction. Read more at ***http://articles.sae.org/13194***.

Sikorsky, NREC Partner for Matrix Application to Demonstrate U.S. Army Autonomous UGV Delivery

The project is an 18-month program sponsored by the U.S. Army's Tank Automotive Research, Development, and Engineering Center (TARDEC) through the Robotics Technology Consortium. Read more at ***http://articles.sae.org/13234***.

Designing Quieter Aircraft via Acoustic Simulation

Greater fuel efficiency and low emission requirements have grown into such an urgent imperative in aircraft design that it often overshadows an equally significant factor in air travel—noise. Airbus shows that it's possible to infuse acoustic simulation into design processes from beginning to end, giving engineers the acoustic simulation intelligence they need to create quieter aircraft, according to Free Field Technologies. Read more at ***http://articles.sae.org/12887***.

Alleviating Memory and Cache Contention in Safety-Critical Applications

In safety-critical systems, the ability to guarantee that safety-critical tasks have sufficient time to execute is key for system integrity and safe operation. A big challenge facing developers of safety-critical software applications is managing the shared resources of memory and cache to minimize worst case execution times (WCET). On-chip cache allows the processor to run at on-chip memory bus speeds and increases overall compute power when executing from the cache. However, task switching and competition among multiple cores can degrade cache performance and have dramatic impacts on WCET. Benchmarks demonstrate that WCET can be 3 times higher than average-case execution time (ACET) on single-core processors, up to an order of magnitude higher or more on multicore processors.

By utilizing real-time operating systems like Deos that support cache partitioning, programmers can isolate safety-critical tasks from detrimental cache effects, thereby reducing WCET and boosting overall CPU time available for time-critical tasks. The ability to bound and control cache effects also simplifies analysis of inter-application interference patterns, thereby streamlining safety certification. Results from benchmarks derived from actual flight software demonstrate these benefits, and are presented later in the article.

Cache Effects

Cache maximizes processor performance by enabling it to access faster on-chip memory. That advantage, however, only exists when the data for the executing task resides in the cache. During a task switch in a memory-partitioned RTOS, the cache must be invalidated, and those portions of the cache that had been altered by the previous task (dirty cache) must be written back to main memory. Only after this is done and the cache is repopulated with data for the new task will the CPU again be able to access memory at chip speeds.

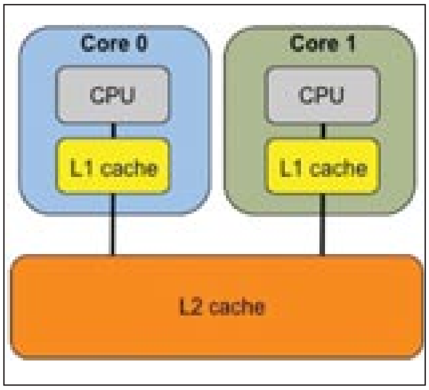


Figure 1. Common Dual-Core Architecture

On a multicore processor, the problem is even worse because no longer is the major impact limited to a process or memory partition context switch. Now, multiple cores will compete for shared cache during normal process execution. A common dual-core processor configuration is shown in Figure 1. In this configuration, each core has its own CPU and small L1 cache, and both cores share the large L2 cache.

In this configuration, applications executing on Core 0 compete for the entire L2 cache with applications executing on Core 1 (note that applications on the same core also compete with one another for the caches). If application A on Core 0 during normal operation uses data that maps to the same cache line(s) as application B on Core 1, then a collision occurs and must be corrected by the hardware.

As an example, suppose A's data resides in L2, and that B accesses data that happens to map to the same L2 cache line as A's data. At that point, A's data must be evicted from L2 (including a potential "write-back" to RAM), and B's data must be brought into cache from RAM. The time required to handle this collision increases B's execution time. Then, suppose A accesses its data again. Since that data is no longer in L2 (B's data is in its place), B's data must be evicted from L2 (including a potential "write-back" to RAM), and A's data must be brought back into cache from RAM. The time required to handle this collision increases A's execution time.

Most times, A and B will encounter such collisions infrequently. In those cases, their respective execution times are considered "average case" (i.e., ACETs). However, on occasion, their data accesses will collide at a high frequency. In these cases, the impacts of the worst possible flip-flopping of cache lines must be included as the "worst case" possible execution times (i.e., WCETs), as it can occasionally happen during normal execution, although infrequently.

When developing certifiable, safety-critical software, one must design and budget an application's execution time for worst-case behavior, since such software must have adequate time budget to complete its intended function every time it executes, lest it cause an unsafe failure condition. With the potential for multiple applications on multiple cores to generate contention for L2, WCETs on MCPs often are considerably higher than ACETs. Because certifiable, safety-critical applications must have adequate time budgets to accommodate their WCETs, this situation leads to a great deal of budgeted but unused time, resulting in significantly degraded CPU availability for time-critical tasks.

Cache Partitioning

Cache partitioning reduces WCET and increases CPU utilization by reducing L2 cache effects on single core systems, and cache competition effects on

3M

3M Defense
Problem. Solved.

Make helo blades repairable on-site in minutes.
Because out here, minutes matter.

3M™ co-curable composite protection films make helicopter blades more durable and repairable on-site. That means blades last longer. It means no more removing and shipping blades when they need minor repairs for erosion or impact damage to the surface. It means fewer extra blades laying around. All of which saves valuable maintenance time and money. For the military, both are at a premium. At 3M Defense, that's just what we do. We solve the military's toughest problems by drawing from our vast resources: people, technologies, products and processes. Find out how incorporating 3M erosion protection technologies into your aircraft can help keep you flying longer at **3Mdefense.com/aerospace**.

Free Info at http://info.hotims.com/49748-783

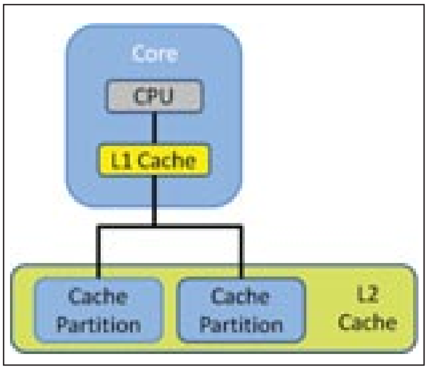


Figure 2. Single-Core Configuration with Cache Partitioning

multicore systems, thereby making it easier to bound and control interference patterns. By setting aside dedicated partitions of the cache for critical tasks (or groups of tasks), developers can reduce interference and provide timely, deterministic access to cache. This reduces the amount of time that must be budgeted for critical tasks by decreasing WCET, thus maximizing the "guaranteed" execution time available for safety-critical tasks.

Figure 2 shows conceptually how (in single-core operation) the large L2 cache can be separated into multiple partitions, thereby allowing a system integrator to isolate critical tasks from the cache effects of other tasks.

Additionally, as shown in Figure 3, the RTOS may partition the L2 cache such that each core has its own segment, or segments of L2, meaning that data used by applications on Core 0 will only be cached in Core 0's L2 partitions. Similarly, data used by applications on Core 1 will only be cached in Core 1's L2 partitions. This partitioning eliminates the possibility of applications on different cores interfering with one another via L2 cache data collisions. By limiting the cache interference, the application WCETs are much closer to its ACETs than is the case without cache partitioning in the system. Hence, by bounding and controlling these interference patterns, application execution times are more deterministic and time budgets can be set far more tightly, thereby keeping processor utilization high for time-critical tasks.

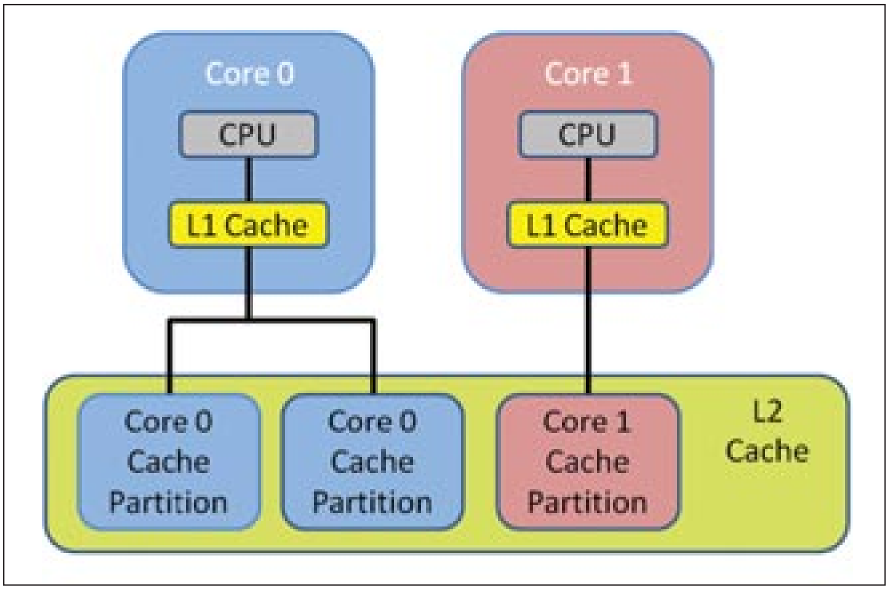


Figure 3. Dual-Core Configuration with Cache Partitioning

Test Environment and Applications

For the testing, actual flight software was used as a test application and the resultant execution times were measured over 1600 frames. Tests were run using single-core operation to highlight the severity of cache effects and benefits of cache partitioning in the more constrained single core environment.

As mentioned earlier, this single-core operation limits the cache impacts on critical tasks to the cache invalidates across context switches, and not the constant cache contention that can occur on a multicore system. On a multicore system, WCET degradation has been measured as 10X over the application's ACET.

Tests were run with and without a "cache trasher" application, which evicts test application data/code from L2 and "dirties" L2 with its own data/code. In effect, the cache trasher puts L2 into a worst-case state where different applications run concurrently and compete for the shared L2 cache.

Each test application was executed under multiple scenarios:

In scenario 1, the test application competes for the entire 512KB L2 cache

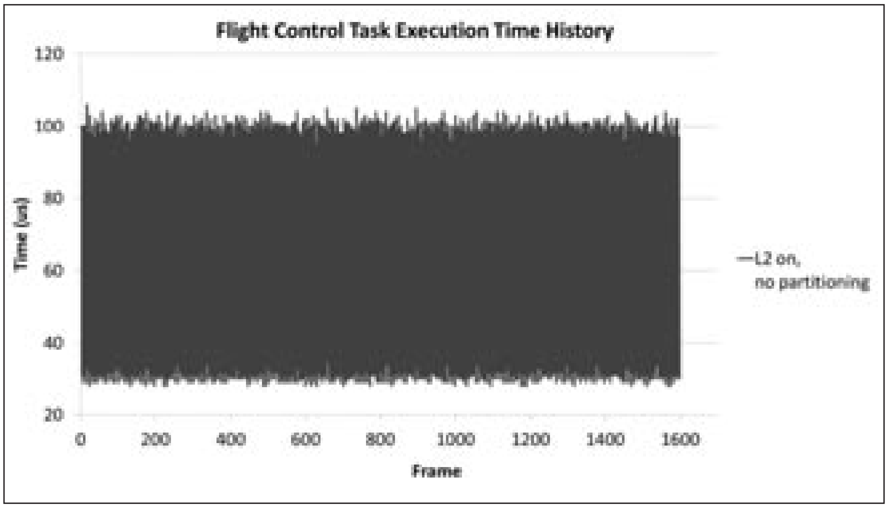


Figure 4. Possible Task Execution Time band in a system without Cache Partitioning

along with the RTOS kernel and a variety of tools. There is no partitioning or cache trashing. This test establishes baseline average performance, each test executing with average to minimal L2 contention.

Scenario 2 also omits cache partitioning, but adds cache trashing. Here, the test application competes for the entire L2 cache along with the RTOS kernel, a variety of debug tools and the rogue cache trasher. This test establishes baseline worst-case performance, each test executing with worst-case L2 interference from other applications, primarily the cache trasher.

In Figure 4, scenario 1 sets the lower band limit, and scenario 2 sets the upper band limit. The area between scenario 1 and scenario 2 represents the normal execution band of a fully loaded system.

Scenarios 3 and 4 are the same as scenarios 1 and 2, respectively, except that the L2 cache is turned off. The red band in Figure 5 shows the performance impact. Scenario 3 sets the low end of the band, scenario 4 the high end of the band. The area between represents how a typically loaded system would be expected to perform if the L2 cache was turned off. Note that best-case scenario 3 performance declines with respect to scenario 1 due to the disabling of the L2 cache. Meanwhile, the worst-case response time for scenario 4 (WCET) improves with respect to scenario 2, as the performance penalty of the cache trasher is limited to the L1 cache.

Scenarios 5 and 6, depicted by the green band in figure 6, add cache partitioning. As the figure shows, partitioning the L2 cache among applications reduces the amount of cache available to each application, thereby reducing average performance. At the same time, however, partitioning the cache also reduces cache contention, which bounds worst-case execution. In this way, cache partitioning strikes a balance, enabling applications to benefit from the cache, but in a way that drastically reduces WCET.

Note that it is possible for applications executing in the same cache partition to interfere with each other. However, such interference is much easier to analyze and bound than the unpredictable interference patterns that may occur between all applications executing on a single core or different cores with a completely shared cache. If necessary, in those situations, applications could be mapped to completely isolated cache partitions.

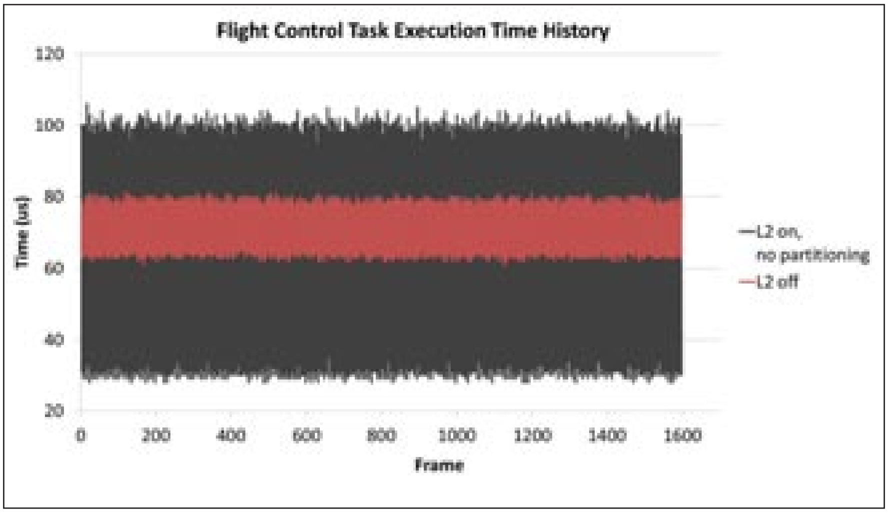


Figure 5. Possible Task Execution Time Band in a system with Cache Disabled

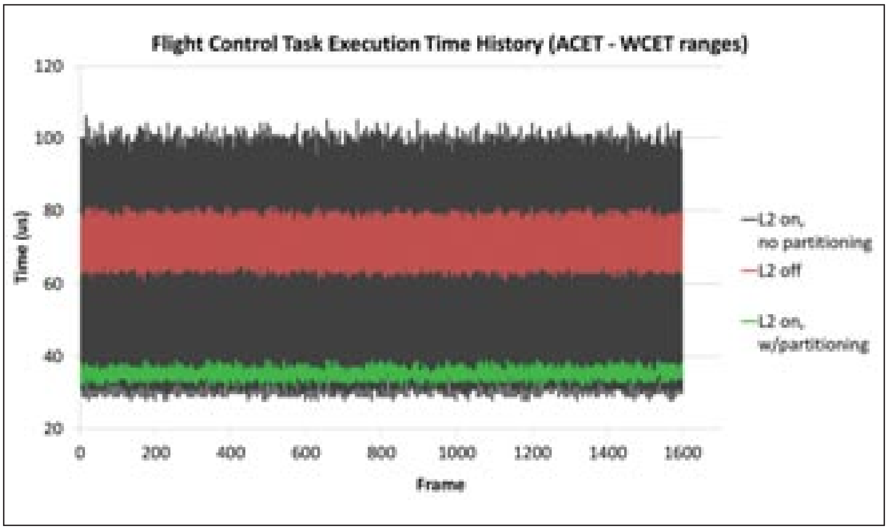


Figure 6. Possible Task Execution Time Band in a system with Cache Enabled and Cache Partitioning

The benchmark results clearly demonstrate that cache partitioning provides an effective means of bounding and controlling interference patterns in shared cache. Though the benchmarks are run on a single core processor, the results would only be amplified greatly if the benchmarks were run on a multicore CPU, where multiple cores would be contending for the same shared cache constantly during normal process execution. Ultimately, worst-case execution times are bounded and controlled much more tightly when the cache is partitioned. This enables application developers to set relatively tight, yet safe, execution time budgets for the tasks thereby maximizing processor utilization in both single- and multicore devices.

This article was written by Greg Rose, VP of Marketing and Product Management, DDC-I, Inc. (Phoenix, AZ). For more information, visit ***http://info.hotims.com/49748-500.***

Next-Generation Mobile Tactical Communications

Figure 1. Mobile device tethered to tactical radio

After many years of development and well-publicized budget overruns, the DoD's Joint Tactical Radio System program (since reorganized and renamed) has recently given birth to a set of handheld voice and data radios — so-called Rifleman radios — built by a number of traditional military radio firms, including Exelis, GD, Harris, and Thales.

Here are some key differences between a Rifleman radio and a modern smartphone:

	Rifleman Radio	Smartphone
Modern Graphical Interface and Apps	No	Yes
Wireless Speed	1 Mbit/s	100 Mbit/s
Application Microprocessor Speeds	Up to 800 MHz	2+ GHz
NSA Type-1 Cryptographic Certification	Yes	No
Approximate Per-Unit Cost	$5,000	$500
Can Speak DoD Tactical Waveforms	Yes	No

Because of their scale, smartphones outpace tactical radios in processing power by a significant margin and at significantly lower production cost. Yet tactical radios require custom radio hardware and software for military environments that would never be of interest to smartphone manufacturers. Rifleman and its associated waveforms were designed strictly for a military combat environment, where robust push-to-talk voice operation is by far the highest priority.

Nevertheless, the advent of smartphones has driven military leadership to consider how best to utilize them. Powerful graphical environments have enabled a new generation of situational awareness applications, but the mobile devices' relatively weak security and inability to communicate on resilient military networks prevent them from being used directly for tactical communications. Instead, smartphones must be tethered to rifleman radios, using the radio's USB data port for sending maps and other data, but still relying on the radio itself for voice input, encryption, and link-layer transceiving (Figure 1).

At an order of magnitude higher in price than a smartphone, governments do not have the budget to enable all field personnel with tactical radios. Today, tactical radio possession ends at the platoon, or at best, squad leader, leaving other team members devoid of the valuable capability.

A next-generation mobile tactical communications solution would ideally meld the tactical radio and modern smartphone worlds, creating a solution that enables:

- Powerful apps associated with modern mobile computing;
- Ability to communicate on military tactical networks; and
- Low cost, so every soldier can have one.

One might wonder why modern smartphone features cannot be simply added to the military radios, imbuing them with improved processing power, battery life, and graphical interfaces. This is not a feasible option because military radio development cycles are much longer than commercial smartphones, due to the need to follow tedious government contracting and certification processes. By the time a military radio actually ships in production quantities, commercial smartphones have evolved several cycles and are multiple generations ahead in hardware and software technology. Instead of trying to fit a square peg in a round hole, we consider a solution in which commercial smartphones are maximally leveraged with a cost and scope-reduced tactical radio.

Two important recent technology revolutions are making this vision possible: NSA CSfC cryptographic solutions and mobile security powered by separation kernel-based hypervisors.

CSfC

Launched in 2012, the NSA's Commercial Solutions for Classified (CSfC) program aims to leverage commercial off-the-shelf solutions to secure classified government networks and information. CSfC is a sharp change from the traditional approach of designing and building expensive government-purpose cryptographic communications equipment.

One of the key principles of CSfC is to implement multiple independent layers of commercial cryptographic products to replace a traditional, single-layer government cryptographic solution. For example, to send classified information over an open network (e.g. the Internet), the traditional government approach is to use a government-certified in-line encryptor, such as TACLANE or Talon. The encryptor contains specialized encryption hardware and software and undergoes a rigorous development and approval process (Type-1 NSA certification). Some Type-1 encryptors are orders of magnitude more expensive than commercial encryption products.

An example CSfC replacement for Type-1 encryptors is a dual-layer VPN, as described in the CSfC program's Virtual Private Network (VPN) Capability Package. In this approach, classified information is encrypted twice, using two commercial VPNs, each of which must be certified to commercial quality standards (e.g. FIPS 140-2 certification) and supplied by different vendors (Figure 2).

The individual products used in CSfC-composed solutions are developed for the larger commercial enterprise and therefore are much lower-cost and not dependent upon or subject to the same government funding and certification overhead used for traditional Type-1 systems. For example, a dual CSfC VPN solution might be composed of standard enterprise Cisco and open source StrongSwan products.

Separation Kernel-Based Hypervisors

Commercial, off-the-shelf bare metal mobile hypervisors have been deployed in standard consumer smartphones and tablets for several years, and the USMC (via its Trusted Handheld, or TH2, program) recently took a leadership role in applying them to improve mission capability while reducing total cost of mobile computing for the government. Mobile hypervisors provide strong isolation between the mobile OS (e.g. Android) and other execution environments (e.g. security components or even a second Android instance) that must be protected even if the Android OS itself is vulnerable and exploited by malware or remote attacks.

TH2 worked with mobile hypervisor technology from Green Hills Software, whose virtualization approach leverages high assurance INTEGRITY separation kernel technology that has been deployed for many years in critical commercial embedded systems, such as medical equipment, industrial controls, and avionics. The hypervisor enables multi-domain use of a single device as well as application of CSfC-compliant data protection. Green Hills' technology powers the basis of Samsung's commercial enterprise mobile hypervisor offering called Samsung KNOX Hypervisor. Figure 3 shows how dual-layer data-at-rest (DAR) and data-in-transit (DIT) can both be implemented using the Samsung KNOX hypervisor to provide a layer of isolated security beyond the mobile operating system itself.

Samsung KNOX Hypervisor can host two mobile OS instances. Under the auspices of the TH2 program, this solution became the first commercial solution to be approved for simultaneous access to the open Internet as well as sensitive government networks (Figure 4), in late 2013.

Applying TH2 to Tactical Radio Communications

USMC recognized that Samsung KNOX Hypervisor provides an extensible execution environment for other critical processing. Developers from Green Hills are now working on an application of this environment to offload some of the tactical radio processing onto the powerful mobile device. The mobile device can then be conjoined with a reduced footprint tactical radio to create a single unit that has the power and flexibility of the modern smartphone or tablet, yet communicates seamlessly on traditional military tactical networks.

A standard tactical military radio, such as the rifleman, includes three main processing environments: a red-side subsystem, a cryptographic subsystem, and a black-side subsystem. Human voice (push-to-talk) enters into and is processed by the red-side subsystem. This data is then encrypted by the cryptographic subsystem before it is transmitted by the black-side subsystem, responsible for all link layer functions. Figure 5 shows the traditional red-black tactical radio architecture.

The cryptographic subsystem is a traditional government-purpose Type-1 component (not CSfC) and is costly to develop and certify. The black-side components include special purpose digital signal processing hardware and algorithms that cannot be easily offloaded onto the general-purpose applications processing hardware on the mobile device. The red-side processing, however, lends itself well to the smartphone execution environment. Fur-

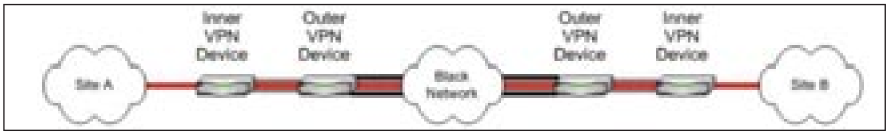


Figure 2. CSfC dual VPN approach

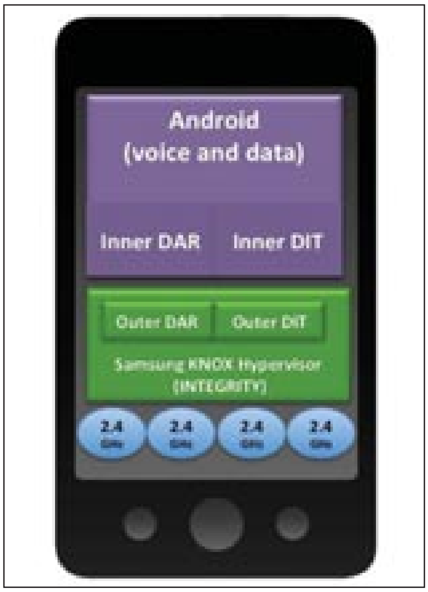


Figure 3. CSfC approach within Samsung KNOX Hypervisor

Figure 4. Example dual domain TH2 Architecture

thermore, the Type-1 cryptographic subsystem can be replaced with a CSfC approach that has already been developed and deployed on the smartphone.

Figure 6 shows the notional concept of a scope and cost-reduced tactical radio, wherein only the black-side processing remains, and the red-side and cryptographic subsystems have been offloaded as additional software applications on the hypervisor-powered smartphone. Furthermore, because the radio hardware is so much simpler, it can be manufactured into a smaller, more flexible form factor, such as a sleeve or attachment on the smartphone itself, enabling the warfighter to carry them easily as a single unit. When the smartphone is connected to the sleeve, the smartphone's built-in communications peripherals are disabled, and all communication is routed to the radio. Even push-to-talk voice can be handled by the smartphone, reducing the complexity of the radio and providing the warfighter with the most modern graphical interface and application environment possible.

This article was written by David Kleidermacher, Chief Technology Officer, Green Hills Software (Santa Barbara, CA). For more information, visit ***http://info.hotims.com/49748-501***.

Figure 5. Traditional red-black radio architecture

Figure 6. Conjoined TH2 with offloaded radio functions and cost-reduced tactical radio/sleeve

Commercial Programs Are Flying High

With economic regeneration underway this year, the rate of ordering new aircraft has been at an all-time high, with the result that backlogs for undelivered new production stretch well into the next decade for some popular models.

by Richard Gardner

An Airbus A350 XWB starting its flight test program. (Photo by e^{x}m company/P. Masclet).

Boeing and Airbus can hardly keep up with demand for 150-seat jets, and both have increased their own monthly production rates to well over 40 aircraft, stretching the capacity of the supply chain to the limit.

The surge in demand is across the broad spectrum of jetliner designs and sizes, and even business jet sales are on the increase again. Yet despite this multi-billion-dollar global demand for new commercial aircraft, the attempts by new entrants in Japan, Russia, and China to take on the existing aerospace leaders have so far failed to make a serious impact beyond their own home markets.

Such is the potential cost-of-market entry at the top end of the commercial sector, that Boeing and Airbus are most unlikely to have to face serious global competition for at least a decade or two.

Airbus and Boeing are continuously developing future aircraft concepts that combine advanced aerodynamics, structures, materials, engines, and systems, so as the time approaches for a current production model to face replacement, the next product is already identified with major aspects of the design already de-risked to a large degree.

This procedure typically takes between 10 and 20 years, but as technological advances mature in shorter timescales, the preferred route for major programs in recent years has involved evolutionary steps rather than giant leaps in technology.

Head-to-Head Battles

The Airbus A330 widebody twin, of which over 1,000 have been delivered, continues to sell well even though its planned replacement, the more advanced A350, is in production and will start to be delivered later this year.

The new assembly facility at Toulouse will be capable of ramping up production rates from two to 10 aircraft a month. The A350 was originally to be a relatively modest upgrade of the A330-200, but due to increased competition from Boeing's all-new 787, Airbus started again from scratch calling it the A350 XWB (Extra Wide Body) to exploit improved engine efficiency and an all-new wing and fuselage with a wider cabin cross section.

Customers liked the changes and soon after launch, the sales total had climbed past the 500 mark and now has achieved over 800 firm sales. With five test flight prototype aircraft engaged in the certification procedure, the A350 has undergone hot-and-high as well as cold-soak trials, and the first aircraft fitted with seats and fully representative cabin systems is involved in long-haul flight tests.

Qatar Airways will be the first to take delivery before the end of this year and has ordered 80 A350s in two versions. Airbus currently offers the aircraft in three different sizes: -800, -900, and -1000, the latter designed to compete more directly with the 777.

In the meantime, Airbus is considering airline requests for an upgraded A330 that might see a new engine fitted, but with minimum other changes. It could potentially help fill a gap in the market for a 250-seat replacement for earlier A330 and 767 models. Integrating a new engine on the A330 while keeping it affordable would be a major challenge, however, and Airbus will not wish to divert too many sales away from the slightly larger A350.

Boeing's 767 remains in production after 32 years, currently as a cargo aircraft since passenger sales were completed recently, but production of this model is to be concentrated in the future on the KC-46A military tanker variant for the U.S. Air Force.

The company faces a dilemma over how best to replace its 200-250 seat 757, which also dates from the 1980s but is long out of production. Boeing could shrink its 787-8, and this would offer a good long-range capability, but the economics of taking out seats and cargo capacity is usually an unattractive business proposition compared to stretching a design.

Another option for Boeing might be to further stretch the capacity of the 737-900 Max, but this would not offer the 4,000-5,000 mile range of the 757, and might require an engine thrust increase and further landing-gear modifications.

The 737 family seems to go from strength to strength, especially for a design that first emerged in 1964. Successive makeovers, aerodynamic changes, and re-engine upgrades have led to a continuous customer demand for the 737 lasting over half a century, a world record for a production jet airliner.

The latest 737 Max series has now achieved a backlog of over 2,000 sales, with a first delivery of the latest Max-8 due in 2017. The direct Airbus rival, the re-engined A320neo, has so far won orders for over 2,600 aircraft. By the end of this year, the combined 737Max/A320neo sales backlog will certainly exceed 5,000 aircraft, in addition to current production 737NG and A320 aircraft yet to be delivered, representing an all-time high that is certain to keep production lines flowing through the rest of this decade and the next.

Both manufacturers once envisaged that new replacement designs would become available in the early 2020s, but such is the undiminished pace of demand for this pair of highly reliable and efficient people-movers, that there seems no prospect of any all-new replacement anytime soon. The rapid growth of low-cost carriers around the world has fueled demand for 150-seat aircraft and now this is being added to the need for replacements for earlier 737s and A320s, some of which may be over 25 years old.

An Airbus A380 in production at Toulouse.

Russian-Italian-French Sukhoi SSJ100 Superjet.

Bombardier's C Series 300 in Atlasjet livery.

To have sufficient customer appeal to break the 737/A320 market stranglehold, the next-generation designs will have to offer a really significant advance in performance in terms of fuel efficiency and environmental benefits. This will probably dictate unconventional aerodynamics with integrated powerplants.

Airbus has indicated the direction it is going toward such futuristic configurations, exploiting new materials and concepts including open rotor engines and hybrid powerplants, as has Rolls-Royce. Boeing has given away little to indicate its preferred future vision (which is, however, known to include integrated wing-fuselage and open rotor designs).

The Boeing 787 has overcome its earlier lithium battery problems and now the new stretched -9 is also rolling off the final assembly lines and about to enter commercial service with the first customer, Air New Zealand. The 787 represents a big step forward for Boeing, with such a large proportion of composite structure and an advanced wing design, which contribute to weight reduction resulting in its impressive long-range performance. The 787 covers the seat capacity range of between 250-320 seats, whereas Airbus's A350 is slightly larger, offering between 270-350 seats.

Boeing faced a challenge in what to do to retain its market leadership with the high-capacity, long-range 777-300ER, which has sales of over 700 aircraft to date, so when it launched the new 777-X family last year, it had to offer a new product that would go beyond a mere upgrade. The resulting 777-8X and 777-9X feature an all new composite wing; new engine, the GE9X; and many cabin features taken from the 787.

As ultra-large fan engines increased in reliability as well as thrust and fuel efficiency, the case for the classic four-engine, long-haul aircraft fell apart. Airlines took one look at what the 777-300ER and 777-200ER could achieve with just two engines, and the days of the 747 and A340 were numbered.

With a maximum mixed class capacity of over 400 seats — approaching that of the much larger, thirstier, and heavier 747-400 — the popularity of the 777 as a jumbo replacement had already been proven. The Airbus A340, with its four engines, was promoted as the ultimate very-long-range airliner, with an added safety factor on lengthy over-water sectors, but such has been the reliability of the 777 and A330 big twins, that operating four-engine aircraft is no longer competitive.

Is Big Beautiful?

When Airbus made the case for its double-deck A380, there was a widespread belief in the airline community that while it looked like a natural 747 replacement, offering the potential in a stretched version for up to 1,000 seats, the most prudent course of action might be to "wait and see" before committing to such a leap in capacity.

With the subsequent market domination of long-haul routes by twin-engine widebody aircraft, the A380 has had to struggle at times to maintain a sales momentum since entering service in 2008, but today nearly 330 have been ordered and the backlog of around 200 aircraft

The Boeing 737 remains the world's biggest-selling jetliner after a production career of nearly 50 years. (Richard Gardner) yet to be delivered will keep the production lines busy for many years ahead.

The present A380 is well short of its ultimate design stretch limits and is flying with plenty of development potential ahead of it, but nevertheless is currently selling relatively slowly, as is Boeing's relaunched super-jumbo, the 747-8. Once passenger capacity rises much above 600 seats, handling issues can arise at many airports, in terminals, and in parking slots, and this has discouraged airlines to press either company for even bigger versions of these aircraft.

In February this year, the London-based leasing company Amedeo ordered 20 A380s and is in discussion with Airbus with a view to fitting 11-abreast economy seating in a four-class configuration that would take a total of 600 passengers. Emirates is planning to fit 617 seats in a 10-abreast, two-class layout, while Russia's Transaero is intending to fit out its A380s with 652 seats. In an all-economy layout, the standard A380 has certified sufficient exit doors so that it could accommodate over 800 seats.

The latest Boeing 777-X, which will be able to accommodate over 400 passengers, features increased wingspan with folding wing tips to try and avoid access and parking problems when docking at terminals, but whether this becomes a standard operating procedure remains to be seen. Ground handling a stretched A380 would challenge many airports.

Eastern Promise?

Russia and China share a common desire to build more aircraft for their own domestic airlines, which currently are meeting new capacity needs by buying Western aircraft. Joint venture and cooperative agreements are in place with many Western suppliers to use modern engines and new-generation avionics to enhance customer confidence in the new aircraft, but now that both Airbus and Boeing are embarked on developments of their own 150-seat aircraft, the claimed efficiency benefits of the rival Irkut MS-21 and Comac C919 are no longer quite so special.

Plans for a new family of widebody Sino-Russian commercial jets are still under discussion and if built, will probably be assembled in China. Russian design input would include experience gained from its previous widebody Il-96 airliner, which was an A340 look-alike but was only produced in very small numbers with negligible export sales.

China would like to make the new widebody, known as the C929, a twin-engine aircraft. Its new narrow-body twin, the C919, falls into the same size category as the A320 family, which highlights the degree of ambition in China to establish a global aerospace capability, bearing in mind that the nation already assembles complete A320s at the Airbus plant in Tianjin in partnership with AVIC.

The first C919 is now in production and is due to make its first flight before the end of this year. Comac has been really struggling for years to bring its ARJ21 regional jet out of development through certification and into service in China, even though it is a very dated design, based on a long abandoned joint program with the U.S., which took the MD-95 as the baseline for the project.

Agreements have been signed between Comac and Bombardier that will see Canadian assistance on marketing and supporting the ARJ21, as well as deeper technical help and general promotional support on the C919 alongside Bombardier's work on its new C Series 130-seat regional jet.

Big Regionals

Russia adopted many Western systems, including a French-Russian engine, the PowerJet SaM146, on its new Superjet 100, built by Sukhoi in cooperation with Italy's Alenia Aermacchi, to widen the export appeal. It is now in service with several Russian airlines, including Aeroflot, and has been exported to Mexico's Interjet.

The aircraft has a high-tech specification with a very spacious interior and cockpit, with the latest displays and avionics. But in the face of massive competition from Embraer and Bombardier in global markets, the SSJ100 has had a hard time winning substantial orders, even

The Comac 919 is being developed as a new Chinese rival to the A320, which is also assembled in China. (Richard Gardner)

Russia's MC21 is being developed as a family in the 150-200 seat category. (Richard Gardner) though some 40,000 flight hours have now been achieved with all operators.

Bombardier has also been suffering from extended development delays on its all-new C Series. The C Series looks almost identical to the SSJ100 but is also being offered in a stretched version that could carry 149 passengers. This program has been a very expensive gamble for Bombardier, as it lifts its regional family of jets into a category that also competes with the lower end of the 737 and A320 families as well as the Embraer E-Series and SSJ100.

Delays have postponed the C Series' scheduled entry into service until the second half of 2015, and it is now using four test aircraft to work toward clearance for the fly-by-wire system and certification next year. So far, just over 200 firm sales have been announced.

Even further delayed in development, Japan's MRJ from Mitsubishi was originally offered as a "next-generation" regional jet featuring a structure with very high composite content and the "then-revolutionary" PW1200G geared turbofan engines. Years later, the program is still at the structural test stage, with first flight now scheduled for 2015.

While these delays have been significantly lengthening the development timescale of the MRJ, Embraer in Brazil has launched its new re-engined and re-winged E2 Series offering capacity from 175-120 seats. The high-aspect-ratio wing design promises to provide ultra-high performance, and with new cockpit and cabin features and P&W GTF engines, the E2 looks destined to take a lion's share of this market over the next decade. It follows on from sales of more than 1,000 E175, E190, and E195 regional jets that makes it a leading contender in this sector.

Embraer's new E2 Series will feature a high-aspect-ratio wing design and a new cockpit, and will follow on from the sales of more than 1,000 E175, E190, and E195 (shown) regional jets

3-D Manufacturing of Titanium Components Takes Off

MRO providers are discovering ways to innovate their procedures while remaining viable and profitable through the current downturn in government spending.

With such challenges as base closings, shrinking defense budgets, and sequestration, the worldwide maintenance, repair, and overhaul (MRO) sector is projected to experience a significant decline over the next few years.

According to Hal Chrisman, leading analyst and Vice President at aviation consultancy ICF SH&E, "it appears that defense operations and maintenance spending will drop nearly 8%." He added "forecasting, which is especially critical in the aftermarket world, is very tricky this year."

Underscoring this problem, international aerospace and defense consultants IHS stated in their report, Overcoming MRO Supply Chain Dysfunction, "Look closely at the product lifecycle within the typical MRO organization and you'll notice that 50% of open work orders are waiting for parts; 30% of in-house stock will never be used; 8% of SKUs are duplications; and, on average, employees spend 25% of the workday looking for parts."

Parts management becomes even more critical as the military fleet ages and consumes all available replacement parts. MRO operators must face difficult financial choices in controlling these costs: either replicate components such as those made from titanium from scratch through a lengthy and costly remanufacturing effort, or delay those expenses by cannibalizing other aircraft for "used" replacement parts, thereby decreasing the reliability of repaired aircraft while rendering some aircraft unflyable.

This landing gear knuckle illustrates how electron beam melting (EBM) technology can be used to produce one-of-a-kind parts rapidly without any tooling. Since the part is built layer-by-layer, the microstructure is completely uniform regardless of whether a thick section or thin section is examined. This homogeneous microstructure translates into uniform, consistent mechanical behavior. The material possesses complete isotropy. Thermal shunts fabricated as the part is being built (visible on the part) are used to keep the temperature isothermal and are easily broken off after the part has been built. (All images: CalRAM)

Tool-less Additive Manufacturing

To address such issues, a cost-effective manufacturing technology is being applied to titanium parts manufacturing for the MRO, aviation, and defense in-

This warm air mixer is a component designed by Northrop Grumman for the U.S. Navy's unmanned combat aerial surveillance system. CalRAM fabricated this complex component in one piece from Ti-6Al-4V using its EBM technology. If traditional manufacturing processes were used, this component would have been made in several pieces that would have had to be joined. The demonstration of part count reduction without the need for tooling illustrates how additive manufacturing can be used to reduce cost and shorten delivery schedule.

dustries. CalRAM fabricates 3-D, near-net-shape components by melting titanium (and other metal) powders one-layer at a time using an electron beam. Employing electron beam melting (EBM) machines built by Arcam, CalRAM's tool-less additive manufacturing technology is said to "rapidly create solid titanium objects faster and with less cost than traditional methods."

Located in Simi Valley, just north of Los Angeles, CalRAM says it is the only independent AS9100C certified, EBM-based manufacturer in the U.S. Offering this technology to MROs and other suppliers in the aviation and aerospace industries, the company has been producing titanium components for airframe primes and gas turbine engine aircraft manufacturers for almost a decade.

During CalRAM's manufacturing process, electron beam paths are defined by proprietary software that "slices" existing 3-D design models into a series of separate layers, much like the views in a modern CAT scan. Powder is spread on the "start plate" by a traversing rake in the build chamber and then sintered to the plate using heat from the electron beam.

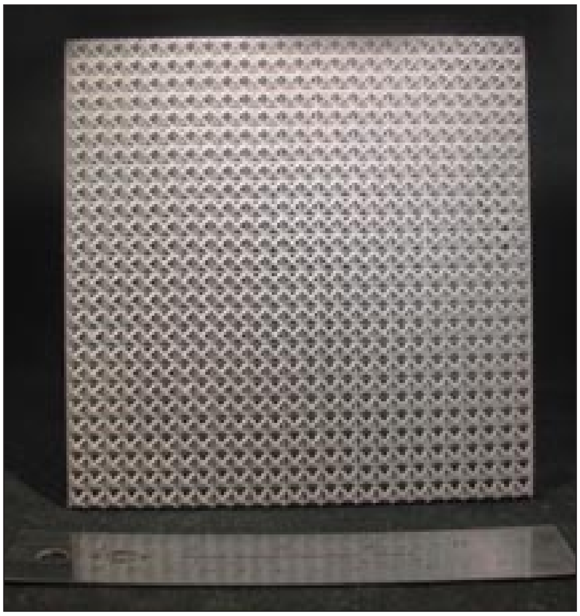
After the layer is sintered to ensure a conductive path for the electrons, the beam passes over the surface a second time at higher energy to melt and consolidate material that will form the finished part. This process is repeated, layer-by-layer, until the entire part is complete. Since parts are formed directly in the powder bed, EBM is fast with maximum build times less than 60 hours. And because EBM requires absolutely no custom tooling, the company's layer-built components can save 85 to 90% of the MRO operator's cost for replacing titanium products.

The process is said to also save designers up to 90% of their development time by substantially compressing the "design-test-redesign" process as well. After receiving the customer's CAD file, CalRAM can deliver a titanium component in about two weeks, making development hardware available for installation and testing in days instead of months. Further iterations, if required, follow the same path, significantly reducing a client's time to market.

A pump-fed, liquid rocket engine uses Shrouded impellers in the turbo pumps for high-efficiency pumping, and they are generally made from high-value materials, like titanium alloys, because of their high specific strength. As such, they are extremely expensive to produce and may take several months or longer to be made. Using EBM technology, they are producible in days and have been shown to meet or exceed burst speeds.

Speed and lower manufacturing costs are not the only benefits of CalRAM's EBM manufacturing process. With additive manufacturing, "complexity is free." To save weight and improve performance, engineers have almost complete geometric freedom to include otherwise impossible-to-fabricate elements such as holes, stiffeners, overhangs, and meshes in their designs.

Iso grid and lattice block structures are actually cheaper to manufacture than less complex designs because they use less material and therefore take less time to produce. In one example, the company built a warm air mixer for Northrop Grumman's unmanned combat aerial system that is being

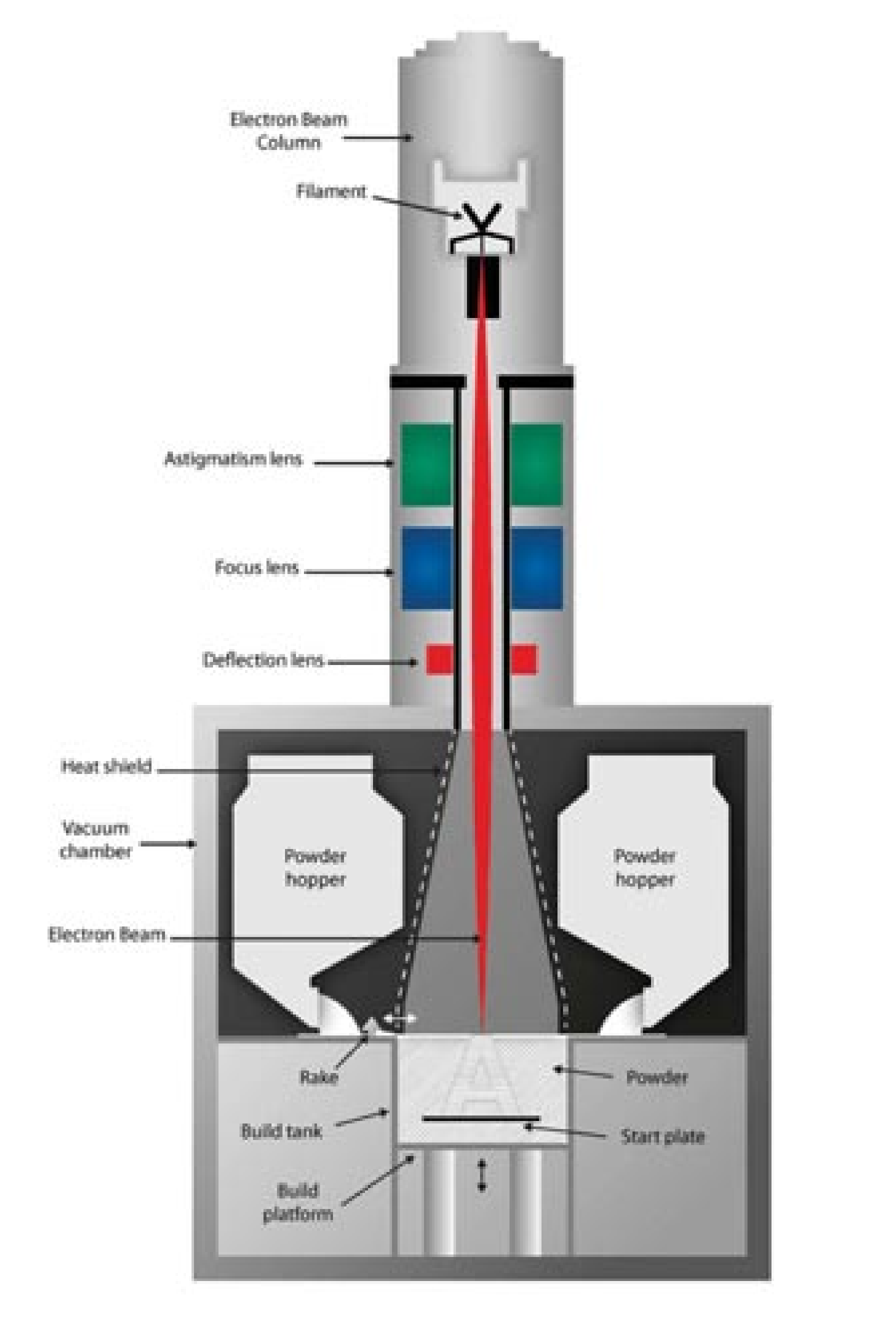


This mesh structure shows the level of detail that can be generated by CalRAM's EBM manufacturing technology. This useful feature for removing weight allows for very high specific properties (strength/density, stiffness/density) to be generated. The mesh structure can also be used to produce a surface with controlled porosity, allowing for enhanced bonding to composites.

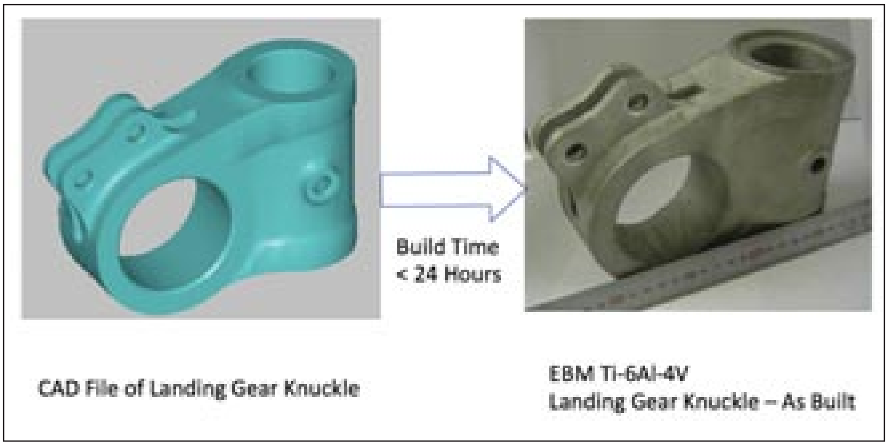
developed for the U.S. Navy. The layer-built component resulted in part count reduction and elimination of post-production assembly costs and time while still being able to meet all of the engineering design requirements.

EBM Advantages Over Laser Melting

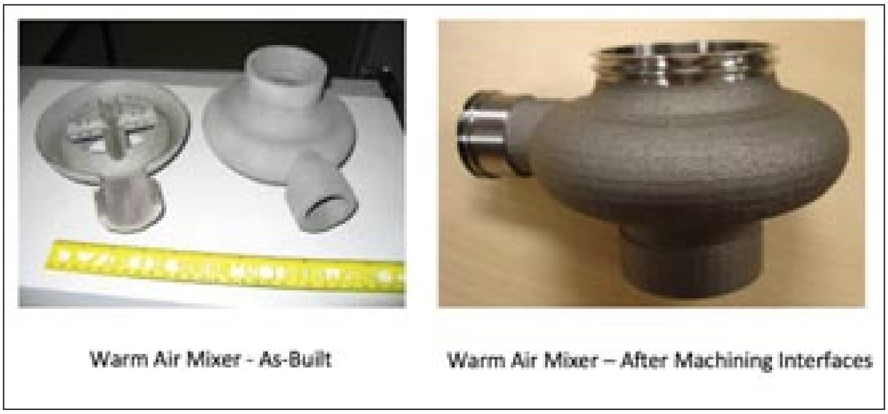
The EBM fabrication process CalRAM has implemented is generally a higher-quality alternative to laser melting manufacturing for titanium components. Operating in a vacuum instead of



The design freedom offered by EDM technology can be used to achieve exceptional strength-to-weight ratios, shorten R&D time, and minimize additional operations. It is particularly suited to prototyping and short-run manufacturing processes, as it offers the material properties of machined titanium with the benefits of design complexity that is impossible to achieve any other way.



With EBM, engineers can take a CAD file for a titanium component and produce a part in under 24 hours.



When the parts are cleaned they are typically sent to a hot, isostatic press (HIP) facility, where the high pressures and elevated temperatures heal any internal micropores, thus increasing product fatigue life. After HIPing, parts are either delivered to the customer or if required, sent out for additional finish machine operations such as grinding, drilling, spot machining, or chemical milling.

an inert gas environment, EBM minimizes oxygen contamination of the titanium melt, leading to improved microstructure with excellent mechanical and physical properties.

The high temperatures used during EBM (700°C for titanium and up to 1000°C for other materials including nickel-based superalloys) leave parts stress-free after cooling, eliminating the need for separate post-build thermal treatments to develop full titanium mechanical properties.

Also, because of the higher energy of the electron beam compared to a laser (3 kW vs. 700 W), EBM is much faster than laser-based processing, producing material at rates up to five times that of laser methods.

Although titanium is often the best material for certain aircraft applications, the metal's high costs, design challenges, and lengthy time-to-design have often prevented its use. Consequently, whenever possible, engineers have selected machined or investment cast aluminum as an alternative material (with appropriate design modifications to adjust for the metal's lower strength), or heavier steels when aluminum was not a satisfactory replacement.

With EBM additive technology, engineers can reconsider using titanium over more of the aircraft, given the cost and schedule benefits of the process.

More on the EBM Process

The process starts with a customer's CAD file. Following a series of proprietary design rules to ensure parts can be built successfully in the Arcam machine, CalRAM technicians lay out the required part in a virtual build space. Temporary features may be added to provide physical support to the part as it takes shape during the build.

The product's formation begins after the chamber is heated to build temperature, when the first layer of powder (typically 50–70 μ thick) is spread over the start plate by an internal rake. All of the material in the first layer is sintered to the start plate and when melted in place, becomes part of the finished assembly.

After the melt layer is complete, the start plate is lowered the thickness of a single layer, the rake distributes fresh powder, and the cycle continues. When the part is complete, the material is allowed to cool in the machine chamber.

The "brick" containing the parts is removed from the machine and sent to the powder recovery station where sintered powder is separated from the finished parts. When the parts are cleaned, they are typically sent to a hot, isostatic press (HIP) facility, where the high pressures and elevated temperatures heal any internal micropores, thus increasing product fatigue life.

After HIPing, parts are either delivered to the customer or if required, sent out for additional finish machine operations such as grinding, drilling, spot machining, or chemical milling. Delivery time for parts that are HIPed, and don't require additional finishing operations after fabrication, is usually three weeks after receipt of order.

In addition to 6Al-4V titanium, CalRAM can also "print" commercially pure titanium, cobalt-chrome steel, gamma titanium aluminide, and nickel-based super alloys including Alloy 625 and Alloy 718. The EBM industry has also conducted fabrication experiments with copper, Invar, and aluminum, so that these materials may be available for EBM fabrication in the future.

This article was written for Aerospace & Defense Technology *by Dave Ciscel, Director of Engineering and co-founder of CalRAM Inc.*

New Technique Could Make Sub-Wavelength Images at Radio Frequencies

Imaging and mapping of electric fields at radio frequencies (RF) currently requires the use of metallic structures such as dipoles, probes, and reference antennas. To make such measurements efficiently, the size of these structures needs to be on the order of the wavelength of the RF fields to be mapped. This poses practical limitations on the smallest features that can be measured.

New theoretical and experimental work by researchers at the National Institute of Standards and Technology (NIST) and the University of Michigan suggests an innovative method to overcome this limit by using laser light at optical wavelengths to measure and image RF fields. The new technique uses a pair of highly stable lasers and rubidium atoms as tunable resonators to map and potentially image electric fields at resolutions far below their RF wavelengths (though not below the much shorter wavelengths of the lasers).

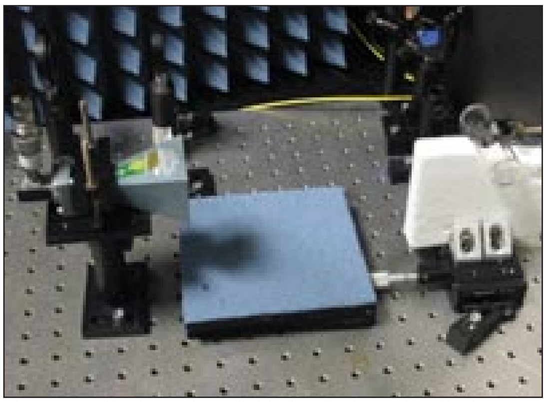
This advance could be useful in measuring and explaining the behavior of metamaterials and metasurfaces — structures engineered to have electromagnetic properties not found in nature, such as the illusion of invisibility. Imaging with sub-RF wavelength resolution also could help measure and optimize properties of densely packaged electronics and lead to new imaging sensors.

Typically, RF field measurements are averaged over antenna dimensions of tens of millimeters or more. NIST's prototype technique has resolution limited by the beam widths of the two lasers used — in the range of 50 to 100 micrometers. The technique was used to map RF fields with much longer wavelengths of 2,863 and 17,605 micrometers — frequencies of 104.77 gigahertz and 17.04 gigahertz, respectively.

The NIST and Michigan researchers mapped field strength as a function of position at resolutions as low as one-hundredth of an RF wavelength, far below normal antenna limits. Such data might be used to make colorized 2D images. In theory, the technique should work for wavelengths ranging from 600 to 300,000 micrometers.

The rubidium atoms are in a hollow glass cylinder, which is traversed down its length by two overlapping laser beams that act as stimulants and filters. First, a red laser excites the atoms, which initially absorb all the light. Then, a tunable blue laser excites the atoms to one of many possible higher energy ("Rydberg") states, which have novel properties such as extreme sensitivity and reactivity to electromagnetic fields.

Next an RF field — at the frequency to be mapped or imaged — is applied. This field alters the frequency at which the atoms vibrate, or resonate, altering the frequencies at which the atoms absorb the red light. This change in the absorption is easily measured and is directly related to the electric field strength at that part of the cylinder. By moving the cylinder sideways on a track across the narrow laser beams, researchers can map the changing field strength across its diameter. The blue laser can be tuned to excite the atoms to different states to measure the strength of different RF frequencies.


The new method uses laser light at optical wavelengths to measure and image RF fields.

The project is funded in part by the Defense Advanced Research Projects Agency (DARPA). Visit ***www.nist.gov/pml/electromagnetics/subwave-061714.cfm*** *to learn more.*

Proven Performance of GORE-FLIGHT™ Microwave Assemblies

A recent study conducted for the aerospace industry showed that more than 29 percent of microwave assemblies fail during installation, and aircraft manufacturers have accepted the practice of simply replacing them. However, with the need to decrease costs, they can no longer afford the total cost associated with assemblies that cannot withstand the installation process and the extreme conditions of aerospace. Manufacturers need assemblies that provide the same level of electrical performance before and after installation as well as throughout their service life.

Performance Testing with an Installation Simulator

W. L. Gore & Associates (Gore) has designed a simulator to evaluate the stress of installation on microwave airframe assemblies. The simulator has several features that replicate minimum bend radius conditions, routing guides that induce torque, and an abrasion bar to simulate routing across sharp edges or through access holes in the airframe structure.

The simulator enables Gore not only to evaluate the electrical performance of various cable assemblies after installation but also to design products that meet real application challenges. Testing electrical characteristics such as insertion loss and VSWR before and after routing through the simulator verifies whether an assembly can withstand the rigorous challenges of installation – resulting in lower total costs and longer service life.

GORE
Creative Technologies Worldwide

gore.com/simulator

Performance That Meets the Challenge

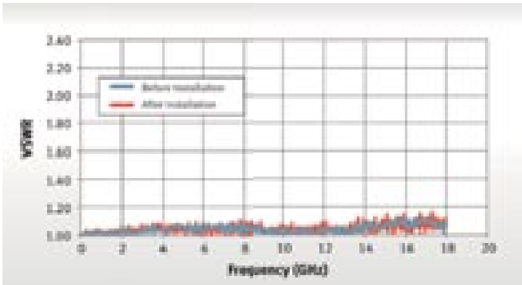
Gore has engineered new ruggedized, lightweight and vapor-sealed airframe assemblies that withstand the challenges of aerospace. These assemblies – known as GORE-FLIGHT™ Microwave Assemblies, 6 Series – improve system performance with:

- Outstanding signal integrity with lowest insertion loss before and after installation
- Lower installation costs due to fewer failures and reduced aircraft production delays
- Improved fuel efficiency and increased payload with lightweight assembly
- Longer system life and reduced downtime due to mechanically robust construction
- Less RF interference among electronic systems due to superior shielding effectiveness
- Proven compliance with MIL-T-81490 requirements

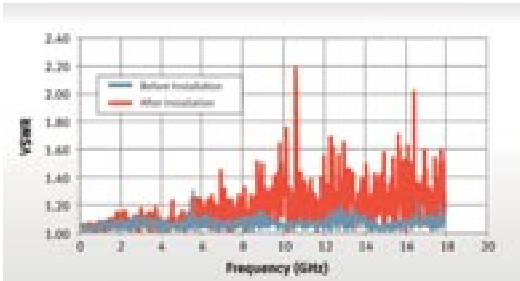
When compared to other leading airframe assemblies, the 6 Series maintain lower insertion loss, more reliable VSWR performance, and consistent impedance of 50 ± 1 Ohms, eliminating insertion loss stack-up issues when routing through airframe bulkheads.

With GORE-FLIGHT™ Microwave Assemblies, 6 Series, a fit-and-forget philosophy is now a reality – providing the most cost-effective solution that ensures mission-critical system performance for military and civil aircraft operators.

GORE-FLIGHT™ Microwave Assemblies, Series 6 VSWR



Alternative Airframe Assembly VSWR



Free Info at http://info.hotims.com/49748-816

Optimizing DSP Techniques for Antenna Site Software Radio

Many applications can benefit from pushing software radio functions up the mast to the antenna as a viable alternative to traditional rack-mounted receiver systems. New technology offers engineers of Software Defined Radio (SDR) systems diverse opportunities to apply digital signal processing (DSP) much closer to the antenna than ever before. Various strategies include the latest wideband data converters, monolithic receiver chips, compact RF tuners, and remote receiver modules using gigabit serial interfaces. Each approach presents benefits and tradeoffs that must be considered in choosing the optimal solution for a given application.

Strategies for the Latest Wideband Data Converters

With the emergence of monolithic A/D converters capable of sampling rates of 5 GHz and higher, engineers can now directly digitize analog RF signals covering a frequency span of more than 2 GHz. This allows the capture of wideband communications and radar signals in a single data stream, eliminating the complexity of splitting a given band into parallel adjacent sub-bands, and the inevitability of input signals straddling them. While these new converters appear to simplify software radio architectures, they also impose many limitations and tradeoffs.

RF signals from the antenna must first be amplified, filtered, and possibly down-converted in frequency to match the input voltage range and usable input bandwidth of the A/D converter. Optimal amplifier gain boosts the strongest signal to the full-scale input range of the A/D. Further amplification to boost weaker in-band signals will cause overloading the A/D, which destroys the signal integrity for all signals. Thus, even one strong interferer will reduce the achievable dynamic range for weaker signals. This significant tradeoff occurs whenever a single A/D is used to handle a large number of signal types in a wide frequency span. To make matters worse, as sampling rates increase, A/D converters deliver lower Effective Number of Bits (ENOB) ratings. For example, a 5-GSample/sec 10-bit A/D converter may only deliver an ENOB of 7.6 bits.

Also, filtering is imperative to eliminate all energy outside the frequency span of interest. Otherwise, aliasing will fold out-of-band noise and adjacent signals into the digitized signal stream, degrading signal-to-noise performance and adding spurious signals.

Lastly, A/D data arriving at several GSamples/sec will overload most DSPs. Data de-interleaving hardware is often built into the A/D to help implementation of the electrical interface, but even so, every data sample must somehow be processed, stored, or transferred. The latest families of field-programmable gate arrays (FPGAs) are especially well suited, not only in dealing with these extremely high data interface rates, but also in processing signals in real time.

One product example is the Pentek 71641 3.6-GHz A/D and Digital Down Converter (DDC) XMC module. It features a 12-bit 3.6-GSample/sec A/D converter coupled to a Virtex-6 FPGA. The A/D de-interleaves samples into eight parallel 12-bit streams, delivering samples to the LVDS ports of the FPGA at 450 MSamples/sec each. Inside, eight parallel engines implement a DDC that tunes across the 1.8 GHz input band (Figure 1). It performs frequency translation to baseband and provides digital filtering of the complex baseband output samples. Selectable output bandwidths of 90, 180, or 360 MHz, representing tunable slices of the input spectrum, are delivered to the system through a native PCIe Gen 2 x8 interface.

Monolithic Receivers

New classes of monolithic silicon receivers offer an impressive integration of diverse RF analog circuitry required to implement a complete software radio tuner front end. These low-cost devices accept input signals directly from the antenna and deliver amplified, translated, and filtered analog baseband outputs suitable for low-speed A/D converters or demodulator chips.

For example, the Maxim MAX2112 targets satellite set-top and VSAT applications including 8PSK modulation and Digital Video Broadcast (DVB-S2) applications. It uses an LNA to boost antenna input signals falling between 925 and 2175 MHz, as well as a programmable gain RF amplifier for 80 dB of overall gain control.

An integrated VCO and programmable fractional-N frequency synthesizer drive a quadrature mixer to tune across the entire input frequency range, downconverting any input signal to I+Q baseband. These baseband signals are band limited with a pair of low-pass filters, programmable from 4 to 40 kHz. This extremely high level of integration on a single chip dramatically reduces the size and cost of the receiver, and is ideal for applications restricted in space, power, weight, and cost or requiring a large number of channels.

However, while these devices work well for applications requiring only modest signal-to-noise ratios like satellite signal interception, they are not suitable for some of the more demanding government and military systems for communications, signal intelligence, and radar.

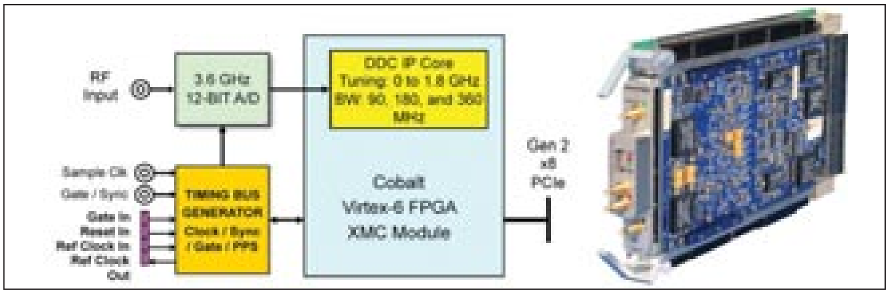


Figure 1. The Pentek 71641 3.6 GHz A/D and Digital Down Converter (DDC) XMC module features a 12-bit 3.6 GSample/sec A/D converter coupled to a Virtex-6 FPGA, which helps deal with extremely high data interface rates and processing signals in real time.

Compact RF Tuners

These higher dynamic range requirements require better RF analog signal processing including multi-conversion designs, amplifiers with lower noise figures, local oscillators with better phase noise and wider tuning ranges, mixers that minimize unwanted spurs, and filters with better pass band flatness, roll off, and stop band performance. Other critical factors include packaging, shielding, isolation, voltage regulation, vibration tolerance, and thermal performance. Boosting overall performance of the system is achieved by progressively improving the weakest of these signal chain elements in iterative cycles until the desired result is reached.

Each level of improvement leads directly to system-level performance benefits such as lower bit error rates for digital communication systems, improved target detection range and classification accuracy for radar systems, higher intelligibility of voice interceptors, and the enhanced precision of target location and trajectory for weapons control systems.

As a result, there is a continuum of required software radio performance levels matching the operational objectives and constraints of a wide range of systems. At the low end, the monolithic receiver described above may suffice, while a very sensitive SIGINT receiver might require a large, highly sophisticated RF subsystem.

As another factor, many applications need to cover only a limited range of input signal frequencies, such as an upper-band GSM receiver handling signals between 1,700 and 2,000 MHz. For these band-limited systems, simpler single-conversion RF tuner architectures can still deliver good performance. In these systems, a single local oscillator and mixer down-convert the RF signal to a lower-frequency IF signal compatible with a high-resolution A/D converter. Of course, judicious selection of amplifiers and filters, and careful analysis and suppression of mixer products, are essential design tasks.

Because of the narrow tuning range, these types of RF tuners are often called "slot receivers." They can be ideal for dedicated applications where limited frequency coverage, cost, size, and weight enable placement of the tuner at or near the antenna.

One example is the Pentek 8111 Slot Receiver. An input bandpass filter rejects signals outside of the defined RF tuning "slot," helping to eliminate both out-of-band noise and discrete signal interferers. The mixer and tunable local oscillator translate the RF input down to an IF frequency of 225 MHz. An IF bandpass filter excludes all signals outside an 80-MHz band centered at 225 MHz, delivering an analog output suitable for 14- or 16-bit A/D converters (Figure 2).

Low-noise amplifiers and programmable attenuators in the signal chain boost antenna signal levels to match the full-scale input voltage of the A/D. Seven different models each cover a different 400 MHz slot between 800 MHz and 3 GHz. An overlap of 100 MHz between adjacent slots ensures that any 80-MHz signal band can be accommodated.

Serial Fabrics, FPGAs, and Remote Receivers

Delivering high-frequency RF signals through long coaxial cables from the antenna to the receiver system has several disadvantages. First, the higher the frequency, the more signal loss in the cable. To mitigate this, Low Noise Blocks (LNBs) located on the antenna are commonly used to down-convert signals above 4 GHz (C-band and higher) to a lower frequency, typically in the L-band

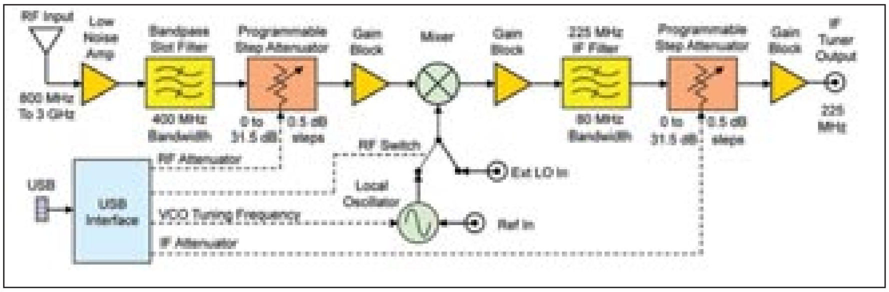


Figure 2. RF tuners, or slot receivers, can be ideal for dedicated applications where limited frequency coverage, cost, size, and weight enable placement of the tuner at or near the antenna. An example of this is the Pentek 8111 Slot Receiver in which an input bandpass filter rejects signals outside the defined RF tuning "slot," helping to eliminate both out-of-band noise and discrete signal interferers.

(1-2 GHz). Nevertheless, cables carrying these analog signals still suffer degradation and present EMI radiation and susceptibility issues. Not only do they impose a tangible weight impact in aircraft and unmanned aerial vehicles (UAVs), they also become maintenance burdens for the extremely long runs and the salt environment aboard ships.

The proliferation of industry-standard gigabit serial digital links offers many benefits in transmission and distribution of these digitized receiver signals. For example, GbE and 10 GbE links are so widely deployed in computer networks, WAN and LAN servers, and data processing centers that commercial competition has driven down costs of components, switches, bridges, cables, and other infrastructure.

In the embedded computing market, FPGA vendors not only offer built-in PCIe ports, they also offer native lightweight gigabit serial protocols such as Xilinx's Aurora and Altera's SerialLite. These, along with SerialFPDP, are ideal for delivering raw A/D or baseband I+Q samples from an FPGA-based front end. At the receiving end, host bus adapters are available for all of these protocols, and many embedded systems processors have native interfaces for SerialRapidIO and PCIe.

Each of these gigabit serial links can be delivered over copper or optical cables. Single-mode fiber cables can connect data from remote receivers up to 10 km away. This benefits large antenna array installations that must collect signals from a grid of widely spaced antennas. Optical cables are free from EMI radiation, eliminating interference to other electronics in tightly packed manned and unmanned aircraft, as well as offering security against eavesdropping. They are also immune to EMI pickup from powerful transmitters, motors, and generators found in shipborne installations. Lastly, optical cables are much lighter than copper cables and are highly resistant to moisture, salt, and chemicals.

FPGAs can implement essential DDC functions and deliver digital baseband samples across an industry-standard digital gigabit serial link. Because these links are full-duplex, the same cable provides a path for control and status functions for the host. Digital receiver data can be easily distributed to multiple destinations using low-cost switches and readily archived on storage servers.

For sensitive signals and classified information, data encryption can be easily included before transmission. Additional preprocessing algorithms such as radar pulse-compression, FFT energy calculations, scanning, and threshold detection can be incorporated within the FPGA to reduce transmission data rates and offload these processing tasks from the host system.

Rethinking Software Radios

There is no substitute for appropriate analog RF signal conditioning prior to A/D conversion, and each technique outlined represents its own application-specific tradeoffs. Nevertheless, the added benefits of antenna site software radio receivers are numerous.

This article was written by Rodger Hosking, Vice President at Pentek in Upper Saddle River, NJ. For more information, visit ***http://info.hotims.com/49748-541***.

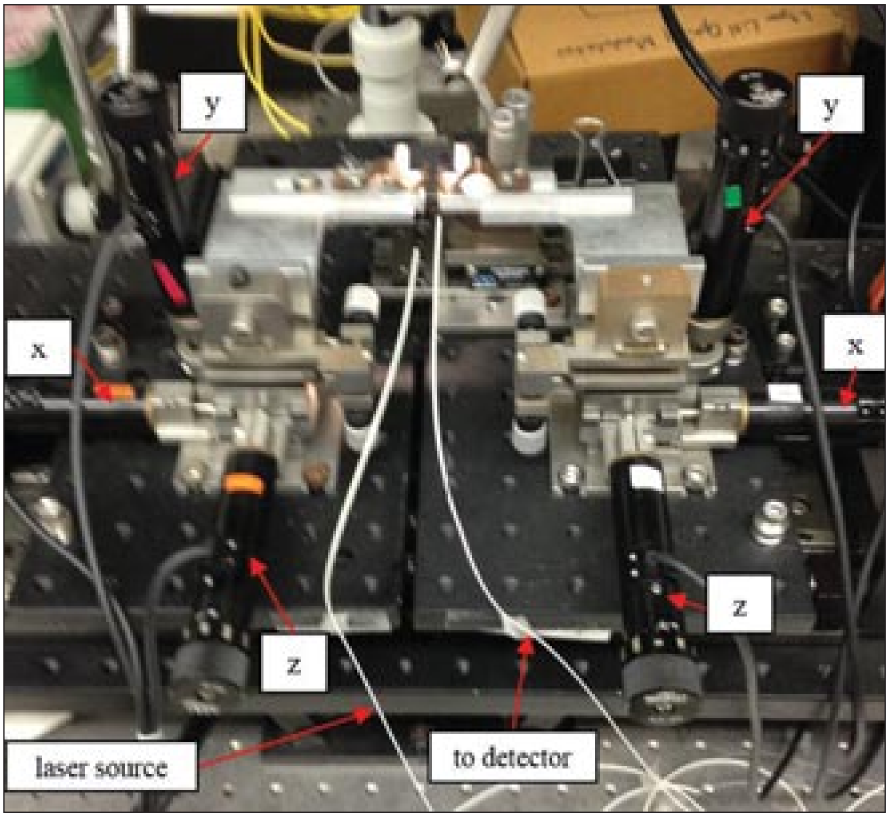
Automatic-Alignment Fiber Optic Coupling System for Optimal Signal Transmission

This system tests the optical characteristics of waveguides on a silicon wafer.

Space and Naval Warfare Systems Center Pacific, San Diego, California

Using the current method of characterizing waveguides manufactured for research in optical communications, it can take up to 8 hours to characterize the waveguides on a single silicon wafer. Using the automatic computer automation system developed, the characterization process has been reduced to less than an hour. After the silicon wafer containing the waveguides is manufactured, the waveguides must be evaluated to determine the optical characteristics of the various waveguides on the silicon wafer.

The figure shows the current setup used to measure the optical properties of the waveguides on a silicon wafer. The silicon wafer is approximately 1 inch square and can contain as many as 50 separate waveguides that need to be analyzed. In this setup, laser light is passed through an optical fiber into one end of the waveguide. At the other end of the waveguide, another optical fiber is used to capture the light exiting the waveguide and is measured using a power meter. Each fiber is attached to x-y-z stages, which allows for fine adjustment of the fiber along three directions. This fine adjustment is needed in order to get the laser light into the waveguide as well as into the fiber on the exit end of the waveguide. Thus, there are six stages used to maximize the laser light passed through the waveguide. In addition to the six stages, there are two stages that are used for coarse adjustments. The coarse adjustments are only along the x-direction, and are used for the initial alignment of the two fibers and for the displacement needed to move to the next waveguide.



The current setup used to measure the optical properties of the waveguides on a silicon wafer.

When a new wafer is placed into the setup, the coarse adjustments are used to get the two ends of the fibers close to the desired location. Next, the six fine adjustments are used to maximize the power through the waveguide. Once the desired data has been gathered, the coarse adjustments are used to go to the next waveguide, and the adjustment process is repeated to maximize power through the waveguide.

The automation of the system to align the fibers to characterize the optical waveguides required the motion control and power measurements to be conducted through a single computer interface. LabVIEW™ software from National Instruments was used to design the computer interface.

The controllers contained a BNC input connection for each axis. The BNC connections allowed for a 0-10 volt input analog signal to be applied for the motion control of the x-y-z fine adjustment stages. Using a USB-3103 eight-channel analog voltage output device, it was possible to control all three fine adjustments for each of the fibers via LabVIEW. The optical power meter contained a USB interface that allowed it to be connected to the computer, and power measurements could then be made using LabVIEW. To optimize the power through the waveguide, two techniques were investigated: the hill-climbing method and the Simplex method.

The hill-climbing method is the most widely used algorithm in the current photonics automation industry. In the hill-climbing method, each movement is based on the comparison between current and previous output light intensity measurements. Motion continues along a particular direction as long as the measurement increases. When the measurement decreases, motion is stopped and then moved to the previ-

ous position where the measurement was a maximum. Then the process is repeated for the next direction.

A simplex is defined as a convex hull with N+1 vertices in an N-dimensional space. These vertices satisfy the non-degeneracy condition that the volume of the simplex hull is nonzero. Each dimension corresponds to a variable or factor in the optimization procedure. Thus, a two-dimensional simplex is seen to be a triangle while a three-dimensional simplex is seen to be a tetrahedron. The algorithm used in the simulation was then used to generate a LabVIEW virtual instrument (VI) for the simplex method.

The main difference between the hill-climbing method and the simplex method is that the hill-climbing method works with only one axis at a time while the simplex method uses two axes at once. Because of this, the simplex method should locate the desired fiber positions that resulted in maximum power quicker than the hill-climbing method. In testing the two methods, it was determined that the simplex method was very sensitive to the values of the parameters used to determine new points for the vertices of the triangles. By making small changes, it was possible for the method to locate the desired position, but when a new starting position was used, the method would often fail and the parameters had to be changed to find the desired location.

The hill-climbing method was more robust and more successful at locating the desired fiber positions for maximum power. In terms of time to converge, the simplex method was about twice as fast as the hill-climbing method in locating the desired position. The hill-climbing method was selected as the method to use for optimizing the power through the waveguide because of its robustness and ability to consistently locate the maximum power position.

This work was done by Ryan P. Lu, Chunyan Lin, and Ayax D. Ramirez of SSC Pacific, and Gabe V. Garcia of New Mexico State University. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Physical Sciences category.*** *SPAWAR-0001*

Detecting Maritime Radiological/Nuclear Threats with Hybrid Imaging

A stand-off detection system for maritime environments enables remote detection of nuclear materials.

Naval Research Laboratory, Washington, DC

The SuperMISTI detection system is a hybrid detection, identification, and imaging system for sources of gamma-ray radiation at stand-off distances. The system is based on the Mobile Imaging and Spectroscopic Threat Identification (MISTI) system designed for the Department of Homeland Security. The SuperMISTI system uses the high-resolution spectra of high-purity germanium (HPGe) detectors to detect and identify gamma-ray sources as well as coded aperture technology, and lower-cost NaI detectors to image and localize the detected sources. The system utilizes a modular design to allow the detection/identification and the imaging/localization portions to be used separately or together, depending on the situation.

Each subsystem is housed in a separate 20-foot refrigerated ISO container that provides humidity and temperature control, and each subsystem can run independently as well as together. Power for each subsystem is provided by an individual clip-on diesel generator capable of providing approximately 5 days of continuous operation. Each subsystem is equipped with a pair of global positioning system (GPS) receivers to determine location, speed, and orientation. External optical cameras provide digital photos of the area to be investigated/imaged. Electronics including iseg high-voltage supplies, mesytec shaping amplifiers, peak-sensing VME digitizers, and onboard servers are mounted in standard electronics racks that are shock-mounted inside each ISO container. External Ethernet ports installed on the containers allow the system to be controlled externally via laptop or remotely via wireless communication.

The SuperMISTI detection/identification subsystem utilizes a pallet-mounted

Figure 1. The SuperMISTI detection/identification subsystem pallet-mounted HPGe array.

Figure 2. The complete SuperMISTI system on a 60-ft barge. The water ballast tanks used to maintain a level barge are shown on the right.

array of 24 HPGe detectors individually shielded from above, below, and the sides by 0.5" lead plates. Each dewar has a cryogenic solenoid valve and a temperature sensor on the exhaust to monitor when the dewar is full. The valves and sensors are plate-mounted atop the palletized array. Separate sensors monitor the pressure on the input lines. The SuperMISTI imaging/localization subsystem consists of 78 NaI detectors mounted into an array on one side of the ISO container. The entire array is shielded from above, below, and the sides by 1" of lead; in addition, a 1" lead flooring provides further shielding from background radiation originating from below, and an additional layer of 1" lead on the back wall provides shielding from the rear.

When operated as a single detection system, the two subsystems are deployed together and connected via Ethernet. The system is started via a simple run GUI (graphical user interface) that records a unique run number, start and stop times, and a user-input run description. Real-time system monitoring is accomplished via a Web GUI that displays an overhead map/satellite image of the area with the truck location and, if applicable, detected source location overlaid.

Source detection and identification are performed with the summed spectra from the HPGe detectors. Summed spectra are produced for integration times ranging from 1 to 120 s. Once a source has been detected and identified, this information is used to determine a ROI in the NaI spectra; the width of this ROI is based on an assumed 8% resolution at 662 keV. The counts in this ROI are used to produce a coded image of the source. A single coded image merely indicates a source direction; however, multiple images taken while in motion allow the system to determine the three-dimensional (3D) location of the source.

In a demonstration, both SuperMISTI subsystems were deployed on a 60-foot barge that was pushed by a tug at speeds of up to 6 kn and at stand-off distances of up to 300 m. The results of this exercise were very close to the expected performance and clearly demonstrate the utility of the SuperMISTI system. All sources that were deployed in the demonstration were successfully detected, identified, and localized at operationally relevant distances ranging up to hundreds of meters.

Since the completion of the demonstration, the number of HPGe detectors in the detection/identification subsystem has been increased from 24 to 48, a modification that significantly enhances the gamma detection/identification capabilities of the system. Further performance enhancements planned for the future include the use of a large-area BF3 detector array to increase neutron detection capabilities and the implementation of better localization algorithms for neutron sources.

This work was done by Anthony L. Hutcheson, Bernard F. Phlips, Eric A. Wulf, Lee J. Mitchell, and W. Neil Johnson of the Naval Research Laboratory; and Byron E. Leas of SRA International. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Physical Sciences category****.* *NRL-0062*

Testing Particle Counters for Detection of Fuel Contamination

The use of automatic particle counters is prevalent in the hydraulics/hydraulic fluid industry.

U.S. Army TARDEC, Warren, Michigan

Fuel quality assurance is accomplished by conducting periodic fuel sampling for the condition monitoring of aviation fuel by detecting, measuring, and reporting the levels of contaminants in the fuel. Current methods have several drawbacks including operator subjectivity, lack of detailed analysis, limitations in providing reliable data, and the turnaround time needed to get the test results.

The U.S. Army and U.S. Navy have conducted laboratory evaluations of particle counter technologies for fuel contamination monitoring. The particle counters tested were unable to adequately distinguish between free water and sediment contamination. Conclusions from the laboratory evaluation indicated that particle counters cannot replace current technology where quantification of both free water and sediment contamination is required. However, this technology showed significant promise for monitoring overall fuel quality.

The U.S. Army conducted tests that clearly demonstrated the online particle counters' susceptibility to providing erroneous results in the presence of air bubbles in the fuel stream. The data had spikes corresponding to the fuel pump automatically shutting off every 10 minutes, and were theorized as being caused due to a "water hammer" effect in the fuel system that shook water free from pockets within the fuel system piping.

Light obscuration particle counters on the Advanced Aviation Forward Area Refueling System (AAFARS) were utilized for this testing. The AAFARS (see figure) was fed fuel from a tanker truck, and a fuel sample port was inserted into the recirculation loop downstream of the filter separator to simulate being in line with the fueling nozzle.

The AAFARS was run under the following conditions to simulate aircraft refueling operations while particle counts where obtained. Fuel was pumped from the tank, through the filter separator, and back into the fuel tank. A valve downstream of the filter separator and particle counter was rapidly opened and closed to create a water hammer effect on the hose line and filter separator. Fuel was again pumped from the tank, through the filter separator, and back into the fuel tank.

Two gallons of fuel were removed from the filter separator vessel, creating a pocket of air in the vessel. The particle counters were started and then the AAFARS fuel pump was initiated, pushing the air from the filter vessel back to the fuel tank. This test was to simulate failing to purge the filter vessel of air following filter replacement of water bottom removal. Air was purged from the filter separator vessel, and fuel was again pumped from the tank, through the filter separator, and back into the fuel tank.

Ideally, these instruments can be left in the field to monitor and collect data for fuel transfers. For this demonstration, the units were configured to pull fuel samples when manually initiated by the operators for each data set.

The data obtained during testing was consistent with the Army's previous experiments utilizing light obscuration particle counters. Following startup of the AAFARS pump, the particle counter was started and took its first reading, falling outside of the Army's proposed particle counter limits due to air in the particle counter sampling line. The following six samples in recirculation mode saw the particle counts drop below the proposed limits and continue to drop as cleaner fuel was pumped through the filter separator.

To simulate the opening and closing of a fueling nozzle, a valve downstream of the pump, filter separator, and particle counter was rapidly opened and closed causing a water hammer effect on the AAFARS. Three particle counter samples were recorded under these conditions with readings higher than the recirculation reading taken just prior, potentially due to the pressure shock on the filter elements shaking dirt off the element and into the fuel stream.

After purging the filter vessel of air, of which there appeared to be none, the fueling simulation was resumed by opening and closing a valve downstream of the pump, filter separator, and particle counter causing a water hammer effect on the AAFARS. This caused the particle count readings to jump above the readings seen when the air was in the system. The increase was again perceived as being caused by the pressure shock on the filter elements pushing dirt off/through the element and into the fuel stream.

To conclude the testing, the AAFARS was returned to recirculation mode and two final particle count readings were taken with readings falling closely in line with the previous recirculation readings. The test results indicate that on-line particle counters, while susceptible to the presence of air found in fueling systems, appear to be compatible to the Army's tactical fueling systems.

The AAFARS fuel sampling port for use with light obscuration particle counters.

This work was done by Joel Schmitigal of the U.S. Army TARDEC. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Physical Sciences category.*** *ARL-0167*

Unmanned Autonomous Helicopter

Northrop Grumman Corp.
West Falls Church, VA
703-280-2900
www.northropgrumman.com

All Navy aircraft must go through electromagnetic interference testing to ensure that they can operate safely in the ship environment. In preparation for ship-board flights, the Northrop Grumman Corporation's MQ-8C Fire Scout will be tested for its ability to operate safely in the intense electromagnetic environment aboard U.S. Navy ships. The MQ-8C Fire Scout uses specially designed Faraday cages to protect the aircraft's sensitive equipment from signal interference.

The MQ-8C is based on a larger helicopter airframe and can fly almost twice as long and carry three times more intelligence-gathering sensor payloads than the MQ-8B variant. The MQ-8C has an overall length of 34.7 ft., weighs 6,000 lbs. with fuel and payload, and flies at a cruise speed of 115 knots. Its top speed is 135 knots and its service ceiling is 16,000 feet.

During the program's design phase, a team of engineers created a modular Faraday cage that protects electronic systems in flight. The Faraday cages are built by Summit Aviation in Somerset, Kentucky, and installed during final assembly at Northrop Grumman's Unmanned Systems Center in Moss Point, Mississippi.

Since Oct. 31, the MQ-8C Fire Scout has flown 102 flights. The initial flight tests will validate that the autonomous control systems of the helicopter are working properly before its first ship-based demonstration.

For Free Info Visit ***http://info.hotims.com/49748-509***

Ethernet Switch and Router Technology

Curtiss-Wright Corporation
Ashburn, VA
973-541-3700
www.curtisswright.com

Curtiss-Wright Corporation's Defense Solutions division recently received a contract from Sierra Nevada Corporation to supply its COTS-based rugged Ethernet Switch and Router technology for use aboard Pilatus PC-12 Intelligence, Surveillance and Reconnaissance (ISR) equipped aircraft under the Knight Ryder program. Under the agreement, Curtiss-Wright will provide Sierra Nevada Corporation with its Parvus DuraMAR® 5915 router and Parvus DuraNET® 3000 switch products. The initial contract is valued at approximately $530,000.

The Pilatus PC-12 is a single-engine turboprop passenger and cargo aircraft manufactured by Pilatus Aircraft of Switzerland. In standard configuration it is powered by a Pratt & Whitney PT-6A turbine engine with 1200 SHP power reduced from 1744 SHP. It can take off from any airfield, including not hardened airfields, and has a cruising range of up to 3,000 km at an average speed of 500 km per hour. The Afghan Air Force has ordered several PC-12 aircrafts modified by

Sierra Nevada Corporation to support counterterrorism (CT) and counternarcotic (CN) operations. The Curtiss-Wright router and switch products will contribute to an ISR suite used on the Pilatus PC-12 aircraft, and will be used to communicate intelligence sensor and video data internal to the aircraft, as well as to ground forces and command and control centers.

The Parvus DuraMAR 5915 is a rugged COTS Cisco® IOS-managed mobile router integrated with Cisco's 5915 Embedded Services Router (ESR) card in an ultra-rugged chassis optimized for harsh military and civil vehicle/aircraft installations. Suitable for IP networking technology refresh and situational awareness applications, including those seeking a migration path for legacy Cisco 3200 (3230/3250/3270)-based router subsystems, the Parvus DuraMAR 5915 features dual WAN uplinks and is available as either a standalone 5-port network router or with an integrated Gigabit Ethernet switch for a total of 19 Ethernet ports.

The Parvus DuraNET 3000 is a ruggedized version of Cisco Systems' IE-3000 industrial Ethernet switch, specifically hardened for use in demanding military/civil IP networking technology refresh applications. This fully managed network switch delivers security, advanced Quality of Service (QoS), high availability, and manageability, including optional Layer 3 IP Routing services. Designed with mechanical enhancements to support deployment of data, video, and voice services in extreme temperatures, shock, vibration, humidity, as well as exposure to dust, water, and EMI/EMC environments, the unit requires no active cooling, is completely sealed, and provides interfaces over MIL-C-38999 style connectors.

The Defense Solutions division will manufacture the products covered by this agreement at its Parvus business unit facility located in Salt Lake City, Utah. The products will be shipped to Sierra Nevada Corporation in Centennial, Colorado.

For Free Info Visit ***http://info.hotims.com/49748-507***

Unmanned Aircraft Must Rise Above Barriers for Commercial Applications

Historically, the unmanned aircraft system (UAS) market has been dominated by military applications from surveillance to active engagement. In the near term, the market's military focus is expected to continue. However, with projected growth from around $6 billion today to nearly $12 billion in 2023 (according to the Teal Group), large-scale commercial adaptation is not only possible, but likely.

On December 30, 2013, the FAA announced six U.S. test sites for the development of commercial drones and support systems. These sites will lay the groundwork for a new set of rules and operating parameters for UASs in and around commercial airspace.

This announcement and initiatives from companies such as Amazon have caused speculation about the different types of operations that could be enabled by drones—from food and flower delivery to high-speed police surveillance. However, a full array of technological and operational roadblocks currently prevent mass commercial adoption of UASs.


While the unmanned aircraft system (UAS) market has been dominated by military applications from surveillance to active engagement, large-scale commercial adaptation is not only possible, but likely.

Aircraft Technology: Autonomy vs. Remote Piloting

In today's intelligent machine world, the line between algorithms and the brain has become blurred. For years, the most sophisticated UASs have employed "autonomous" algorithms that allow them to operate for hours without human intervention or control. This autonomy can be perceived as true intelligence but also as dangerous—raising concerns about accidents and moral and legal accountability.

Although autonomy is alluring to commercial users thanks to lower personnel costs, it is unnecessary and overcomplicated for most near-term commercial applications and may inhibit regulatory approval and public acceptance.

Researchers from Jabil Defense and Aerospace Services and UAS SafeFlight believe that for the next 10 years, "human-in-the-loop" aircraft that use autonomous systems to alert the operator and allow the person to take control will have the best chance of winning over regulators and the public alike.

Although less elegant than fully autonomous systems, this hybrid approach is significantly more palatable and pragmatic as an initial step. This is not to suggest that full autonomy is impossible. However, the researchers consider a UAS launching, delivering a drink or supporting a police officer and then returning to base without human intervention, to be a scenario beyond the 10-year timeframe.

The UAS designs most likely to be certified for flight in urban areas will use this hybrid approach. Therefore, highly reliable communication between the drone and the human operator, using a system able to prioritize traffic, is a critical concern. However, current cellular bandwidth is not adequate and existing protocols for line of sight (LOS) systems are not scalable.

Modular Scalability and Standardization

In the airframe and propulsion areas, UAS developers can draw insight from the standardization of military and commercial aircraft. Currently, there are more than 120 different unmanned aerial vehicle (UAV) models with varying payloads, propulsion systems, and power sources. By comparison, there are less than a handful of new fighter jets and only a few standard commercial aircraft models, with only three engine manufacturers.

Standardization of UAS hardware is essential for cost-effective manufacturability that will help drive mass commercialization. The future will depend upon modular components that are fit for purpose, aligned with industry standards, and easy to scale up as demand increases. However, the UAS manufacturing landscape is currently fragmented and not standardized.

Today, the largest gap in fit-for-purpose is in UAS propulsion systems. Smaller drones are operating with adapted model airplane engines, either gas or battery powered. These engines were not designed to carry valuable goods and lack sufficient reliability for operating in commercial airspace. In the near term, the authors anticipate the emergence of a liquid fuel engine that is based on existing technology but designed specifically for UASs and able to pass engine reliability tests similar to those for commercial engines.

The myriad of missions expected to be performed by UASs will require modularity to drive down costs. A single UAS platform and engine must be able to complete several different types of missions to provide economic benefit to the end user.

For example, to justify investment in a UAS, a municipality needs to be able to configure the same vehicle for different uses, such as speed monitoring, first responder support, and crowd surveillance, using modular kits. In a commercial example, a business delivering goods may need to modify the hardware to accommodate different payloads such as fragile flowers, perishable food, or bulky books. These modules should be quickly and easily interchangeable.

To achieve modularity and cost-effective, scalable production, the industry must draw on models from the commercial aviation and consumer electronics sectors, which are based on global standards and produced using consolidated global manufacturing, rather than disparate assembly operations at the level of a hobby shop.

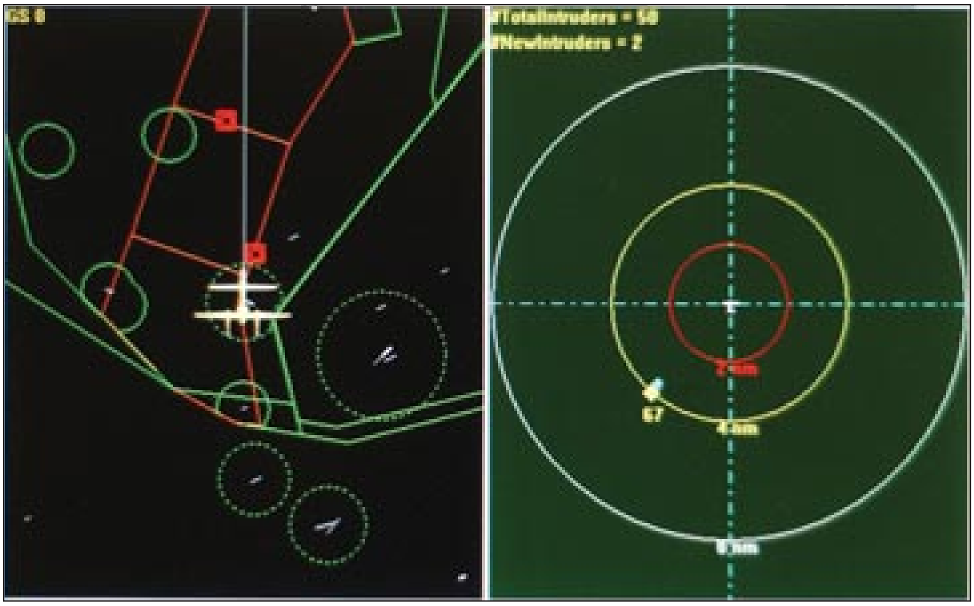
Communications Efficacy

Historically, U.S. DOD drones have relied on line-of-sight (LOS) solutions or satellite communication (SATCOM) approaches. Although these point-to-point solutions have proven adequate so far, primarily because the number of UASs operating in any one geographical area continues to be quite limited, they will not meet the needs of commercial drone operations.

Currently, it would be difficult to find any 5 square mile area on earth in which even 10 UASs have operated at the same time. However, by 2018, 7500 small drones are expected to be in the air over the United States.

Networked mobile technology and connectivity are expanding exponentially. Using networked mobile infrastructure as the backbone of UAS piloting communication will be essential to support the growth of commercial drones. To this end, networked mobile protocols and approaches must be

It is expected that consumer product delivery and high-speed police surveillance will be enabled by drones.



Sophisticated UASs have employed "autonomous" algorithms that allow them to operate for hours without human interention or control. This autonomy can be perceived as true intelligence but also as dangerous – raising concerns about accidents and moral and legal accountability.

adapted to meet the connectivity needs of a high concentration of UAVs in flight.

Solutions at Scale

To address the above issues, the authors propose efforts across three main areas: adoption of standards for propulsion and power solutions, adoption of open architecture modularity to drive fit for purpose, and adaptation of mobile communications protocols.

- **Industry-standard propulsion hardware**

The combustion engine has been a reliable solution for nearly 100 years. Despite several billion dollars invested in batteries and hybrid power solutions, very few technologies have come close to the energy density

Commercial UAS command and control systems will need to leverage multiple personal communications service (PCS) connections through multiple streams.

or cost-efficiency of gasoline/diesel engines. Existing small liquid fuel engines (two-stroke technology) can provide a viable solution for commercial applications, providing on-station time surpassing that of batteries and high reliability in operation. The FAA should select two to three engine designs and require a Federal Aviation Regulations FAR 33 or similar test to prove their reliability. UAS designers can then focus on airframe variations.

- **Modular mission kits**

Scalability of UAS manufacturing requires basic architecture with interchangeable, mission-specific modules, such as cargo payloads, sensors, and transmitters, rather than separate, customized designs, akin to today's computers and smartphones. UAS manufacturers should focus on systems architecture as well as software and data algorithms, while leveraging existing electronics suppliers—which have the required expertise and infrastructure—to cost-effectively manufacture the modules and their electronics. It took 500 years for the shipping industry to adopt the modular container, but under 20 years for personal computers to become interchangeable. It is expected that UAS designs will become common and modular in even less time.

- **Communication over mobile technologies**

Commercial UAS command and control systems will need to leverage multiple personal communications service (PCS) connections through multiple streams. These communications are likely to utilize existing carriers and their installed cellular infrastructure and towers and will require from a few to more than 20 simultaneous cellular connections. Multiple connections will ensure both safety and redundancy across different UAS classes and missions. For example, a mission that requires continuous video feed at high speed will demand more connections, whereas a simple delivery may only need a few.

In a scenario where a UAS mission requires 12 simultaneous connections in an area served by three unique cellular carriers (e.g., Verizon, ATT, and Sprint), hardware and software must balance bandwidth for four connections each across the three providers. For efficacy and redundancy, the system must drive connections with each carrier across a unique tower. In most cases, a UAS with an altitude of 100 m will naturally distribute the four connections among available cellular towers, but must be coordinated through purpose-adapted software and hardware.

In addition, the hardware on the drone needed to establish multiple connections must be effectively managed and size, weight, and power (SWAP) must be considered. Modern manufacturing and the latest electronic advances will be required to effectively make the trade-off between minimizing SWAP and maximizing connections. Once custom hardware utilizing multiple compact cellular data solutions is tested and certified across platforms, up to 20 simultaneous connections for commercial drones will become a reality.

Under the assumption that a human operator must be able to take control of a UAS at any time, command and control technology is of paramount importance. UAS command and control is bi-directional: the UAS must send operational sensor data (position, avoidance system detections, etc.) and the human-in-the-loop must be able to send control data (e.g., turn left, maintain altitude) to the UAS. Latency in the network system must be minimal or it can adversely affect safety and operability.

However, the overall amount of data being sent, in either or both directions, is (compared to the capacity of the system) rather small. Even when the human-in-the-loop is operating the UAS, low data rate video, on the order of a few frames per second, is sufficient. With the exception of low data rate video, command and control data comprises a few thousand bits per second.

The most simplistic approach would be to send all command and control data over all available paths. While this is not bandwidth-efficient, the trade-off (in simplicity of implementation and practically guaranteed delivery of the data) makes it a good option. However, to be viable, current bandwidth software must be developed to account for duplicative receipt from multiple channels with very high efficacy and low latency. This type of software exists, but needs to be adapted for UAS purposes and subsequently tested and certified by the FAA.

Overall, the future use of UASs in myriad commercial operations is highly likely. How rapidly this becomes commonplace depends on the ability of UAS operators, designers, and regulators to reduce barriers and align on key technology goals. Existing communication, propulsion, and manufacturing technologies can and should be rapidly adopted for mass commercialization of UASs. However, adoption will require industry collaboration and agreement, potentially in conjunction with FAA test sites and certification.

This article was written for Aerospace & Defense Technology by Scott Gebicke, President, Jabil Defense and Aerospace Services (St. Petersburg, FL) and Tim Krout, Founder, UAS SafeFlight (White Plains, NY)

FREE

2014 CONTINUOUS ENGINEERING VIRTUAL SYMPOSIUM:

CUTTING-EDGE APPROACH TO SYSTEMS ENGINEERING

Thursday, September 4, 2014
8 a.m. to 5 p.m. U.S. EDT
www.sae.org/events/cevirt/

A free online summit for mobility professionals worldwide to explore the major trends impacting today's systems engineering teams – all from the comfort of your office or home.

Attend three thought-provoking hour-long panel discussions with leading industry experts throughout the day in the virtual theater. Submit questions during the live Q&A.

Feature Theater Presentations:

- **The Exciting Road Ahead for Intelligent Vehicles** (9:30 a.m. – 10:30 a.m. U.S. EDT)
- **Aerospace Experts on Cyber Attacks and Security** (Noon – 1 p.m. U.S. EDT)
- **Simplifying Interoperability Across Systems & Software Lifecycle With OSLC** (2:30 – 3:30 p.m. U.S. EDT)

For 2014, the Continuous Engineering Virtual Symposium will examine ways to help design engineers speed delivery of today's complex and connected products and accelerate learning throughout the lifecycle while managing cost, quality, and risk. Attendees will learn about improving design efficiencies, preventing rework, verifying requirements at all stages of product lifecycle, and achieving faster time to quality.

Virtual Symposium Attendee Experience:

- Explore two **Exhibit Halls**: Technology Exhibit and Career Advancement Exhibit
- Participate in three thought-provoking **Theater Presentations with live Q&A**
- Tune into various 20-minute **Speaker Sessions**
- Download an array of valuable documents at the **Resource Center**

SAE International Contact:

Martha Tress
e: mtress@sae.org

Hosted by IBM

Content Reviewed and Facilitated by SAE INTERNATIONAL

P140711

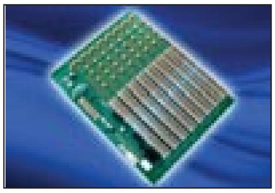
Free Info at http://info.hotims.com/49748-782

New Products

DAQ and I/O Control Platforms

United Electronic Industries (Walpole, MA) has announced two military-grade DAQ (Data Acquisition) and I/O Control platforms. Using a modular architecture, the DNR-MIL and DNA-MIL are supported by over 50 plug-and-play-compatible analog, digital, and communications I/O boards. Specific interfaces are available for: ARINC-429, MIL-1553, CAN, RVDT/LVDT, synchro/resolver, RS-232/422/485, strain gauge, quadrature encoder, high-voltage analog outputs, high-drive outputs up to 50 mA, analog inputs up to 300V, DIO to 150V, and other applications. All I/O boards are accessed through 38999-style connectors using a single API layer. Each platform is factory tested, rated for operation from -40°C to +70°C, and able to withstand 5g vibration and 100g shock.

For Free Info Visit http://info.hotims.com/49748-510



Custom cPCI Backplane

Verotec (Derry, New Hampshire) offers a custom 6U, 2 x 4 slot CompactPCI backplane for flight simulation applications. In addition to integrating two independent 4-slot systems on a single backplane, additional I/O headers and other interfaces are incorporated. Verotec offers a range of standard PICMG2.0 Rev 3 compliant CompactPCI backplanes in 3U, 6U, and 9U heights, 2 to 16 slots wide. The products are available in various configurations: 32/64-bit, 33/66MHz, left or right system slot, and 5V/3.3V voltages. Other bus structures, such as VPX, VXS, VME64, and VXI architectures, are also supported with backplanes and development systems.

For Free Info Visit http://info.hotims.com/49748-511

RF Inductors

Gowanda Electronics (Gowanda, NY) has announced military approval for four thru-hole RF inductor series: MLRF10M, MLRF15M, MLRF18M, and MLRF17S. The wire-wound, molded, thru-hole RF inductors meet the military's Qualified Product List (QPL) requirement for MIL-PRF-15305. MLRF10M is approved for MIL-PRF-15305 Military Part Numbers MS75083 (phenolic core), MS75084 (iron core), and MS75085 (ferrite core). Performance includes: inductance from 0.10 to 1000 µH; Q Min from 25 to 55; SRF MHz Min from 3.40 to 680; DCR Ohms Max from 0.08 to 72; and Current Rating DC mA from 28 to 1350. Operating temperature range is -55°C to +125°C for MS78083; -55°C to +105°C for MS75084 and MS75085.

For Free Info Visit http://info.hotims.com/49748-512

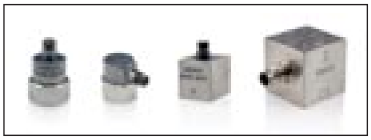
Power Supply Boards

ADL Embedded Solutions (San Diego, CA) has announced a 150W ADLPS104ISO-150 power supply board. The technology, designed for -40°C to +85°C operation, provides ATX voltages in a stackable PCI/104-Express form factor. The ADLPS104ISO-150 offers up to 500V of galvanic isolation from dirty power and unwanted transients.

The ADLPS104ISO-150 includes an MTBF greater than 600,000 hours. The board also features ATX-compliant signaling to allow ACPI/APM power management. The ADLPS104ISO-150 is available in two variants. One allows an input voltage range of 7-36V, but provides only the 5V, 5VS, and 3.3V outputs. The other option has a narrower input voltage range of 15-36V, but provides 5V, 5VS, 3.3V, and 12V outputs. A MILCOTS filter for MIL-STD 704/1275/461 applications is also available.

For Free Info Visit http://info.hotims.com/49748-515

Accelerometers



Meggitt Sensing Systems (Irvine, CA), a Meggitt group division, has extended its set of Endevco-brand Isotron accelerometers. Features include multiple sensitivity options; wide-band frequency response; signal ground isolation from case; low noise floor; and TEDS capablity.

The new Endevco models, 41A, 42A, and 43A, are general purpose, single-axis accelerometers. 10, 25, 100, 500, and 1000 mV/g sensitivities are available for the 41A and 42A, with 100, 500 and 1000 mV/g for the 43A. Amplitude response of +/-5% is 1 to 10000 Hz. The stud-mounted accelerometers have a 10-32 threaded hole. Optional accessories include cables, an adhesive mounting adapter, and signal conditioners.

The Endevco model 45A is a general-purpose, high-sensitivity, triaxial accelerometer in a 20-mm cube shape. The 45A includes 500 mV/g (10 g range) and 1000 mV/g (5 g range) options. Amplitude response of +/-5% is 1 to 6000 Hz for y- and z-axes, and 1 to 3000 Hz for x-axis. Optional accessories include cables, an adhesive mounting adapter, isolated mounting adapters, and signal conditioners.

For Free Info Visit http://info.hotims.com/49748-513

Switches

VadaTech (Henderson, NV) offers 40G/10G Layer 3 managed switches for AdvancedTCA (ATCA). Designers can choose throughput levels: 320G, 480G, or 640G. Each slot runs either 40G or 10G. The ATCA switch provides two ports of 40GbE/10GbE to Zone 3 RTM, 13 ports to the Fabric Channel, and one port to the Update Channel. Dual 10G ports route to the RTM (Zone 3). Front panel ports include octal 10/1000/1000 Ethernet, one GbE, and one RS-232 via RJ-45.

For Free Info Visit http://info.hotims.com/49748-514

Air Data Computer

Curtiss-Wright Corporation (Ashburn, VA) has introduced the Air Data Computer Module (ADCM). Designed and manufactured by Defense Solutions' Avionics & Electronics business unit, the ADCM provides aircraft avionics designers with a compact, slot-based technology for integrating air data processing directly into their platform's existing host equipment. The vibrating cylinder sensor technology can be integrated into existing avionics such as Attitude Heading Reference Systems (AHRS), Electronics Flight Instrument Systems (EFIS), Inertial Reference Systems (IRS), or Global Navigation Inertial Reference Systems (GNIRS).

For Free Info Visit http://info.hotims.com/49748-516

AEROSPACE & DEFENSE TECHNOLOGY

www.aerodefensetech.com

Published by Tech Briefs Media Group (TBMG), an SAE International Company

Editorial

Thomas J. Drozda
Director of Programs & Product Development (SAE)

Linda L. Bell
Editorial Director (TBMG)

Kevin Jost
Editorial Director (SAE)

Bruce A. Bennett
Editor (TBMG)

Jean L. Broge
Managing Editor (SAE)

Lindsay Brooke
Senior Editor (SAE)

Billy Hurley
Associate Editor (TBMG)

Patrick Ponticel, Ryan Gehm
Associate Editors (SAE)

Kendra Smith
Managing Editor, Tech Briefs TV

Matt Monaghan
Assistant Editor (SAE)

Lisa Arrigo
Custom Electronic Products Editor (SAE)

Kami Buchholz
Detroit Editor (SAE)

Richard Gardner
European Editor (SAE)

Jack Yamaguchi
Asian Editor (SAE)

Terry Costlow, John Kendall, Bruce Morey, Jenny Hessler, Jennifer Shuttleworth, Linda Trego, Steven Ashley
Contributing Editors (SAE)

Production/Circulation

Adam Santiago
Production Manager (TBMG)

Lois Erlacher
Art Director (TBMG)

Bernadette Torres
Designer (TBMG)

Marilyn Samuelsen
Audience Development/Circulation Director (TBMG)

Jodie Mohnkern
Circulation and Mail List Manager (SAE)

Martha Saunders
Audience Development/Circulation Assistant (TBMG)

Sales & Marketing

Scott Sward
Publisher, Periodicals & Electronic Media (SAE)

Joseph T. Pramberger
Publisher (TBMG)

Debora Rothwell
Marketing Director (TBMG)

Marcie L. Hineman
Global Field Sales Manager (SAE)

Lorraine Vigliotta
Marketing Client Manager (SAE)

Kaitlyn Sommer
Marketing Assistant(TBMG)

Tech Briefs Media Group, an SAE International Company
261 Fifth Avenue, Suite 1901, New York, NY 10016
(212) 490-3999 FAX (212) 986-7864

TBMG Sales Representatives
www.techbriefsmediagroup.com/home/sales

SAE International Sales Representatives
http://sae.org/reps

Ad Index

For free product literature, enter advertisers' reader service numbers at www.techbriefs.com/rs, or visit the Web site beneath their ad in this issue.