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The Engineer's Guide to Design & Manufacturing Advances

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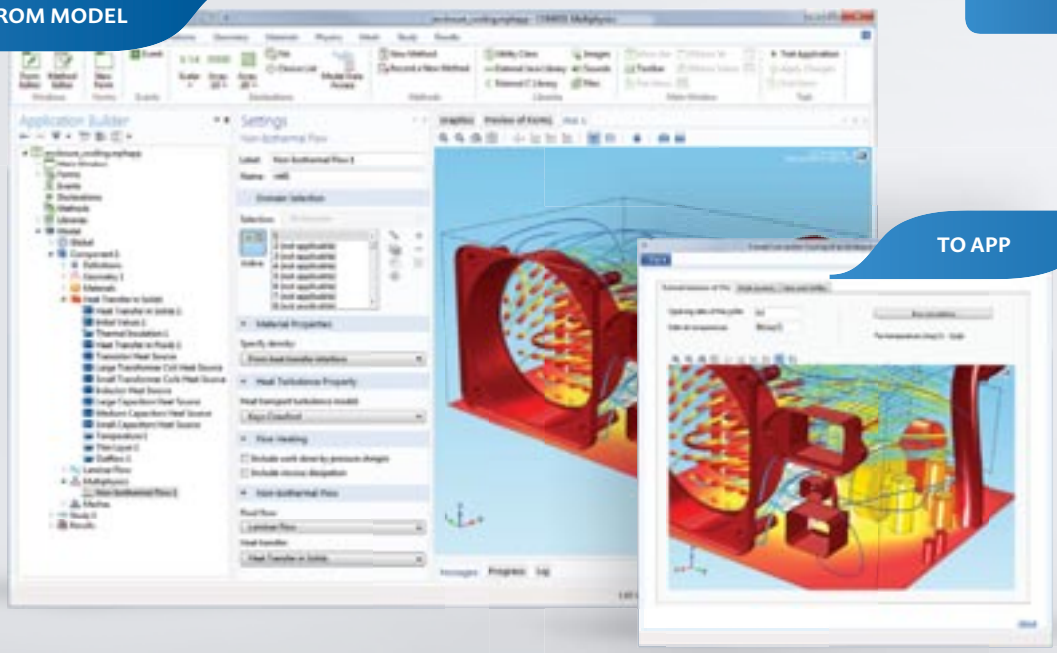

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ON THE COVER

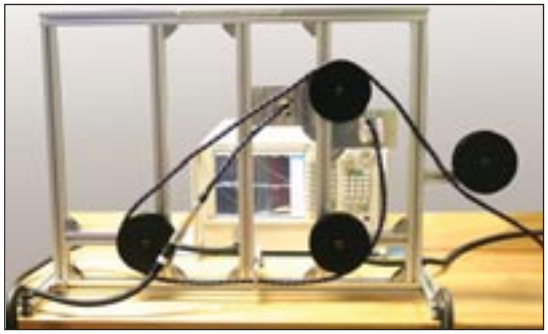
Artist's depiction of an all-electric propulsion 702SP (small platform) satellite similar to those being built for ABS and Eutelsat by Boeing Space & Intelligence Systems. The unique all-electric propulsion system uses xenon, an inert and non-hazardous element, as the propellant, resulting in a lighter spacecraft that offers customers more affordable launch options and the ability to nearly double payload capacity. To learn more, read the Technology Update beginning on page 41.

(*Image courtesy of Boeing*)

Top Products

Cable Installation Simulator

A cable installation simulator from W. L. Gore & Associates aids in evaluating the stress of installation on microwave airframe assemblies, thereby minimizing the risk of cable assembly damage or failure during installation. By comparing signal integrity before and after installation, Gore can engineer assemblies that withstand airframe installation as well as the demands of the aircraft's flight envelope. Use of the installation simulator gives aircraft manufacturers and installers evidence that their assemblies will provide the same level of electrical performance after installation as when they are new. More detail at ***http://articles.sae.org/13287***.



W.L. Gore's new aircraft cable installation simulater.

Custom Grounding Cables and Clips

Custom grounding cables and clips from Mueller Electric help prevent the generation of electrical sparks caused by static electricity, which can damage equipment and lead to safety hazards. The products support the typical grounding and bonding requirements found within aircraft fueling, electrical equipment, marine, oil and gas tanks and drums, and pump grounding systems. More detail at ***http://articles.sae.org/13241***.

Surface Microphone

PCB Piezotronics' surface microphone for R&D testing features a low-profile design ideal for testing in confined spaces and windy environments. The low-profile (1/8-in height) microphone and surface mount pad reduces the impact of undesired air pressure on the microphone during the measurement process. Model 130B40 is an all-in-one, prepolarized microphone and preamplifier combination with a water- and dust-resistant cover. Maximum dynamic range allows measurements to 142 dB and a 32 dBA low noise floor. More detail at ***http://articles.sae.org/13242***.

Modeling Database

Three high-performance thermoplastics from Victrex have been added to the Digimat-MX material and modeling database to accelerate the application development process while helping to minimize component weight and costs. The software suite from e-Xstream engineering offers data on Victrex PEEK 150CA30, Victrex PEEK 90HMF40, and Victrex PEEK 150GL30. Victrex PEEK 150CA30 is typically used to replace metals such as aluminum, titanium, and stainless steel. More detail at ***http://articles.sae.org/13284***.

Top Articles

Following are the most-read articles over the past month at ***http://articles.sae.org***, covering the aerospace, automotive, and off-highway industries.

Nvidia Chipset to Enable Greater Autonomy

Powerful visual computing processors for dashboard displays are now taking on safety-critical driver-assistance functions. Read more at ***http://articles.sae.org/13314***.

Nvidia's Tegra K1 system-on-a-chip module handles digital dashboard displays and, increasingly, driver's-assistance functions.

The Drive for Driverless Vehicles

Autonomous vehicles are a hot topic, most noticeably in the automotive world. But automated driving/operation is making significant headway in the off-highway realm as well, especially in mining applications. John Williamson of Komatsu America Corp. and Serge Lambermont of Delphi Electronics & Safety provide some insights on the topic. Read more at ***http://articles.sae.org/13300***.

Chrysler's new Hellcat V8 gets 707-hp SAE rating

The actual J1349 rating is more than 100 hp more than Chrysler engineers teased in late May. The automaker's first production supercharged V8 uses a Lysholm-type twin-screw supercharger supplied by IHI. The engine's high-output spec required extensive upgrading of engine reciprocating components to handle the extra loads. Read more at ***http://articles.sae.org/13227***.

New power steering concept uses variable displacement pump

A new electrohydraulic power steering system uses pump displacement control, eliminating throttling losses associated with hydraulic control valves by controlling the displacement of a variable displacement pump. Read more at ***http://articles.sae.org/13281***.

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Fully Autonomous Unmanned Vehicles

Lockheed Martin
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Lockheed Martin, in collaboration with the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), successfully conducted a fully autonomous resupply, reconnaissance, surveillance and target-acquisition demonstration using its Squad Mission Support System (SMSS) unmanned ground vehicle, K-MAX unmanned helicopter and Gyrocam optical sensor.

During the "Extending the Reach of the Warfighter through Robotics" capability assessment at Fort Benning, Georgia, K-MAX delivered SMSS by sling load to conduct an autonomous resupply mission scenario for soldiers defending a village. At mission completion, SMSS proceeded to an observation point where it raised its Gyrocam sensor and began scanning the area for enemy forces. In an actual mission, upon observation of enemy forces, the remote operator would notify the commander on the ground, who would assess the threat and determine the appropriate method of neutralizing it.

"Fully autonomous capabilities as we've just demonstrated will allow service members to focus on important missions and remain out of harm's way," said Scott Greene, vice president of ground vehicles for Lockheed Martin Missiles and Fire Control. "This successful demonstration with both unmanned air and ground vehicles shows us that these missions are not only possible, but can be available much sooner than you would expect."

In 2011, K-MAX became the first unmanned aircraft system to deliver cargo in-theater for the U.S. Marine Corps. As troops were frequent targets of improvised explosive devices and insurgent attacks, K-MAX answered the call to reduce the number of truck resupply convoys and their troop escorts to protect soldiers on the ground.

Manufactured by Kaman Aerospace Corporation and outfitted with its mission package of systems and sensors, the heavy-lifting K-MAX unmanned system is a transformational technology that can lift 6,000 pounds of cargo at sea level. Capable of flying delivery missions day and night, K-MAX can reach remote locations without risking a life.

During the test, the Gyrocam 9-inch, mid-wave surveillance sensor provided constant video surveillance during each phase of the mission, including while in flight. The elevated system scanned for threats and provided geo-location coordinates of hostile personnel for indirect-fire missions.

Both SMSS and K-MAX were equipped with mobile Satellite Communications (SATCOM) systems as well as local line-of-sight communications systems. A remote operations center equipped with SATCOM controlled and monitored the vehicles' activities throughout the demonstration.

TARDEC develops and integrates the right technology solutions to improve current force effectiveness and provides superior capabilities for future force integration. TARDEC's technical, scientific and engineering staff lead cutting-edge research and development in ground systems survivability; power and mobility; ground vehicle robotics; force projection; and vehicle electronics and architecture. TARDEC is a major research, development and engineering center for Research, Development and Engineering Command and an enterprise partner in the TACOM Life Cycle Management Command.

To watch a video demonstration of a simulated resupply mission utilizing Lockheed Martin's K-MAX unmanned helicopter and SMSS unmanned ground vehicle, go to ***www.techbriefs.com/tv/resupply.***

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Unmanned Demonstrator Flight Control Systems

North Atlantic Industries
Bohemia, NY
631-567-1100
www.naii.com

North Atlantic Industries (NAI) has been chosen by Lockheed Martin Skunk Works® to provide navigation system solutions for the Aerial Reconfigurable Embedded System (ARES) vertical takeoff and landing (VTOL) demonstrator. Vehicle management computer (VMC) and actuator interface unit (AIU) requirements were met utilizing NAI's commercial-off-the-shelf (COTS) SIU6 chassis.

Built on NAI's Custom-On-Standard Architecture™ (COSA™) platform, the SIU6 chassis is populated with highly configurable PowerPC-based single board computer (SBC) and multi-function I/O 6U VME boards (64EP3 & 64C3). This provides a flexible system solution that allows Lockheed Martin to quickly mix and match functionality based on the ARES application demands.

As part of the ARES navigation system, the SIU6 sensor interface unit enables Lockheed Martin to populate each board

with function specific modules. This unique modular architecture offers a selection of up to 10 different or same functions from a broad assortment of low-power, high density modules. Functions include: programmable discretes, analog I/O (A/D, D/A & RTD), communications (RS-232/422/485 & ARINC-429), LVDT measurement, RVDT simulation and LVDT/RVDT AC Excitation. The SWaP-C efficient design increases packaging density, saves enclosure slots and reduces power consumption. In addition, the SIU6 incorporates automatic background Built-in-Test (BIT) testing that is always enabled and continually checks the health of each channel.

Utilizing the 64EP3 6U VME single board computer with configurable multi-function I/O, combined with the U3 PowerPC Processor, ARES' VMC is triple redundant and controls actuators and various I/O for advanced autonomous flight control. The VMC also communicates with the AIU, which has redundancy by using two AIUs in the system.

The Defense Advanced Research Projects Agency's (DARPA) ARES program is currently in its third and final phase. "Transporting and resupplying troops in rugged, austere terrain has become a major challenge, especially as the U.S. military shifts to using smaller and more distributed combat units," said Kevin Renshaw, Lockheed Martin Skunk Works senior principal engineer for ARES. "ARES seeks to demonstrate several key technologies to achieve an operational VTOL system with a more compact footprint than those of conventional helicopters and couple this with higher cruise speeds."

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Autonomous Black Hawk Helicopter

Sikorsky Aircraft Corporation
Stratford, CT
1-800-946-4337
www.sikorsky.com/

Sikorsky Aircraft, a subsidiary of United Technologies Corp., is developing its first product to feature Matrix™ Technology by converting a retired UH-60A Black Hawk helicopter into an optionally piloted variant capable of a wide spectrum of missions. With the autonomous Black Hawk, Sikorsky plans to build on the success of its Matrix Technology and Manned/Unmanned Resupply Aerial Lifter (MURAL) autonomy programs to deliver a new level of mission flexibility to combat and logistic planners. The product will integrate autonomy and advanced fleet management technology with refurbishment experience to provide a cost-effective, dependable and sustainable system.

The autonomous Black Hawk helicopter will offer the flexibility of internal and external cargo capability, the strength to lift up to 9,000 pounds, and the productivity of high cruise speeds. The design is targeting a system loss rate of one per 100,000 flight hours.

Design of a prototype system has been underway for more than a year, and induction of the first Black Hawk helicopter was scheduled to begin in May of this year. Sikorsky will conduct a series of technology maturation tests during the build period using the Sikorsky Autonomy Research Aircraft (SARA), which is based on an S-76® commercial helicopter.

In collaboration with the U.S. Army, Sikorsky successfully demonstrated the ability of a UH-60M Upgrade Optionally Piloted Black Hawk helicopter to conduct autonomous flight and autonomous cargo resupply demonstrations through its MURAL Program earlier this year.

For the past year, Sikorsky has been working on advancing helicopter autonomous flight with its Matrix Technology program. The Matrix test aircraft, SARA, has conducted continuous flight testing to increase capabilities, adding advanced perception flights to its latest phase of envelope expansion.

Sikorsky is also working on a project with the National Robotics Engineering Center (NREC) of Carnegie Mellon University to demonstrate an autonomous delivery of an Unmanned Ground Vehicle (UGV) by an Optionally Piloted Black Hawk helicopter enabled with Matrix™ Technology. The UGV will subsequently execute a mission to investigate a potentially contaminated area, while keeping human personnel out of harm's way. 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. The NREC-led "Extending the Reach of the Warfighter Through Robotics" effort launched in March and will culminate with a final demonstration in September 2015.

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The NREC is providing the UGV, a modified Land Tamer® all-terrain vehicle which uses key elements of several NREC world-class autonomy systems to support on-road and off-road autonomous exploration. The team of unmanned ground and air vehicles will autonomously survey sites with suspected chemical, biological, radiological, or nuclear contamination.

Sikorsky introduced its Matrix Technology in July 2013 to develop, test and field systems and software that will improve significantly the capability, reliability and safety of flight for autonomous, optionally piloted, and piloted vertical take-off and landing (VTOL) aircraft. Matrix™ aims to give rotary and fixed wing VTOL aircraft a high level of system intelligence needed to complete complex missions with minimal human oversight and at low altitudes where obstacles abound.

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SRW Radio System

Thales Defense & Security
Clarksburg, MD
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Thales Defense & Security, Inc. has been awarded an Indefinite Delivery/Indefinite Quantity (IDIQ) contract by the U.S. Army for its Soldier Radio Waveform Appliqué (SRW A) radio system: the AN/VRC 121 Vehicle Integrated Power Enhanced Rifleman, or VIPER.

Developed jointly with Ultralife Corporation's Communications Systems business, VIPER met the U.S. Army's requirement for a single-channel, vehicle-mounted radio running SRW. The technology can be installed into the Single Channel Ground and Airborne Radio System (SINCGARS) Combat Net Radio (CNR) vehicular mount or used in a standalone configuration. The radio system provides an independent or second-channel option for vehicle communications installations, acting as a conduit for voice and data among the dismounted soldier, mounted platforms, the Unit, and higher headquarters.

VIPER integrates, and interacts seamlessly, with an installed AN/PRC 154A Rifleman Radio. The Rifleman Radio, which was co-developed and is being co-manufactured, by Thales and General Dynamics C4 Systems under the Joint Tactical Radio System Handheld, Manpack, and Small Form Fit program of record, has been fully tested, certified, and deployed. VIPER also provides "Jerk and Run" access to the installed Rifleman Radio, enabling a quick transition between mounted and dismounted operations without losing communications.

With more than 19,000 Rifleman Radios manufactured, the VIPER solution ensures that the U.S. Army has immediate interoperability with currently fielded radios, while soldiers gain greater operational flexibility due to its ability to operate in both UHF and Lbands.

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Reaching the Benchmark in Secure Unmanned Vehicle Software

Security concerns currently dominate software thinking wherever sensitive or safety-critical information is potentially accessible. Embedded software is no exception. Security researcher Barnaby Jack demonstrated this in 2011 when he used a modified antenna and software to wirelessly attack and take control of Medtronic's implantable insulin pumps. He demonstrated how such a pump could be commanded to release a fatal dose of insulin. Obviously, that vulnerability puts dependent diabetics at risk.

But, what about military vehicles? Their vulnerability raises security concerns to a whole new level. The strategic advantage given to an enemy capable of interfering with or interrogating military vehicle positioning and tracking systems could jeopardize the safety of the driver and crew. But even in unmanned vehicles the exposure of information about the vehicle's intended course could compromise an entire military strategy.

MIL-STD-1180B is concerned with military vehicles and has been in existence since 1986, before any of this became a concern. Yet its demand for "full consideration…to military mission requirements" is perhaps more relevant now than ever before, especially in the context of the United States 2013 National Defense Authorization Act. While that act may be primarily concerned with large IT systems, the threat posed to embedded software can be every bit as real.

Safety considerations impact any discussion on secure software simply because safety and security are so interwoven. From a developer's perspective, many unsafe software practices are also insecure, and vice versa. Similarly, the end user diabetic suffering the consequences of an incorrect dose from an insulin pump will consider it unsafe, whatever the technicalities of the software's safety or security vulnerability.

It follows that security issues are often an extra level of complexity to consider in tandem with the adherence to existing safety-related software standards. It is, therefore, useful to consider how this confusing array of standards helps to address rising concerns over embedded software security.

Common Critria Evaluation Assurance Level (EAL)	Process rigor required for development of an IT product
EAL 1	Functionally tested
EAL 2	Structurally tested
EAL 3	Methodically tested and checked
EAL 4	Methodically designed, tested and checked
EAL 5	Semi-formally designed and tested
EAL 6	Semi-formally verified, designed and tested

Table 1. ISO 15408 defines a range of Evaluation Assurance Levels (EALs), which determine the process rigor associated with each software component.

What the Standards Suggest

There are two kinds of standards to consider:

- Process standards describe the development processes to be followed to ensure that the finished product is written to behave in a safe manner (such as IEE/EIA 12207, or ISO 26262 for road vehicles) or a secure manner (ISO 15408)
- Coding standards describe a high-level programming language subset (MISRA C , secureC) that ensures the software is written as safely and securely as possible

There are many widely agreed principles when it comes to best practice for software development, whether that software is required to be high integrity or not. In the high-integrity markets, process standards originally designed for safety-critical work provide a sound basis for security-critical software too, provided that security risk considerations replace or supplement safety risk assessment.

This assertion is underlined by the Automation Standards Compliance Institute's recommendations. These suggest the implementation of a Software Development Security Assessment by referring to existing process standards such as ISO 26262, and superimposing best practice security measures on them.

ISO 15408 (also known as the "Common Criteria" with reference to the merged documents from which it was derived) is an international process-oriented standard that defines IT security requirements. Reference to that standard underlines the similarity between security and safety related software development, with the seven Evaluation Testing Assurance Levels (EALs) of ISO 15408 being highly analogous to the concept of Safety Integrity Levels adopted in such standards as ISO 26262.

The process standards present a path to build in security to the whole development process. In turn they require the use of coding standards as typified by language subsets such as CERT C, secureC and MISRA C:2012. These coding standards consist primarily of lists of constructs and practices for developers to avoid in order to ensure high integrity code.

Building Security In

Most software development focuses on building high-quality software, but high-quality software is not necessarily secure software. Testing is generally used to verify that the software meets each requirement, but security problems can persist even when the functional requirements are satisfied. Indeed, software weaknesses often occur by the unintended functionality of the system.

Building secure software requires adding security concepts to the quality-focused software development lifecycles

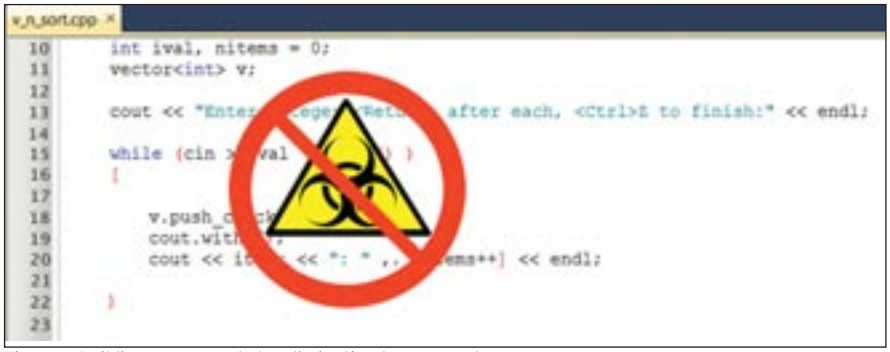


Figure 1. Building secure code by eliminating known weaknesses.

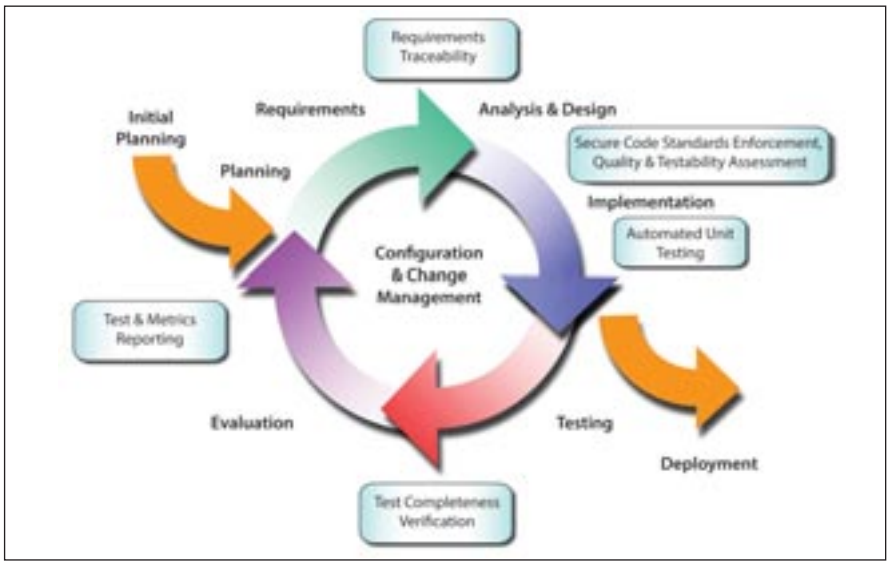


Figure 2. Secure Coding in the Iterative Lifecycle.

promoted by such as ISO 26262 so that security is considered a quality attribute of the software under development. Building secure code is all about eliminating known weaknesses (Figure 1), including defects, so by necessity secure software is high-quality software.

Security must be addressed at all phases of the software development lifecycle, and team members need a common understanding of the security goals for the project and the approach that will be taken to do the work.

The starting point is an understanding of the security risks associated with the domain of the software under development. This is determined by a security risk assessment, a process that ensures the nature and impact of a security breach are assessed prior to deployment in order to identify the security controls necessary to mitigate any identified impact. The identified security controls then become a system requirement.

Adding a security perspective to software requirements ensures that security is included in the definition of system correctness that then permeates the development process. A specific security requirement might validate all user string inputs to ensure that they do not exceed a maximum string length. A more general one might be to withstand a denial of service attack. Whichever end of the spectrum is used, it is crucial that the evaluation criteria are identified for an implementation.

When translating requirements into design, it is prudent to consider security risk mitigation via architectural design. This can be in the choice of implementing technologies or by inclusion of security-oriented features, such as handling untrusted user interactions by validating inputs and/or the system responses by an independent process before they are passed on to the core processes.

The most significant impact on building secure code is the adoption of secure coding practices, including both static and dynamic assurance measures. The biggest bang for the buck stems from the enforcement of secure coding rules via static analysis tools. With the introduction of security concepts into the requirements process, dynamic assurance via security-focused testing is then used to verify that security features have been implemented correctly.

Secure Software Through Coding Standards

In his book *The CERT C Secure Coding Standard*, Robert Seacord points out that there is currently no consensus on a definition for the term "software security". For the purposes of this article, the definition of "secure software" will follow that provided by the US Department of Homeland Security (DHS) Software Assurance initiative in *Enhancing the Development Life Cycle to Produce Secure Software: A Reference Guidebook on Software Assurance*. They maintain that software, to be considered secure, must exhibit three properties:

1. Dependability - Software that executes predictably and operates correctly under all conditions.
2. Trustworthiness - Software that contains few, if any, exploitable vulnerabilities or weaknesses that can be used to subvert or sabotage the software's dependability.
3. Survivability (also referred to as "Resilience") - Software that is resilient enough to withstand attack and to recover as quickly as possible, and with as little damage as possible from those attacks that it can neither resist nor tolerate.

There are many sources of software vulnerabilities, including coding errors, configuration errors, architectural and design flaws. However, most vulnerabilities result from coding errors. In a 2004 review of the National Vulnerabilities Database for

their paper "Can Source Code Auditing Software Identify Common Vulnerabilities and Be Used to Evaluate Software Security?" to the 37th International Conference on System Sciences, Jon Heffley & Pascal Meunier found that 64% of the vulnerabilities resulted from programming errors. Given this, it makes sense that the primary objective when writing secure software must be to build in security.

Fitting Tools Into the Process

Tools that ease and automate the path towards the development of secure applications exist for each step of the development process. The more integrated those tools are, the easier that process will be. For example, Figure 2 shows how such tools fit into an iterative development process.

- **Static analysis** – automating the process of static analysis and enforcement of coding standards such as CWE or CERT C Secure Coding guidelines ensures that a higher percentage of errors is identified in less time. Static software analysis tools assess the code under analysis without actually executing it (Figure 3).

  They are particularly adept at identifying coding standard violations. In addition, they can provide a range of metrics that can be used to assess and improve the quality of the code under development, such as the cyclomatic complexity metric that identifies unnecessarily complex software that is difficult to test.

  When using static analysis tools for building secure software, the primary objective is to identify potential vulnerabilities in code. Example errors that static analysis tools identify include:
  - The use of insecure functions
  - Array overflows
  - Array underflows
  - Incorrect use of signed and unsigned data types.
- **Requirements traceability** – a good requirements traceability tool is invaluable to the build security in process. Being able to trace requirements from their source through all of the development phases and down to the verification activities and artifacts ensures the highest quality, secure software.
- **Unit testing** – the most effective and cheapest way of ensuring that the code under development meets its security requirements is via unit testing. Creating and maintaining the test cases required for this, however, can be an onerous task. Unit testing tools that assist in the test-case generation, execution, and maintenance streamline the unit testing process, easing the unit testing burden and reinforcing unit test accuracy and completeness.
- **Dynamic analysis** –analyses performed while the code is executing provide valuable insight into the code under

analysis that goes beyond test case execution. Structural coverage analysis, one of the more popular dynamic analysis methods, has been proven to be invaluable for ensuring that the verification test cases execute all of the code under development. This helps ensure that there are no hidden vulnerabilities or defects in the code.

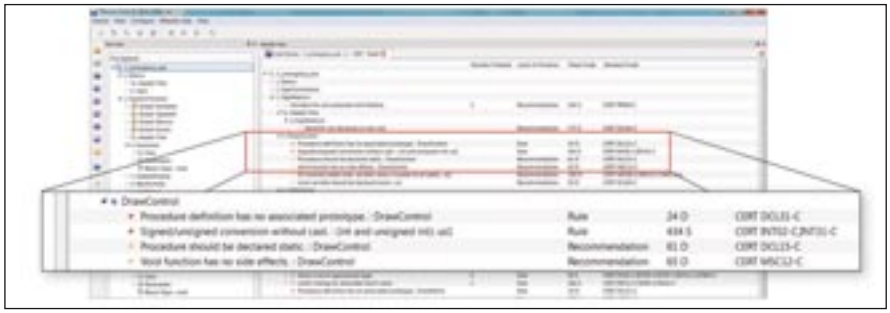


Figure 3. LDRA TBvision showing improper data type sign usage resulting in buffer overflow vulnerability.

Conclusion

It is not surprising that the processes for building security into software echo the high-level processes required for building quality into software. Adding security considerations into the process from the requirements phase onwards is the best way of ensuring the development of secure code, as described in Figure 2. High-quality code is not necessarily secure code, but secure code is always high-quality code.

An increased dependence on Internet connectivity drives the demand for more secure software. With the bulk of vulnerabilities being attributable to coding errors, reducing or eliminating exploitable software security weaknesses in new products through the adoption of secure development practices should be achievable within our lifetime.

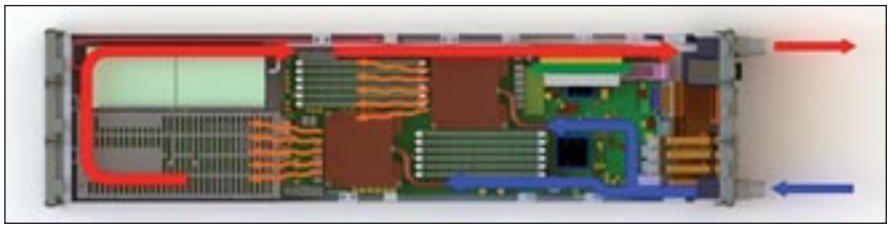
By leveraging the knowledge and experience encapsulated within the CERT-C Secure Coding Guidelines and CWE dictionary, static analysis tools help make this objective both practical and cost effective. Combine this with the improved productivity and accuracy of requirements traceability, unit testing and dynamic analysis and the elimination of exploitable software weaknesses become inevitable.

This article was written by Mark Pitchford, Field Applications Engineer, LDRA (Wirral, UK). For more information, visit ***http://info.hotims.com/49750-500****.*

Submersion and Directed Flow Cooling Technology for Military Applications

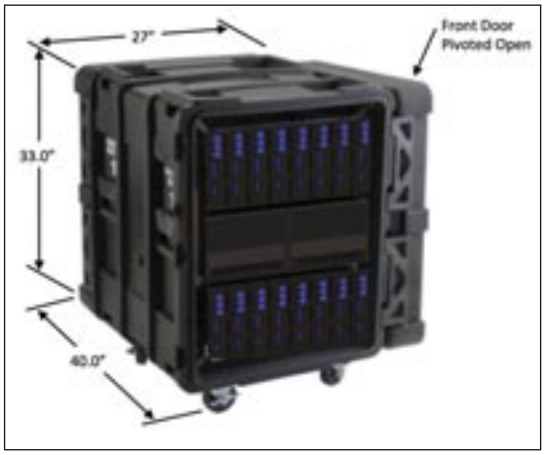
As the US military shifts from boots on the ground to drones in the sky, there will be an increasing need for computing power on foreign soil, under the sea and in the air. Design objectives will be difficult to achieve with legacy technology. Electronic gear must be deployed by transport plane and require rapid setup once the destination is reached. Systems will need to be hardened to survive extreme temperatures, desert sand, salt air and pollution. Fuel logistics to serve remote locations can be difficult and expensive. Every kilowatt-hour of electricity converted to heat must be dissipated and, ideally, the waste energy should be recycled. For ground installations, it will be useful to consider distributing computing resources around rather than concentrating them at a single location that may be vulnerable to attack. Silent operation also is desirable.

The traditional method of cooling electronics by circulating air around and through components achieves none of these objectives. The cooling system comes in pieces, and field assembly takes time. Fans used to circulate massive amounts of air waste energy, take space, make noise and expose computing equipment to corrosion and air pollutants. Mechanical refrigeration systems to maintain humidity levels and cool equipment in hot weather waste even more energy.



In the LCS server, all electronic components are submerged in the dielectric coolant, which is directed to the hottest components first and then circulated throughout the enclosure to capture the rest of the heat.

Liquid cooling, applied intelligently, can be an ideal solution, but not every approach is suitable for military applications. Cold plates, which circulate water through heat sinks mounted on the processing chips to a heat exchanger in the sever chassis, were developed to move heat away from hot spots, not save energy or isolate electronics from harsh environments. Only 60% of the heat is generated by processors in most servers, so fans are needed to remove heat from the other components. These pumps, fans and heat exchangers in each computer chassis are subject to failure, and when a leak occurs and water touches electronics the result is catastrophic. Other cooling solutions, designed for extremely high power systems, involve refrigerants that remove heat by evaporation, but these two-phase systems add cost and unnecessary complexity.



A ruggedized 16-server liquid-cooled rack for harsh environments and military applications.

If the thermal load is less than 100 kilowatts per rack a single-phase cooling system, where all electronic components are submerged in a non-conducting dielectric liquid, is the best alternative. This technology decouples electronic components from the environment, and offers a long list of important benefits for military applications. Electronics are isolated from oxidation and air pollution; there is no noise, vibration or extreme temperature fluctuation; fans and mechanical refrigeration are eliminated; there is no need for humidity control; and heat is recovered in a convenient form for recycling. Because the heat transfer liquid is circulated through the racks and IT devices from a central pumping station, there are no fans, pumps or other moving parts in the chassis.

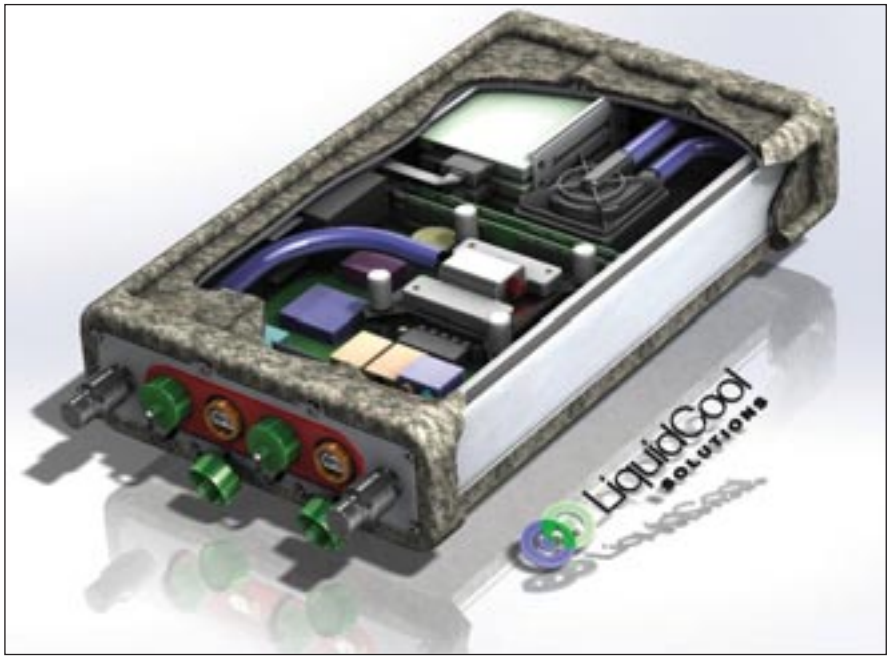
Total Immersion Technology

Three companies offer total immersion systems: Green Revolution Cooling, Iceotope and LiquidCool Solutions. Instead of submerging electronics in an air bath, which is current practice, the fluid in the bath is a dielectric liquid that does not conduct electricity or harm electronic components. Properly formulated dielectric fluids are maintenance free and never replaced during the useful life of an IT device. While the technology developed by all three companies that offer total immersion is similar, they differ in scalability, maintainability and cost efficiency. The devil is in the details.

Green Revolution Cooling's cooling system resembles a rack tipped over on its back, with modified servers inserted

vertically into slots in the tank. The tank is filled with a coolant similar to mineral oil, which is circulated through the tank by an external pump. This approach requires a relatively large amount of floor space, limiting scalability in a multi-rack environment. The system is not fully sealed, which could lead to fluid contamination in certain environments. Moreover the liquid-filled tank is heavy and assembly in the field would make its deployment for most military applications expensive, time consuming and logistically challenging.

Iceotope's version of immersion cooling includes off-the-shelf motherboards mounted inside sealed hot-swappable cartridges that are flooded with a dielectric fluid. There is a secondary circuit with water, pumped from a central station, snaking through a channel inside one wall of the cartridge to take the heat out of the dielectric fluid. This two-circuit approach adds cost, introduces



Cutaway view of a ruggedized small form factor computer designed for total immersion cooling.

	Air-Cooled Systems	Cold Plates	2-Phase Refrigerant Systems	Green Revolution Cooling	Iceotope	LiquidCool Solutions
Ship by Transport Plane	Yes	Yes	Yes	No	Yes	Yes
Rapid Setup in the Field	No	Yes	No	No	Yes	Yes
Fans Required	Yes	Yes	No	No	No	No
Mechanical Refrigeration Required	Yes	Yes	No	No	No	No
Humidity Control Required	Yes	Yes	No	No	No	No
Energy Usage	High	High	High	Low	Low	Low
Hardened for Extreme Temperatures	No	No	Yes	Yes	Yes	Yes
Hardened for Polluted Air	No	No	Yes	Yes	Yes	Yes
Ability to Distribute Computing Resources	No	No	Yes	No	Yes	Yes
Ability to Recycle Waste Heat	No	Yes	Yes	Yes	Yes	Yes
Water in the White Space	No	Yes	No	No	Yes	No
User Friendly Rack Management	Yes	Yes	No	No	No	Yes
Easy to Maintain	Yes	No	No	No	No	Yes
Scalable	Yes	Yes	No	No	Yes	Yes
Cost Efficient	No	No	No	No	No	Yes

water to the white space and interferes with maintenance.

LiquidCool Solutions currently holds 17 patents surrounding cooling electronics by total immersion in a dielectric fluid. For rack-mounted servers the dielectric fluid is pumped from a central station through a manifold mounted on the rack into sealed IT devices, flooding each chassis and slowly flowing over and around the circuit boards and internal components via directed flow. Within each device, coolant is circulated directly to the components with the highest power density while heat from the remaining components is conveyed by the bulk flow as the coolant is drawn through the unit to a return manifold.

LCS patents also cover the rack system that connects IT devices to the central coolant flow via dripless couplings, which facilitates access for rack management and device maintenance; it is possible to hot swap a rack-mounted IT device in less than two minutes. Once the coolant exits the enclosure, it is circulated outside the datacenter where the heat is captured for commercial reuse or rejected to the atmosphere by a commercially available fluid cooler.

The adoption of immersion liquid cooling technology has been slowed by a perception that the equipment is expensive and difficult to maintain. Critics, chained by inertia, argue that the technology will be practical only when power densities are too high for air cooling. However the benefits of immersion cooling are compelling enough to convert today regardless of power density.

Over a century ago the world began trading the horse & carriage for a horseless carriage, not to go 30 miles per hour, but to get rid of the horse! The horse ate, wasted space and polluted the environment, and it did not take long for everyone to understand the value proposition of the new technology. Total immersion cooling eliminates fans in IT devices and datacenters. Fans chew up energy, waste space and expose electronics to pollution. They are the root cause of most IT equipment failures, either because the fan itself fails or exposure to air causes electronic components to degrade. So eliminating fans reduces the amount of maintenance required. Eliminating fans is akin to getting rid of the horse!

The Value Proposition

Comparing the value proposition with legacy air systems, or other forms of liquid cooling for that matter, immersion cooling saves energy, saves space, enhances reliability, operates silently, and can be surprisingly easy to maintain in the field. Immersion cooling systems also simplify upgrades because there is enough cooling capacity in the chassis to accommodate future heat loads so only the boards need to be changed. When produced in volume, efficiently designed immersion cooling devices will cost less than air-cooled equipment because they have no moving parts and last longer. Oh, and by the way, immersion cooling systems can dissipate 100 kilowatts per rack.

The above table summarizes the benefits and challenges associated with the universe of cooling solutions for military applications:

As is so often true with innovations that change the world, the military will pave the way as an early adopter of liquid cooling technology to solve problems that legacy systems cannot. Conventional datacenter users will follow soon thereafter as they come to appreciate immersion cooling's comprehensive value proposition.

This article was written by Herb Zien, CEO, LiquidCool Solutions (Rochester, MN). For more information, visit ***http://info.hotims.com/49750-501****.*

Flying on Vegetation

Airlines, aircraft companies, and other stakeholders are taking the long view in developing sustainable alternatives to petroleum-based jet fuels.

by Bruce Morey

In May 2014, an Airbus A330-200 of KLM Royal Dutch Airlines used a 20% blend of sustainable fuel made of used cooking oil, for a 10-h flight from Schiphol airport in Amsterdam to the Dutch Caribbean island of Aruba. It was part of a pilot project in the European initiative called ITAKA (Initiative Towards sustAinable Kerosene for Aviation), with the fuel supplied by SkyNRG. (Airbus)

Fuel is expensive for airlines. According to sources interviewed for this article, fuel accounts for 30 to 50% of operating costs, depending on the size of the aircraft. And fuel prices remain volatile.

At the same time, there are few alternatives to powering aircraft. While land transport has some available options—think electric vehicles and hydrogen fuel cells—aviation depends on liquid fuels with high energy density. Emissions are another concern. According to the Air Transport Action Group (ATAG), aviation is responsible for 2% of global manmade CO^2 emissions.

Fuel supplies may be stressed even more as worldwide air travel demands continue to grow. According to the Boeing 2014 Current Market Outlook forecast, world passenger traffic will continue to grow at a rate of 5% annually. Similar forecasts come from Airbus.

Fuel price volatility, increasing demand, emissions from fossil fuels, and lack of alternatives are pushing the industry into a search for renewable, sustainable, low-carbon alternatives such as biofuels.

Fuels, Certifications, and Challenges

A key issue is sustainability. To be sustainable, suppliers must produce biofuel through non-destructive agriculture and in doing so emit no more carbon than its product saves. Boeing describes sustainable biofuel as emitting 50 to 80% less carbon compared to fossil fuel.

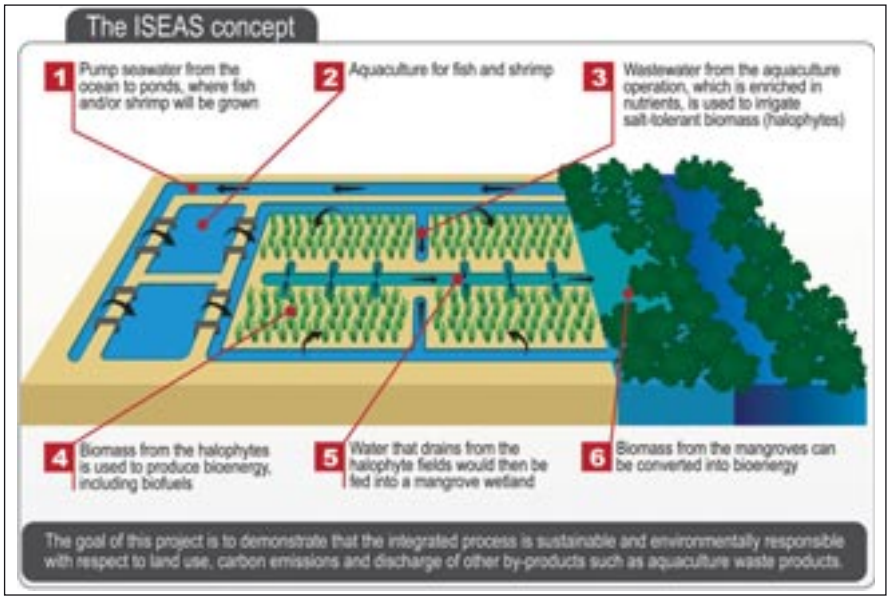
Brazilian airline GOL committed to fly its Boeing 737 fleet with up to a 10% blend of the renewable fuel farnesane. Initial flights were to begin in July 2014.

Another constraint for biofuel suppliers is that aviation industry needs "drop-in" fuels—fuels that can blend directly with petroleum jet fuel without requiring modification to existing jet engines, airplanes, or fueling infrastructure.

To ensure compatibility, ASTM must approve the fuel before aviation regulatory agencies would allow its use, according to Dr. Ric Hoefnagels. He is a Researcher with the Copernicus Institute of Sustainable Development, part of Utrecht University in The Netherlands. He contributes to the Climate-KIC project Fuel Supply Chain Development and Flight Operations (Renjet). The project includes partners such as Schiphol, KLM Royal Dutch Airlines, SkyNRG, and Imperial College London, among others. The goal is to create a self-sustaining network of regional renewable jet fuel supply systems in the European Union, and Renjet is grappling with aviation biofuel issues ranging from supply to compatibility.

"Until recently, there were only two ASTM-certified pathways for jet fuel production from biomass," he explained. One is hydro-processing of esters and fatty acids (HEFA) using vegetable oils or used cooking oil as feedstocks. This is sometimes referred to as Bio-SPK. The vast majority of commercial flights on biojet have been fueled by HEFA fuels.

Salicornia is showing promise in sustainable aviation biofuel research at Masdar Institute of Science and Technology in Abu Dhabi. (Boeing)



This infographic from the Sustainable Bioenergy Research Consortium depicts the Integrated Seawater Energy and Agriculture System (ISEAS).

While initial capital cost is lower, "the main issue [for Bio-SPK] is that those fuels are quite expensive," said Hoefnagels. "It is really difficult to reduce these costs because either the supply potential is limited, as in the case of used cooking oils; or the cost is in the feedstocks, as in the case of vegetable oils."

Another certified pathway uses high-temperature gasification of biomass or waste, such as municipal waste, which is converted into syngas. The syngas is then subjected to Fischer-Tropsch synthesis reaction to form synthetic paraffinic kerosene, sometimes called FT-SPK. The synthesis process in its essence is similar to coal-to-liquid (CTL) or natural gas-to-liquid (GTL) refining, and is similarly capital-intensive. It requires large, complex refineries.

"However, it has potential to reduce cost in the future," Hoefnagles said, though it requires large investments in research, development, demonstration, and deployment.

ASTM in a June 2014 press release announced approval of a third type of fuel, Renewable Synthesized Iso-Paraffinic (SIP) aviation biofuel for use in commercial airplanes through its ASTM D7566 specification. This followed an announcement by Amyris and Total that the companies are preparing to market a drop-in SIP jet fuel that contains up to 10% blends of farnesane, a renewable biofuel that is made from plant sugars and will be blended with petroleum jet fuel. Amyris uses a proprietary process for converting sugars into jet fuel, using a pathway they call Direct Sugar to Hydrocarbon (DSHC). This will open biofuel development in places like Brazil, where Amyris is using sugarcane or other plants with a high sugar content, such as sugar beets.

Future Projects and Technology

"There is only so much arable land and fresh water to go around," said Michael Lakeman, Regional Director of Biofuel Strategy for Boeing Commercial Airplanes, in an interview with *Aerospace & Defense Technology*. "It's important to make a paradigm shift in thinking about biofuel production. Instead of viewing biofuel as a "food or fuel" situation, develop new models where producing biofuel enables more food production—producing "food and fuel."

A pilot project that Boeing is helping to fund in the UAE is doing just that. Conducted by the Sustainable Bioenergy Research Consortium (SBRC) at the Masdar Institute of Science and Technology, a program will evaluate the feasibility of producing biofuel using desert plants called halophytes. These are saltwater-tolerant and can be irrigated with seawater. Other funding partners include Etihad Airways and Honeywell UOP. SBRC research to date has found that entire shrub-like halophytes, such as salicornia, can be turned into a biofuel more efficiently than many others

The key to sustainability is to think beyond jet fuel to integrate aviation biofuel production into regional aqua-

Etihad Airways conducted a 45-min demonstration flight on Jan. 18 with a Boeing 777-300ER powered in part by the first sustainable aviation biofuel produced in the UAE.

culture, or fish farming, Lakeman said. "Fish farms produce a lot of waste, which is a real challenge."

Typically, effluent from aquaculture operations, when pumped back into natural water bodies, causes pollution or eutrification from algae blooms. With the system being developed in the UAE, fish waste is used as fertilizer to grow the halophytes. In the process it cleans the seawater, which is returned to the ocean, Lakeman explained.

He admits there are challenges, including domesticating a wild plant for the first time. "There is a lot of work, and we know it is not a short-term win here." It's a long-term play that could pay off big.

Sustainability Today

An example of current biofuels distribution is the company SkyNRG. According to Sierk de Jong, a researcher with the Copernicus Institute and part-time employee of SkyNRG, the company was

founded in 2009 as a joint venture with KLM, Spring Associates, and Argos Oil, a downstream oil distributor. Its mission is to develop a market when there are no producers or buyers of aviation biofuel.

Price remains a key obstacle that SkyNRG has been tackling. De Jong describes the fuel from SkyNRG as Bio-SPK. "In 2009, sustainable jet fuel was twenty times more expensive than fossil kerosene," he said. "We have today driven it down to two or three times."

Even so, airlines are reluctant to pay even that. So, the price premium is co-funded through corporate clients associated with KLM. "Eventually, with technology developments, I believe that we can drive down the price further," said de Jong.

"Because it's a specialty product," he continued, "there is currently very little dedicated sustainable jet fuel production capacity in the world. Creating scale is crucial. So SkyNRG's main long-term effort lies on increasing production capacity. The company is teaming up with governments, airlines, and airports around the world to create so called "BioPorts"—regional dedicated supply chains to produce sustainable jet fuel."

Markets and Investments

Both Boeing's project with Masdar and the SkyNRG joint venture confirm observations from PwC's survey in April 2014 gauging interest in the total biofuels market. About 52% of the executives surveyed were optimistic about aviation biofuels. Brian Carey, PwC's U.S. Cleantech Advisory Leader, told Aerospace & Defense Technology that "a number of players see biofuels as the Holy Grail, helping to guarantee price stability."

However, the Holy Grail is not upon us yet. The technology needs to improve and the industry needs to scale up to drive costs down. Carey pointed out that price parity is vital to acceptance.

What he is observing is the difference in the type of organizations willing to make the investments needed to finally achieve that price parity.

"Four or five years ago," he said, "there was a fair number of venture capital investments in early-stage advanced-biofuels companies. Some [biofuel] companies tried IPOs too soon; these companies were trying to do too much too fast."

Today he is seeing investments from airlines, airplane OEMs, and others with a strategic stake in the development of biofuels—including a few select oil and gas companies.

"Airlines are willing to pay for pilot projects," he said. "They are willing to put in place joint ventures with advanced biofuels companies to keep their options open."

Avionics Heat Up, in a Good Way

As was apparent at Farnborough, if there is a single technology theme that today dominates how aircraft are designed, built, and operated, it is the transformational progress being made in aerospace avionics, and the human-machine interface.

by Richard Gardner

Main panoramic display screen designed by Elbit for helicopter use. (Elbit)

The common feature shared by recent aviation platforms is the high level of systems integration, and the way in which information is displayed or made accessible, allowing previously unimaginable levels of situational awareness to be available to pilots and ground controllers. This has greatly eased the pilot workload and enhanced flight safety, especially when flying in poor weather or operating in unfamiliar or hazardous terrain.

The transition from analog to digital cockpit displays has been comprehensive, but more recently the development of interactive applications and associated technologies has promoted even more rapid progress, notably with the growing adoption of touchscreens, head-up displays (HUDs), and helmet-mounted displays (HMDs). The fusion of synthetic (computer generated) images with real-time inputs from onboard sensors has created a display revolution that is now working its way into a wide variety of avionics products aimed at aircrew and, in the case of commercial passengers, into global interconnectivity.

The current standard in commercial cockpits, complete with HUDs, inside the Boeing 787-9. (Richard Gardner)

2020 Keeps Getting Closer

At the 2012 Farnborough International Air Show, Thales unveiled a proposal for a future one-piece "wrap around" touchscreen display panel that could be adapted to fit any cockpit and which would replace separate screens and control panels. The company has now moved on from this and at this year's Farnborough presented its latest iteration of how the next-generation "cockpit of the future" might look.

While less science-fiction looking than the previous design exercise, the new concept, "Cockpit 2020" is a more practical stepping stone toward a new way of exploiting the large amount of information that is available from onboard sensors and data links, as well as from stored data. The unitary displays comprise very large integrated flat touchscreens that can display interchangeable information between pilot and co-pilot positions, or can be configured flexibly as required.

The intention is to provide both a "strategic" picture of the entire flight

The F-35 pilot's office—ultra simple with panoramic touchscreen. (Richard Gardner)

The Thales future Cockpit 2020 aims to replace all switches and console controls with touchscreens. (Richard Gardner)

profile, from start to finish, as well as the more "tactical" en route information, which will include upcoming weather, terrain, and air-traffic-movement information, and such factors as fuel states, optimum speed, and altitude data.

Instead of giving the pilot a massive level of information to absorb, the 2020 concept prioritizes what is actually required at each stage of the journey. For example, after start up, the system will merge data provided from an onboard airport map database, with electro-optical sensors (which will give day or night vision) and GPS positioning, and will overlay visually the taxiing route as directed from the airport control tower.

After takeoff the main display will show the flight plan, in 3-D, with a vertical display chart available, and all other information as requested by selecting from the menu and touching the screen. Such hazards as bad weather ahead will be shown in a contrasting color. The background will be in a "soft" monocolor with selected items highlighted in brighter markings or a different color.

The 2020 timescale envisages initial applications in new commercial aircraft, business jets, and civil helicopters. Thales sees this development as a user-friendly half-way solution between HUDs and head-down displays (HDDs), with all the benefits from both.

Development work for Thales' 2020 uses real displays, hardware, and interfaces, and is presently adding new functionalities, such as provision for a pilot to "slot in" an individual tablet device in a central pedestal location that will have been pre-loaded with flight information and other items. There will be secure entry/exit procedures for any such external devices introduced into the cockpit.

Thales is now looking at how to optimize the use of this technology, taking a modular approach so that in the future software can be added to give even more flexibility without having to re-certify the whole system. An open architecture is the key to bringing all this innovation together within a realistic timescale.

A Look Into the F-35 Cockpit

The F-35 didn't make it across the Atlantic for its planned international debut, but the week before the show, Lockheed Martin provided a media briefing day where there was a detailed update on the status of the program and the in-service evaluation and crew-training progress. Also offered was a chance to "fly" the F-35B simulator and to sample the game-changing situational awareness in this true 21st Century cockpit environment.

Understandably, with over eight million source lines of code (four times that in the F-22 Raptor) contained within its multi-million dollar airframe, getting everything to work as advertised in an operational setting is a huge challenge, and one that is not yet ticking all the boxes. But one-by-one the glitches are gradually being overcome and it is clear that when released for unrestricted operational service (probably around 2020) the aircraft will be in a class of its own.

Talking with the U.S. and U.K. pilots who are already flying the machine on a daily basis as the training program

ramps up, all agreed that this airplane is the easiest they have ever flown, with an "unbelievable" electronics-enabled capability. As more software enhancements, networked connectivity, and weapons are added over planned Block inserts, it's expected the aircraft will only get better.

So what exactly is it like in the driver's seat and how are avionics changing things so radically? The first thing that stands out as unusual is a spacious cockpit almost devoid of switches, with all essential controls grouped close together within easy reach around the left throttle control and right flight control side-stick.

Compared to most fourth-generation fighters, where every available space is taken up with added-on display panels and switches, the F-35 "office" looks empty. One reason for this is the single panoramic cockpit display in front of the pilot, offering 20 x 8 inches of touchscreen. This widescreen display, supplied by L-3, is comprised of two side-by-side units that have aircraft state information across the top strip while below are four changeable display groups that have all the tactical and mission information in a format selected by the pilot.

Typically, on a mission, the pilot will call up half the screen showing tactical information, such as navigation, hazard information, and aircraft movement data—including friendly and hostile aircraft and missile tracking—with the other half of the display showing the status of the aircraft systems, such as weapons availability and fuel states.

Touching the screen symbols or selecting from drop-down menus enables the pilot to access information instantaneously. Early fears that touchscreens might not be easy to use accurately in severe turbulence or high g combat conditions have not proved to be an issue, and the pilots destined for an operational career flying F-35s have adapted very quickly to this new way of doing things.

Above this display the view ahead through the massive canopy is unobstructed as there is no HUD on top of the combing. All the key in-flight information and critical mission data is prioritized by the display-management computer that integrates all the inputs from the different sensors and then projects the appropriate symbols in front of the pilot's eyes on the HMD system visor, developed by Vision Systems International. Initial versions suffered serious issues, so the Joint Program Office contracted BAE Systems to develop an alternative design. This showed great promise, but in the meantime VSI introduced various modifications to overcome the earlier performance shortcomings and is now back on the program.

BAE has continued to work on its own design, which has now evolved into the Striker 2, a much enhanced version of its current Striker HMD, which is

F-16 cockpit upgrade for South Korea from BAE Systems. (Richard Gardner)

used on the European Typhoon and Gripen fighters.

The F-35's HMD has a very demanding technical specification as it has to work in all day and night conditions and allow the pilot to look around through 360˚ (yes, even under and behind the aircraft due to full spherical cover provided by the Northrop Grumman-supplied Distributed Aperture System (DAS), which fills in beyond the pilot's physical viewing limits.) The information relevant to the pilot's field of view is prioritized for display on the HMD, but an alternative 360˚ display of the tactical situation can also be displayed on the panoramic HDD.

Systems information is all fused, so target identification and tracking can be acquired from the Northrop Grumman APG-81 AESA radar, the DAS, and the Lockheed Martin-developed Electro-Optical Targeting System (EOTS). Combined, this gives an unprecedented situational awareness around the aircraft day or night. EOTS combines forward-looking infrared (FLIR) and infrared search and track (IRST) functions that offer the F-35 pilot maximum flexibility when deciding to operate sensors in a passive or active mode, depending on the combat situation.

The built-in electronic warfare suite provided by BAE does away with the need for specialist EW aircraft carrying bulky external pods and gives both a self-defense warning capability against hostile aircraft or missiles and the ability, alongside the advanced synthetic aperture radar, to jam hostile radars, transmit false information, or gather signals intelligence. The airplane can thus take on a powerful networked ISR role within a larger air group in addition to providing its own air defense and attack capability, with its low radar cross-section qualities giving it a decisive edge over any adversaries.

As all the onboard systems are fully integrated and data fused, the F-35 promises to deliver the optimum mission solution in all envisaged circumstances. Taking most of the pilot workload out of the mission comes at a high cost but is what air forces have been dreaming about for generations. The reality is getting nearer, but it has not arrived yet, much like the plane itself to Farnborough.

Situation Awareness and Comfort for the Future

At Farnborough, there were many other examples of new avionics developments from all the major suppliers. Thales has developed and put into mass production its TopOwl for military helicopter use. It is claimed to be the widest-angle binocular helmet with a visor-projected display, ensuring that the pilot's natural vision of the outside world by day or night is preserved at all times.

Each helmet is individually tailored to the pilot for optimum comfort and performance with a finely tuned center of gravity, improving safety and reducing fatigue on long endurance missions of up to eight hours. Along with flight and cueing symbology with a precise head-tracking system that can be slaved to onboard weapons, it features an advanced computer-generated augmented reality to aid operations in poor flying conditions and at night with intensified night vision and FLIR imaging.

Thales also demonstrated its new lightweight Scorpion full-color helmet-mounted cueing system now in full production for use on Airbus helicopters as well as U.S. aircraft including the F-16, A-10, and AC-130W. Dynamic flight and mission data is projected directly into the pilot's line of sight via a large field of view, fully transparent, optical waveguide assembly. It's also compatible with night vision goggles. HMD symbology and patented features include integration with bar-coded canopy-mounted sensors (which require no extra cockpit wiring or intrusion into the avionics bay) that provide enhanced situational awareness in conjunction with other onboard sensors.

Isreal's Elbit was also very active at the show, exhibiting a range of HMDs. A new lightweight HMD, Skylens, aimed at civil helicopter operators was shown, which is part of the Clearvision enhanced flight vision system family from the company and is a goggles-like display that is as easy to wear and compact as a pair of sunglasses.

Skylens is supported by a low-impact single miniature tracker reference unit and gives pilots high-resolution images, information, and video, increasing safety on such missions as offshore oil and gas support operations. The Clearvision family also includes enhanced vision systems specifically designed for helicopters, the Skyvis monocular next-generation HMD, HDD, and HUD synthetic vision systems.

In case anyone thinks that HUDs are becoming obsolete, BAE revealed more

The Clearvision Skylens enhanced vision system from Elbit. (Elbit)

information on its latest HUD development, the Digital Light Engine (DLE), which generates the image source using digital techniques rather than using a cathode ray tube. The DLE increases display resolution (which degrades in time with a conventional HUD, requiring more power) by using waveguide optical technology rather than conventional optics.

According to the company, the new system allows a tenfold improvement in HUD reliability and a 50% reduction in repair costs. The resulting simplification in the design enables the HUD to be integrated easily with new displays, bringing new opportunities in upgrades to older, but still very capable combat aircraft such as the F-16.

But Farnborough was not just about military aviation. IntelliCabin, the latest cabin system offered by BAE, offers an upgraded experience for economy passengers—and could be on commercial airlines as early as 2015. IntelliCabin is an integrated approach to cabin management that provides a modular, scalable architecture for capabilities such as in-seat power, LED lighting, wireless tablet-based in-flight entertainment, and dimmable windows.

Its in-seat power solution reduces weight and costs while offering a smart distribution of power based on the needs of each passenger and the overall cabin. LED lighting and dimmable windows create a more relaxed ambience and assist with setting the environment for a comfortable onboarding and travel experience. Using either the central control panel or handheld devices, which can be utilized anywhere in the aircraft, cabin crew are able to adjust temperature and light settings to optimize levels of comfort for passengers throughout the flight.

Although most economy passengers are concerned with extra legroom, there is no doubt that other onboard facilities are set to improve as the avionics revolution continues to impact everyone who flies.

Airborne Antenna Considerations for C-Band Telemetry Systems

It is fairly well known within the aerospace community that telemetry is moving from the traditional L-band and S-band frequency ranges up to C-band. It is widely understood that the reason for this push to C-band is two-fold. First, traditional L and S frequency bands have been greatly reduced through reallocation for a variety of reasons by different markets, and second, the bandwidth required for most applications has seen exponential growth. This has not only been seen in military applications, but in civilian aerospace platforms as well.

Conformal antennas come in a variety of different shapes, sizes, and configurations, from discrete radiators such as a Flexislot™ (Figure 1a) or a patch antenna (Figure 1b), to arrays such as a Wraparound™ (Figure 1c). The Flexislot, or patch-style antennas, provide hemispherical coverage, while the Wraparound provides omnispherical.

In telemetry applications, it is usually desirable to cover as much of the radiation sphere as possible to ensure data is received during an abnormal event. This is why the Wraparound configuration is often the optimal solution. There are times, however, where it is not feasible to use a Wraparound. For example, it might not be feasible when there are obstructions on the vehicle that will prevent the utilization of the full circumference, or when the vehicle geometry is non-circular or physically so large that a Wraparound is simply not possible. The use of discrete elements on large geometries is but one consideration that must be taken into account in this transition to C-band telemetry.

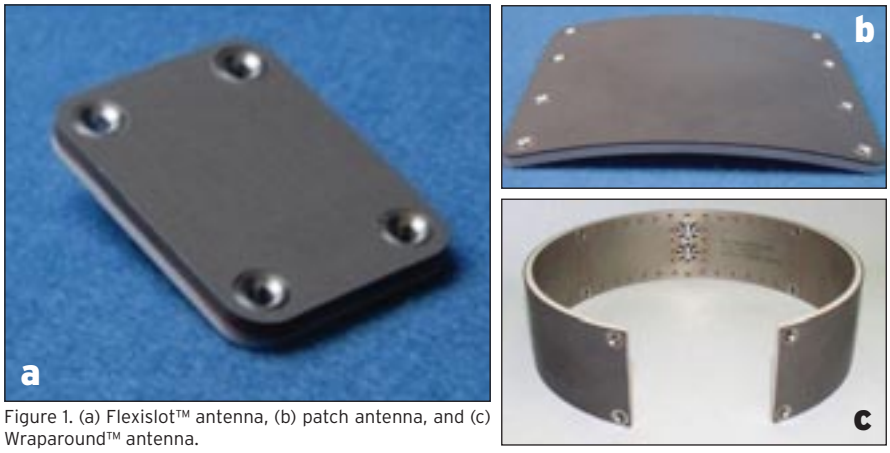


Figure 1. (a) Flexislot™ antenna, (b) patch antenna, and (c) Wraparound™ antenna.

Antenna Construction

For Wraparounds, there are two construction techniques: microstrip (Figure 2) and stripline (Figure 3). Microstrip has typically been the more popular technique and generally works well for L-band and S-band applications. The circuitry used to feed the multiple elements of a microstrip Wraparound is unshielded. The feed is reasonable in size at S-band or L-band. When the frequency is increased 2.5 times, however, this is no longer the case. Unlike the resonant patch, which decreases in size with an increase of frequency, the feed network is nearly invariant with frequency. At C-band, the feed network is physically large as compared to individual patches. It is common for high field areas to exist on the feed network itself (Figure 4).

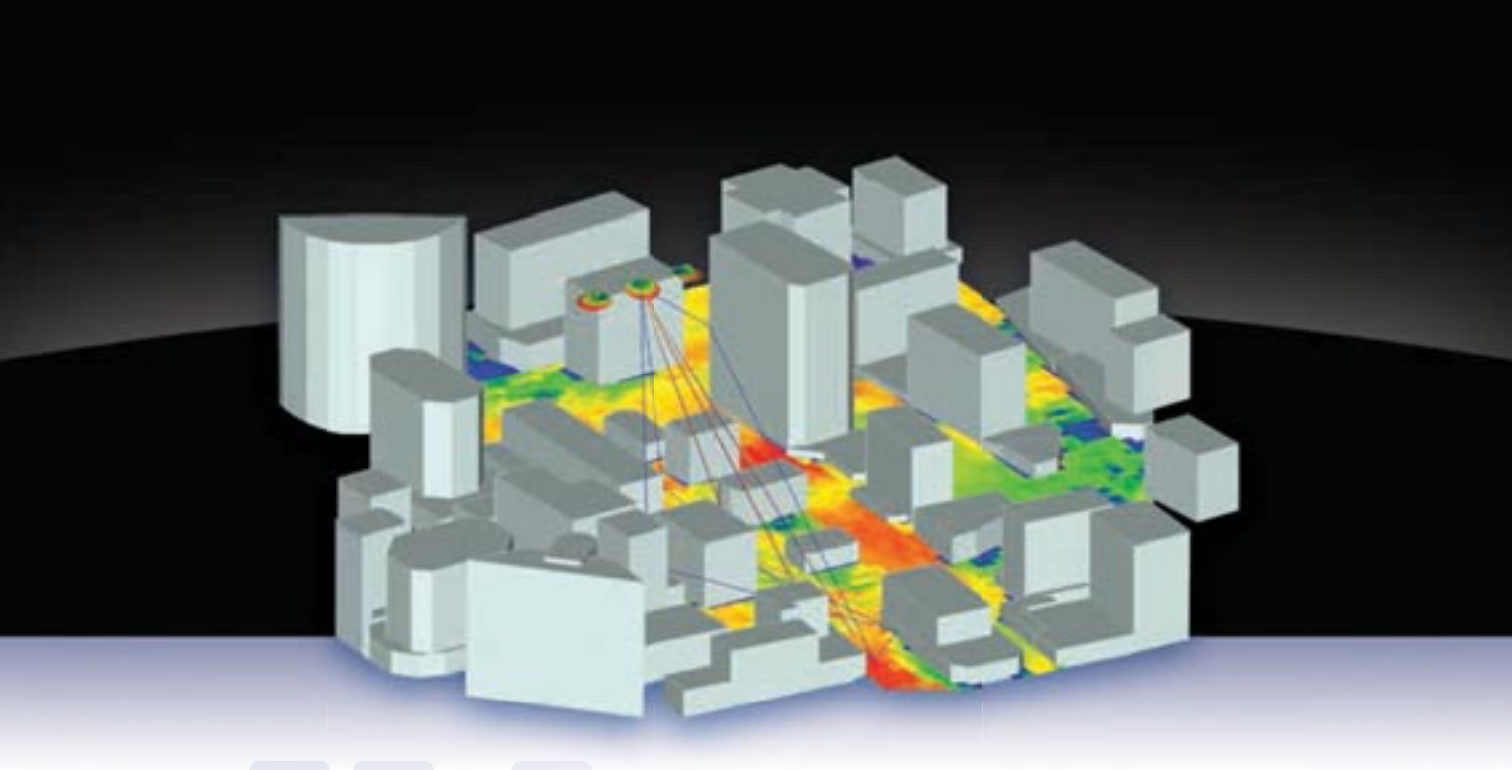
Given that the feed network on a microstrip design is unshielded, spurious radiation will occur. The radiation pattern is no longer strictly a result of the energy coming from the individual patches, but is also a function of this parasitic or spurious radiation from the feed network. This can result in a very messy radiation pattern. While there are certain design techniques that can be used to reduce the amount of this spurious radiation, it is still unshielded. Stripline construction is fully shielded. It radiates through a series of slots cut out in the ground plane, and can be superior in terms of radiation characteristics. Control of the pattern shape is one of the most important parts of antenna design.

Vehicle Influence

Antennas that provide omni-coverage induce surface currents on the ground plane (vehicle). When these surface currents hit a discontinuity such as a wing, fin, or ground-plane edge, they can radiate. The resulting antenna pattern is then not only due to the contribution from the antenna elements directly, but also the contribution of these additional sources. This can be demonstrated by mounting a hemispherical radiator on a cylinder 1 meter in diameter. The elevation pattern (with defined ends) contains a ripple, while the roll plane (without defined ends) is smooth. While the changes are not necessarily detrimental, it demonstrates that ground-plane or vehicle effects need to be considered.

To further highlight the impact vehicle geometry can have, the radiation patterns of a Wraparound were calculated when mounted first on a smooth cylinder, then with strategically shaped and placed fins near the antenna. The patterns for both cases are given in Figures 5 and 6, respectively. While this is certainly a dramatic case, it is not out of the realm of possibility. These types of parasitic structures can have a dramatic effect on pattern characteristics, and the pattern needs to be considered up front through simulations of the antenna on the vehicle geometry. This will help optimize the antenna design and/or location of the antenna on the vehicle before it is too late.

The effect the vehicle's geometry has must be considered, regardless of what frequency you are using. It becomes even more important as frequency increases, since fins, wings, or other parasitic struc-



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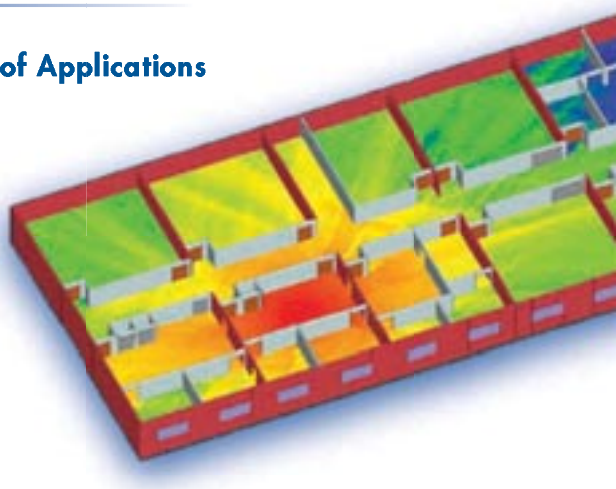

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tures are electrically larger at C-band than at L- or S-band.

Optimal Number of Elements to Use

When a full array such as a Wraparound cannot be used, it is widely thought that more is better – this is certainly not the case. In one example, we start with a single element and two hemispherical radiators on a cylinder, 180 degrees apart. With the exception of the area directly above and below the pattern, coverage is reasonably good. Adding additional elements results in a precipitous drop in pattern coverage, as this results in rather wide, deep nulls. Eventually there are enough elements added to achieve the optimal number of elements, and an omni-spherical pattern is obtained. This is the Wraparound configuration.

It is not always possible to utilize a full-circumference Wraparound, so the next best thing is almost always the two-element case. Certainly, two S-band elements will have far fewer nulls as compared to two C-band elements on the same diameter cylinder. There are limitations on the number of elements that can be utilized for a given configuration.

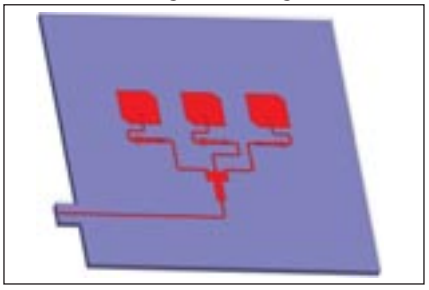


Figure 2. Typical microstrip circuit

Figure 3. Example of stripline (circuitry is shielded)

Positive Effects of Moving to C-Band

Due to the small wavelength, C-band antennas can be made considerably smaller and lighter than their L- and S-band counterparts. In addition, not only does the bandwidth grow proportionally with frequency, but percent bandwidth is actually greater. This means that if you have 100 MHz at S-band, you will have more than 250 MHz at C-band, most likely in the order of 300 to 400 MHz with the same type of design, just scaled up in frequency.

Transition Antennas

While the transition to C-band is taking place, certain areas are still utilizing L-band and S-band. It is therefore highly desirable to have an antenna that will handle all three — L-, S-, and C-band — as using a one-antenna solution simplifies system changeover.

Monopole and dipole antennas naturally provide multi-band performance with regard to voltage standing wave ratio (VSWR); however, only the lowest frequency band provides the desired radiation pattern. A common mistake is utilizing the VSWR solely to evaluate antenna performance. To get the full picture, radiation patterns must also be considered.

There are antennas specifically designed to maintain radiation pattern characteristics over frequency. The radiation patterns are essentially invariant as a function of frequency. The minor differences are actually caused by the ground plane changing in electrical size as we go from 1.4 to 5.25 MHz. The VSWR of the antenna is well under 2:1 over all of the telemetry bands.

Conformal Multi-Band Antennas

There are several ways that both S-band and C-band, or all three (L-, S-, and C-band), can be achieved in a conformal design. Certainly, the simplest is to have a

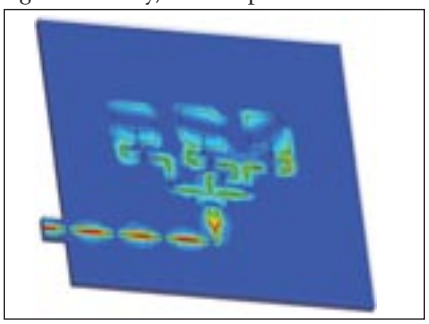


Figure 4. Microstrip circuit with fields

dual-band antenna with two distinct arrays within the same physical package, and two distinct connectors. This would result in possibly having to change to the correct RF connector (band) before use. An alternate approach embeds a diplexer inside a conformal antenna, L- or S-band radiators for legacy systems, and C-band radiators that are all fed through the embedded diplexer. This results in a single-port design. It is also possible to do this with a tri-band configuration of L-, S-, and C-band.

Given that the C-band, L-band, and S-band radiators are optimized for their respective bands, pattern characteristics would be the same and there would be no degradation. This multi-band conformal antenna would require additional space over the legacy L- or S-band antennas. In some cases, it may not be feasible to change the vehicle geometry to accept this larger antenna, but a C-band antenna can always be packaged to replace the lower-frequency legacy units.

Conclusion

There are several antenna considerations when changing from the legacy bands to C-band for telemetry. Choosing the wrong construction type, number of elements, and/or placement can have a major impact on overall performance. While all of the effects cannot be fully mitigated, in most cases, performance can be optimized, which will result in a successful link.

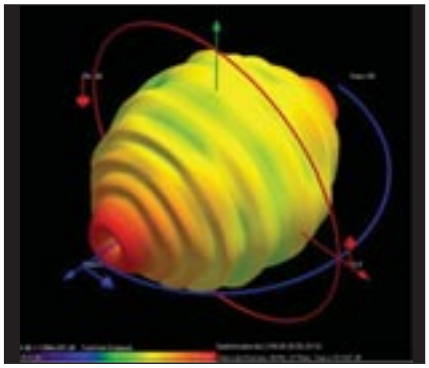


Figure 5. Smooth cylinder with no fins

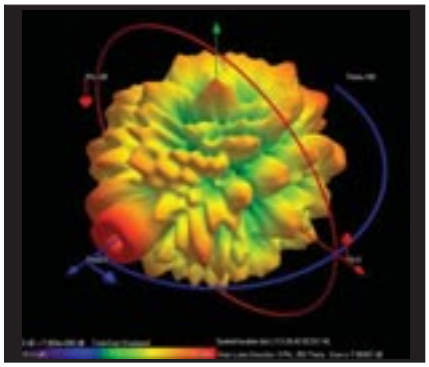


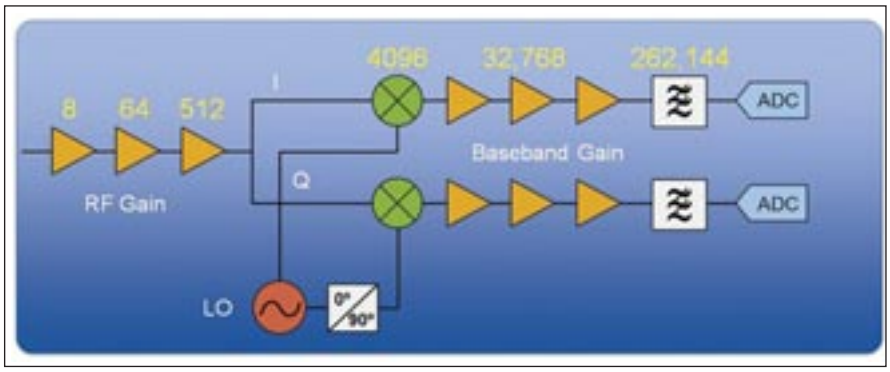
Figure 6. Smooth cylinder with strategically placed fins

This article was written by David Farr, Chief Executive Officer, and Dr. William Henderson, Chief Technology Officer, at Haigh-Farr, Inc. (Bedford, NH). For more information, visit ***http://info.hotims.com/49750-541****.*

Software-Designed System Improves Wireless Test Speed and Coverage

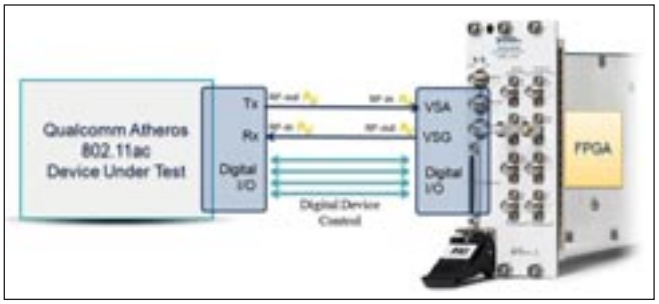
As wireless standards become more complex, the number of operational modes for these devices increases exponentially. As progression continues to the latest WiFi standard, new modulation schemes, more channels, more bandwidth settings, and additional spatial streams are added. Additionally, characterizing WLAN transceivers is especially challenging when faced with thousands of independent operational gain settings.

Each component of a WLAN transceiver has multiple gain stages. To develop a high-performance radio in a low-cost CMOS process, the design team at Qualcomm Atheros relies on flexible operation at each stage of the radio structure. Multiple gain settings drive a geometric increase in the number of possible setting combinations as each stage is added, which results in hundreds of thousands of data points for a single operational mode. These hundreds of thousands of data points are only for a single radio transceiver, and the number of permutations continues to increase for MIMO configurations where the system uses multiple antennas. This geometric increase in the number of possible setting combinations poses a significant challenge in preventing test times from increasing as well.



A block diagram of a typical WLAN receiver shows how each component has multiple gain stages, resulting in hundreds of thousands of different possible gain settings for a single receiver.

To tackle these test time challenges, Qualcomm Atheros uses the NI PXIe-



Qualcomm Atheros digitally controls the device under test using LabVIEW to program the FPGA on the NI vector signal transceiver.

5644R vector signal transceiver. Because it features an onboard field-programmable gate array (FPGA), Qualcomm Atheros can control the digital interface to the chip simultaneously with the RF signal generator and analyzer included in the vector signal transceiver.

Traditionally, FPGAs have been programmed using the VHSIC hardware description language or Verilog. Many engineers and scientists are either not familiar with these complex languages, or require a tool that gives them faster design productivity at a higher level of abstraction to simplify the process of generating FPGA code. LabVIEW is well suited for FPGA programming because it represents parallelism and data flow, so users who are both experienced and inexperienced in traditional FPGA design can productively apply the power of reconfigurable hardware.

Qualcomm Atheros used LabVIEW to program the FPGA on the NI vector signal transceiver for device under test control and data processing. The processing can take place within the instrument itself rather than requiring transfers back and forth over the bus to the controller, resulting in significantly faster test times.

Traditional rack-and-stack measurements are limited to best-estimate gain table selections. In this setup, Qualcomm Atheros determined a final solution through iterative estimations, each of which required a regression of the gain table characterization. This was a slow process that produced approximately 40 meaningful data points per iteration. After switching to the NI vector signal transceiver, the team could perform full gain table sweeps instead of using the iterative approach because of the test time improvements. The team could then characterize the entire range of radio operation in one test sweep per device to acquire all 300,000 data points for better determination of the optimal operational settings empirically. The availability of this data provided a view of the device operation never seen before so the team could explore operational regimes not previously considered.

By synchronizing the timing of digital control directly with the RF front end of the instrument, the team has seen test times improve by more than 20X over the previous PXI solution, and up to 200X over the original solution that used traditional instruments.

This article was written by Doug Johnson of Qualcomm Atheros, San Jose, CA, using National Instruments hardware and software. For more information, visit ***http://info.hotims.com/49750-542****.*

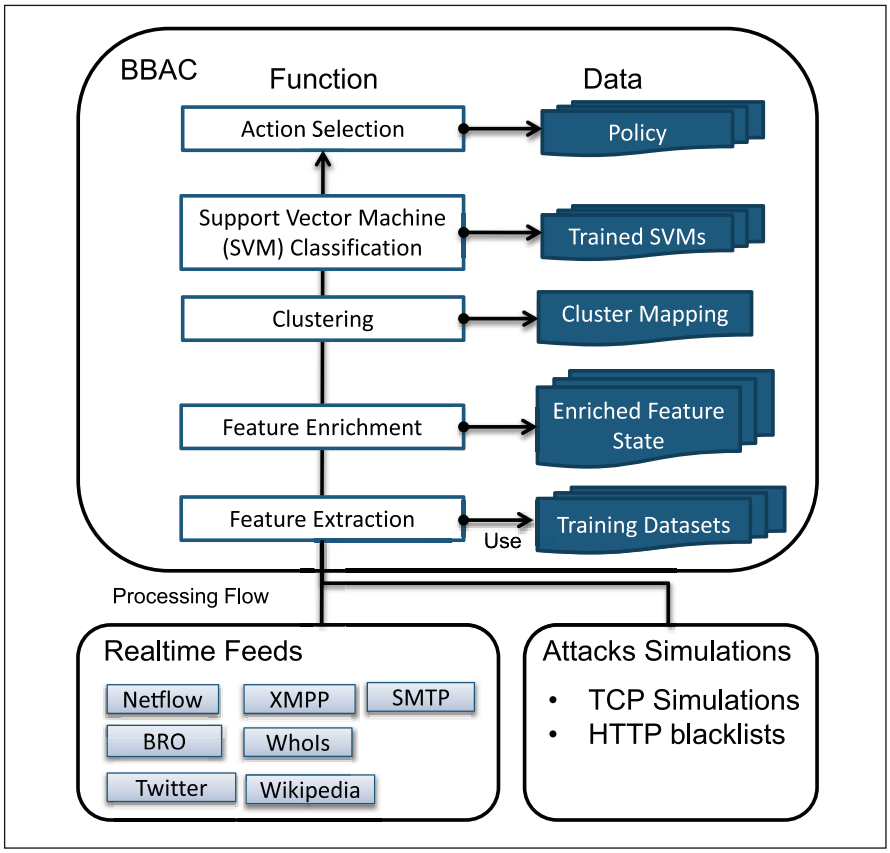
Developing and Validating Statistical Cyber Defenses

The development and validation of advanced cyber security technology frequently relies on data that captures normal and suspicious activities at various system layers.

Air Force Research Laboratory, Rome, New York

Enterprise business processes are more connected than ever before, driven by the ability to share the right information with the right partners at the right time. While this interconnectedness and situational awareness is crucial to success, it also opens the possibility for misuse of the same capabilities by sophisticated adversaries to spread attacks and corrupt critical, sensitive information. This is particularly true for an insider threat scenario in which adversaries have legitimate access to some resources and unauthorized access to other resources that is not directly controlled by a fine-grained policy.

Behavior-Based Access Control (BBAC) augments existing authorization frameworks such as Firewalls, HTTP proxies, and application-level Attribute Based Access Control to provide a layered defense in depth. The specific focus of BBAC is to analyze behaviors of actors and assess trustworthiness of information through machine learning. BBAC uses statistical anomaly detection techniques to make predictions about the intent of creating new TCP connections, issuing HTTP requests, sending emails, or making changes to documents. By focusing on behaviors that are nominally allowed by static access control policies, but might look suspicious upon closer investigation, BBAC aims to detect targeted attacks that are currently going unnoticed for an extended amount of time, usually months before defenders are aware of cyber attacks.



BBAC is a data-intensive system that turns real-time feeds into actionable information through a combination of unsupervised and supervised machine learning (clustering and SVMs).

The figure shows a high-level diagram of the processing flow in BBAC, together with the various data sets involved. As shown on the bottom, BBAC needs to ingest a large variety of data from real-time feeds through a feature extraction process. During online use, this data will be used for classification purposes. After parsing the raw observables, BBAC proceeds to go into a feature enrichment phase, where aggregate statistics are computed and information from multiple feeds is merged into a consistent representation. At this stage, BBAC needs to manage intermediate state required for more complex enrichment functions, e.g., calculating periodicity of events.

BBAC is a data-intensive system with successful execution hinging on (a) access to a large amount of external data, and (b) efficient management of internal data. Specifically, meaningful data sets are needed to develop and validate the accuracy, precision, and latency overhead of the BBAC algorithms and prototypes. BBAC's analysis techniques work best with data that has a rich context and feature space. What is needed is a large amount of granular data to do statistical inference. Getting access to more granular information generally means installing software on end-systems or even recompiling applications (to map memory regions etc.), both of which raise practical concerns. To address granularity issues, BBAC focuses its analysis on data that is easily observable without new software or modifying end systems.

Since BBAC performs analysis at multiple different system layers, it not only needs access to data from sensors at these layers, but the data in each layer needs to be linked to the other layers to represent a consistent picture of observables. To address the problem of independence between data sets, BBAC uses an approach for injecting malicious URLs into request streams of benign hosts. Known bad HTTP requests are retrieved from black-

lists, and intelligently inserted into existing connection patterns. It is important to keep the ratio of normal vs. abnormal traffic roughly equal allowing the resulting classifier to make decisions both on known proper behavior as well as known improper behavior.

Development and validation of statistical cyber defenses needs a well-labeled, appropriately sized, and readily available amount of relevant data to make innovative progress, yet too little of such data sets is available today. Agile project management techniques help deliver innovative technology in a difficult-to-work-in, data-intensive environment.

This work was done by Michael Jay Mayhew of the Air Force Research Laboratory, Michael Atighetchi and Aaron Adler of Raytheon BBN Technologies, and Rachel Greenstadt of Drexel University. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Information Technology category.*** *AFRL-0231*

Next-Generation Spectrometers for Rapid Analysis of Complex Mixtures

Spectrometers in chemical sensors are used in environmental and air quality monitoring, detection of hazardous gases and chemical warfare agents, and breath analysis in medical applications.

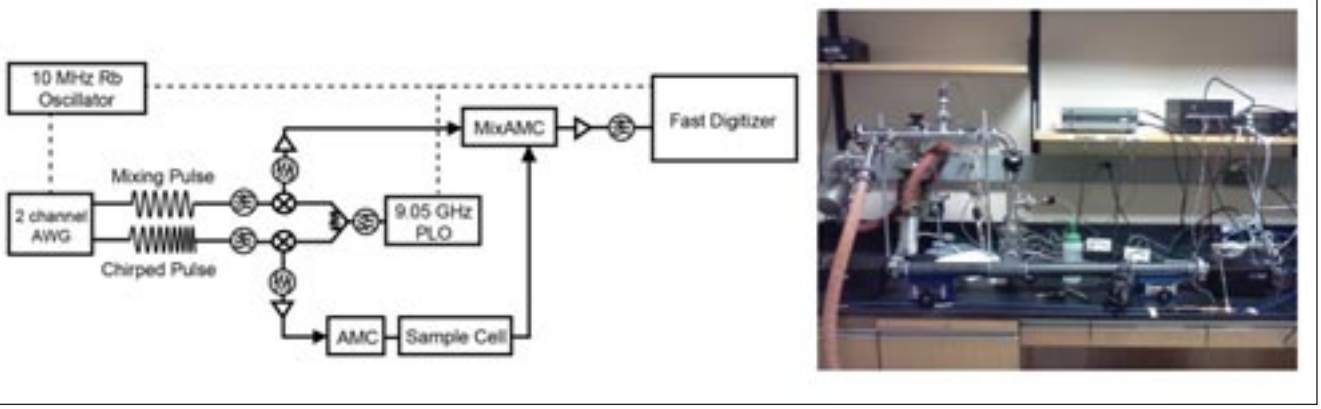
Office of Naval Research, Arlington, Virginia

Molecules have internal motions that are characteristic of their structure and identity. These motions can be studied by spectroscopy in different regions of the electromagnetic spectrum. Molecular spectra can be used as a "fingerprint" to unambiguously state whether or not a particular chemical is present and in what amount. As such, small portable spectrometers are frequently used as components of chemical sensors.

The spectrometers described here are used to study rotational motions of molecules. In principle, rotational spectroscopy can be used to detect any chemical compound with a dipole moment. Rotational spectra have traditionally been collected in the microwave/cm-wave region of the spectrum (2 – 50 GHz) at low temperatures (1 – 5 K). Achieving such low temperatures requires large, bulky instrumentation that is not suited for small, portable devices. Operation at room temperature significantly relaxes these requirements, but comes at the cost of signal intensity at cm-wave frequencies, meaning that optimal sensitivity will be obtained at millimeter or sub-mm frequencies, from 100 GHz to 1 THz.

A fast mm-wave spectrometer was developed that is amenable to miniaturization. The work was done in three main steps. First, a new FPGA-based digitizer that can average molecular signals in real time was used to improve data throughput to allow for the acquisition of very large numbers of averages. Second, a chirped-pulse mm-wave spectrometer was constructed using x12 amplified multiplier chains (AMCs) to generate mm-wave radiation from cm-wave sources, and to detect it via heterodyne mixing with a cm-wave local oscillator. Third, schemes to reduce the size of the spectrometer sample cell were tested.

The real-time digitizer can acquire 1 million averages of a 10 ms trace, sampled at 40 GS/s (record length of 400,000 points), in just under 12 seconds. Once the speed enhancement was confirmed, phase stability of the digitizer was tested by collecting 1 and 100 million averages of a molecular sample (nitromethane) and verifying the expected factor of 10 improvement in signal-to-noise ratios. After completing digitizer testing in the cm-wave range, the 110-170 GHz spectrometer was assembled and tested. Once chirped-pulse



The 110-170 GHz spectrometer. (Left) The two-channel arbitrary waveform generator (AWG) produces both a constant frequency mixing pulse and a chirped pulse. Each pulse is filtered, frequency shifted by mixing with a 9.05-GHz local oscillator, and amplified before being sent to x12 multiplier chains. The AWG, digitizer, and phase-locked oscillator are all synchronized with a 10-MHz Rb oscillator. (Right) The 1-meter-long PVC sample cell, the vacuum system, and a few of the components, power supplies, and cables.

generation and detection were tested, methanol was used to find optimal conditions for spectrum collection.

Overall, this project had three primary goals. The first was to incorporate real-time digitizers into spectrometers to drastically increase data throughput. The second was to construct a millimeter-wave spectrometer using this technology to benefit from the natural thermal population of molecules at room temperature. The third was to then use these combined benefits to explore reductions in sample cell volume for future miniaturization efforts. The first goal was definitely met and the digitizer performance was excellent. Spectra of 1 billion averages were collected over the course of a few hours. The second goal was met, but with some caveats. Output power limitations of the amplified multiplier chain required use of relatively low bandwidth chirped pulses to sufficiently excite the molecules, which in turn meant that the full 60-GHz bandwidth could not be covered with each repetition cycle. The third goal was not met, due in part to the fragility of these devices, and possibly due to the low power handling ability of the millimeter-wave receiver, which has a damage threshold below that of the typical output power of the amplified multiplier chain. Multi-pass designs that have longer effective pathlengths, but reduce instrument footprint, are likely the best route.

This work was done by Steven Shipman of New College of Florida for the Office of Naval Research. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Physical Sciences category****. ONR-0032*

Wireless Vital Signs Monitor for Trauma Patients

This monitor enables users to triage, prioritize transport, and track changes in numerous casualties from a remote location.

Army Medical Research and Materiel Command, Fort Detrick, Maryland

A miniature, portable wireless vital signs monitor (MWVSM), called Mini-medic™, could aid in the triage and diagnosis of trauma patients with and without traumatic brain injury (TBI). The MWVSM consists of two components, both of which are the approximate size and weight of a cellphone: one is a sensor that is placed either on the forehead or the fingertip of a patient, and the other is a monitor that receives a wireless signal transmitted up to 100 m carried by the medic.

The MWVSM was developed to capture whatever useful biological data is possible from small sensors placed on the forehead (or at a peripheral extremity site) of up to five casualties, then wirelessly transmit to small, cellphone-sized monitors carried by any first responder within range. To evaluate the MWVSM, it was hypothesized that changes in multiple parameters or derived variables monitored from the forehead (or extremity) of a severely injured patient correlate favorably with conventional vital-sign monitors, either before or after definitive treatment at a level 1 trauma center.

This study was comprised of 151 patients; an additional 23 pre-hospital patients were excluded because of missing or incomplete data. The majority of pre-hospital transports have finger sensors for logistic reasons, i.e. many patients are strapped to a backboard and the head strap is in the exact location for the MWVSM forehead sensor. The monitoring period varied from <10 minutes to >60 minutes. Some sensors fall off during transport. In many cases, valid

data are obtained for only a portion of the pre-hospital time.

Over a 20 to 40-minute pre-hospital monitoring period, the MWVSM heart rate sensor agrees with the heart rate measured by the conventional monitor, but the MWVSM SpO2 sensor does not. It should be emphasized that continuous digital data from MWVSM are averaged over the entire transport time for each patient and compared to the average of intermittent spot checks from the standard monitor obtained from the pre-hospital run reports. The data suggest that R-wave detection in the MWVSM more or less agrees with a standard monitor: it deviates 1-6 beats/min relative to a standard monitor. However, the MWVSM SpO2 detector is consistently 5-7% lower than the standard monitor.

These data show that the R-wave detection and pulse oximeter in the MWVSM finger probe are more accurate and follow changes better than those in the forehead probe in trauma patients. The results of this trial led to a redesign of the method for affixing the forehead sensor to the skin.

In summary, pre-hospital data showed there are major demographic differences in the characteristics of trauma patients and non-trauma patients. The MWVSM tracks heart rate within 1-6 beats/min, but the MWVSM SpO2 sensor consistently underestimates true SpO2, and this is almost entirely due to problems with the forehead sensor.

This work was done by Dr. Kenneth G. Proctor of the University of Miami for the Army Medical Research and Materiel Command. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Bio-Medical category.*** *ARL-0168*

Analysis of an In-Ear Dosimeter for a Single Hearing Protection Device

This data could help prevent permanent hearing loss in military personnel working in extreme noise environments such as those generated by jet aircraft.

Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio

US national and many international hearing conservation programs (HCPs) have adopted a noise exposure criterion of 85 dBA for a time-weighted average of 8 hours, with a 3 dB per doubling exchange rate (safe exposure duration was cut in half for each 3 dB increase in noise level). Military personnel who work in extreme noise environments require high attenuation from hearing protection in order to complete a normal duty day without risk of permanent hearing loss. Improvements to both hearing protection and noise dose monitoring have been consistently recommended and pursued as a means to reduce risk for noise-induced hearing loss.

The goal of adequately protecting the hearing of military personnel in high noise environments could not be achieved without considering the bone/tissue conduction flanking pathways of noise, in addition to the air-conducted pathways through the ear canals. It was important to understand the combined effect of sound energy transmission pathways when attempting to calculate an individual's true noise dose. Since temporary threshold shifts (TTS) is an auditory response to noise dose, it was used in this study to account for the total effect of noise exposure on the auditory system.

TTS studies in humans represent the only ethical means to accurately investigate the effects of noise on human hearing. While the risk of permanent hearing damage was not nonexistent, data from previous human studies at

Subjects wore the in-ear dosimetry earplugs (left) for occluded ear sessions. Each earplug had an integrated microphone for use in determining noise dose. (Right) The in-ear dosimeter, calibration device, and analysis equipment.

the same noise levels and exposure times used in this study indicated a less than 1% risk for permanent hearing loss. Test subjects were introduced to a brief duration of noise (5 minutes at 97 dB overall sound pressure level (OASPL), 10.5% of daily allowable noise dose) to ensure that subjects were comfortable with simply being in the noise environment, as well as to eliminate any subject with an unusually susceptible auditory system.

The first component of the experiment was conducted in a reverberant chamber — a specialized hearing test facility in which a subject's behavioral hearing thresholds were assessed using Békésy tracking in a diffuse sound field. Subjects wore in-ear dosimetry earplugs for occluded ear sessions. Each in-ear dosimetry earplug had an integrated microphone for use in determining noise dose. Each subject's predicted dose level was calculated to ensure subject safety. The subject's passive noise attenuation was calculated for that day's fit across seven octave band frequencies. The subject's fit remained unaltered between the measurements and the noise exposure. The noise level in the room was determined using the octave band method. Based on the subject's auditory responses to open ear sessions, it was determined if the subject should be exposed at 25%, 50%, or 100% noise dose from the individual susceptibility to threshold changes.

Pre- and post-noise exposure DPOAE measurements were collected for left and right ears at 3000, 3250, 4000, and 6000 Hz. Initially, data were collected at 91 dB as well as 97 dB; however, it was determined that 94 dB would be the only level used for determining the calibration factor. The maximum open ear TTS data at 94 dB for each subject were used to calculate a second-order polynomial function to display the individual TTS growth. The maximum occluded TTS was entered into the polynomial function to determine the effective noise dose for each individual subject.

Based on the subjects' maximum TTS results from this study, exposed at 94 dBA in the single hearing protective device condition, the in-ear noise dosimeter substantially overestimated the noise dose by an average of 11 dB. Preliminary findings indicate that human subject data are extremely important in developing and calibrating the effective noise dose for any type of noise dosimeter, but particularly so for in-ear dosimetry. Additional studies should include investigating the dosimeter calibration under double hearing protection, investigating middle ear impedance using laser Doppler vibrometry, evaluating subjective and objective measures of stress during noise exposures, and examining TTS responses from noise generated inside the ear canal as opposed to outside the hearing protector.

This work was done by Hilary L. Gallagher and Richard L. McKinley of the Air Force Research Laboratory, Melissa A. Theis of Oak Ridge Institute for Science and Education, and Valerie S. Bjorn of the Naval Air Systems Command, Arnold Air Force Base. ***For more information, download the Technical Support Package (free white paper) at www.aerodefensetech.com/tsp under the Physical Sciences category.*** *AFRL-0232*

Production of Satellite with First All-Electric Propulsion System Advances

Boeing is "running on schedule" as it continues to achieve production milestones for the first of its all-electric-propulsion 702SP (small platform) satellites.

The company says the 702SP will be the world's first all-electric-propulsion satellite when it is launched later this year or early next.

Earlier this year, Boeing announced that it had completed static qualification testing, verification, and assembly of the primary structures for 702SP inaugural customers ABS and Eutelsat, with the spacecraft scheduled to be launched as a pair in a stacked configuration. The initial contract was signed in 2012 between Boeing and Satmex. Eutelsat acquired Satmex in January 2014.

Joanna E. Climer, Communications Specialist, Boeing Space & Intelligence Systems, confirmed to *Aerospace & Defense Technology* on July 10 that the program is on track.

"We will be first to launch a commercial all-electric satellite, providing customers new flexibility, and next-generation technology for increased performance," Craig Cooning, Vice President and General Manager of Boeing Space & Intelligence Systems, said in a March 24 press release. "The all-electric propulsion design gives customers more affordable launch options and the ability to nearly double payload capacity."

Boeing is building two pairs of 702SP satellites under a joint four-satellite agreement with ABS and Eutelsat. Production on the 702SP satellites began in 2013, after the spacecraft passed its critical design review in May of that year.

The Boeing 702SP couples proven technology from Boeing's previous designs with next-generation technology and processes, resulting in an affordable, lightweight alternative design to meet customer needs, according to Climer. She explained to *Aerospace & Defense Technology* that the 702SP's all-electric propulsion system relies exclusively on xenon as the propellant: "This propellant is an inert and non-hazardous element. Previous hybrid designs used a combination of xenon gas and other chemical propellants, such as hydrazine and nitrogen tetroxide. In the hybrid design, these other chemical propellants were used for both orbit-raising and positioning, while xenon gas was only used for positioning. The all-electric propulsion 702SP now uses xenon as the only propellant."

Because of the lower mass enabled by all-electric propulsion, two satellites can be launched on a single launch vehicle. Depicted here is the all-electric satellite for Boeing customer ABS. (Boeing)

Production of the 702SP satellite is on schedule, Boeing says.

Most satellites use something similar to combustion for propulsion, but since there is no oxygen in space they need to carry both the fuel and oxygen with them, "which is heavy," Climer continued. "With the xenon ion propulsion system (XIPS) engine in the 702SP, instead of using fuel and an oxidizer, you have a gas—in this case xenon. The xenon gas is charged, electrically ionized, and travels at a high velocity through the XIPS engine to create thrust, propelling the satellite forward. This makes the 702SP more efficient and lighter in weight. Weight is a main factor in launch costs."

The 702SP is an evolution of the Boeing 702 satellite. Its lightweight design accommodates launch on most commercial launch systems, including Falcon 9, Ariane 5, Sea Launch, Proton, Soyuz, Atlas V, and Delta IV.

Because of lower mass owing to the lighter-weight components of a xenon-ion propulsion system compared to that of a conventional one requiring liquid fuel, two satellites can be launched on a single launch vehicle, resulting in a cost savings of up to 20% when compared with existing launch options, according to Boeing.

A typical spacecraft will carry between 1800 and 2800 kg of liquid bipropellant to achieve orbit-raising and on-station position / orbit slot change. An all-electric XIPS system only requires around 300 kg of xenon gas to do the same, said Climer.

The disadvantage of all-electric propulsion is that it generates less thrust than conventional propulsion and thus takes longer to move and position the satellite. Climer said a typical XIPS thruster provides 0.165 N thrust. When fired in pairs, this equates to 0.33 N. Typical chemical thrusters are 10 N and 22 N (for control jets), and up to 440 N LATs (liquid apogee thrusters).

Patrick Ponticel

Boeing Reveals Innovative Method of Building 777 Fuselages

Boeing announced on the opening day of the Farnborough Air Show that it is in the final phases of testing and production readiness of a new method for building 777 fuselages "as part of its ongoing technology investment strategy."

Known as the Fuselage Automated Upright Build (FAUB), this advanced manufacturing technology is expected to improve workplace safety and increase product quality. The technology has been in development by Boeing since 2012.

Boeing is in the final phases of testing and production readiness of a new method for building 777 fuselages. Known as the Fuselage Automated Upright Build, this advanced manufacturing technology is expected to improve workplace safety and increase product quality.

With this new technology, fuselage sections will be built using automated, guided robots that will fasten the panels of the fuselage together, drilling and filling the more than approximately 60,000 fasteners that are today installed by hand.

FAUB offers numerous benefits including an improvement in employee safety. The nature of the drilling and filling work makes it suitable for an automated solution. According to Boeing, more than half of all injuries on the 777 program have occurred during the phase of production that is now being automated. In addition, the automated system is expected to reduce build times and improve first-time quality of the build process. For a video of how the process works, go to ***www.techbriefs.com/tv/boeing***.

"This is the first time such technology will be used by Boeing to manufacture wide-body commercial airplanes," said Elizabeth Lund, Vice President and General Manager, 777 program and Everett site, Boeing Commercial Airplanes. "We're excited to continue improving the production process here and we're positioning ourselves to begin building 777X airplanes in the future."

The 777 program has already begun testing FAUB at a facility in Anacortes, WA. Production readiness preparations are underway and the system will be installed in Everett in a new portion of the main factory that is under construction now. The technology is expected to be implemented in the next few years.

The robotic system, designed for Boeing by KUKA Systems, is the latest in a series of strategic advanced manufacturing moves on the 777 program, which have already included new systems for painting wings and other drilling operations.

Jean L. Broge

Tata Technologies Researchers Use CFD to Predict Cavitation in Liquid Ring Pumps

Liquid ring pumps are used in aircraft fuel systems in conjunction with main impeller pumps. These pumps are used for priming the pump system as well as to remove fuel vapor and air from the fuel. Prediction of cavitation in liquid ring pumps is important as cavitation degrades the performance of these pumps and leads to their failure. As test-based assessment of cavitation risk in liquid ring pumps is expensive and time consuming, recent approaches have been to assess and predict the risk of cavitation using CFD methods with the goal to quicken the design process and optimize the performance of these pumps.

CFD models have demonstrated the ability to be used as a cost-effective tool to analyze cavitation phenomenon in pumps for aerospace industry. Pump reliability is of utmost importance in both commercial and military fixed wing and rotary wing aircrafts due to their need of vapor or air free fuel that is required to be supplied to their engines at all flight missions. As liquid ring pumps serve the function of removing fuel vapor and air from the fuel, their reliable functioning plays a critical role in determining the safe operation of aircrafts during flight. As cavitation has the potential to severely limit the operability of these liquid ring pumps and in severe cases may lead to their structural failure, accurate prediction of cavitation in liquid ring

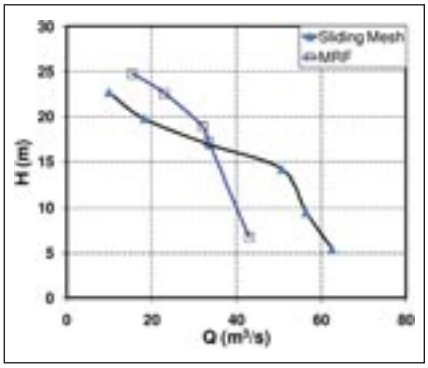
pumps is extremely important to design these pumps for safe operation.

The cavitation phenomena occur in regions where large pressure drops cause the local pressure to fall below the vapor pressure resulting in formation of vapor bubbles. Typically for pumps, cavitation occurs in the suction side of the pump blades that, in turn, results in a reduction of effective area of blade thereby diminishing the efficiency of the pumps. The formation of vapor bubbles and their subsequent bursting creates pressure impulse on the blade surfaces, which leads to vibration and fatigue induced structural damage leading to pump failures.

Researchers from Tata Technologies Ltd. used steady state Multiple Reference Frame (MRF) methodology and the transient sliding mesh methodology to assess cavitation, pump performance, and Net Positive Suction Head (NPSH) in liquid ring pumps using ANSYS-Fluent CFD software.

Results of the research show a considerable difference in the characteristic curve obtained using the two approaches. The results obtained using the MRF approach show a sudden slope change in the performance curve when the flow through the pump exceeded 30 m^3/s. This unphysical behavior that is not observed in the transient sliding mesh attests to the possible inaccuracy that could result when simulating cavitation using the steady state MRF approach.

Typically cavitation occurs near the hub surface, and investigation of the



The CFD predicted pump performance curves using the steady state MRF and the transient sliding mesh approaches are shown. The results show a considerable difference in the characteristic curve obtained using the two approaches.

pressure distribution in the hub area is important to understand and analyze the cavitation phenomenon. Cavitation occurred in the first, second, and fourth quadrant of the hub. The cavitation region extends from around 0° to 50° and from around 270° to 360°. The results show the appearance of pressure spikes that coincide with the fluid compression and subsequent ejection through the outlet port. The pressure spikes result in an implosion or collapse of the vapor bubble, which is formed during the cavitation process. The large magnitude of the pressure spikes, the value of which can be as much as 2.25 MPa for the pump configuration considered in this study, creates pressure impulse load at the impeller surfaces, which may lead to structural failure. Furthermore, the cyclic nature of the pressure impulses leads to fatigue of the impellers that further expedites their structural failure.

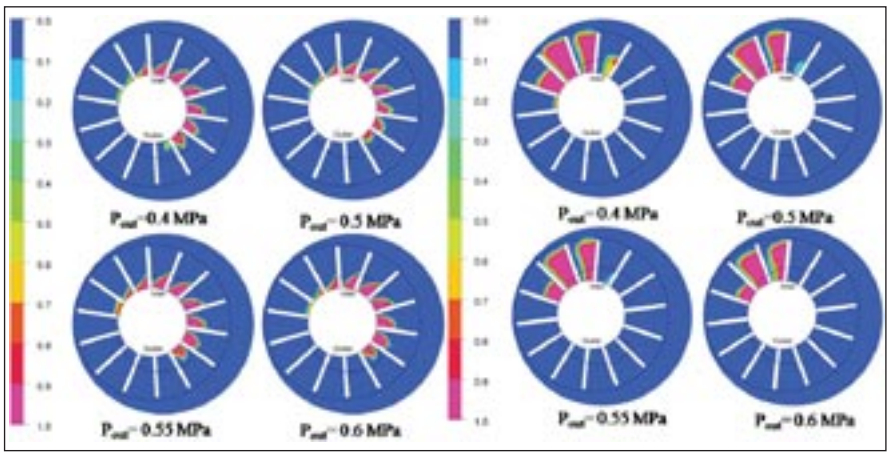


Figure 1: The predicted volume fraction of fuel vapor at pump mid-section using the transient sliding mesh (left) approach and steady state MRF (right) approach are shown.

To compare the results obtained using the steady state MRF approach and the transient sliding mesh approach, the volume fraction distribution at the pump mid-section plane are shown in Figure 1. These distributions of volume fraction and pressure are shown for varying values of outlet pressure ranging from 0.4 MPa to 0.6 MPa. The results demonstrate that cavitation occurs in the region between the inlet and the outlet port along the direction of rotation of the impeller. Further-

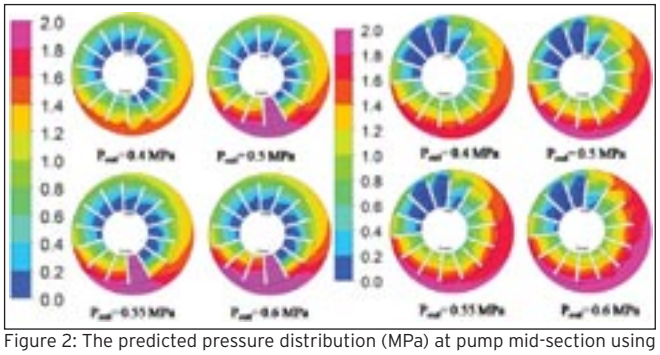
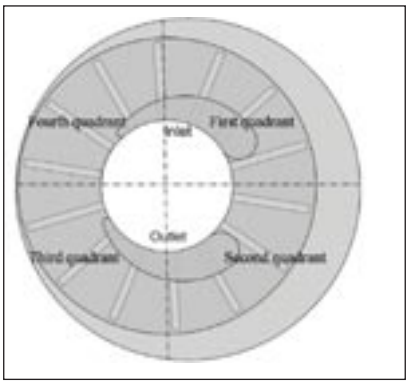


Figure 2: The predicted pressure distribution (MPa) at pump mid-section using the transient sliding mesh (left) approach and steady state MRF (right) approach are shown.

more, the results show that the cavitation area shrinks with an increase in outlet pressure. The distribution of the vapor fraction shows the accumulation of liquid fuel around the periphery due to centrifugal forces and the accumulation of the vapor bubbles in and around the hub region as these regions experience the low pressure regions that lead to cavitation.



The liquid ring pump configuration that was studied consisted of a single stage impeller with 14 blades arranged in an equi-spaced manner circumferentially.

The vapor fraction distribution predicted by the MRF approach indicates an unrealistic unphysical location of cavitation. The MRF model predicts that the cavitation occurs near the inlet port which is physically unrealistic.

Figure 2 shows the distribution of absolute pressure at the pump mid-section plane as predicted by the transient sliding mesh and the steady state MRF methodology, respectively. As expected, regions of low pressure near the inlet port and regions of higher pressure near the outlet port are observed.

The results indicate that though the computation efforts are cheaper for the steady state MRF model, the results obtained are unphysical. The computationally expensive transient sliding mesh approach results in realistic predictions. Due to unavailability of experimental data, a quantitative validation of the sliding mesh approach for cavitation prediction could not be performed, but the trends observed in the results show promise in this approach as compared to the MRF approach. Further investigation, along with experimental validation, would be required to refine the prediction fidelity of the transient sliding mesh based cavitation model for liquid ring pump applications.

This article is based on SAE International technical paper 2013-01-2238 by Manoj Radle and Biswadip Shome of Tata Technologies Ltd.

Single Board Computer

EMAC (Carbondale, IL) has introduced the iPAC-9X25, an ARM-embedded single board computer, based on the Atmel AT91SAM9X25 processor. The technology has an industrial temperature range of -40°C to +85°C and utilizes 4GB of eMMC Flash, 16MB of Serial Data Flash (for boot), and 128 MB of DDR RAM.

The iPac-9X25, a Web-enabled microcontroller, can run an embedded server and display the current monitored or logged data. The Web connection is available via two 10/100 Base T Ethernet ports or 802.11 wireless Wi-Fi networking when using the proper Linux modules and adapters. The microcontroller has all connectors brought out as headers on a board.

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DRAM Modules

DRAM modules from Innodisk Corp. (Taipai, Taiwan) feature conformal coatings that protect against moisture, dust, and chemical contaminants. The layer thickness varies from 0.03mm up to 0.13mm, depending on the demands of the application and the materials used. The coating also protects against issues caused by electrical or thermal conduction, static electricity, and heat, and observes MIL-I-46058C.

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Enclosure Gaskets

Beryllium-copper fingerstock gaskets from Leader Tech (Tampa, FL) provide electrical contact between parallel seams (mating surfaces) that are created by enclosure access doors and panels. Once installed, the hardened Alloy 25 gaskets effectively shield over a broad frequency range. Leader Tech fingerstock gaskets, available in multiple plating finishes, can be cut to application-specific lengths. In addition, the wiping action of gasket fingers acts as a self-cleaning mechanism during every compression cycle.

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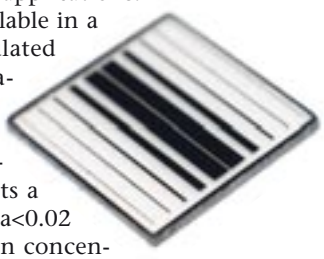
All-Diamond Packaging Solution

In collaboration with the University of Warwick, Element Six (Santa Clara, CA) has developed an all-diamond sensor structure for electroanalytical applications. The synthetic electrode is available in a variety of geometries encapsulated in co-planar insulating diamond. Element Six's Diafilm EA-grade electrode material features 100 percent phase purity, and the electrode presents a typical surface roughness of Ra<0.02 µm. Precisely controlled boron concentrations provide metal-like ohmic conductivity while achieving low capacitance.



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3D Printing Materials

To create 3D objects with deterministic mechanical properties, Arevo Labs (San Jose, CA) offers proprietary carbon fiber and carbon nanotube (CNT) reinforced high performance materials. Supported polymer materials include KetaSpire® PEEK, AvaSpire® PAEK, Radel® PPSU, and PrimoSpire® SRP.

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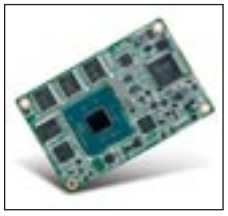
COM Express Mini Module

Advantech (Irvine, CA) has released the SOM-7567 COM Express® Mini Type 10 module, featuring Intel® Atom™ E3800/Celeron® N2930/J1900 processors. Measuring 84 × 55 mm, SOM-7567 supports onboard memory up to 4GB and 64GB flash memory. The model can support up to 15 simultaneous 1080p full-HD video decoders.



The SOM-7567 includes range voltage input from 4.75 ~ 20V and flexible options from 1 to 4 cores. The onboard flash and memory has anti-vibration features. To centralize monitoring and management of all their embedded devices, SOM-7567 also comes with Advantech SUSIAccess and API bundled for system integrators.

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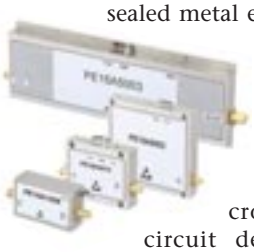
L- and S-Band High Gain Amplifiers

Pasternack Enterprises (Irvine, CA) has announced a new portfolio of L- and S-band high gain amplifiers. The modules, packaged in hermetically-sealed metal enclosures, are optimized for 1.2 – 1.4 GHz and 3.1 – 3.5 GHz radar applications. The RF amplifiers utilize a hybrid microwave integrated circuit design and GaAs pHEMT technology. The devices also feature built-in voltage regulation, bias sequencing, and reverse bias protection.



Two of the new products are low noise amplifiers (LNA) that demonstrate noise figure performance of 1.1 dB to 1.5 dB at high gain levels of 40 dB. Also offered are 10 Watt and 20 Watt high power amplifiers that have gain performance of 40 – 47 dB, with 1.0 dB to 1.5 dB gain flatness. Pasternack is also releasing an L-band driver amplifier that displays gain performance of 47 dB while delivering gain flatness of 1.5 dB.

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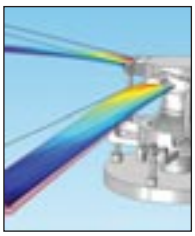

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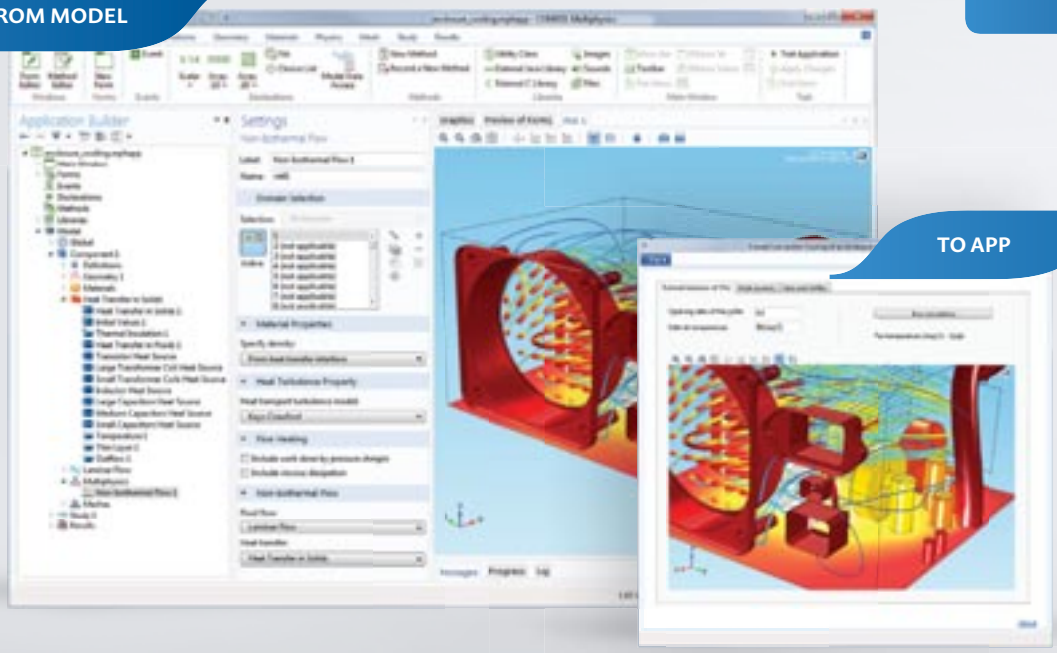

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