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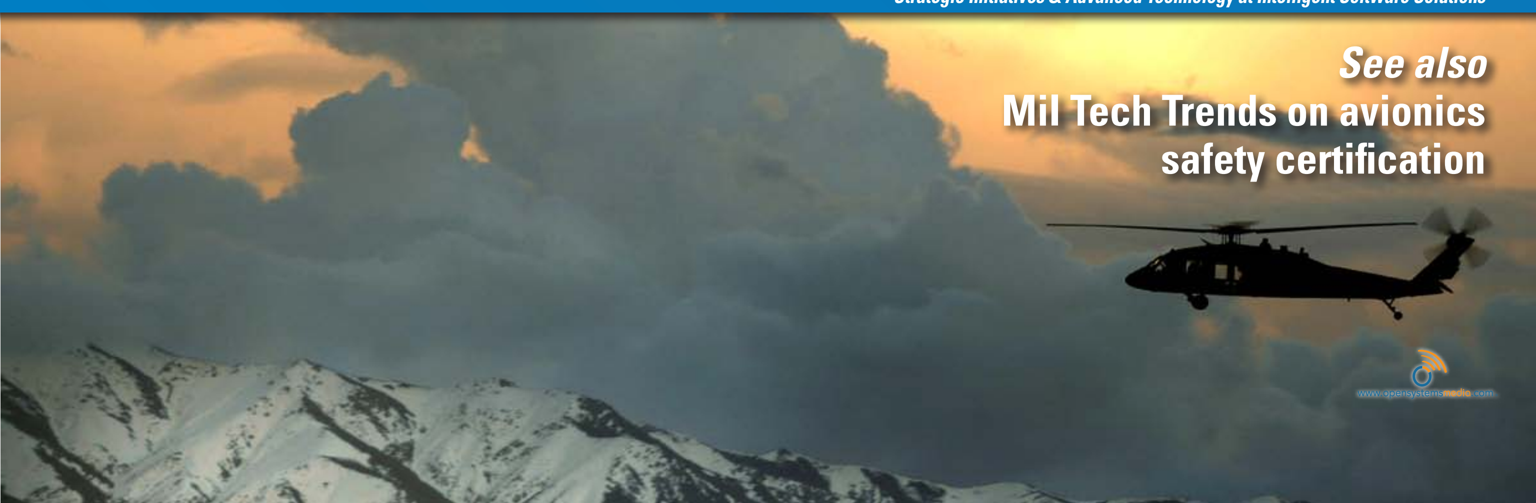
John McHale
Avionics retrofits get dollars in FY 2013

Field Intelligence
Routing data at the tactical edge

Mil Tech Insider
UAVs in commercial airspace

Military cockpit upgrades embrace open architectures

Interview with Carl Houghton, Vice President, Strategic Initiatives & Advanced Technology at Intelligent Software Solutions



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ON THE COVER:
The Black Hawk UH-60M's upgraded cockpit uses Rockwell Collins avionics and synthetic vision technology. Photos courtesy of Rockwell Collins.

March 2012 | Volume 8 | Number 2

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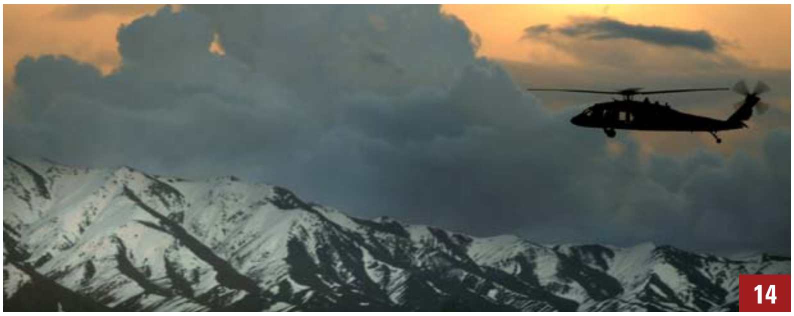

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FY 2013 DoD budget request shrinks, but avionics retrofits get dollars

By John McHale, Editorial Director

To no one's surprise, the U.S. Department of Defense (DoD) Fiscal Year 2013 budget request was down over last year's as the department was forced by the current economic climate to tighten its belt and streamline military procurement. The DoD cut back on procurement of major programs such as the Joint Stroke Fighter (JSF) and increased its funding for retrofits of current aircraft programs such as the Chinook and Apache helicopters.

DoD requested $525.4 billion overall for FY 2013, down $5.2 billion from FY 2012 enacted numbers. Funding for Overseas Contingency Operations (OCO), including missions in Afghanistan and Iraq, were funded separately in the FY 2013 budget request at $88.5 billion, down $26.6 billion from the FY 2012 enacted level of $115.1 billion.

The drop has been expected by military embedded computing suppliers and, as they forecasted, funding continues and even increases in their niche areas such as avionics and unmanned systems. Below are some highlights of aircraft funding from the FY 2013 request.

Overall aircraft funding within the FY 2013 budget request dropped from $54.2 billion in the FY 2012 budget to $47.6 billion in FY 2013 – with $3.8 billion slotted for Unmanned Aerial Vehicles (UAVs).

Avionics opportunities

Army avionics retrofits and upgrades, which leverage a great deal of Commercial Off-the-Shelf (COTS) hardware and software, will continue to get funding under the FY 2013 budget request. Army rotorcraft retrofit programs funded in the FY 2013 request include upgrades to the AH-64 Apache, CH-47F Chinook, and UH-60 Black Hawk. Funding for the Light Utility Helicopter (LUH) also is going forward. (For more military avionics, see the Special Report on page 14, entitled *New aircraft platforms get cut back, opening the door for avionics retrofits that leverage COTS hardware and software.*)

The AH-64 Block 3 program is broken down into remanufactured and new-build aircraft. The budget request calls for the remanufacture of 40 aircraft and the production of 10 new aircraft in the AH-64 D Longbow Block 3 configuration. Remanufacture is up from $654 million in FY 2012 to $809 million in FY 2013 and new Apache aircraft procurement from $758 million to $1.109 billion in FY 2013. Under the Apache Block 3 program, the Army is adding fire control radar and night vision technology.

Chinook funding in FY 2013 also includes digital cockpit upgrades and a digital data bus to enable the Army to add more communications and navigation equipment. Within the FY 2013 request, the DoD is looking for 25 new Chinook F models and 19 remanufactured/Service Life Extension Program aircraft.

The FY 2013 request continues support for the UH-60 Black Hawk five-year Multiyear Procurement (MYP) contract for FYs 2012-2016, though it is down slightly to $1.305 billion from $1.705 billion in FY 2012. DoD will procure 59 base funded aircraft – this number is down from 72 in FY 2012. UH-60 variants funded include the Utility UH model and the Medical HH model.

Funding for the Light Utility Helicopter program also made it into the FY 2013 budget request. The LUH will replace the UH-1 and the OH-58 Kiowa Warrior A and C models. The FY 2013 budget calls for production of 34 helicopters.

F-35 and F-22

The F-35 JSF program continues to get billions of dollars in the budget, but the numbers are down from last year as the program is restructured to save money. F-35 Research, Development, Test, and Evaluation (RDT&E) funding is down slightly from $2.708 billion in 2012 to $2.699 billion in FY 2013. The FY 2013 budget plans for procurement of 29 aircraft – 31 were procured in FY 2012. The 29 include four Carrier variants for the Navy, six Short Take-Off Vertical Landing variants for the Marine Corps, and 19 Conventional Take-Off and Landing variants for the Air Force.

Overall funding for the F-22 Raptor program is down from $916 million in FY 2012 to $808 million in FY 2013, which continues the fighter's capability upgrades, which includes Increment 3.1, calling for electronic attack capability, emitter-based geo-location of threat systems, and ground-looking Synthetic Aperture Radar (SAR) modes. Increment 3.2 will include radar electronic protection, Automatic Ground-Collision Avoidance System (AGCAS), and intraflight data link improvements.

UAVs

UAV funding for the DoD continues to be important as the department plans to procure 34 Reapers and 19 Gray Eagles to eventually reach a total 65 Predator and Reaper Combat Air Patrols (CAP)/orbits by FY 2017. RDT&E funding also increased from $971 million in FY 2012 to $1.103 billion in FY 2013 for the RQ-4 Global Hawk program as DoD looks to procure three Air Force NATO Alliance Ground Surveillance (AGS) aircraft, payloads, and integrated logistics support for the three aircraft.

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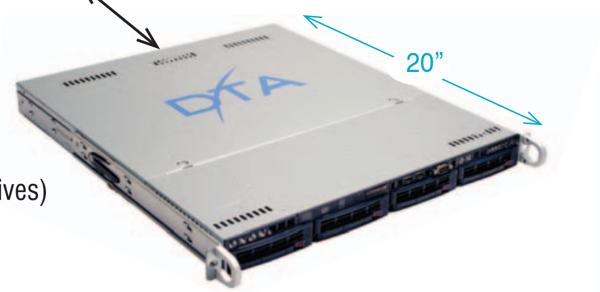

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Routing data at the tactical edge

By Charlotte Adams

As military networks reach out to individual soldiers and their vehicles at the tactical edge, the promise for intelligence and command and control is great, but so are the risks unless security is built in from the ground up.

Despite the specter of budget cuts and program cancellations, the U.S. military continues to stress high-speed, high-bandwidth, agile, and secure communications. The first strategy-based equipment imperative listed in the *Army Modernization Plan 2012* is "network the force." Of the handful of mission-critical systems identified in that document, four focus on communications or information superiority.

U.S. forces envision bandwidth-hungry transactions such as HD video feeds in the tactical space. Programs and concepts have emerged to support such aims, including the proliferation of high-speed communications and processing nodes on the battlefield. This expansion of tactical connectivity, however, is based on IP, a core component in commercial-enterprise architectures but a magnet for attacks.

IP vision

The first "critical" program listed in the *Army Modernization Plan 2012* is the Joint Tactical Radio System. This family of Software-Defined Radios will provide tactical end-to-end IP data and voice communications. These include the Warfighter Information Network-Tactical, an IP-based broadband backbone; the Ground Combat Vehicle, which will exploit networking advances; the Army's portion of the Distributed Common Ground/Surface System for intelligence information access; and the Joint Battle Command-Platforms effort that involves integration of computer hardware and software and networking capability into tactical vehicles, aircraft, and dismounted forces.

High-bandwidth tactical communications would be a force multiplier, improving coordination in the field. Multiple tanks or armored vehicles, for example, each equipped with a router to connect the nodes, could set up a mesh network for data sharing. Some of the vehicles might also be equipped with powerful cellular and satellite links to communicate with dismounted soldiers or over longer distances. The vehicles could also serve as processing nodes for dismounted soldier applications.

The tactical "cloud" computing environment described in the preceding example could support applications such as facial recognition. Soldiers could transmit photos of persons via smartphones to determine whether those persons should be detained. Tactical cloud resources could be distributed between forward bases and mobile assets. Current concepts envision routers and processors embedded in ground vehicles, drones, airplanes, ships, and satellites.

Figure 1 | RTR8GE rugged, intelligent IP router from GE Intelligent Platforms

Challenges

Deployment won't be easy. The common attacks that bedevil the commercial IP world – where bandwidth is high and reliable, links are fixed, and processing and storage resources are generous and stationary – are more likely and dangerous in a hostile environment where bandwidth is uncertain, assets mobile, and resources limited. Moreover, IP was built for openness. Hackers cut their teeth on Internet Denial of Service (DoS), spoofing, and malware attacks.

Many security measures are already in place, using physical and procedural protection, encryption, authentication, and other techniques. However, new attacks are invented every day. Government-sponsored or subsidized attacks would also be likely in a hostile environment. That is why routers – the heart of the network – are adding firewall and intrusion detection hardware and software, building in security at the ground floor. An example of these emerging products is the GE Intelligent Platforms RTR8GE, a small, rugged, intelligent IP router with tunable security, using the COTS-hardened Junos OS (Figure 1).

Technology dividends

Routers are more intelligent than switches. They can detect errors, retransmit packets, and change data paths, depending on the circumstances. But modern secure routers can do much more. Using hardware-based Deep Packet Inspection (DPI), these devices can scan packets from the physical to the application layer, for example, flagging a word in an email message. Whereas software-based DPI struggles to keep up with the line rate, hardware-based DPI can monitor data flows without inducing crippling delays.

Emerging technologies, such as Radio Aware Routing (RAR) protocols, allow the router to monitor link status and reliability. The router will be able to choose the best link – satellite, cellular, or traditional ground radio – and the best path to the destination. As the quantity and variety of wired nodes grow, network bandwidth and reliability are enhanced. The RAR and similar protocols will help enable the goal of secure mobile ad hoc networking, allowing fast, networked communications.

For more information, contact Charlotte at cburtonadams@yahoo.com.

Certifiable avionics takes off as UAV fleet operates in commercial airspace

By Curtis Reichenfeld

The new U.S. Defense budget significantly increases deployment of Unmanned Aerial Vehicles (UAVs). Under the new budget, the UAV sector is soon expected to approach one-third of all military aircraft platforms. With expanded missions, UAVs will more frequently operate in the U.S. national airspace and the airspace of other countries, alongside commercial and private aircraft. UAVs currently fly in restricted airspace during take-off and landing and quickly ascend to altitudes high above commercial air traffic. Operation of UAVs in commercial airspace will require the use of safety-certified software in embedded avionics systems.

Electronics suppliers need to provide software artifacts and certification evidence to enable their customers' platforms to successfully achieve DO-178B (for software) and DO-254 (for firmware) certification. DO-178B defines guidelines for developing software for airborne systems and equipment. DO-254 applies the same basic design assurance principles to develop safety-critical firmware written for complex devices used in the subsystem, such as FPGAs and programmable logic devices.

While some military avionics vendors are frequently required to show adherence to DO-178B, they may not necessarily be certified by the Federal Aviation Administration (FAA) or European Aviation Safety Agency (EASA). Nevertheless, many military systems integrators are using DO-178B (and soon DO-178C) design assurance guidelines as a replacement for obsolete military design standards.

UAV safety certification requirements emerge

The FAA is currently working to define specific safety certification rules for the deployment of UAVs in the National Airspace System (NAS). Critical capabilities such as "Sense-and-Avoid" and "due regard" are needed to ensure the safe operation of autonomous and remotely piloted vehicles that can encounter commercial and private aircraft. The industry is already seeing requirements in UAV electronic systems for DO-178B and DO-254. Development of software and hardware that can successfully be certified at the platform level requires the collection of all development artifacts, including plans, requirements, design, integration, test, verification, and validation of those products.

Industry response: Certifiable OSs and BSPs

Safety-critical systems require certification artifacts at the Operating System (OS) and Board Support Package (BSP) levels. Safety-certifiable OSs such as Green Hills' INTEGRITY, Wind River's VxWorks 653, Linux, and Express Logic's ThreadX demand a rigorous development process. These specialized certifiable OSs can be costly, with the price of some certification packages ranging from $300,000 to $500,000. Also BSPs for use in UAVs must have the same level of certifiable artifacts as the safety-certifiable OS. Electronics vendors have to ensure that the software development processes for the safety-certifiable OSs and BSPs generate all of these artifacts. Certification artifacts for safety-critical applications such as flight control and mission software are provided to the platform provider and reviewed by the certification authorities.

An example of a DO-178B and DO-254 certifiable electronic subsystem is Curtiss-Wright Controls Defense Solutions' Versatile Flight Control Computer (VFCC), a high-performance embedded processing system optimized for Size, Weight, Power, and Cost (SWaP-C) (Figure 1). This rugged subsystem features dual 600 MHz ARM Cortex-A8 processors, dual TMS320C64x+ DSPs, and three Xilinx FPGAs, developed under IRAD. It is the first application in an AgustaWestland program for use in commercial and military versions of its Rotorcraft Technology Validation Programme (RTVP) helicopter.

Figure 1 | The VFCC from Curtiss-Wright Controls Defense Solutions

Certified development for critical software

Critical software requirements flow down to system providers from prime contractors, who in turn receive their requirements from government agencies. It is critical for electronics providers to have a rigorous development process in place to meet these needs. In addition to DO-178B, prime contractors are seeking vendors who have a Capability Maturity Model Integration (CMMI) Level 3 appraisal as a minimum. The CMMI rating system is overseen by the Software Engineering Institute (SEI), a federally funded research and development center sponsored by the DoD. Prime contractors are typically needed to meet higher levels, CMMI 4 and 5, which in turn is driving demand for electronics providers who can support these development processes with a Level 3 rating. As unmanned vehicles increase operations in commercial aerospace, the need for rigorous development processes to the level of commercial aircraft is critical to the safety of the general public.

To learn more, e-mail Curtis at creichenfeld@curtisswright.com.

DEFENSE TECH WIRE

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By Sharon Hess, Managing Editor

NEWS | TRENDS | DoD SPENDS

Boeing delivers upgraded V-22 to USMC

Is it a helicopter or a fixed-wing aircraft? Certainly the V-22 Osprey has capabilities of both, and was at the center of a recent product delivery (Figure 1): The USMC has received the first V-22 Osprey with Block C upgrades courtesy of The Boeing Company and Bell Helicopter. The upgrades comprise expanded Electronic Warfare system capacity, a new weather radar system, greater situational awareness via improved cabin and cockpit displays, and even an upgraded Environmental Conditioning System to provide increased comfort for soldiers and aircrew. Dubbed a "tiltrotor," the V-22 Osprey can hover, land, and take off vertically similar to a helicopter, and when in the skies, it can transition into a turboprop airplane that delivers high-altitude, high-speed flight.

Figure 1 | The Boeing Company and Bell Helicopter recently delivered the first Block C upgrade-equipped V-22 Osprey to the USMC. Photo courtesy of Boeing

Raytheon offers free upgrade

Is anything really free? Seems this one is, at least to end users: Raytheon Company is giving away a free upgrade to the Integrated Waveform (IW) software for AN/ARC-231 airborne radio terminals, touted to triple the terminals' satellite capacity. Having undergone Defense Information Systems Agency (DISA) field testing, the Satellite Communication (SATCOM) software upgrade is provided for every U.S. Army Aviation aircraft in addition to some USAF aircraft that already have AN/ARC-231 terminals. The impetus for the complimentary upgrade is to help resolve in-theater radio communication delays. Additionally, the Ultra High Frequency (UHF) satellite system now in place will soon become obsolete, and the IW software (and, therefore, its upgrade) can bridge the gap between UHF and its replacement – the Mobile User Objective System (MUOS). Meanwhile, the IW software upgrade is slated to "provide an increase of several hundred networks for ARC-231 SATCOM users," the company reports.

L-3 gets kudos from AAAA, acquires new business

The Army Aviation Association of America (AAAA) held an awards banquet last month, and one of its honorees was L-3 Communications' L-3 Army Fleet Support (L3-AFS) unit. L3-AFS was given the 2011 Army Aviation Materiel Readiness Award for a Contribution by a Major Contractor, for performance rendered Nov. 1, 2010 through Oct. 31, 2011. The Army Aviation service branch renders aircraft maintenance, supply chain management, and logistics support. In other L-3 news, the company acquired Danaher Corporation's Kollmorgen Electro-Optical unit. The new unit will operate as "L3-KEO" and cost L-3 about $210 million. The new division manufactures and designs fire control systems for ships, periscopes and photonics systems for submarines, ground electro-optical systems, and visual landing aids.

BAE to supply Iraqi Army with 400 M113s

In conjunction with the Anniston Army Depot (ANAD), BAE Systems will be sprucing up 440 M113A2 carriers for the Iraqi Army, per a recent $31 million foreign military sales contract. Though just announced by BAE, the contract work of swapping damaged and old equipment wares for new components to restore mission capability is slated for fulfillment this April. Work will be completed at BAE's Anniston, Alabama locale, with ANAD lending a hand in the refurbishment. Under another contract, BAE is additionally slated to supply ANAD with materials for ANAD's refurbishment of 586 more Iraq-bound M113A2s. Boasting 80,000 vehicles internationally in 40 flavors, the M113 armored tracked vehicle carries a driver and 12 soldiers and is amphibious and rough-terrain/high-speed savvy (Figure 2).

Figure 2 | ANAD and BAE will team to spruce up 440 M113A2 carriers for the Iraqi Army, per a $31 million foreign military sales contract. M113 photo by PFC Brandon E. Loveless, USMC

General Dynamics MUOS demo succeeds

General Dynamics has successfully demonstrated – via the Joint Tactical Radio System (JTRS) Handheld, Manpack, Small Form Fit (HMS) radio dubbed the AN/PRC-155 (Figure 3) – that the Mobile User Objective System (MUOS) SATCOM waveform can indeed deliver secure data and voice communications. The demonstration featured the AN/PRC-155 loaded with MUOS waveform software "to transmit encrypted voice through a MUOS-satellite simulator to the MUOS ground station equipment that will soon be deployed in Sicily," the company reports. The MUOS system is slated to facilitate secure mobile, networked comms internationally, regardless of environment extremity. MUOS waveform completion is anticipated by the third quarter of this year, with MUOS capability fielded to soldiers by year's end on the AN/PRC-155.

Figure 3 | General Dynamics has demonstrated via the JTRS HMS radio that the Mobile User Objective System (MUOS) SATCOM system can deliver secure voice and data.

Lockheed Martin vs. battlefield IEDs

IEDs often plague the battlefield, and a recent DoD/Lockheed Martin contract will help thwart such dangers. Specifically, the U.S. General Services Administration (GSA) Federal Systems Integration and Management Center (FEDSIM) awarded Lockheed Martin a $900 million (maximum) Operations Support (OPS) Services IDIQ contract supporting the DoD's Deputy Secretary of Defense-directed Joint Improvised Explosive Device Defeat Organization (JIEDDO) initiative. JIEDDO's mission is to overturn enemy IED campaign strategies, and Lockheed Martin will assist by providing JIEDDO's analytical team with combat support, analysis, operations, and IT support – in the form of reach-back or in-theater support. The contract – slated for two-year fulfillment and piggybacked with a triad of one-year contract options – is one of five such JIEDDO support contracts.

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Figure 4 | The AFRL recently issued contracts to SRI International and ObjectVideo, Inc., both to simplify intelligence extraction from surveillance video and imagery. U.S. Air Force photo by Tech Sgt. Randy Redman

AFRL contract boosts imagery usefulness

Surveillance video/imagery is a wonderful thing – but only if someone (or something) can derive some valuable military intelligence from it (Figure 4). Accordingly, the Air Force Research Laboratory/RKIF recently issued two contracts: One $12 million contract was awarded to SRI International for the design of indexing and visual exploitation tools that can quickly "extract mission-relevant visual intelligence from large quantities of diverse, ill-defined, unstructured imagery captured from multiple adversary sources," reports the DoD website. Meanwhile, the second contract was granted to ObjectVideo, Inc., which will develop an "analyst tool" by integrating pattern matching and computer vision algorithms already incarnated. The tool will then be used to gather pertinent information from imagery that is unstructured and has no or little metadata. Both contracts are anticipated for completion in February 2016.

Northrop Grumman is right on target

As part of a 2010 seven-year, $920 million IDIQ contract, Northrop Grumman recently received orders for a duo of follow-on LRIP versions of its LITENING SE advanced targeting pods, for a combined pricetag of $66 million. Having recently undergone a recent USAF flight test program aboard A-10C (Figure 5) and F-16 Block 40/50 aircraft, LITENING SE features the latest in data link, laser imaging, and sensor technologies and comprises 1Kx1K forward looking infrared, two-way multiband data link, enhanced zoom, short wave infrared sensors, and tracker improvement – all designed to provide improved target ID at longer ranges and reducing pilot workload at the same time.

Figure 5 | Northrop Grumman received a duo of follow-on orders for its LITENING SE advanced targeting pods, which completed a USAF flight test program aboard A-10C (pictured) and F-16 Block 40/50 aircraft. U.S. Air Force photo by Senior Airman Willard E. Grande II

New aircraft platforms get cut back, opening the door for avionics retrofits that leverage COTS hardware and software

By John McHale, Editorial Director

Military cockpits – from helicopters to cargo jets to fighter aircraft – will be depending on open architecture designs and Commercial Off-the-Shelf (COTS) hardware and software to keep them flying beyond the next decade as DoD budgets scale back on new platforms. Meanwhile, industry and government experts formed a consortium to enable affordable, platform-agnostic avionics.

The Black Hawk UH-60M cockpit uses Rockwell Collins avionics and synthetic vision technology in the right-hand inboard multifunction display.

Doing more with less is becoming the modern-day mantra of the U.S. Department of Defense (DoD) when it comes to funding military technology procurement. As DoD officials reduce spending across the services – especially when it comes to big-ticket platforms like the Joint Strike Fighter (JSF) – greater emphasis will be placed on maintaining current airborne platforms for at least another decade or more.

No longer will the DoD fund technology development from the ground up. Consequently, the industry is forced to become more cost effective in system designs for avionics retrofits by leveraging common standards and Commercial Off-the-Shelf (COTS) technology that can be used on multiple platforms.

The U.S. financial crisis is not getting settled any time soon, but the world's not getting any safer either, and the U.S. military will need to maintain and improve its capability during that time, says Mark Grovak, avionics business development for Curtiss-Wright Controls Defense Solutions. Newer platforms such as the F-22 Raptor and JSF will continue to face delays and cutbacks, so the U.S. military will have to update the current aircraft fleet to support current and future missions, Grovak continues. This is good news for COTS suppliers, he adds.

"Retrofits and upgrades to current programs are a huge opportunity given the government's resistance to fund new programs, while asking the military services to do more with their existing equipment," says Mac Rothstein, Product Manager, Systems, GE Intelligent Platforms in Charlottesville, VA.

In a lot of avionics upgrades, "we use today COTS processors and many other components," says Dan Toy, Principal Marketing Manager at Rockwell Collins in Cedar Rapids, IA. "We leverage what is being developed throughout the electronics industry. The telecommunications industry has poured huge amounts of money into the development

Figure 1 | The IPS511 from GE Intelligent Platforms generates 360-degree views for improved situational awareness.

of electronics that are applicable to military avionics systems. We vary away only when we have a unique need that commercial markets cannot provide."

"Basically we build thousands of processor cards a year and we use COTS chip technology in a Rockwell Collins processor design," says Brett Tinkey, Program Manager, Rockwell Collins Airborne Solutions. "That's primarily how we leverage COTS; we buy COTS devices such as Freescale chips and we design around the chipset."

A typical component Rockwell Collins leverages is FPGAs, Tinkey says. "One of the best ways to effectively meet reduced size, weight, and power requirements is to leverage FPGAs, which enable you to reduce the footprint or size of a product." In one upgrade, Rockwell Collins engineers were able to reduce the footprint for one processing function from three boards to one 6U VME board by taking advantage of high-performance commercial components such as FPGAs, he continues. Reducing the footprint enables the system to grow and add capability for the military customer, Tinkey adds.

Moore's Law shows that the trend toward smaller designs with great capability will continue and is why a VME card today versus one from five years ago "has almost twice the functionality and twice the horsepower," says Doug Patterson, Vice President of Business Development for Aitech in Chatsworth, CA.

Board-level COTS

"At the board level, we evaluate the efficiencies of building the boards ourselves versus buying completed boards from a manufacturer," Toy says.

"When we build units ourselves for programs that are one-offs, we will go buy and leverage COTS suppliers such as Curtiss-Wright and GE Intelligent Platforms," Tinkey says. "Cycle time is an issue in this decision process as well," as COTS suppliers with a good track record can provide boards and cards more quickly than an integrator would. Design cycles are also trending shorter in the current DoD procurement climate.

"The key in being a COTS supplier is that you can get your customer at least 80 percent of the way to their final desired solution with an off-the-shelf product," Rothstein says. "In reality, the chances of having an off-the-shelf product that meets all of your customer's I/O, environmental, and mechanical requirements is very high if you offer enough variations of a subsystem to cover most requirements. Customers can use the off-the-shelf solution to begin their software development while we work with them on the final 10 to 20 percent of the modified system."

A rugged GE Intelligent Platforms system used in avionics applications is the IPS511, which generates 360-degree views for improved situational awareness (Figure 1). The subsystem can process multiple simultaneous analog video inputs for a variety of different video display configurations for two simultaneous video outputs. For more information, visit http://defense.ge-ip.com/products/3613.

Military avionics integrators "want higher levels of software and hardware integration and reductions in size, weight, power, and cost," Patterson says. Regarding hardware and software integration, the military customer base wants products that can come from different suppliers to be able to work together in their system, Patterson continues. This integration is the burden of the supplier, he adds.

COTS pedigree is important

Military program managers don't believe PowerPoint presentations anymore; they want to see real hardware and know that the supplier has a pedigree or past history of success in other platforms, says Curtis Reichenfeld, Chief Technical Officer of System Solutions for Curtiss-Wright Controls Defense Solutions in Ashburn, VA. Technical Readiness Levels (TRLs) are driving government procurements, he continues. Products earn high TRLs for new programs when they have been demonstrated or designed into military programs with similar requirements. Military aviation program managers want to reduce risk on programs by having suppliers with a proven program pedigree or high TRL – in other words a history of successful avionics design-ins on fielded platforms, Reichenfeld says.

Military customers want suppliers that have "history, heritage, and pedigree," Patterson says. For example, imagine a program where a customer needs a new acoustic sensor for hostile fire detection on HMMWV [High Mobility Multipurpose Wheeled Vehicle], he continues. They would have to start from the ground up developing hardware; it would be six months before they had a prototype and another six months to a year before they could ruggedize it to stick in a vehicle to go through hard testing – which is about when the software team would start their development process, Patterson explains. If they leverage COTS hardware that

NAVAIR sponsors the Future Airborne Capability Environment (FACE) along with Army PEO Aviation, Lockheed Martin, and Rockwell Collins. For more information on FACE, visit www3.opengroup.org/getinvolved/consortia/face.

FACE consortium enables affordable, platform-agnostic avionics

FACE consortium enables affordable, platform-agnostic avionics

Industry and government avionics experts have joined hands in an effort to effectively manage avionics design costs through the use of open standards and COTS technology. The effort is a consortium called the Future Airborne Capability Environment (FACE), which is independently hosted by The Open Group.

The FACE initiative was initiated by officials at the U.S. Navy Naval Air Systems command (NAVAIR) in Patuxent River, MD, says Dave Lounsbury, Chief Technical Officer with The Open Group in Natick, MA. NAVAIR had new avionics procurements coming up and wanted to stretch taxpayer dollars a little farther by designing affordable avionics that could be used on different aircraft platforms so they came "to talk to us at the Open Group about putting together something with industry collaboration."

NAVAIR sponsors FACE along with Army PEO Aviation, Lockheed Martin, and Rockwell Collins.

The Open Group helps provide infrastructure and guidance on the collaboration, Lounsbury says. "The FACE members bring the energy and the answers, and we make sure that it's all open and neutral." The Air Force is involved, but is not yet a member directly, Lounsbury says. However, "We have people who work with the Army and Navy, who work with the Air Force and do participate in the meetings."

FACE will bring together peers in industry and government to select the correct standards that focus on openness, safety, integrity, and security, says Dan Toy, Principal Marketing Manager at Rockwell Collins in Cedar Rapids, IA. It is about creating an open computing environment that enables avionics software applications to move from one platform to another in an affordable way, he adds. Rockwell Collins was one of the original sponsors of FACE, Toy says. "NAVAIR contacted us to discuss how to go about the FACE concept and turn it into an industry consortium."

"We've just released the FACE standard," Lounsbury says. "We went from forming the consortium to releasing the FACE 1.0 specification in 18 months. That's pretty quick. We try to attack it from all dimensions, but ultimately it is about making standards work. We think that the standards technology lays the basis for interoperability and affordability."

One of the main objectives of FACE is to have a library of avionics hardware and software technology for avionics suppliers (such as Curtiss-Wright Controls Defense Solutions and Green Hills Software) to register to show they are FACE compliant, Lounsbury continues.

Curtiss-Wright has been involved with FACE for more than a year, says Mark Grovak, avionics business development for Curtiss-Wright Controls Defense Solutions in Ashburn, VA. "Our ability to support the FACE environment is one more reason why we can get access to a lot of platforms and support multiple applications."

For more information on FACE, visit www3.opengroup.org/getinvolved/consortia/face.

Sidebar 1 | The Future Airborne Capability Environment (FACE) consortium, hosted by The Open Group, comprises industry and government avionics experts working to manage avionics design costs through open standards and COTS technology.

The Black Hawk UH-60M's cockpit uses COTS avionics components from Rockwell Collins.

is already qualified, the software team could get up and started immediately, shaving cost and development time, he says.

Aitech's rugged COTS avionics offerings include the M595 PMC and M597 XMC cards (Figure 2). Both use the advanced AMD/ATI E4690 Graphics Processing Unit (GPU) operating at 600 MHz with a 512 MB on-chip GDDR3 SDRAM frame buffer. The E4690 works with an integrated, onboard FPGA to support additional video output formats, overlay, underlay, and keying features. For more information, visit www.rugged.com.

Managing the avionics component life cycle

COTS avionics components and systems cut the design cycle and are more affordable but must be closely managed to effectively refresh designs and deal with obsolescence in military platforms that last for decades.

Special Operations HC/MC-130J

Special Operations HC/MC-130J upgrading with COTS network storage solution from Curtiss-Wright

Lockheed Martin Aeronautics engineers in Marietta, GA, upgraded the storage capability for the avionics and mission systems on the U.S. Air Force Air Combat Command's HC/MC-130J Super Hercules with the Vortex Compact Network Storage (CNS) subsystem from Curtiss-Wright Controls Defense Solutions in Ashburn, VA. The storage system will be used in the Network File Server (NFS) for the aircraft (Sidebar Figure 1).

Vortex is a rugged, conduction-cooled NFS device that enables data sharing over the HC/MC-130J's internal network. Data is stored securely on solid-state memory and encrypted with the AES-256 algorithm, according to a Curtiss-Wright public release.

The HC/MC-130J's data recording requirement called for data to be recorded in nonvolatile memory for running analysis and debriefing functions, says Tom Bowman, Senior Product Manager, Curtiss-Wright Controls Defense Solutions. They can record a very high degree of fidelity – the entire mission as well as when they bring out the mission plan, he continues. "It can include graphics and many other digital forms of information that you couldn't put on a PMCIA card in the past."

Sidebar Figure 1 | The Vortex Compact Network Storage (CNS) subsystem from Curtiss-Wright Controls Defense Solutions is flying on the HC/MC-130J Super Hercules.

Sidebar 2 | Lockheed Martin Aeronautics upgraded the storage capability for the avionics and mission systems on the USAF's HC/MC-130J Super Hercules with the Vortex Compact Network Storage (CNS).

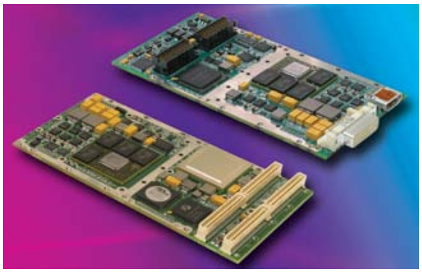

Figure 2 | Aitech's rugged M595 PMC and M597 XMC cards are used in avionics applications.

Rockwell Collins engineers have been leveraging common COTS processors, boards, and other components across Army Aviation platforms for more than 15 years through their Common Avionics Architecture System (CAAS), Toy says. CAAS was originally created to refresh variants of the Army's MH-47G Chinook and MH-60L/M Black Hawk Special Forces helicopters, Toy says. CAAS systems are based on an open architecture approach that leverages adopted industry standards across multiple helicopter platforms, which cuts down technology insertion costs as well as capability retrofits.

CAAS is still going very well for Army Special Operations programs, Toy says. "All of the avionics systems are performing very well and we are beginning to field the second generation of processors." One of Rockwell Collins' most recent CAAS upgrades was on the MH-47F Chinook to keep that rotorcraft flying through 2030, he adds.

Because of CAAS, Army Aviation program managers are able to provide a large level of commonality across their fleet of Special Operations helicopters, Toy says. For example, the UH-60M Black Hawk has many of the same avionics display components of the MH-47F Chinook, he adds.

Using one set of cards or boards across multiple platforms "allows us to benefit from economies of scale to manage those common designs," Toy continues. "We frequently take our approach to develop synergies between various offerings."

Obsolescence can be managed

Eliminating development costs is not the only reason military customers work with traditional COTS suppliers, Grovak says. Another is that they also want to reduce the total ownership cost of the product. Military systems will need to operate effectively for many years in the field, and the customer needs a strong logistic support plan so they don't have components go obsolete that cannot be supported anymore, Grovak says.

The most important thing when managing obsolescence is to pick the right components, Tinkey says. "We're buying a lot of the same parts from our vendors, which will help extend the longevity of our products through a common set of parts in all Rockwell Collins products. The other thing you do is work closely with vendors from the beginning on a life-cycle management plan. It helps that many of the successful suppliers already have product longevity plans in place." **MES**

DO-178C brings modern technology to safety-critical software development

By Tim King and Bill StClair

Avionics software technology has improved by leaps and bounds since DO-178B was introduced in 1992. DO-178C will bring safety-critical software development into the modern era, adding support for advanced techniques such as UML and mathematical modeling, object-oriented programming, and formal methods. The ready availability of third-party tools, platforms, and certification services will hasten the adoption and deployment of DO-178C.

U.S. Air Force photo by Staff Sgt. Austin M. May

As software becomes more complex, it becomes hard to manage the design of that software at the code level. Object oriented programming (C++, Ada, and Java) and modeling (UML, mathematical, and so on) simplify the development of complex software by enabling designers to conceptualize, architect, and encapsulate their design at a higher level. Formal methods, which are related to model based development, make it easier to assess correctness of complex software functions like control loops.

DO-178C inherits the DO-178B core document, principles, and processes, while adding support for high-level modeling, object oriented programming, and formal methods, with an emphasis on two-way traceability from model to executable code and back (Sidebar 1). DO-178C also provides a tools supplement for addressing in detail the qualification and capabilities of the tools used for not only modeling, object-oriented programming, and formal methods, but also for other development technologies such as procedural software and assembly-level programming.

The DO-178C supplements

The DO-178C working group has produced three development technology supplements: Object Oriented Technology and Related Techniques (OOT & RT), Model Based Development and Verification, and Formal Methods. It also greatly expanded the tool qualification guidance present in DO-178B. These four supplements have been published by the RTCA as:

- DO-330, Software Tool Qualification Considerations
- DO-331, Model-Based Development and Verification Supplement to DO-178C and DO-278A
- DO-332, Object-Oriented Technology and Related Techniques Supplement to DO-178C and DO-278A
- DO-333, Formal Methods Supplement to DO-178C and DO-278A

Note that DO-278A is the ground system equivalent of DO-178C.

Object Oriented Technology and Related Techniques

The Object Oriented Technology and Related Techniques (OOT & RT) is a comprehensive safety-critical software guide for hand code development and verification. It encompasses not only object oriented software development, but also techniques that are used in procedural languages. These related techniques include such things as dynamic memory management, overloading, parametric polymorphism (such as templates in C++ and generics in Ada) type conversions, and virtualization. The net result is that the OOT & RT supplement could be invoked on most projects utilizing procedural languages as well as OOT.

The most significant addition to the OOT & RT is the definition of new objectives. Objectives identify which development assets, integrated processes, and verification artifacts must be produced for a product to be certifiable. The OOT & RT defines two new verification objectives: The first verifies local type consistency, which enables subclass methods to safely override parent class methods. The second verifies that the use of the dynamic memory management system is robust. In particular, it verifies the following characteristics of the dynamic memory management system: reference ambiguity, fragmentation starvation, deallocation starvation, memory exhaustion, premature deallocation, lost updates and stale references, and unbound allocation or deallocation time.

Model Based Development and Verification (MBD&V)

The biggest and most contentious challenge in reviewing and approving the MBD&V supplement was determining the final verification method used on the Executable Object Code (EOC) compiled, linked, and loaded on the target system. In the context of the MBD&V systems under consideration, the EOC is directly traceable to the source code automatically generated by the model. Historically, there has been a precedent set in the verification of some avionics software that was tested both by and in the model itself without doing target testing on the EOC, effectively obviating the objectives for EOC testing in the DO-178C "core document." Instead, the DO-178C plenary agreed that a form of independent verification must be performed on the EOC on the target system, thereby preserving the EOC objectives of DO-178C.

Notwithstanding the consensus reached with respect to EOC verification, the MBD&V supplement did add many objectives that provide certification credit for verification activities performed by the model, or at least defined by the model, on the model architecture and model code. These verification activities are primarily performed by "simulation cases," which are run in lieu of test cases and other forms of verification.

Probably the most definitive of the FAQs added to any of the DO-178C tech supplements were those added to the MBD&V supplement. The scope of the new FAQs spans development and verification, including not only standard high- and low-level software requirements and the associated specification and design models, but also the system requirements allocated to software. Historically, the gaps between these model types and requirements hierarchies and their various provenances have been a leading cause of ambiguity and poorly realized designs in MBD&V projects.

Formal methods supplement

The Formal Methods supplement follows a similar trajectory to that of MBD&V in that it also eventually agrees to preserve the EOC objectives of the core document by stipulating independent verification for the EOC ultimately produced by formal methods or mathematical proofs. A key question that has not been definitively addressed by either the Formal Methods or MBD&V supplements is the obvious domain overlap that can occur between these supplements. That is, Formal Methods (FM) as a development and verification technology utilizes a form of model based development itself. This and other potential domain overlaps will be addressed by the FAA in circulars, which will be published this year.

Enhanced verification technology

The incorporation of advanced modeling and object oriented programming techniques places new demands on verification. The system must be verifiable and traceable at the model level, and verification evidence at the model level must be available to the broader verification and traceability framework.

In DO-178B, traceability is one-way and top-down, from the requirements to the target code, and provides no support for high-level modeling or object oriented programming. DO-178C introduces a distributed and collaborative two-way traceability mechanism that enables designers to trace from their models and requirements down to each line of code, and back from the code to the requirements and model, including all interceding work products and test cases.

DO-178C defines traceability requirements for all of the safety integrity levels, from Level D to Level A. At Level D, where no coverage analysis is required, designers need only be able to trace to the high-level requirements. At levels A, B, and C, where coverage analysis is introduced, designers must be able to trace all the way from the high- and low-level requirements to source code and back to low- and high-level requirements. Level A adds another level of traceability, also found in DO-178B, which requires traceability from the source code to the executable object code.

Traceability also requires that the executable code be intact relative to the source code. Many compilers, for example, add branch points to the executable code that are not present in the original source code. These branch points must be identified and tested. Conversely, some optimizations can remove constructs, data in particular (especially static data).

Sidebar 1 | The incorporation of advanced modeling and object oriented programming techniques in DO-178C places new demands on verification.

Software tool qualification considerations

Qualification of a tool is needed when processes of DO-178C are eliminated, reduced, or automated by the use of a software tool without its output being verified as specified in the standard. The purpose of the tool qualification process is to ensure that the tool provides confidence at least equivalent to that of the process(es) eliminated, reduced, or automated.

SOFTWARE LEVEL	CRITERIA		
	1 – Replacement of DO-178B development tool	2 – Expanded tool use in new DO-178C methodologies	3 – Replacement for DO-178B verification tool
A	TQL-1	TQL-4	TQL-5
B	TQL-2	TQL-4	TQL-5
C	TQL-3	TQL-5	TQL-5
D	TQL-4	TQL-5	TQL-5

Table 1 | The Software Tool Qualification Considerations document introduces a new tool qualification structure that consists of three criteria and five Tool Qualification Levels (TQLs).

The Software Tool Qualification Considerations document introduces a new tool qualification structure that consists of three criteria and five Tool Qualification Levels (TQLs) as shown in Table 1.

- Criteria 1's applicable TQL is the replacement for the development tool in DO-178B.
- Criteria 2 is new for DO-178C and is intended to address the expansion of tool use in new methodologies. Criteria 2 basically requires an increased level of rigor over DO-178B criteria for tools used on software level A and B in order to increase the confidence in the use of the tool.
- Criteria 3, which consists entirely of the level TQL-5, is the replacement for the verification tool in DO-178B.

To help safety-critical developers take full advantage of DO-178's advanced capabilities, tools that automate and streamline the development, verification, and certification process have become essential. For example, DO-178C, section 11 introduces Trace Data, which it describes as reference links among life-cycle data items such as requirements, design, source code, and test cases. A key aspect of tools that automate life-cycle data traceability is a facility for establishing traceability forwards and backwards, from requirements down through the decomposition tree, onto the executable code and back again, including verification tasks.

Automated tools greatly reduce the time and cost associated with developing

DO-178-compliant software. DO-178 certification, however, is still an expensive, time consuming, and arduous process. To help expedite this process for avionics equipment makers, some companies, such as DDC-I, offer Eclipse-based development tools and RTOS platforms that have already undergone DO-178B Level A certification, in addition to turnkey development and certification services for both DO-178B and DO-178C.

DO-178C simplifies avionics development

DO-178C marks a big step forward for developers of complex avionics software that must be certified to the highest levels of safety criticality. DO-178C simplifies the development process by embracing formal methods, high-level modeling, and object oriented techniques that enable designers to conceptualize and encapsulate their software at a higher level. It also streamlines the verification and certification process by providing two-way traceability that extends from the models and requirements to the executable code and back again. Together with automated tools, platforms, and certification services, DO-178C greatly clarifies the risk and potential means of reducing the costs associated with developing, certifying, and deploying complex safety-critical avionics software. **MES**

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TRANSITIONING FROM
DO-178B TO DO-178C

Trusting the tools: An agile approach to tool qualification for DO-178C

By Dr. Benjamin Brosgol
and Greg Gicca

The new avionics software safety standard DO-178C, along with its supplemental Software Tool Qualification Considerations *(DO-330), has clarified and expanded the tool qualification guidance provided in DO-178B. The challenge of maintaining qualification-ready tools throughout a system's evolution can be expedited through an approach based on agile development principles.*

U.S. Air Force photo by Tech. Sgt. Mike Tateishi

If a manual activity required for avionics software certification is reduced or replaced by an automated tool, and the output of that activity is used without being verified, then the developer needs to qualify the tool: demonstrate that the tool is at least as trustworthy as the activity that it is replacing. The new avionics safety standard, DO-178C – together with its companion *Software Tool Qualification Considerations*, DO-330 – has clarified and expanded the tool qualification guidance defined in DO-178B. The following discussion summarizes the new guidance and describes an agile approach to maintaining qualification-ready tools in the presence of system maintenance and changes.

Tool qualification in DO-178B

DO-178B[1], a commercial avionics software safety standard that is finding increasing usage in military aircraft development, is often referred to as "process based": It specifies an interrelated collection of software life-cycle processes, each comprising a set of activities and associated objectives. The activities produce outputs ("artifacts") that are evaluated by certification authority personnel to see if they comply with the objectives specified in DO-178B. The applicable objectives (and thus the applicable activities and artifacts) depend on the Software Level: the criticality of the software in ensuring aircraft and occupant safety. The levels range from E (no effect) to A (software failure can directly lead to loss of aircraft and, therefore, lives).

Some DO-178B activities are automatable, and the standard describes how a tool can be trusted to replace or reduce a manual activity if the tool's output is used without being verified. It defines two categories: development tools and verification tools. A *development tool* generates output that is part of the airborne software and thus has the potential to introduce errors. An example is a code generator that produces source code from a model-based design. *A verification tool* cannot introduce any errors but may fail to detect

> “The distinction between a verification tool and a development tool is not always straightforward. Moreover, a verification tool might not simply automate a specific activity; its output may also be used to eliminate or reduce some other activity.”

errors, for example, a static analysis tool that identifies variables that are read before being initialized.

Tool qualification entails preparing, among other data items, the Tool Operational Requirements (TOR). The TOR defines various properties of the tool including its features, installation, usage, and operational environment.

A development tool needs to be qualified if, and only if, the software generated by the tool will not be subjected to the same applicable certification objectives as the other airborne software. Development tool qualification entails meeting the same objectives as for the certification of the airborne software. (Although compilers and linkers are development tools, qualification is not required since their output is verified through other DO-178B activities. Indeed, qualification would be expensive and would not simplify the effort in meeting other objectives such as traceability analysis.)

Qualifying a verification tool is considerably simpler than qualifying a development tool, in part because DO-178B's philosophy is to encourage the use of such tools to automate activities involving repetitive and rule-based tasks, which are better performed by automated tools than by humans. Qualifying a verification tool basically consists in demonstrating that the tool complies with its TOR.

Tool qualification in DO-178C

Tool qualification has been an important part of DO-178B certification, but several issues have arisen in practice:

- The distinction between a verification tool and a development tool is not always straightforward. Moreover, a verification tool might not simply automate a specific activity; its output may also be used to eliminate or reduce some other activity.
- Requiring a development tool to meet the same objectives as the airborne software is unnecessarily restrictive, since the operational environments are different. For example, an unbounded recursion in the avionics software could exhaust stack storage and lead to a system failure; the same behavior in a development tool would not present a safety hazard.
- Although tool qualification is intrinsically in the context of a specific system, it would be beneficial if the qualification requirements expedited reuse of qualified tools on a modified version of an existing system.

All of these issues are addressed in either DO-178C[2] or its accompanying supplement DO-330, *Software Tool Qualification Considerations*[3].

- The terms "development tool" and "verification tool" have been replaced by three criteria. Criterion 1 corresponds to a development tool (that is, the tool could insert an error into airborne software). Criterion 2 corresponds to a verification tool that could fail to detect an error and is used to reduce other development or verification activities. Criterion 3 corresponds to a verification tool that could fail to detect an error but is not used to reduce other development or verification activities.
- The required qualification for a tool – its Tool Qualification Level (TQL) – depends on its Criterion and on the Software Level of the software that the tool is used for, as shown in Table 1. The TQL ranges from 5 (comparable to a DO-178B verification tool) to 1 (similar to Software Level A). The activities and data items associated with each TQL are defined in a separate document, DO-330, with the same structure as DO-178C. DO-330 provides comprehensive guidance for tool qualification and recognizes the differences between the execution environments for the airborne software and the tool.
- DO-330 explicitly covers the usage of previously qualified tools. In brief, the reuse of a previously qualified tool is allowed as long as the developer can demonstrate, through a change impact analysis, that the tool still complies with its TQL requirements despite any changes in the operational environment or to the tool itself.

Table 1 | The required qualification for a tool – its Tool Qualification Level (TQL) – depends on its Criterion and on the Software Level of the software for which the tool is used.

Tool Qualification Level Determination

Software Level	Criterion		
	1	2	3
A	TQL-1	TQL-4	TQL-5
B	TQL-2	TQL-4	TQL-5
C	TQL-3	TQL-5	TQL-5
D	TQL-4	TQL-5	TQL-5

Reuse of previously qualified tools

The ability to reuse, or easily adapt, the qualification artifacts for a previously qualified tool is especially important. DO-178B provided no explicit guidance here. Tool qualification that was performed for one system would need to be repeated for any new system or if any aspect of the tool or environment changed. As a result, a project manager would commonly choose the operational environment and tools at an early stage, and then commit to these versions so that the tool qualification artifacts could be used during final system certification. This is sometimes referred to as the "big freeze," where the environment and tools are locked in early.

DO-330 addresses these issues. Specific guidance for previously qualified tools allows reuse of the qualification artifacts as long as nothing has changed that would affect qualification. It considers three scenarios:

- Reuse of a previously qualified tool without change – An example is when a tool is used for related projects or on multiple phases of an existing project. The developer needs to identify the approach and rationale in the plans.
- Changes to the tool operational environment – The developer needs to update one or more of the plans, but the bulk of the original qualification artifacts may be reused as is. Only the updated artifacts related to the operational environment need to be reviewed by the certification authority.
- Changes to the tool itself – A change impact analysis has to be provided, but tool requalification still has a reduced cost, essentially only requiring activities associated with aspects that have changed or are affected by the change. The key is to be able to exactly determine and specify what has changed and what these changes impact, or perhaps more importantly, what they do not impact.

Agile requalification

Based on the tool qualification guidance – either from DO-178B or from DO-178C and DO-330 – it is possible to define a framework for tracking the changes to a tool or its operational environment and for automatically initiating the tool qualification activities triggered by the changes.

For example, a tool can be initially developed and qualified based on the objectives defined in DO-178C and DO-330. The full tool development life-cycle processes and their associated qualification artifacts can be captured and maintained in a Configuration Management (CM) system, including all dependence relationships (see Figure 1). The core CM system allows basic regeneration of all qualification data and artifacts needed to reproduce a tool qualification. The full structure allows impact and change analysis. In this way any change to the tool's operational environment or to the tool itself can be tracked. Most importantly, the structure will clearly show which parts of the tool and its artifacts are not affected and thus can remain unchanged and retain their previous review and qualification readiness.

Transitioning to the new qualification guidance

DO-178B is effectively a subset of DO-178C. Thus, a project can continue with the development and certification plans established for DO-178B while migrating chosen portions to DO-178C, for example, to exploit the tool qualification objectives in DO-330. Therefore, both existing DO-178B projects and new DO-178C projects can take advantage of DO-330's cost-effective guidance on tool qualification and requalification.

The AdaCore Qualifying Machine framework[4], an in-progress implementation of the agile technique described

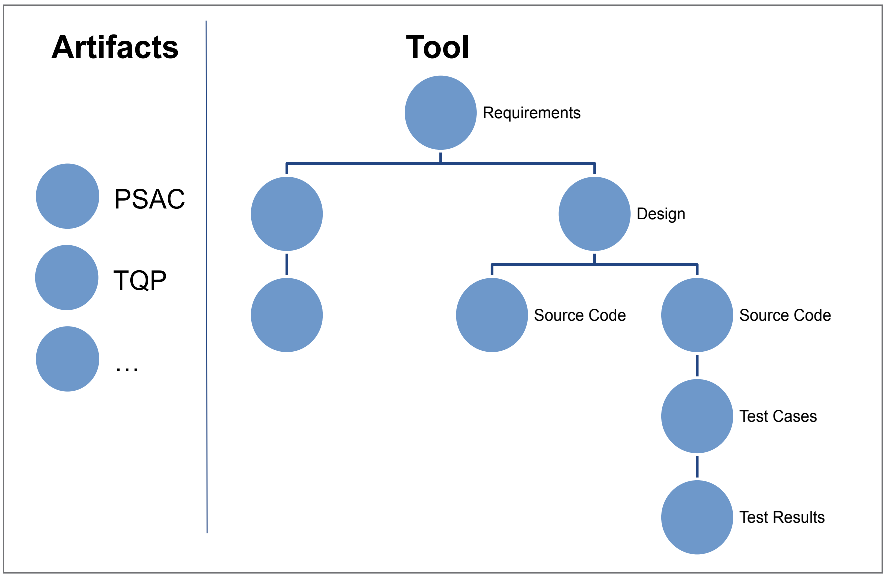


Figure 1 | The full tool development life-cycle processes and their associated qualification artifacts can be captured and maintained in a Configuration Management (CM) system, including all dependence relationships.

in the previous section, supports this approach. It can help projects avoid the "big freeze," so that tools and development environments can evolve smoothly. Tools may be upgraded to newer versions as updates become available, without the risk of losing the tool qualification required for system certification. **MES**

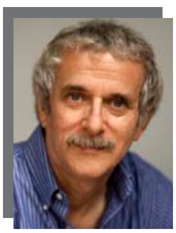
References:

[1] RTCA SC-167/EUROCAE WG-12. RTCA/DO-178B – Software Considerations in Airborne Systems and Equipment Certification, December 1992.

[2] RTCA/DO-178C – Software Considerations in Airborne Systems and Equipment Certification; publication expected in 2012.

[3] RTCA/DO-330 – Software Tool Qualification Considerations; publication expected in 2012.

[4] www.open-do.org/projects/qualifying-machine



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SOFTWARE ANALYSIS

Open source clears up the military stovepipe mess

Interview with Carl Houghton, Vice President, Strategic Initiatives & Advanced Technology at Intelligent Software Solutions

INTERVIEW

Editor's note: *While the issue of military stovepipes continues on, Government Off-the-Shelf software provider Intelligent Software Solutions' toolkit – already in use by several branches of the U.S. Armed Forces – is thwarting the challenge by making it possible to link several disparate databases or data sources that would have otherwise not been able to "talk" to each other. As Managing Editor Sharon Hess found out when she recently talked to Carl Houghton, Vice President, Strategic Initiatives & Advanced Technology at Intelligent Software Solutions, the "real-time" ability of the software to combine data fast and automatically notify operators of data changes greatly simplifies the challenge for command and control operatives, as well as other government personnel. Meanwhile, the open source software company also does a thing or two with iOS and Android – and watches to see which one will capture the market. Edited excerpts follow.*

Can you tell me more about your company, Intelligent Software Solutions – what you do, where you're located, what your focus is, and so on?

HOUGHTON: Intelligent Software Solutions is a software and public services company founded about 15 years ago and headquartered in Colorado Springs. The company was started by four software engineers who still own the company. We've got close to 700 employees today, with offices in Tampa, Florida; Rome, New York; Washington, D.C.; and Hampton, Virginia; and we just opened an office recently in Boston. We've got four major business units in the company: One focuses on Command and Control and Intelligence, Surveillance, and Reconnaissance. We also have a National Systems division, focused on D.C. area customers and the Coast Guard. Then we have our Enterprise System Division, which used to be called Combat Systems and provides support to ongoing operations in Afghanistan and a couple other places. And then we've got my division, Strategic Initiatives, and we focus on advanced technology development. We are doing things for DARPA and other service laboratories and research and development work, both IRAD as well as government-funded research and development.

You're focused on Government Off-the-Shelf [GOTS], I believe?

HOUGHTON: Yes, we develop software for desktop, Web, and mobile device applications; we're predominantly a Government Off-the-Shelf software provider: The government owns unlimited use rights to everything we develop, so they don't have to license for each deployment. What is nice about that model is that we've got this ubiquitous data access framework on the backend that can connect up to a lot of different data sources. And then we can use that to push the data out, whether it be to a desktop application, a Web application, or a mobile application. And so we try to reuse these government off-the-shelf frameworks as much as we can in our applications.

Can you tell me which government entities you work with and which kinds of open source software you're providing them?

HOUGHTON: Our largest contract is actually with the Air Force Research Laboratory [AFRL], and they use our WebTAS-TK toolkit. It started out as a $350 million indefinite delivery/indefinite quantity [AFRL] contract, but any government agency can use [the contract] to purchase software and services. The toolkit is software that provides ubiquitous data access, visualization, and data analysis for a wide range of applications. And what's nice about it is we can build on top of that framework. [When] you want to build the new application, we have a 70 to 80 percent solution at the starting point and then we can build what we call "business layers" on top of that to extend it to solve different problems. So for the Coast Guard, we could take a piece of Government Off-the-Shelf software, build a business layer on top of that that is specific to their requirements and workload, and they have a solution without having to start from scratch and [without having to] ask for licensing and software. So we replicate that model across the government space.

We do a lot of work with the Air Force and the Army and some work with the Coast Guard, as I mentioned. We typically provide them with WebTAS-TK or perhaps CIDNE, which is software that tracks events. So if you have a series of events that takes place and you want to track it and you want to track who was involved, for example, CIDNE enables you to do that. So the main two applications we deploy to our customer base right now are WebTAS-TK and CIDNE. We've got other types of software that are more minor applications. We do service oriented architecture infrastructures for the space community and for several others.

Are WebTAS-TK and CIDNE used by warfighters or by operators at a desk?

HOUGHTON: Yes to both. The users could be [soldiers] deployed in Afghanistan, who use the software for various visualization/analytical purposes [and transmit that information] to people who are back in the U.S. using the data for Command and Control purposes. The Coast Guard is using it for maritime operations for securing our ports.

Let's drill down on how WebTAS-TK works.

HOUGHTON: Sure. So the software itself is predominantly a Java-based framework that allows us to do database connections. We can use JDBC- or ODBC-type connections to connect to relational databases. We can connect to other relational data sources; we can connect to Web services and various streaming data sources. I can't go into specific details about specific applications on the government space, but I can give you some information. For example, if you had 20 different relational databases that range from Excel spreadsheets through Access databases all the way up to enterprise Oracle instances and you wanted to federate those into a single data space that could have a single logical object monolog you could query against – [WebTAS-TK] provides the ability to federate and provide that single logical object model and data space.

So once you have that, then we have a whole series of different analytical tools that allow you to visualize and analyze data temporally, geospatially, and internodally to look for interesting bits of data from your federated data space.

Tell me more about the Web and mobile applications you work on.

HOUGHTON: On the Web side, we use a wide variety of technologies, anything from Java server faces to Flex and Flash. We do a lot with pure Flash with Flex and ActionScript. We also were doing some HTML5 applications, and all of those have the ability to come through the WebTAS-TK backend or provide Web-based access to that data. In the mobile space we develop on both iOS and Android, and we get to those through the use of JSON or other transport media to get the information from a WebTAS-TK backend to a mobile device on the front end.

Can you give a scenario of how the military would use WebTAS-TK?

HOUGHTON: Let's say you had a Command and Control application requirement and that you have a database that has information on where a particular aircraft is located. And maybe you have other sources of information that say, "Here is the status of all the various bases." And then you've got a third database that has maybe targets for flying purposes, and you need to federate those things so you can plan missions, know what your available resources are and what their status is, and know which targets you are going to plan against. And you need the ability to eventually bring that data together from these three disparate databases that don't talk to each other in order to be able to do that planning. That is what you could do with this software. You could imagine that could be 50 different databases. Today it is a classic problem [in the military] of "I've got all these different stovepipes and no way to federate and look across them such that I can make those decisions."

Does WebTAS-TK deliver the data, analyses, and so on in real time?

HOUGHTON: It's real time. It can operate transactionally. So as a database or data source gets updated in real time or when a table gets data added to it or updated, or a Web service fires an event to say "Hey, something has changed," the software can make a real-time update to the displays and the analytics and notify the operator. I know you're talking embedded systems, so when you talk "real time," it may be on a different sort of scale or level, but in a database transaction level, we are real time. If there has been a transaction in the database, we're talking less than a second that the other data is updated and the operator can be made aware there has been a change to a database table.

So the change notifications are automatically generated by the software?

HOUGHTON: Correct. So the services piece that we do is customization of the software to a particular domain. But we're not a data producer.

Since your products are deployed to the military or government, is there a security feature built into the software?

HOUGHTON: Yes. There is a security manager built into the software and it does go through security accreditation by the appropriate government agency(ies) for deployment. Both CIDNE and WebTAS-TK go through accreditation for every release.

Can you tell me more about CIDNE – how it works or a real-life military scenario?

HOUGHTON: I can't go into as much detail on CIDNE specifically. I am basically constrained as to what is in the public domain on the program. But we use Adobe ColdFusion; it runs on top of the Microsoft SQL Server database and allows people to enter events of interest and track those events over time and space.

Is it looking for just a preset, specific event like "I am looking for a man wearing a hat going into a building," or does it look for similarities between events?

HOUGHTON: In and of itself, it is not an analytical program. It is really a database, a federated database of events. So really it's a series of forms where people can enter events, and they really can be any kind of event. So it could be that we've got burglaries around San Antonio and I want to be able to track those burglaries for the police department. It will allow users to track who was involved, where the burglaries took place, geospatially and temporally, and gives you a standardized way of everybody entering that information. But that is just one class of events; you could have a thousand classes of events and you could track them all in a single database. That is really what the power of the thing is.

You said that military is using CIDNE now?

HOUGHTON: Yes, but I can't really go into the details of that, unfortunately.

What would you say is the focus of your government and military customers? What are the trends?

HOUGHTON: I think what we see and again when you look at constrained budgets going forward, they don't want to necessarily pay huge licensing fees for software. And then the ability for them to fund just development on the specific functionality that they want and the ability to rapidly get that functionality into their hands.

What else – any specific technology capabilities?

HOUGHTON: Yeah, the ability to provide ubiquitous data access and connect up to and federate all those data sources is something that is very attractive. The other functional thing that people like is the ability, for instance, to send output to Google Earth. Seemingly that is a very simple thing, but when you get in and say, "OK, I want to take Google Earth and I want to connect up to 50 different data sources with it," there is not a way to do that out-of-the-box using just Google Earth – especially if those are relational databases with very complex data models. And so we have a lot of users that use us as kind of an intermediary to translate from all the databases they want to get at and send to Google Earth on the other side.

All the software your company designs – WebTAS-TK and CIDNE and your software for mobile devices – that's ALL Government Off-the-Shelf?

HOUGHTON: That is correct. Everything we do is GOTS.

Would there be security issues in using GOTS software for commercial customers, if your commercial customers knew how to use the same software that government customers were using?

HOUGHTON: No, because the core software itself is rather innocuous. There are no security issues with providing that in the commercial space. We have gotten approval from the government to actually sell it as a commercial product, so they have gone through the security reviews and have no issues with it. We have also gone through the Commerce Department and gotten a commerce jurisdiction to sell it externally to foreign countries. And anytime we deal with potentially foreign military sales, we have to go through ITAR, which is, of course, a rather involved review before we can export anything.

Are there any new trends in open source software?

HOUGHTON: The biggest one that we are seeing is the transition to rich Internet technologies – and the trend over the past year to push toward more HTML5 functionality in the rich Internet application space and even in the mobile application space. With Adobe announcing this year that they are giving up on Flash runtime on the mobile devices and feeding that to HTML5, it's really interesting. One of the best things with HTML5 is that it provides the ability to do all the things you can do with Flash in terms of having a rich experience inside the browser (the ability to play video and to play audio and to have interactive content) – without having any plug-ins. HTML5 is still not a standard ratified by the World Wide Web Consortium, so Internet Explorer and Microsoft are still not fully compliant with the HTML5 spec. But other browsers such as Google Chrome and Safari are implementing all the functionality.

The other huge growth area that we are seeing is just Android being proliferated as an open source operating system on mobile devices and really providing an [alternative] to iOS. The fact that you have an open source operating system in a mobile space is very attractive. So I think the proliferation and growth of Android and in particular in the tablet space is going to be interesting as they try to compete with the iPad and iOS. **MES**

Carl Houghton, Vice President, Strategic Initiatives & Advanced Technology at Intelligent Software Solutions (ISS), is responsible for facilitating strategic business development goals across numerous business units in the company. Carl is a combat veteran of the U.S. Air Force. He flew more than 2,000 combat hours in support of operations in the Middle East and Bosnia and Herzegovina. He has a Bachelor's of Science in Information Technology and is a graduate with honors from the Defense Language Institute in Modern Standard Arabic. Contact him at carl.houghton@issinc.com.

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SOFTWARE ANALYSIS

Symbolic execution techniques identify vulnerabilities in safety-critical code

By Paul Anderson

Multicore processors are becoming increasingly popular in safety-critical applications because they offer significant price and performance improvements. However, writing multithreaded applications for multicore hardware is notoriously difficult and could result in catastrophic failures. The following describes symbolic execution techniques for identifying issues including data races – one of the most common concurrency defects – and how static analysis can help developers find and eliminate them.

U.S. Air Force photo by Senior Airman Nadine Barclay

Maximizing performance is especially important for military embedded systems because of the growing need to keep costs low while satisfying the requirements of connectivity in an increasingly digital battlefield. As manufacturers reach the limits of what can be wrung from increased miniaturization and integration, the best approach to increased performance is the use of multicore processors.

The downside is that to take full advantage of many cores executing in parallel, the software must be written to be intrinsically multithreaded. Software written to be single-threaded for a single core processor will realize little or no performance benefit when executed on a multicore processor: It must be rewritten or adapted to use multithreading. The key challenge is to keep the cores busy as much as possible, while ensuring that they coordinate access to shared resources properly. Unfortunately writing such code is much harder than writing single-threaded code. When there are defects such as deadlocks or race conditions, they can manifest in ways that are difficult to diagnose. Traditional techniques for finding and eliminating concurrency bugs may be ineffective.

One of the core reasons why concurrency bugs are so difficult is because there is an enormous number of ways in which the events in the threads can be interleaved when those threads execute. As the number of threads or instructions increases, the number of interleavings increases exponentially. If thread A executes M instructions and thread B executes N instructions, there are ${}^{N+M}C_N$ possible interleavings of the two threads. For example, given two trivial threads with 10 instructions each, there are 184,756 possible interleavings of those instructions. Even with very small programs it is clear that it is next to impossible to test all possible combinations. Secondly, even if it is possible to identify a single interleaving that leads to a failure, it can be very difficult to set up a repeatable test case that uses that particular interleaving because scheduling of threads is effectively nondeterministic. Consequently, debugging concurrent programs can be very expensive and time consuming. A race condition is a class of concurrency defect that is easy to accidentally introduce and difficult to eliminate with conventional testing. However, there are techniques programmers can use to find and remove them.

Potential catastrophic failures

Compared to single-threaded code, entirely new classes of defect can occur in concurrent programs, including deadlock, starvation, and race conditions. Such defects mostly cause mysterious failures during development that are very difficult to diagnose and eliminate. One avionics manufacturer we have worked with spent two person-years applying traditional debugging techniques in an effort to find the root cause of an intermittent software failure that turned out to be a race condition. Sometimes the consequences can be dire – two of the most infamous software failures ever were caused by race conditions. The Therac-25 radiation therapy machine featured a race condition that was responsible for the deaths of several patients[2]. Similarly, the 2003 Northeast blackout was exacerbated by a race condition that resulted in misleading information being communicated to the technicians[3].

"Compared to single-threaded code, entirely new classes of defect can occur in concurrent programs, including deadlock, starvation, and race conditions. Such defects mostly cause mysterious failures during development that are very difficult to diagnose and eliminate."

There are several different kinds of race conditions. One of the most common and insidious forms – data races – is the class of race conditions involving access to memory locations.

A data race occurs when there are two or more threads of execution that access a shared memory location, at least one thread is changing the data at that location, and there is no explicit mechanism for coordinating access. If a data race occurs it can leave the program in an inconsistent state.

Consider avionics code that controls the position of a flap. In normal circumstances the flap is in a position dictated by the flight control software, but the pilot can override that position by pressing a button on his control panel, in which case a manually set position is used. To keep things simple, let's say that there are two threads in the program: one that controls the flap and one that monitors the position of the elements on the control panel. There is also a shared Boolean variable, named *is_manual*, that encodes whether the manual override is set or not. The flap position thread checks the value of *is_manual*, and if true, it sets the position accordingly. The control panel thread listens for button press events, and if the override button is pressed, it sets *is_manual* to true. Figure 1 shows the code that one might write to implement this specification. This code is likely to work most of the time; however, because the is_manual variable encodes a state that is shared by both threads, it is vulnerable to a data race because access to it is not protected by a lock. If the flap positioning code is being executed at the exact time that the pilot hits the override button, then the program may enter an inconsistent state and the wrong flap position will be used. Figure 2 shows how this might happen.

This example neatly illustrates one of the properties of data races that makes them hard to diagnose: The symptom of corruption may only be observable long after the data race has occurred. In this case, the fact that the wrong flap position is being used may only be noticed when the pilot notices the aircraft is not responding as expected.

A widely held belief is that some instances of data races are benign and can be tolerated. However, it is now clear beyond doubt that this is only rarely true. The C standard[4] states unambiguously that compilers are allowed to

Flap position thread

```
...
if (is_manual)
    position = manual_setting;
else
    position = auto_setting;
set_flap_position();
...
```

Control Panel thread

```
...
if (override_button_pressed)
   is_manual = true;
else
   is_manual = false;
...
```

Figure 1 | Code in two threads that access a shared variable

An interleaving of instructions that causes a data race that results in the wrong flap position being used

1	`if (is_manual)`	
2		`if (override_button_pressed)`
3		`is_manual = true;`
4	`position = auto_setting;`	
5	`set_flap_position();`	

Figure 2 | An interleaving of instructions that causes a data race

assume that there are no data races, so optimizers can and do make transformations that are valid for improving the performance of single-threaded code but which introduce bugs when there are apparently benign race conditions. These are subtle effects – even experienced programmers are regularly surprised by them. (See reference [1] for a full explanation and several compelling examples.) Because of this, to achieve high levels of assurance and avoid disastrous failures, it is very important to find and remove all data races.

Eliminating concurrency defects

Given that concurrency defects, and data races in particular, are so risky, it is important to use multiple techniques to eliminate them. Traditional dynamic testing is not well suited for finding many concurrency defects because of non-determinism. A program that passes a test hundreds of times may later fail in the same environment with exactly the same inputs because the bug can be exquisitely sensitive to timing. Engineers looking for high assurance must turn to other techniques if they are to eliminate concurrency defects.

Static analysis tools offer a means for finding such bugs. The key difference between testing and static analysis is that it tests a particular execution of a program for a given set of inputs, whereas static analysis finds properties that are good for all possible executions and all inputs. (In practice, static analysis tools make approximations to achieve acceptable performance and precision, so fall short of this ideal model. Nevertheless, they do cover many more cases than would ever be possible with traditional testing.)

Roughly speaking, static analysis tools work by creating a model of the program and by doing a symbolic execution of that model, looking for error conditions along the way. For example, GrammaTech's CodeSonar static analysis tool finds data races by creating a map of which locks are held by which threads and by reasoning about the possible interleavings that could result in unsynchronized access to shared variables. Deadlock and other concurrency defects (including lock mismanagement) are found using similar techniques.

Custom concurrency constructs: A case study

Standard defect detection techniques are most useful when programs use standard ways of managing concurrency. Most tools recognize and can reason about the special properties of standard libraries such as the POSIX threads library or proprietary interfaces such as VxWorks. However, many systems use custom techniques for managing concurrency.

For example, another manufacturer we worked with built a safety-critical device on a platform that used a custom pre-emptive multithreaded software interface. In this design, a key constraint was that all data instances that could be accessed from multiple priority levels of threads had to be protected with proper guard constructs. Prior to using static analysis, validating that this constraint was respected required a person-month of manual analysis. To reduce the cost, they sought a solution by turning to static analysis. An important property of modern advanced static analysis tools is that they are extensible: They provide an API with abstractions that make it convenient to implement custom static-analysis algorithms. Using CodeSonar's API, they were able to program a solution that piggybacked on the algorithms used at the core of the existing analyses to find locations in the code where the design constraint was being violated. The resulting tool, implemented as a plug-in, is able to find violations of the key constraint automatically, all at a fraction of the cost and in much less time than was previously possible.

Multicore trade-off

There are compelling reasons to move to multicore processor designs, but the risk is that doing so introduces the possibility of concurrency defects in the software. These are easy to introduce – even apparently innocent code can harbor nasty multithreading bugs – and notoriously difficult to diagnose and eliminate when they occur. Traditional testing techniques alone are inadequate to ensure high-quality software, mainly because of the high degree of nondeterminism. The use of advanced static analysis tools that use symbolic execution is one approach that can help because such tools can reason about all possible ways in which the code can execute. These tools can find defects such as data races and deadlocks in code that uses standard multithreading libraries, and can even be adapted to designs that use nonstandard concurrency constructs. **MES**

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SOFTWARE ANALYSIS

Automated performance measurement and timing analysis help military embedded systems avoid early obsolescence

By Dr. Andrew Coombes

The ongoing success of military embedded systems on land, sea, and air depends on the ability to modify the systems to meet emerging requirements. Over time, accumulated modifications to software-based systems result in degradation of the performance of that system. Eventually, the resulting performance degradation leaves system developers with the choice of either abandoning planned new features or replacing the hardware and accepting early obsolescence. There is an alternative. Automated performance measurement and timing analysis technology provide developers with the tools to optimize away much of the performance degradation resulting from accumulated modifications, thereby avoiding either abandoning features or early obsolescence.

Photo courtesy of BAE Systems

Military embedded systems are typically enhanced many times during their lifetime. Many of these enhancements are software updates. Over time, the software updates cumulatively increase the demands placed on the computing platform. This can lead to the hardware's capabilities becoming insufficient to meet application demands, potentially resulting in intermittent failures. System developers then face the difficult choice of either abandoning planned new features, leading to capability decay, or replacing the hardware (that is, early obsolescence).

A viable alternative requires the identification of high-impact, low-risk strategies for optimizing software, thereby maximizing the service life of the computing platform. This alternative includes automated performance measurement and timing analysis.

The problem of performance

Military embedded systems, and especially avionic systems, such as the BAE Systems Hawk's mission control computer, are often real-time embedded systems. Real-time systems are distinct because their correct behavior depends both on their operations being logically correct, and on the time at which those operations are performed. Engineers developing these systems must be able to provide convincing evidence that the software always executes within its time constraints.

The nature of software means that every time it is executed, it could take a different path through the code, leading to different execution times. Even when using the system in the same way, differences in the internal state could mean that the user sees widely varying execution times. Because of this, it is entirely possible to rigorously test software without seeing any timing problems, then to encounter a situation in actual use that results in significant timing problems. So to be sure a system always meets its execution time, it is necessary to establish its Worst-Case Execution Time (WCET), which is also a consideration for DO-178B.

Finding Worst-Case Execution Time

Measurement is an approach often taken to obtain confidence in the timing behavior of a real-time system. To measure timing, engineers typically place instrumentation points at the start and end of sections of code they wish to measure. These points record the elapsed time, either by toggling an output port (monitored via an oscilloscope or logic analyzer) or by reading an on-chip timer and recording the resulting timestamps in memory.

Unfortunately, these high-water marks might not reflect the longest time that the code could take to execute. This happens when the longest path through the code has not been exercised by tests, as illustrated in Figure 1. Two tests, represented in Figure 1 by the green path and the blue path, are run. The observed execution times from these tests are 110 and 85 respectively. Despite these tests executing all code in the software, there is a third path (shown in red), which has an execution time of 140, making it the longest path.

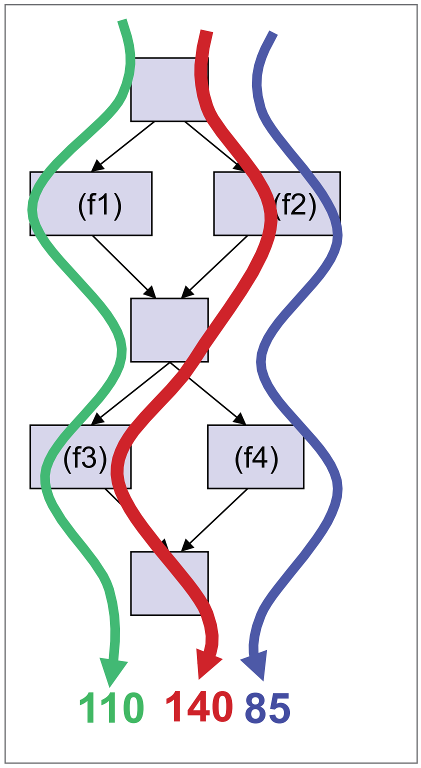

Figure 1 | Execution paths: High-water marks might not reflect the longest time that the code could take to execute. This happens when the longest path through the code has not been exercised by tests.

This example shows that simply executing all code isn't enough to exercise the longest path. For nontrivial code, it is very hard to devise tests that are certain to drive the code down its longest path. This situation can be avoided by adding instrumentation points at each decision point in the code. Whenever an instrumentation point is executed, its ID and a timestamp are recorded. Running a series of tests on the system results in the creation of a timing trace. Combining the timing information from the trace with information about the structure of the code makes it possible to find information about the timing behavior of the software, including predictions of WCET.

For typical military applications, which can run into millions of lines of code, it would be extremely laborious to instrument programs by hand; moreover, the volume of trace data typically produced would make manual attempts to combine trace data with program structural information infeasible. Fortunately, the tasks of program instrumentation, trace processing, combining trace data with program structural information, and data mining/presentation are all amenable to automation. RapiTime from Rapita Systems is an automated performance measurement and timing analysis technology that helps solve the challenge of obtaining detailed timing information about large military embedded systems implemented in C, C++, or Ada.

Performance optimization

Knowing the WCET is only one part of the solution: When faced with the problem of a software component that overruns its execution time budget, it is essential that a systematic, scientific approach is taken to optimizing the component's performance.

Software performance optimization requires three questions to be answered:

- Where is the best place to optimize?
- Is the proposed optimization making an improvement?
- How much improvement can be made?

Where is the best place to optimize?

In a typical complex application:

(1) Most subprograms are not actually on the worst-case path; they contribute nothing to the worst-case execution time. Optimization of these subprograms would not reduce the WCET at all.

(2) Many subprograms contribute a small amount to the WCET and so do not represent good candidates for optimization. Effort spent optimizing these subprograms would not constitute an effective use of resources.

(3) A small number of subprograms contribute a large fraction of the overall WCET (Figure 2). Therefore, the subprograms are potential candidates for optimization.

By inspecting WCET information, engineers can easily identify a relatively small number of components where optimization could potentially have a large impact on the overall worst-case execution time.

Am I improving things?

It is sometimes tempting to try to short circuit the analysis process by guessing where the worst-case hotspots are, optimizing that code, and then seeing what the effects are. However, the experience of software optimization tells us that even highly skilled software engineers with an in-depth understanding of their code find it almost impossible to identify the significant contributors to the WCET, and hence the best candidates for optimization, without access to detailed timing information.

"Often it seems so obvious – 'It must be that section of code that makes all those floating-point calculations that is the best candidate for optimization' – when actually, some innocuous-looking assignment hides a memory copy that is taking nearly all of the time."

Often it seems so obvious – "It must be that section of code that makes all those floating-point calculations that is the best candidate for optimization" – when actually, some innocuous-looking assignment hides a memory copy that is taking nearly all of the time. The answer to this problem is simple: Don't guess, measure. Then repeat the

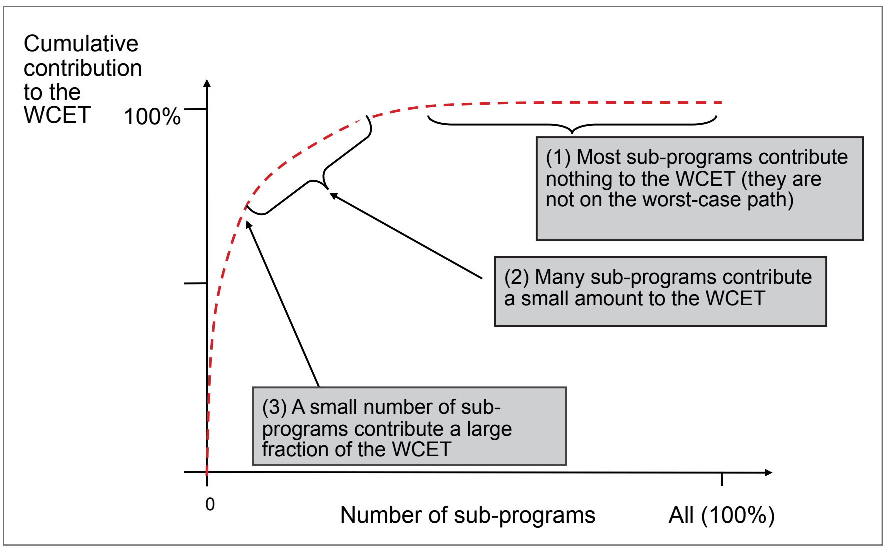

Figure 2 | Cumulative contribution of subprograms to the overall WCET

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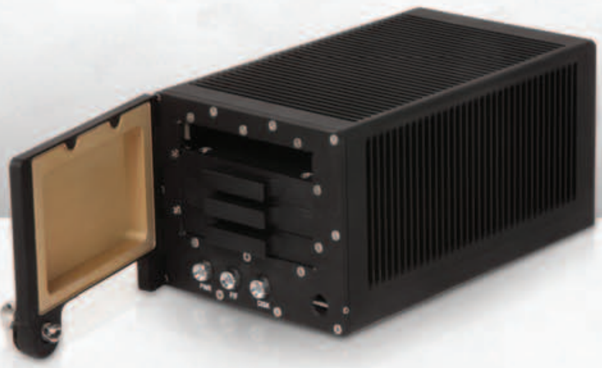

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Partition	Language	Notes	Optimization Level	Percentage Improvement
U	Ada	High data throughput	Design level	60%
V	Ada	Spark exception	Low level	10%
W	Ada	Efficient block copy	Sub-program	40%
X	Ada	Multiple simple optimizations	Low level	10%
Y	Ada	Efficient block copy	Design level	50%
Z	Ada	Loop variables	Sub-program	15%

Table 1 | Optimization improvements on a BAE Systems Hawk mission computer

measurement to quantify the improvement (or lack thereof).

How much improvement can be made?

Table 1 indicates the level of improvements in Worst-Case Execution Times that can be obtained through a simple process of software optimization. These results were achieved using RapiTime technology to provide detailed timing information on the mission computer of a BAE Systems Hawk. These optimizations led to an overall decrease of 23 percent in WCET.

The benefits of WCET and performance optimization

Access to automated performance measurement and detailed timing analysis during the modification of military embedded systems can provide a number of advantages to the developer:

1. A systematic and scientific approach is utilized in obtaining confidence in the system's timing behavior.
2. Detailed information about worst-case execution time allows candidates for optimization to be quickly identified.
3. Automated measurement allows the effectiveness of candidate optimizations to be assessed.

The ability to do the best possible timing optimizations means avoiding making the hardware unnecessarily obsolete and eliminating the need to abandon planned new features or replace the hardware and accept early obsolescence. **MES**

__Dr. Andrew Coombes__ is Marketing and Engineering Services Manager at Rapita Systems. For the past 15 years, he has helped develop and commercialize software tools for embedded, real-time applications. He received his DPhil in Computer Science at the High-Integrity Systems Engineering Group at the University of York (UK) before working in a consultancy and for the BAE Systems Dependable Computing Systems Centre (DCSC). Contact him at acoombes@rapitasystems.com.

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3D handheld display for warfighters

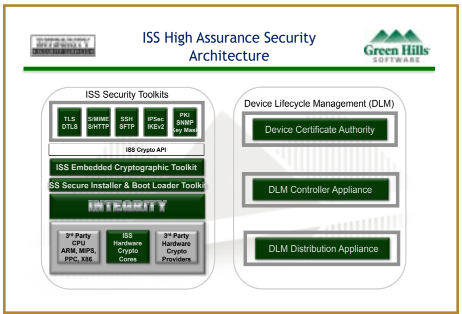
Leveraging 3D film technology from 3M, engineers at IEE in Irvine, CA, developed a 4.8-inch handheld control display unit for warfighters that does not require 3D glasses. The display – targeted for military remote observation applications and training missions – was originally designed for functions such as terrain mapping, enhanced video feeds, and remote robotics control.

Other features include Light Emitting Diode (LED) backlight technology, which helps reduce power consumption. The device cuts down on common problems with 3D devices: off-axis image reversals and color distortions. It can also revert to 2D that displays similar quality images to that of commercial smartphone technology. The display's resolution is 800 x 480 x RGB and has a brightness of 200 cd/m^{2}in 2D and 3D modes with an optimum viewing distance of 16 inches. External dimensions of the unit are 3.45 x 5.98 x 1.22 inches.

IEE provides a System Integration Development (SID) that will be available for government agencies and prime contractors this year.

IEE | www.mil-embedded.com/p367429 | www.ieeinc.com/handheld devices

New crypto tool suite provides authenticated software security for embedded products



Officials at Green Hills Software in Santa Barbara, CA, released a security solution consisting of Suite B-Compliant Security Protocol Toolkits and Device Lifecycle Management (DLM) system, designed by the company's INTEGRITY Security Services (ISS) business unit. Packaged with the Green Hills INTEGRITY Real-Time Operating System (RTOS) the ISS Security Protocol Toolkit adds an additional reliability level and authenticated security that ensure all embedded devices powered by ISS solutions are secure.

The ISS solutions will address: authentication, authorization, network access control, confidentiality, integrity, and remote management. Authentication ensures that users, devices, and software on a network are correctly identified. Authorization grants the right to access resources and perform specified actions. Network access control limits access to the network to authenticated and authorized devices, software, and users. Confidentiality ciphers transform data to make it unreadable to anyone except those authorized and authenticated. INTEGRITY detects unauthorized changes to transmitted data through the life cycle of a device, software, and data remote management monitors, and updates and manages remotely manufactured and fielded devices.

The ISS DLM System and the ISS Embedded Cryptographic Toolkit are based on the Green Hills Federal Information Processing Standards (FIPS)-compliant Embedded Cryptographic Toolkit and Security Protocol Toolkits.

Green Hills Software | www.mil-embedded.com/p367432 | www.ghs.com

MEMS-based attitude heading reference system for helicopters

Engineers at Northrop Grumman Corp. are improving helicopter navigation with a new Micro-Electromechanical Systems (MEMS)-based Attitude and Heading Reference System (AHRS), called the LCR-300. The new device has a MEMS-based inertial measurement unit designed and developed by navigation system engineers at Northrop Grumman LITEF GmbH in Germany.

The LCR-300 is smaller with a reduced weight. The AHRS enables directional gyro mode to reduce magnetic compass errors. The unit also has hybrid navigation by making use of global navigation satellite system data. Flight testing of a demonstration LCR-300 on three midsize twin helicopters was completed last year.

The new LCR-300 has a 4.2-lb AHRS unit, which accepts satellite-based GPS velocity and position data, a magnetometer, a calibration programmable read-only memory unit, and a mounting tray. The product debuted at HELI-EXPO 2012.

Northrop Grumman Corp. | www.mil-embedded.com/p367431 | www.ngc.com

MC-130J avionics to DO-178B tool from Presagis

Managing avionics safety certification challenges is a costly and time-consuming procedure, whether it is in military or commercial aircraft. Engineers at Presagis in Montreal, though, are making it a little easier for military avionics designers through a Human Machine Interface (HMI) solution called VAPS XT-178.

The tool, which is being used by Lockheed Martin Aeronautics engineers for developing embedded graphics displays on the MC-130J Increment 3 program run by the Air Force Special Operations Command (AFSOC), can be used with ARINC 661 and non-ARINC 661 programs. Through its runtime architecture, it can produce displays that run on multiple hardware and software environments. The Presagis tool also has a path for compliance with the new DO-178C guidance standard. VAPS XT-178 is based Presagis's VAPS XT.

Presagis | www.mil-embedded.com/p367430 | www.presagis.com

SDR enabled by Virtex-7 FPGA modules from Pentek

FPGAs are a game changer for many signal-processing applications and especially for Software-Defined Radio (SDR). Each generation of FPGA enables more performance than the previous generation, enabling designers to shrink the footprint of military systems, providing more and more performance in even smaller packages. The new Onyx Virtex-7 line of FPGA modules is another example of that trend. The new Model 71760, the next generation of the company's Virtex-6 Cobalt line, is a four-channel, 200 MHz A/D XMC module targeted at SDR and signal-processing applications in military radar, communication, and Unmanned Aircraft System (UAS) programs.

The new Onyx devices have the same modular I/O interfaces as their Virtex-6 FPGA Cobalt line of products, while increasing memory, I/O performance, and logic. The 71760, for instance, is similar to the Pentek Cobalt 71660, but has twice the memory capacity and I/O bandwidth. Because of the compatibility of Cobalt and Onyx, developers will be able to port software originally designed for Cobalt to corresponding Onyx modules.

Enhancements in the Onyx product line include doubling the DDR3 memory in size and speed to 4 GB and 1,600 MHz, respectively. The PCIe interface was upgraded to Gen 3, delivering speeds as fast as 8 GBps. The 71760 FPGA comes preconfigured with a suite of built-in functions for data capture, synchronization, tagging, and formatting. Onyx also has enhanced FPGA loading modes for easier live reconfiguration. About 12 more Onyx products will be released throughout the year.

Pentek | www.mil-embedded.com/p367433 | www.pentek.com

New control unit provides Condition Based Maintenance (CBM) for military ground vehicles

Leveraging Intel Atom-based processing technology, engineers at Aitech Defense Systems in Chatsworth, CA, are able to provide a rugged, lightweight, control unit for military ground vehicles. The NightHawk RCU, weighing only 4.5 lbs, provides Condition Based Maintenance (CBM) for military tracked and wheeled vehicle applications to reduce the overhead costs of preventative vehicle maintenance.

The NightHawk, which has a slimmer profile than similar models, also can be used for data concentrator and remote interface applications such as manned and unmanned ground or airborne vehicles as well as low Size, Weight, and Power (SWaP) Data Concentrator Unit (DCU) and Remote Interface Unit (RIU) applications. The device is also designed for extreme environments through natural convection/radiation cooling that dissipates as much as 22 W at +55 °C in stagnant (non-flowing) air, or at as hot as +71 °C with an optional low-pressure fan or baseplate.

Using a low-power Intel Atom processor that operates at 1.6 GHz, the new Aitech product provides as much as 2 GB DDR2 SDRAM as well as between 4 and 8 GB of SSD memory with an optional expansion up to 250 GB for extended and remote data collection and storage applications. Optional I/O includes MIL-STD-1553B, ARINC 429 and ARINC 708, CANBus, WiFi and WAN ports, as well as video capture and processing, discrete and analog I/O, and an eight-port GbE switch.

Aitech Defense Systems | www.mil-embedded.com/p365005 | www.rugged.com

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EXECUTIVE SPEAKOUT

Maximizing compute density while reducing net system weight

An interview with Michael Bowling, President of Trenton Systems

Since 1977 Trenton has been an acknowledged industry leader in designing and building high-performance single board computers and backplanes. These key military computing system building blocks form the basis of a wide variety of field-deployed platforms. Trenton has added long-life, dual-CPU motherboards and an extensive military systems integration capability to its product offerings. Accordingly, in the following Executive Speakout, Trenton's president, Michael Bowling, talks about how Trenton has dealt with compute density issues in military systems.

How do you address compute density in military applications?

BOWLING: There are a couple of things we do at Trenton to maximize compute density. First off, the use of quad-core and soon-to-be-available long-life 6- and 8-core processors with hyperthreading helps. Next, we design these multicore CPUs into dual-processor SBCs and motherboards. In the case of dual-processor SBCs, we incorporate these boards into 2-, 4-, and 6-segment backplanes. This approach enables us to integrate a multisegment backplane and a number of DP single board computers into a single 19" rack-mount computer. That way, the individual SBCs can either operate together as an ultra-dense computing cluster or as 2, 4, or 6 individual computers in a single chassis enclosure.

Doesn't your approach to compute density create system heat problems?

BOWLING: It sure can if you don't do your engineering homework at both the board and chassis design level.

What do you mean?

BOWLING: Well, at the board design level you need to ensure that you place components in the optimum location to maximize the efficiency of the chassis' airflow design. At the chassis level you need to select and place cooling fans correctly and ensure that the power supply and system air filters are selected to exceed the customer's environmental requirements.

I see how this design approach maximizes compute density, but how does it reduce system weight?

BOWLING: Airborne surveillance platforms require a significant amount of computer systems to carry out the requirements of the mission. All of this equipment hardware adds up, so anything you can do to consolidate hardware into common enclosures helps to lighten the load. Using a multisegment backplane design approach to consolidate computer platforms enables significant weight savings. We enhance the weight consolidation savings by using shallow-depth, all-aluminum 19" rack-mount computer chassis.

How much system weight can you save?

BOWLING: The short answer is, "that depends." Obviously, the specific amount of weight savings depends on the application details such as the size and type of aircraft, the mission profile of a specific aircraft, and any specific computer hardware requirements. Overall space and weight reductions in the neighborhood of 70% are not unheard of in these types of applications.

You have concentrated on compute density issues and how Trenton addresses them in airborne applications. Are these system design approaches applicable to other military computing applications?

BOWLING: Yes indeed, vehicle-mounted, shipboard, and submarine applications have similar issues. In most cases, the weight savings are not as critical, but in submarine applications, where rack-mount component space is at a premium, shallow-depth enclosures play a significant role in addressing compute density. In military and government server room applications, a multisegmented backplane and multiple SBC design approach can address the need of increasing computer capability while using fewer rack-mount computer enclosures.

Michael Bowling is President of Trenton Systems, with overall responsibility for engineering, product development, and manufacturing operations. Contact him at mbowling@TrentonSystems.com.

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