Raytheon’s Net-Centric Communications
Building a Foundation for Innovative Solutions
A Message From

Mark E. Russell
Vice President of Engineering, Technology and Mission Assurance

It was a productive summer for Raytheon’s Engineering, Technology and Mission Assurance community. We held another successful Mission Assurance Forum; honored the recipients of the Raytheon Six Sigma™ Awards and the Excellence in Operations and Quality Awards; refined the company’s technology strategy for the coming year; and on July 1, I took on responsibility for the ET&MA organization as its new vice president.

It is an honor to be leading this group of nearly 45,000 world-class people. I have been a member of this team since joining Raytheon as an engineer more than 25 years ago. During that time I have touched just about every part of the organization, from working in design engineering, operations and field testing, to providing project and program management for radar, missile and communications systems.

Many of us have also spent the summer preparing and planning for November’s MILCOM 2008, the premier military communications conference, which Raytheon is proud to be hosting. More than 6,000 government and industry representatives from 30 countries are expected in San Diego for the 27th annual gathering, which will focus on the theme “Assuring Mission Success.”

It seemed appropriate therefore to devote this issue of Technology Today to some of Raytheon’s key communications capabilities — technologies and innovations that ensure our customers’ missions in the areas of net-centric operations, information assurance, and modeling and simulation.

In this issue’s Leaders Corner column, we hear from Jerry Powlen, vice president of Integrated Communications Systems in Raytheon’s Network Centric Systems business. Jerry talks about the breadth of Raytheon’s communications expertise and describes some of our disruptive technologies, new development contracts, and future focus areas.

I hope to see you in San Diego.

Mark E. Russell
As I was reading the third installment of Stephenie Meyer’s acclaimed book series, I thought about the complex and highly attuned communication system between some of her characters. They had a unique system that provided instant and complete information to every member of the team the split-second they needed it to plan and execute the best possible scenario for enemy engagement, ensuring their ultimate victory. This reminded me of the sophisticated and innovative technologies Raytheon is now developing in its net-centric communication systems for the warfighter to give them the tactical advantage that ensures mission success.

This issue highlights some of those transformational technologies that are pushing the boundaries of the global information grid out to the tactical edge, like Deep Siren Tactical Paging for enhanced submarine communications, virtual world technology and mobile ad-hoc networking, to name a few. These technologies are just some of the topics that will be presented at this year’s MILCOM 2008 Conference (http://www.milcom.org) — an event hosted by Raytheon that will showcase new products, breakthrough technologies and exciting industry trends.

Also in this issue, you’ll read about iTracker — a suite of tools for program analysis and management, the Net-Centric Software and Systems Consortium, as well as two of Raytheon’s certified architects.

Enjoy!

Lee Ann Sousa
About 10 years ago, Vice Adm. Arthur Cebrowski and John Garstka introduced the concept of “Network Centric Warfare” (NCW) and sparked a whole new approach toward command and control (C2) of military forces. In network-centric warfare, the fundamental premise is that military force effectiveness can be significantly improved by migrating away from platform-centric operations and by moving toward network-centric operations and leveraging information technologies. Since their publication, an extraordinary body of work has been created in form of scientific advisory boards, military and industry conferences, and numerous publications. To underscore the importance of this new concept to C2, the U.S. Department of Defense (DoD) created the Office of Force Transformation. This office refined the key principles of network-centric warfare into the following:

- A robustly networked force enables information-sharing
- Information-sharing improves the quality of the information and creates a shared situational awareness
- Shared situational awareness engenders collaboration
- Collaboration increases the speed of command and execution performance

From these principles, a clear prerequisite to NCW is a robustly networked force. The U.S. DoD Chief Information Office established the vision of a Global Information Grid (GIG) to chart a path in transforming the force from platform-centric to network-centric. A number of new, transformational research and development (R&D) programs were launched to create components for this new GIG. Some of the more significant programs included the next generation of tactical radios, the Joint Tactical Radio System; Global Information Grid–Bandwidth Expansion, leveraging the overbuilt fiber infrastructure to expand the terrestrial network; and Transformational Satellite Communications, a new military satellite communications program for providing significantly greater capacity for mobile users.

The “wired” GIG upgrade has been the first transformational capability to roll out to operational capability, due largely to its near total leverage of commercial-off-the-shelf technologies (COTS). The “wireless” GIG has been a much greater challenge — mainly because COTS products and services do not translate as readily to challenging
battlefield environments. Notable stumbling blocks in translating COTS to the battlefield are the military’s unique spectrum requirements, coupled with waveform robustness and mobility requirements without dependence on fixed infrastructure. These same COTS stumbling blocks often present significant R&D challenges for the DoD acquisition programs. As a result, the wireless GIG is lagging in its build-out to support NCW objectives. Some of these stumbling blocks are being addressed through forward-leaning technology initiatives, and others through innovations in existing technologies.

Gaining access to spectrum for wireless communications is clearly the most challenging stumbling block. Spectrum access is managed through an extremely slow and deliberate set of processes that seeks to protect spectrum rights and minimize interference for spectrum-dependent users. Spectrum is used for sensing, navigation and communications, and must support military, civilian and industrial applications. Certain portions of spectrum permit good signal propagation and can be accessed by inexpensive antennas. These spectrum “sweet spots” fall roughly into the 20 MHz to 2 GHz regime and are highly valued for both military and commercial applications. Network-centric warfare creates increasing demand for wireless capacity which, in turn, increases demand for spectrum to support wireless communications. Techniques for addressing scarcity of spectrum include: improving spectrum efficiency of waveform techniques, incorporating dynamic spectrum access techniques and migrating to higher frequency systems. At Raytheon, such techniques are being developed and applied through our R&D programs. For our lower frequency radio communications systems, we are experimenting with techniques that increase the bits per Hz or spectral efficiency of the waveforms. At the other end of the spectrum, we are developing new technologies that will make free-space optical (laser-based) communications more capable.

The other major stumbling block to COTS reuse is dependence on infrastructure like fixed relay towers. In a tactical environment, infrastructure elements may impede mobility, complicate network planning and present a highly visible target for adversaries to attack. To create a more resilient communications infrastructure, technologies are being developed to enhance mobility of our line-of-sight communications systems and increase capacities for beyond line-of-sight communications systems. For our line-of-sight communications systems, mobile ad-hoc networking (MANET) technologies are being developed to form an Internet-like network of tactical radios without dependence on a delicate, fixed routing infrastructure. Many years of customer-funded technology development and internal research are now culminating in a set of highly robust protocols that Raytheon is incorporating into its next-generation radio products. For beyond-line-of-sight systems, we are exploiting troposcatter communications paths to provide high capacity links as well as developing satellite communications terminals for mobile users that provide access to commercial and military communications satellites.

Near-term expectations for a Global Information Grid that is both pervasive and robust in the battlefield environment are tempered by technological challenges at the wireless edge — largely due to spectrum constraints and mobility demands. However, Raytheon is advancing critical technologies that will be incorporated into our emerging products. These advances in communications and networking technologies are key factors in being able to push the Global Information Grid out to the tactical edge. Some of this will be discussed in detail in this issue of Technology Today. Others will be addressed in November during MILCOM 2008, hosted by Raytheon in San Diego.

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1See U.S. Naval Institute’s “Proceedings,” Jan. 98
Integrating Wideband Communications on a Platform

COMSET: A robust simulation and modeling tool

Current State of Wideband Waveforms

The need for long-range and high-data-rate communications resulted in the development of various wideband waveforms. Most implementations of new wideband communications waveforms — like mobile user objective systems (MUOS) and wideband networking waveforms — will be on existing platforms with legacy narrowband communications systems. These communications systems compete for the use of the available frequency spectrum assigned to the platform, resulting in a conflict in legacy narrowband link frequency assignments and wideband link frequency assignments.

The development of multi-channel communications systems is complex due to the potential interference that can result from the collocated emitters. For example, the MUOS uplink (transmit) channels operate in the 280 to 320 MHz band and SATCOM DAMA downlink (receive) channels in the 240 to 270 MHz band (see Figure 1). This, combined with multiple communications channels (in a densely populated frequency spectrum), results in a higher likelihood of interference. These wideband systems need higher transmitter powers and more sensitive receivers due to range requirements.

The wide MUOS transmit spectral power falls into the SATCOM DAMA band and surrounding UHF communications spectrum. Thus, the platform interference mitigation solution has to address the entire platform communications system. Figure 2 illustrates the impact of the power amplifier (PA) on the MUOS QPSK signal generated in a software-defined radio (SDR). The basic QPSK waveform (blue data) is generated in the SDR with spectral containment. However, the PA regenerates spectral growth (gray data). Optimizing the cost and performance, along with the time to design the platform RF distribution architecture, is critical in the development of these communications systems. Therefore, a platform interference analysis approach for RF architecture development that is more accurate than current alternatives is needed.

A Solution to Platform Interference Problems

Raytheon has developed a Communication System Engineering Tool (COMSET) to specifically address platform RF architecture development for the wideband waveforms that are a potential interference source to platform-critical systems such as navigation, guard receiver, and air traffic control systems (see Figure 3).
COMSET’s platform analysis includes the total legacy platform RF performance to provide a successful integration of the wideband waveforms. The complexity of this integration may expand due to dual-purpose hardware, such as shared apertures, or size, weight and power constraints. Also, platform performance limitations are considered, which affects the CONOPS, simultaneity and frequency plans.

COMSET is a fast, repeatable, easy-to-use system-performance design tool that evaluates and allocates system performance requirements within the platform RF communications system in an operational environment. System performance requirements are easily evaluated from the proposal stage through the final design and into the test stage of the program. The specific platform interference sources can be selected to examine their individual contributions to the overall platform performance. This allows the system engineer to isolate these interference impacts, from which hardware and system requirements can be generated or accepted.

Detailed platform performance analyses have been successfully applied to platforms that include complex maritime, airborne and fixed sites, and mobile platforms in their operational environments.

COMSET can easily evaluate concept of operations on the platform RF communications architecture and identify specific areas for improvement with performance and SWaP (size, weight and power) impacts due to the improvement. This feature allows the system designer to evaluate such questions as, “If it’s only a two-percent operational problem, is it worth the cost to correct the problem?”

With COMSET, platform performance can be examined at all phases of the program to refine the system requirements for cost and performance impacts. Complex platform systems — which include Mission Systems Integration, homeland defense, C2 systems and command centers — could all benefit from COMSET.

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With the end of the Cold War, the mission of the submarine has changed, with greater emphasis on integrating the subsurface fleet into joint operations. Communications at Speed and Depth (CSD) is one of the U.S. Navy's top undersea priorities and the submarine force's number-one communications priority. CSD provides the submarine fleet with the capability to communicate while operating at tactical speed and depth, providing integration into the Global Information Grid, or GIG, thus extending the FORCEnet below the ocean surface. This enables the submarine commander to share situational awareness, plan collaboratively, and fight synergistically with other forces. These increased operational capabilities allow submarines to remain fully engaged in covert missions while maintaining real-time communications and stealth.

Tactical paging supports this priority by providing the ability for a local tactical unit such as special operations forces or the Submarine Operating Authority (SUB-OPAUTH) — ashore or afloat — to reliably transmit tactical messages to a submarine operating below periscope depth. The only radio system that provides this capability works at very long wavelengths and requires the submarine to deploy and trail a towed buoy or buoyant cable antenna, both of which impact the operational posture of the submarine. Tactical paging supports this priority by providing the Submarine Fleet With Communications at Speed and Depth

Raytheon recognized the need for this capability in 2005 and put together an industry team to deliver a tactical paging system. During 2005 and 2006, the Raytheon team performed engineering tests at Canadian Forces Maritime Experimental and Test Range near Vancouver Island; conducted an at-sea demonstration with the U.S. Navy at the Pacific Missile Range Facility in Kauai, Hawaii; and participated in Rim of the Pacific Exercise. In August 2007, the Navy awarded Raytheon a $5.2 million contract to deliver this innovative tactical paging solution for a series of Navy-conducted system tests. These tests will culminate in a Military Utility Assessment, positioning the system for possible fleet operational deployment in 2009.

Acoustic Technology

Deep Siren Tactical Paging (DSTP) provides paging capability via acoustic, expendable buoys that, when contacted via an Iridium communications satellite, can send encoded tactical messages to submerged submarines. Acoustic messages can be sent at any time and received by the submarine without the need to come to periscope depth or deploy a towed antenna, both of which greatly impact the operational posture of the submarine. Figure 1 shows an operational view of the DSTP system.

The Deep Siren acoustic technology uses advanced digital-message processing to ensure submarine message receptions at tactical operating speeds and ranges greater than 50 nautical miles, depending on local topography. Buoy transducer depth can be optimally chosen to maximize performance as a function of thermal layers and acoustic propagation characteristics. Deep Siren uses digital signaling at low acoustic frequencies to achieve these capabilities.

Figure 2 shows the components of the DSTP system: command station, receive station, and Deep Siren expendable buoy. The portability of the command station enables deployment of Deep Siren in multiple tactical scenarios. In addition to being deployed from shore-based command centers, the command station may be utilized from a surface ship or airborne platform, allowing deployed buoys to be called from anywhere in the world.

Buoy and Submarine Launch Vehicle

The buoy employs an Iridium satellite link for bi-directional worldwide communication over the Iridium satellite system. It can be deployed from a surface ship, airplane or from the submarine itself. The buoy is deployed from a submarine through the trash disposal unit using a submarine launch vehicle (SLV). It is pre-programmed, prior to launch, with a message to be sent back to the base station upon deployment. Once the SLV reaches its pre-programmed depth, a float mechanism is deployed. The buoy separates from the SLV and ascends to the surface.

After the initial communication link is established, the buoy stays in standby mode...
for up to three days while waiting for reception of a command via satellite, instructing it to send a message acoustically. It features two hours of Iridium transmission time and one hour of full-power acoustic transmission time. The acoustic transducer depth setting is preconfigured for optimal range. The buoy pays out its lower electronics unit with the acoustic transducers to the preconfigured depth.

Command and Receive Stations
The command station supports multiple types of acoustic messages and also a locator ping capability. Messages are encoded with a proprietary acoustic waveform providing high probability of receipt. A locator ping is a single-frequency tone with duration, repetition, pause and frequency defined by the command station operator. A user can select which buoy to communicate with and which message to send from this station and can monitor buoy status. The command station also provides buoy management. It maintains a list of available buoys and can request buoy data, such as GPS position, life information and status. It is also used to remotely scuttle the buoy if necessary.

A receive station is deployed on the submarine to receive and decode acoustic messages transmitted by the buoy. The messages are decoded and displayed in real time without operator intervention. This station connects to the output of a SONAR array onboard the submarine and processes the acoustic signal. The receive station indicates to the operator on board the submarine that a message has been received, along with the content of the message.

Mission Systems Integration
With a history of providing the submarine fleet with communications capabilities, Raytheon leads the multinational DSTP industry team and provides mission systems integration. RRK Technologies, Ltd (United Kingdom) supplies the Deep Siren long-range acoustic transmit-and-receive algorithms, and Ultra Electronics Maritime Systems (Canada) builds the expendable buoy and launch vehicle, permitting submarine deployment.

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Waveform Portability

Software-defined radios (SDR) are playing an increasingly important role in both military and commercial communications. There are two key characteristics of an SDR: 1) Some or all of the baseband or RF signal processing is accomplished through the use of software, and 2) The signal processing can be modified post-manufacture. One of the primary advantages of an SDR is the capability to operate with one waveform. Instead of the legacy paradigm in which each waveform required its own radio, an SDR can implement multiple waveforms by reconfiguring with the appropriate software.

In SDR usage, the term waveform is used to describe the entire set of radio functions that occur from the user input to the RF output, and vice versa. A waveform typically includes physical- and link-layer functions. Physical-layer functions on the transmit side typically include error correction coding, interleaving and modulation. The receive side includes the complementary functions, as well as time, frequency and spatial (antenna) tracking. Link-layer functions may include time or frequency division multiplexing as well as signaling protocols associated with allocating link-layer resources.

Although relatively simple, low-throughput waveforms may be implemented almost entirely on general-purpose processors (GPP). The complex, high-throughput waveforms used for above-2 GHz satellite communications are generally implemented on a combination of GPPs, digital signal processors, and field-programmable gate arrays (FGPA).

The advent of SDR technology has led to the concept of waveform portability. There are two main goals for waveform portability:

1. A waveform developed for one platform (set of users) should be adaptable to a different platform with minimum changes.

2. It should be possible to port a waveform developed for one hardware implementation to a different hardware implementation with minimum changes.

The first goal implies platform independence — that a common waveform should not depend on the particulars of where and how it is used. For example, the U.S. Army, Navy and Air Force all use interoperable satcom waveforms, including the MIL-188-165A waveform and the LDR, MDR and XDR EHF waveforms. Since interoperability implies that the physical- and link-layer processing is compatible, it should not be necessary to develop different waveforms for each service. The key to achieving this waveform portability goal is defining the waveform boundary to exclude those components that depend on a particular platform. For example, while most waveform physical- and link-layer functions are identical among all platforms, the implementation of time, frequency and spatial tracking loops depends on whether a platform is stationary or mobile. This implies that the tracking loops themselves should be excluded from the waveform boundary and that the waveform should provide a generalized interface to the tracking loops. A commonality and variability analysis of waveform components across the full range of platforms is essential for defining the waveform boundary to maximize portability among different platforms.

The second goal implies hardware independence; a waveform implementation should depend as little as possible on the specifics of the hardware on which it executes. Advances in technology generally make a particular hardware configuration obsolete in only a few years, while waveforms have lifetimes measured in decades. When a new hardware configuration is developed to address the needs of a new application or to solve a technology obsolescence issue, it should be possible to

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Design things and then see how they work. It is this passion that led Hendry to get his Bachelor of Science in electrical engineering from the Massachusetts Institute of Technology in 1975, and to continue with a career in engineering.

Now a 31-year veteran of Raytheon, Hendry is focusing on systems engineering for military satellite communication systems. Some of his major projects include working on HC3, the next generation of Army Satellite Communications terminals; HDR-RF, a U.S. Air Force program that has developed a very high-data-rate programmable modem for satellite communications; and Objective Gateway, another Air Force program to develop a family of gateways that will interconnect different types of communication systems.

A New Jersey native, Hendry is most proud of the work he did on the on the first generation of extra high frequency (EHF) satellite communications terminals for the U.S. Navy.

“We started with a clean sheet of paper and designed a terminal that implemented the most complex waveform devised up to that time,” Hendry explained.

The test with the first satellite was very successful, and this served as the foundation for Raytheon’s EHF SATCOM business.
use an already-developed waveform with a minimum number of changes. Since different applications may have different hardware configurations because of specific requirements, (e.g., cooling, form factor, environments) hardware independence is also important in achieving platform independence.

One of the keys to achieving hardware independence is the hardware abstraction layer (HAL). The concept of a HAL is best described by an example (Figure 1). Without a HAL, the designer of an FPGA waveform component that interfaces to external memory must account for the particular interface presented by that memory. This inherently makes the FPGA component dependent on the particular hardware implementation. Porting that waveform component to a different hardware module that uses a different type of memory requires changing the component accordingly. Hardware dependencies are not limited to external memory. Other interfaces, including data converters, processors, and interconnection paths present the same issues. A HAL presents a uniform interface to the FPGA component regardless of the hardware implementation. One side of the HAL implements the interface required by the specific hardware implementation. The other side of the HAL presents a uniform, standardized interface to the waveform component. The developer of the hardware module is also responsible for developing the associated HAL that provides a standardized interface between waveform components and the specific features of the hardware module.

Analog-to-digital and digital-to-analog converters present a more complex problem for a HAL. Typically the waveform components that interface to these components, including modulators and demodulators, are designed with specific assumptions about sampling rate, resolution, and other performance characteristics of the data converters. In this case, the waveform must set minimum standards for the data converters in much the same way that it sets minimum standards for memory, FPGA resources and other processing resources. Even in this area, a HAL can significantly decouple the waveform from the hardware implementation. In this case the HAL takes the form of a sample rate conversion (SRC) function. This digital signal processing function converts between the actual sampling rate of the data converters (the hardware implementation) and the sampling rate expected by the waveform. Although the hardware implementation must meet minimum standards for data conversion to be suitable for a particular waveform, the use of a SRC function in the HAL significantly enhances waveform portability.

In 2007, Raytheon demonstrated the critical concepts of waveform portability by porting the advanced extremely high frequency (AEHF) waveform to a hardware implementation different from that for which it had originally been designed. The AEHF waveform is among the most complex of waveforms in use today, with a number of features designed to provide anti-jam, low probability of intercept and high data-rate performance. In the past, such waveforms have typically been tightly coupled to a particular hardware implementation with memory, interconnection, data converter, and processor interfaces specific to that hardware. As part of this effort, a HAL layer was inserted between the waveform and the hardware implementation to decouple the waveform from the specifics of the hardware. The HAL includes an SRC function that mediates between the data conversion sample rates implemented by the hardware platform and the sample rates assumed by the waveform designers. This six-month effort resulted in an AEHF waveform implementation that is now portable by virtue of the standardized interfaces and HAL. This is essentially a one-time effort, now that the waveform itself is portable; few if any changes will be needed to port it to yet another hardware implementation that uses the same HAL construct.

This effort demonstrated that the additional work required to make a waveform portable is small compared to the benefits it provides. The effort would have been even less had it been done at the time the waveform was originally developed rather than afterward. Given the major advantages for both the developers and the users of waveforms, it is likely that design-for-portability will become more of a requirement for waveform development.

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Figure 1. Hardware Abstraction Layer
Virtual reality, or virtual world, technologies are not new. Many of us were first exposed to this domain through the book *The Metaphysics of Virtual Reality*, by Michael Heim. In this book, Heim identifies seven different concepts of virtual reality: simulation, interaction, artificiality, immersion, telepresence, full-body immersion and network communication. Hollywood first made this idea popular through Steven King’s *The Lawnmower Man*. Other futuristic examples can be found in popular media such as *Star Trek* with its “holodeck” and *The Matrix*, where a “head-plug” was used to place individuals in a simulated reality.

Virtual world technology and the capabilities it provides allow users (humans) to interact with a computer-simulated environment. The environment may be based on real-world scenarios, such as a corporation’s human resources or training organizations, or imaginary, such as those typically found in action games. The quality of the virtual reality experience is based on the sophistication of the software applications and the inherent computer and image processing power available. Additionally, in distributed environments, such as for telemedicine, the available communications bandwidth can play a dramatic role in the usability of the system. Initially, virtual reality-based systems were primarily visual in nature. However, recent advances enhance the experience through audio, touch and smell. Such feedback capabilities are critical to the experience, especially in medical and gaming applications.

Users interact with the virtual environment through input devices that now range from a keyboard and mouse to neural-based sensory devices that users wear and, through their thoughts, control their interactions with the virtual environment. Output devices include high-fidelity stereophonic headphones or loudspeaker systems that nearly make the listener believe they are actually there, to odor-delivery systems. Some of the most interesting work in the area of simulating visual, audio, smell and touch is in the treatment of post-traumatic stress disorder in veterans. By exposing them to combat simulations, complete with smells, it is possible to provide treatments that address directly those feelings and fears that haunt these servicemen and women.

The technologies that make virtual reality a usable and inherent part of society continue to move forward. However, it is unclear what the future holds. The most popular forum for virtual world capabilities today lies within a hosted environment called Second Life®. In a recent interview by Cisco Systems, Inc., CEO John Chambers appeared at a virtual press conference in Second Life and predicted that virtual world technologies will “explode” for business usage and make significant impacts in society. Google recently also unveiled its own virtual world, called Lively. Lively allows its members to create avatars, decorate their own virtual rooms, invite friends to their “rooms,” and
do things that one would not normally do in the real world, such as fly to the moon.

Virtual Worlds – Why Are They Important?
Virtual worlds and virtual reality technologies are growing in importance not because of their entertainment value, but because they are also becoming critical tools within the U.S. military and intelligence communities for training and other purposes.

The implication of this is twofold. First, should the U.S. military increase funding for furthering the use of virtual reality? The answer for this question has become obvious based upon recent investments by the U.S. Department of Defense (DoD). The DoD is reportedly planning to build a virtual world called “Sentient Worldwide Simulation.” The objective of this system is to mirror the real world and automatically follow world events in real time. In addition, both JFCOM (Joint Forces Command) and TRADOC (Training & Doctrine Command) are using virtual world technologies to provide training environments targeted at developing skills in urban warfighting operations.

Second, recently released intelligence data indicates that our adversaries are also using virtual worlds to provide terrorist organizations with more realistic training environments. This finding possibly allows U.S. intelligence organizations to gain valuable insight into the behavioral aspects of our adversaries.

As the use of virtual world technology spreads through the military and intelligence services, the concern over the threats and risks that this new technology presents become paramount in terms of the entire enterprise. Virtual reality is based primarily on Web content capable of supporting three-dimensional views. This is made possible through the use of Web 2.0. Web 2.0 is a second-generation language used to create communities, or social networks, where content is not just viewed, but where a user can dynamically create, modify and share Web content. Web 2.0 and virtual reality technology presents numerous challenges to maintaining a secure infrastructure.

Virtual Worlds – What Are the Risks?
Risks lie primarily in two areas. The first centers on the use of Web 2.0 for interactive Web content. The second lies with the underlying technologies used for authentication, confidentiality and integrity services. Web 2.0 applications can be divided into three categories: rich interface applications, syndication, and user participation. Each of these introduces its own set of vulnerabilities and risks. Protecting against session and cookie tampering, SQL injection, directory traversal, and cross-site scripting-attacks becomes significantly harder to prevent. The result is a much broader attack space as the security processing moves from the Web server to the client.

Providing authentication, confidentiality and integrity take on a new level of complexity with virtual reality. Techniques normally used in standard information-management environments do not provide the necessary dynamics to deal with authentication of users and their associated avatars, or providing confidentiality and integrity for virtual reality communities and their associated content.

When using virtual worlds in the military and intelligence areas, capabilities such as data encryption, biometrics, malware detection, digital signatures, identity rights management, etc., must be used to validate user activities in the virtual world. Auditing all ongoing transactions becomes infinitely more complex as the collected log files must be aggregated, correlated and validated against potentially millions of virtual reality objects.

Why Is Raytheon Investing in Virtual Reality?
As part of Raytheon’s overall research and development investment strategy, virtual reality and virtual worlds have surfaced as prime candidates for investment, because of their direct applicability to many of the training and weapon systems Raytheon delivers. Additionally, virtual reality is viewed by many as a technology that is still in its infancy, and thus it represents a new domain where Raytheon can add value by applying new capabilities it is developing in information operations and information assurance.

Through virtual reality, Raytheon believes it is able to make significant strides in the methods by which its customers can be trained on the various complex mission systems it delivers. As a premier Mission Systems Integrator, Raytheon continuously strives to enhance its solutions through the introduction of innovative technologies and methods. Through virtual reality, Raytheon believes it can significantly reduce the cost of system development and user training, and dramatically improve a user’s proficiency in a shorter time period.

Before this is possible, however, new advancements must be made in the security features of virtual reality environments. Raytheon’s initial investments in virtual reality are targeting those challenges with pervasive identity rights management within a virtual world. Ensuring that users’ identities are not stolen, cloned or otherwise impersonated are critical to ensuring the confidentiality and integrity of the services provided through a virtual reality environment. Raytheon is leveraging previous research in its Compartmented High Assurance Information Networking architecture to develop new access-control and identity-rights methods that can be applied at the avatar level.

Raytheon’s objective is to develop of suite of solutions that can be applied to virtual reality through internal research and development and by collaborating with academia to advance the methods used today.

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Raytheon has developed a novel approach to mobile ad-hoc networking (MANET) — one that is applicable to many environments. The basic technology has been developed through experience in science and technology efforts spanning the last 20 years. Raytheon participated in DARPA efforts on packet radio in the 1980s; global mobile networks in the early 1990s; Airborne Communications Node and Small Unit Operations Situation Awareness System in the late 1990s; the DARPA Future Combat System Communications in the 2000s and the AMRDEC NetFires Communications in the early 2000s. Added to these experiences are Raytheon’s development activities and field experience with the Enhanced Position Location Reporting System (EPLRS) radio technologies during the past 20 years.

Through these experiences, Raytheon has developed a complement of MANET technologies, collectively referred to as RAYMANET, that create a broadband tactical IP-based mobile backbone to enable net-centric warfare. An instantiation of this system seamlessly interconnected multiple heterogeneous networked radio systems during the DARPA NetCentric (NC) demonstration at Ft. Benning, Ga., in January 2006. This system served as the high availability terrestrial backbone link between dismount units that were otherwise beyond communications range. Real-time tactical video, video, and situation awareness data were reliably delivered over the network to support the planning and execution of a simulated tactical mission with all radio network operation conducted by active-duty U.S. military personnel. Each NC node operated as a vehicular or airborne relay mobile ad-hoc router for the terrestrial backbone tactical network and a host system node.

The RAYMANET technology suite redefines each functional component in the traditional data link radio to create a network paradigm. This technology suite adapts to each individual user’s communication path without user intervention. Failed physical layer paths are overcome through cooperation in signal coding, channel-access scheduling, and routing decisions to maintain robust end-to-end delivery. The system provides both high-data-rate and long-range communications by autonomously adapting each link in the ad-hoc network topology to deliver the maximum possible throughput under dynamically changing link conditions. Prioritized delivery of time-sensitive and high-value traffic is achieved through novel quality-of-service (QoS) mechanisms implemented in both the media access control (MAC) and network layers to ensure that the most important traffic is delivered during periods of network congestion. The reliable autonomous adaptation of the networked radio allows warfighters to focus on events during tactical maneuvers without having to worry about communications connectivity.

The RAYMANET technology suite is implemented to accommodate new advances and has been continually updated throughout the past eight years of development. Key features of the technology suite are its MAC and network layers. The MAC layer manages access to the physical RF resource. Most MAC layers are designed for fairly static resource assignments. The RAYMANET MAC layer has incorporated dynamic resource assignment protocols and adaptive algorithms to dynamically schedule time-slot transmissions and receptions and enable ad-hoc connectivity. The MAC protocols include node activation multiple access for omnidirectional antenna implementations, and receiver oriented multiple access for directional antenna implementations. The MAC algorithms include an adaptive data-rate algorithm and a segmentation and reassembly algorithm. These algorithms automatically maintain the highest supportable reliable data rates to all neighbor nodes. In addition, QoS is implemented to maintain the users’ desire for data delivery, and may be configured to support priority, weighted round robin, or hybrid queuing.

The network layer contains protocols and algorithms that establish and maintain routes between mobile network nodes. The network layer routing functions include unicast, multicast and transit routing path discovery and maintenance. The unicast routing protocols include scoped link state routing (SLSR) and tactical on-demand routing (TOR). SLSR is a proactive protocol and employs multilevel “scoping” to reduce routing update overhead in large networks. TOR is a reactive protocol and employs multilevel “scoping” to reduce routing update overhead in large networks. TOR is a reactive protocol and employs multilevel “scoping” to reduce routing update overhead in large networks. Routes are found using reverse path forwarding with persistence. Paths are maintained as long as they meet the QoS metrics, otherwise a
new path is chosen from the reverse path maintained in the route discovery packets. The multicast routing protocols include receiver/sender oriented multicast (ROM/SOM) and multicast dissemination protocol (MDP). ROM/SOM applies “on-demand” routing techniques to avoid channel overhead and increase scalability. MDP is a flooding mechanism that does not require path maintenance.

The transit networking capability of the RAYMANET suite exports routes into the standard wired Internet routing protocols to provide a transit capability in support of wireless and wired network integration. Unicast routes discovered in SLSR and TOR are exchanged dynamically with standard Internet unicast routing protocols including routing information protocol and open shortest path first. Multicast routes discovered in ROM/SOM are exchanged dynamically with the standard multicast protocol, protocol-independent multicast and the Internet group multicast protocol.

The RAYMANET technology suite is evolving to support newer applications that require ad-hoc connectivity. In the lower-band spectrum, RAYMANET has been ported into software-defined radios for vehicular and airborne communications that employ dedicated omni-directional antennas. Physical-layer communications are provided through an orthogonal frequency division multiplexed modulation technique that is robust and spectrally efficient. Similar physical-layer techniques have been developed and demonstrated for directional antenna systems as well. However, directional antennas demand significant size, weight and power (SWAP) footprint on mobile platforms. Therefore, for high-frequency systems, we are exploring aperture reuse techniques. Many tactical platforms have high-frequency, directional apertures for radar functions. Resource management protocols are in development that permit reuse of these apertures for ad-hoc communications without jeopardizing the radar performance. Also, Raytheon is participating with strategic partners to create pulse-based physical layer modulation techniques for even higher capacity MANET systems. This combination of the pulse-based modulation, resource management and RAYMANET technology will enable high-capacity MANET without the SWAP burden of special communication apertures.

In parallel with these advances in MANET technology, Raytheon has been developing the premier tactical data radio network with more than 20,000 EPLRS radios built. EPLRS radios have been deployed to U.S. Army, Marine Corps, Air Force, National Guard and Reserve units, as well as coalition partners. This unique experience has resulted in exceptional insights and capabilities, such as network test beds and field-validated network models. Leveraging the Value Engineering Change Proposal process, we have been able to enhance the radio functionality and reduce its overall cost. Through this process, advanced features of the RAYMANET suite are being incorporated into the existing product lines.

The RAYMANET technology suite provides a springboard into the military goal of network-centric operations. Reliance on pre-planned communications and infrastructure for IP-based communications is inconsistent with tactical communications in the network-centric warfare age. The ad-hoc networking capability enabled by the RAYMANET-based technology suite supports the emerging warfighting concepts for network-centric warfare. Along this path, Raytheon envisions multifunction systems as the next wave of the future.

Multifunction systems will perform communications, sensing and deliver radio frequency effects using the same hardware set to maximize the capability for the warfighter.

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**Tim Hughes**  
Technical Area Director,  
Mobile Ad-hoc Networking,  
NCS

From the telephone and television to CB radios and cell phones, Tim Hughes has always been fascinated by communications. “I have always wanted to know how and why these systems work,” said Hughes.

This passion and interest led Hughes to the University of Scranton in Pennsylvania, where he earned a Bachelor of Science in electrical engineering. He later earned a master’s degree in electrical engineering at West Coast University in California.

As the mobile ad-hoc networking (MANET) technical area director for Raytheon Network Centric Systems in Fullerton, Calif., Hughes is focused on developing MANET technology to support opportunistic connectivity for sensors, dismounts, vehicles and airborne instantiations.

Hughes describes it as ubiquitous communications without a reliance on infrastructure. “Our military cannot always rely on the convenience of an infrastructure and are in need of the connectivity which requires a new paradigm to gain the same experience,” explained Hughes. “I have made it my career goal to achieve this model for the military user.”

The initial solution developed by Hughes’ team is being adopted by the Enhanced Position Location Reporting System program. The advancements have been slow, he said, but the field of research is rich. “There are potential breakthroughs occurring each day and our challenge has been to stay at the forefront,” said Hughes.
In developing communications systems, we cannot always build a demonstration version to show how the system will operate. For a number of years, we have taken the alternate approach of understanding the architecture of the system, and then analyzing a model that simulates that architecture.

To develop the architecture of a communications system, we use the Raytheon Enterprise Architecture Process (REAP), which standardizes architecture development, description, evolution and assessment throughout Raytheon. The REAP is a systems architecting process extended with enterprise architecture concepts and techniques. This union of systems and enterprise architecting leverages best practices between the two and ensures that enterprise context, constraints and relationships guide the development.

For the modeling and simulation effort, we make use of the resources developed in conjunction with Raytheon’s Enterprise Modeling & Simulation (EMS) effort. EMS has a LEGO® brick-like structure with standard interfaces to allow rapid development and demonstration of high-fidelity simulations driven from desktop computers.

The Communication Reference Architecture comprises REAP architecture products and is one of the key enablers for the development of communications systems. The base applicable products (and associated framework products) are determined by the current lifecycle phase of the program or project that will be used as a starting point. The three lifecycle phases are: concept refinement, technology development and system development. The output of working with the Communication Reference Architecture is a set of architecture products that includes attributes that are key to architecture quality.

As an architect starts to work the reference architecture, understanding the mission objective (see figure) and the needs of a communications system allow for the selective tailoring of the artifacts within the Communication Reference Architecture to quickly develop the resulting system architecture. This system architecture is then used to pull together modeling and simulation modules for analysis of the system.

To perform the detailed modeling, simulation and analysis to support design and development of new communications systems, the modeling team employs a variety of commercial best-of-breed tools that are widely used in the civilian and defense communications sectors and are well suited to general analysis of both ground-based and airborne point-to-point links and communications networks. Selection and use of particular tools are dependent on the requirements of the individual program. However, a key characteristic of all of these tools is the ability to create and use custom-built models based on C- and C++-like functions and structures. This translates into the ability to seamlessly transition from modeling and simulation into communications system software and protocol development. The architect is able to begin development using abstract models of basic system functionality and use an iterative approach to progressively increasing the detail and fidelity level of the models as the design matures. The ultimate result of this process is fully functional code that can be directly transitioned from the simulation environment into operational hardware. Likewise, this process can be reversed, where operational software from a communications system can be ported.
and executed in the simulation environment. Being able to test and evaluate the performance of communications-system protocols in a simulated RF environment can drastically reduce the risk associated with the traditional field-test approach.

In cases where the communications system is satellite-based, the modeling effort can integrate additional commercial best-of-breed satellite simulation tools for establishing and controlling satellite orbit characteristics, coverage footprints and link characteristics. Likewise, the perspective of the MS&A can be expanded to the platform level through the integration of multiple co-site and coverage analysis tools, as well as the use of specialized terrain models to reflect system performance in urban and subterranean environments.

For Mission Systems Integration initiatives, the perspective of architecture and simulation activities will often transition from one in which the performance of the communications system is the only question, to an environment where overall Mission Assurance and system-of-systems performance are the primary questions of interest. Thus, communications performance becomes only one of many second-order characteristics of the analysis. These efforts also frequently involve the incorporation of actual operational hardware, software and system users into an integrated test bed or experimentation environment commonly categorized as hardware-, software- or human-in-the-loop. As a result of simulation run-time requirements and the limitations of traditional methods for federating simulations in these cases, our modeling groups developed the Distributed Communications Effects Module (DCEM). DCEM is a framework that supports integration of communications and networking models — of variable levels of fidelity — into a wide range of test-bed and experimentation architectures for the purpose of including the effects of communications system performance into larger mission-level analysis. DCEM has been specifically designed to achieve wall-clock simulation run-time requirements. It includes models of several current military communications systems, can be adapted to existing distributed test-bed architectures, and is fully integrated into EMS and our experiment test-beds. In addition to models of specific communications systems, DCEM includes a “generic” communications model that allows architects to postulate the characteristics of future communications and networking systems and perform what-if analyses on them.

The future of architecture and communications we are looking at include the analysis of network communications centers and understanding mobile ad-hoc networks (see the article on page 14 in this issue). The infrastructures needed to support the topics in this article are being built to accomplish tasks such as quickly transiting the Communication Reference Architecture into simulation and analysis models to determine the effectiveness of different systems and approaches to the customers’ needs. This provides the ability to quickly trade different approaches for proposing the best solution for the problem. It also allows for developing and refining the requirements for the performance of the resulting communications system.

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With a son in the U.S. Army, the importance of Mission Assurance resonates with Terry Dorschner. “All of our products just have to work,” he said.

In his current role as the principal fellow championing NCS’ goal of building a new business in laser communications based on optical phased arrays, Dorschner keeps the Mission Assurance commitment at the forefront of everything he does. “We strive to make sure the components and systems are engineered from the bottom with the warfighter in mind,” he said.

Dorschner’s love of science led him to the Massachusetts Institute of Technology for a Bachelor of Science in electrical engineering and the University of Wisconsin for a Ph.D. in electrical engineering. He undertook a post-doc in millimeter wave communications at the Technische Universität Braunschweig in Germany. Dorschner enjoys the daily technical challenges of his job and the opportunity to mentor younger colleagues.

As co-inventor of the Raytheon multi-oscillator laser gyroscope — a product spun off to Litton and consequently used for inertial navigation of all Airbus aircraft — Dorschner has a lot to be proud of. But his accomplishments are not limited to his career. The Green Bay, Wisc., native is the father of two successful sons. One son is in medical school, and the other is a captain in the U.S. Army preparing to become a foreign area officer in China.

Outside of work, Dorschner enjoys tinkering and building things, as evidenced in his passion for repairing his pre-Civil War house.

ENGINEERING PROFILE

Terry Dorschner
Principal Fellow, NCS

RAYTHEON TECHNOLOGY TODAY 2008 ISSUE 3 17
Instant, reliable communications have always been critical for providing a safe, timely response during any emergency. Comprehensive communications during a major crisis are even more important. The foundational communications technology for public safety and first responders since the 1930s has been two-way mobile radio, and is now generally referred to as land mobile radio (LMR), even though it is also used to provide communications with marine and airborne public safety personnel. The functionality has essentially remained unchanged since the beginning: provide two-way voice communications for users in a simple, reliable manner. The need for such communications continues to grow, and the pressure for more and more channels continues. In the quest for more channels, the range of spectrum used for such applications has increased, moving from 30 MHz to low-band VHF to high-band VHF to UHF to 800 MHz — and now the 700 MHz band. Channel bandwidth and channel spacing have more or less evolved in an ad-hoc manner, even from the same vendors.

All of this has led to interoperability problems, where national, state and local first responders cannot communicate with each other using the equipment they have acquired. One of the primary reasons in the past has been a lack of standards. This is now changing, and the P25 standard will address many of these issues. However, using different frequencies of operation still presents an interoperability problem. The Federal Communications Commission and others are attempting to address this issue by allocating spectrum at 700 MHz to be used nationwide by all first responders.

Unfortunately, these efforts only address narrow-band voice and low-rate data needs, while the need to exchange large data files, photographs, graphics and streaming video is increasing. These needs require mobile data systems capable of providing broadband, high-rate data communications services. In addition to providing basic communications, there is also a need to provide resource tracking (including patients, food, water, personnel, vehicles, medical supplies, etc.). Thus, providing total interoperability requires integrating not only traditional LMR systems, but also broadband communications, networks, software, video and backhaul elements in a total networked environment across all levels of local, state and national agencies.

Raytheon believes there is an unfulfilled need to develop and deploy modern broadband interoperable communications capabilities across the nation to support state and local public safety and emergency operations. Thus, we developed and deployed a pilot system to provide a working laboratory to evaluate and demonstrate many different broadband communications technologies and their application to public safety and first responder needs. Figure 1 depicts the pilot wireless network. It includes a microwave backhaul ring topology to provide independent connectivity between five cities, eight 4.9 GHz WiMAX wireless nodes for broadband fixed services, and two 1.79 GHz nodes for broadband mobile communications. Applications served by this network include remote video surveillance, remote monitoring of cameras in a high school, provision of broadband data access to mobile vehicles, and the interconnection of all the cities’ networks. The fire department uses the system to access remote databases from fire trucks. Police use the system to view video from cameras, access records, view mug shots and, in conjunction with license-plate recognition software, to identify stolen vehicles or persons with outstanding warrants. The cities use the system to exchange...
System Description

The wireless network consists of three major segments: (1) A microwave backhaul system operating at approximately 30 GHz in a ring topology, (2) A 4.9 GHz WiMAX subsystem that provides fixed access to various users, and (3) A 1.79 GHz 802.20 wireless access subsystem to support mobile users. The backhaul system operating frequency is susceptible to significant rain attenuation, and hence was designed with large rain margins (>30 dB) to provide a link availability of 0.9999. The maximum distance between nodes is less than five miles. The ring topology was chosen to provide protection against total network outage due to a single failure or link outage. When the ring is fully functioning, the backhaul provides 60 Mbps of capacity between adjacent nodes. The ring terminates at the network operations center (NOC).

The 4.9 GHz nodes are implemented as either two-sector or three-sector cells, providing 240-degree or 360-degree coverage, respectively. The nominal radius of coverage from each base station is 2.5 miles. (Actual coverage depends on terrain and cultural features of the area.) This system provides non-overlapping coverage of an area of approximately 60 square miles. The 4.9 GHz operating frequency was selected because the cities owned the license for the 4.9 GHz public safety band, and equipment that implements the 802.16 standard is available in this band. This system was used to connect remote video cameras, pump stations, building-to-building networks, nomadic users, high school video systems and different LMR systems.

Since the 802.16 standard for mobility had not been approved at the time the network was deployed, Raytheon deployed a new technology operating at 1.79 GHz to support mobile operations. The system architecture was designed along the draft IEEE 802.20 standard. It provides fully mobile broadband communications at data rates up to 1 Mbps (now 2 Mbps), with cell-to-cell handoff. The unique feature of the system is the use of “smart antenna” technology to improve range and spectrum efficiency. Two such base stations were deployed and covered approximately 10 square miles in the downtown area of three cities.

The NOC provides several functions, including network management of the backhaul system, the 4.9 GHz WiMAX system and the 1.79 GHz mobile system. It also provides continuous monitoring of the health and status of the entire network, a means for tracking and recording alarm events, a means for configuring and provisioning the network, etc. The NOC is used to demonstrate numerous capabilities available in the network, including video monitoring; pseudo-dispatch functions for setting up interconnections between LMR talk groups; and the exchange of voice, video and data with mobile users. It is also used to host numerous applications, including the multimedia communications application, the virtual private network server, the DNS/DHCP server, etc. The NOC can be located anywhere on the network and provides the center of operations for the network. Thus it can be located at an IT center, the police or fire department, or an independent facility provided just for this purpose.

Summary

Raytheon has demonstrated several communications technologies and the use of several applications to significantly improve the ability of first responders to execute faster, safer and better responses in an emergency. The primary objective is to provide complete interoperability across all media and all jurisdictions. This includes not only LMR voice interoperability, but also video, data, interjurisdictional networks, disparate database formats, multiple frequencies, etc. The pilot has demonstrated our ability to achieve these objectives.

The pilot has also played a significant role in evaluating numerous technologies as well as acting as a working laboratory for users to evaluate the technologies. The pilot has contributed significantly to our ability to understand the operational uses of interoperable communications systems and the issues associated with getting multiple jurisdictions to work together, including both technical challenges and governance challenges.

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Jerry Powlen
Vice President, Integrated Communications Systems
Network Centric Systems

Technology Today sat down with Jerry Powlen, vice president of Raytheon Network Centric Systems’ (NCS) Integrated Communications Systems (ICS) business. With 29 diverse years of experience at Raytheon, Powlen brings a unique skill set to ICS. Technology Today spoke with Powlen about this experience, the various challenges facing the business, and his outlook for the future.

TT: You’ve been in your current role for the past five years and have led ICS through a period of strong growth. What are the main ingredients for developing a successful business?

JP: Ultimately creating a successful business starts with your team. That has been our success story. Bringing together top talent from across Engineering, Finance, Business Development, Contracts, Supply Chain management, and other functions helps to form a team with strong and diverse capabilities that, together, can create and deliver innovative customer solutions.

TT: What are the biggest challenges in your current role?

JP: Because of the significant geographical dispersion of our team, a key challenge is bringing together the different parts of our business and exploiting the natural synergy between them. While each ICS business has tremendous talents in its own right, the creative interaction that occurs when they work together helps us offer more robust and comprehensive communication solutions to our customers. Now take that to the next level and think about the power of bringing together multiple businesses across Raytheon.

TT: What are the experiences in your career that have helped you excel in your current role?

JP: Clearly the different business and functional departments I have worked in have helped me tremendously. Over the past 29 years, I have held positions in multiple Manufacturing, Business Development, Finance, Quality and Contracts organizations. Because of these experiences I am able to view issues and problems from these diverse perspectives and ensure the solutions take into account everyone’s concerns. Also the merger of the different legacy companies that now make up Raytheon has also taught us all the importance of collaboration for success. At times a painful lesson, but a foundational one.

TT: What advice would you offer Raytheon employees to be successful on an individual level?

JP: I would encourage employees to seek out different ideas and opinions when dealing with problems by building a network. This network should include not only colleagues within the company, but also peers outside of the company. Teammates, suppliers and even competitors can be invaluable links within one’s network.

TT: What do you consider to be some of the more disruptive communication technologies within Raytheon?

JP: One of the most significant is our Optical Phased Array (OPA), which is a device that can electronically manipulate a laser beam. It significantly increases reliability and cost effectiveness far beyond the current state of mechanically steered beams. It also has utility beyond communication applications.

TT: What are some of the exciting opportunities for new engineers at Raytheon?

JP: We have been fortunate to have won several new development contracts over the past year in all of our different business areas. One such program is the Navy Multiband Terminal (NMT) that will be in development for a couple more years. Also we’re developing a leading edge, wideband, fully mobile ad-hoc networking (MANET) tactical radio. Work in the civil communications markets — for example, the public safety sector — is also expected to grow at a much faster rate than our core Department of Defense (DoD) market. As we branch into these adjacent markets, we face the challenge of how to take existing DoD and commercial technologies and build on our systems integration capabilities to deliver new system solutions. All of these areas offer exciting opportunities to our engineers.

TT: What are the key factors driving this market now and for the next five years?

JP: In both our DoD and civil markets, providing interoperability and increased bandwidth to the customer remain a top priority. Also, there has been more emphasis on protected communications: Providing technology that is anti-jam and has a low probability of intercept and detection in the field is very important. It is also very important to push communications down to the tactical edge; getting critical information into the hands of the soldiers or first responder will continue to be critical going forward.

TT: What processes within Raytheon do you see working particularly well?

JP: Without a doubt, our Integrated Product Development System (IPDS) is a
world-class set of processes that even our competitors have benchmarked. But we’re not resting on our laurels, because IPDS is an evolving tool into which we continue to incorporate best practices as we find them across the company and in industry.

**TT:** Are there any processes that need more focus to help Raytheon grow?

**JP:** Our business capture process, a sub-element of IPDS, is something we need to continue improving. We also have realized that it takes a specialized skill set to be a capture manager, and we have started to focus on talent development in this area.

**TT:** Why is it so important to have venues like MILCOM to share communications technologies?

**JP:** Venues like MILCOM provide an excellent forum to interface with our customers and to be sure we’re aligned with their vision and focused on both their immediate and future problems. Also, innovation tends to flourish when different groups come together to talk about similar issues. MILCOM allows for engineering talent from across academia, the government and the private sector to meet and discuss the same problems and how we are working similar solutions but with diverse approaches.

**TT:** How does MILCOM’s theme, Assuring Mission Success, tie into Raytheon’s own Mission Assurance efforts?

**JP:** They tie very closely together because our own Mission Assurance starts with our customer. It is what Raytheon is all about. We want to provide the best technologies and solutions to the warfighter and MILCOM promotes just that. It also provides everyone with a view not only of what issues the customer is facing today, but also what tomorrow will bring.

**TT:** Continues on page 22
Innovative Solutions to Unique Challenges

Providing quality shipboard power is a challenge unique to military vessels, where powerful electric motors and communications equipment draw current from the same power bus. Motors turning on and off almost always affect collocated equipment sharing the same power connection. (This unique shipboard power quality is defined in Mil-Std-1399-300B, “Electric Power, Alternating Current.”)

The challenge was to create a Raytheon solution for this demanding power environment, and then package that solution in an affordable design.

The result is a power system architecture that isolates load fluctuations from the prime power events by using a step-down transformer and feeding three separate power-factor correction (PFC) modules, one for each power input phase. The step-down transformer reduces or eliminates over-voltage transients on the prime power line before they reach the power-conversion electronics. The three PFC modules, developed by our partner, Advanced Conversion Technology, Inc., keep the voltage and current in-phase across all of the operating load conditions. As a result, the NMT operates as a well-behaved power consumer. This architecture ensures that the prime power delivered to collocated equipment on the same power line is not distorted. System performance is thereby maintained across a power range of greater than 5:1 to support the nine different configurations.

Once this well-behaved input was established, the next task was to store power locally to accommodate power drops resulting from automatic bus transfers and under-voltage conditions. This was done via energy storage capacitors. A current-sharing arrangement between the PFCs and the energy storage capacitors permits sharing across the three prime-input power phases. This arrangement provides some immunity to partial or total loss of a single prime-power phase.

The team then focused on powering the different electronics loads and antennas. Three different communication electronics sets support Q, X and Ka transmissions, as well as five different antenna types for ship, shore and submarine; all nine different installed configurations are supported. The power system solution is a common, modular supply with a 28VDC and a 280VDC output capable of powering either an antenna–transmitter assembly or circuit cards in electronics chassis.

The control of this power system benefited from valuable user-community, human-factors and safety-engineering inputs. The control panel, which provides power system status to help reduce errors and improve operational safety, was designed to be easily read by users of different heights, and at different angles. Additional status and monitoring electronics are available for system diagnosis of both the power system and all of the different loads powered by the system.

Overall, the NMT power system technology supports NoDoubt™ mission performance by providing a solid foundation for a stable, reliable, warfighter communications system.

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Applying Service Oriented Architecture to the Tactical Domain: Road Map for Success

Service Oriented Architecture (SOA), a new system-design pattern used in the commercial domain, has technologies and principles that can significantly reduce life-cycle development costs when integrating, designing and evolving diverse systems. It is not just a buzzword. SOA and its associated technologies have been proven in commercial industry and now run the stock market, the banking industry and other immense integrated spaces.

Despite these successes and the great military demand for SOA, it has not been widely used in the tactical domain. This is because SOA technologies do not fully meet military requirements such as tactical deterministic reliable messaging and information assurance. Raytheon is working to change that, and our skill in applying SOA to emerging military applications will be a powerful discriminator in demonstrating our world-class capabilities as a Mission Systems Integrator (MSI).

Raytheon's extended SOA technology can reduce the time needed to integrate legacy military applications from months or years to days. These integrated applications can then use a library of Raytheon-developed common services to extend their existing capabilities and lower lifecycle costs.

What Is SOA?
SOA is an evolution of object oriented programming that allows open reuse of software across multiple software environments and infrastructures. SOA technologies, such as an enterprise service bus (ESB), not only allow tightly coupled monolithic stove-piped applications to run as they do today, but also make such applications available as SOA services. SOA services publish and subscribe information to each other in a standardized infrastructure to allow a dynamic flow of information.

However SOA is not “just” an infrastructure-provided magic bullet that can instantly...

Continued on page 24

Simplified tactical SOA road map
ARCHITECTURE & SYSTEMS INTEGRATION

Continued from page 23

solve every integration problem. Actually, ~40 percent of SOA design is the process of correctly defining–refining–wrapping services to allow open, understandable and discoverable communication. And ~20 percent is governing a SOA implementation.

Why Is Tactical SOA Important?

Even before the SOA concept emerged, Raytheon’s need to provide world-class capability has always led us to champion system interoperability, standards-based development and reusability.

Recently, the Department of Defense (DoD) released several joint 2020 road maps outlining the need to re-engineer a large portion of its existing coupled systems and decouple them into a “systems-of-systems” architecture made up of any sensor and any shooter. This architecture defines that existing systems have capabilities such as engage–launch on composite remote, distributed algorithms–information, common services, global resource management and global command and control. This integration challenge is the natural domain of SOA technology, and DoD system acquisition requirements have changed accordingly.

However, the government SOA specifications only define basic SOA technology standards that, in their current form, are not sufficiently complete to meet the tactical performance needs of the systems they govern. In addition, raw commercial infrastructures cannot meet these performance needs either, despite many marketing claims. Raytheon is therefore extending SOA technologies to meet these tactical performance requirements. We must understand, develop, use and lead tactical SOA to remain a Mission Systems Integrator of choice and implement the “system of systems” concept.

Despite our competitors’ assertions that “system of systems” integration is just an IT infrastructure problem, the heart of the challenge lies in the governance and service design. An in-depth knowledge of existing systems is needed to re-architect existing applications into reusable, discoverable services, and then only a tactically extended SOA infrastructure can actually meet customers’ needs. To address this challenge, Raytheon is driving a tactical SOA infrastructure and pulling functionality from its deployed programs into common services for use in that infrastructure.

How Are We Driving Tactical SOA?

Our strategy for driving world-class tactical SOA technologies is to actively drive standards and extend the technologies of commercial companies. Raytheon has used its experience to merge SOA technologies with tactical technologies and affect our partners’ road maps.

The technology evolution shown in the accompanying road map describes at a high level where we are driving tactical SOA technologies with our industry partners. Our unique tactical SOA will have advantages in hard real-time speed requirements, interoperability, security, information assurance and other requirements of the tactical domain.

The Raytheon Tactical SOA Steering Group

To coordinate the internal–external efforts depicted on this road map, the author leads a companywide Tactical SOA Steering Group created from the Mission Critical SOA Technology Interest Group (TIG) which he also co-chairs. This steering group currently includes more than a dozen cross-company programs driving infrastructure and reusable services.

The steering group ensures that each of the member’s products is interoperable and that we create a tactical SOA story as one company. The group enables us to provide a unique composition of a tactical SOA infrastructure and a library of reusable common services for new and legacy programs of multiple requirements.

Raytheon employees who want to support this technology or group may contact the author or join the Mission Critical SOA TIG. ● Benjamin Wilson benjamin_j_wilson@raytheon.com

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University Partnerships Offer Unique Force-Protection Opportunities and Directions

Military environments can be extremely challenging and often involve seemingly conflicting requirements, such as the need for materials that are both extremely lightweight and very, very strong. Taking nature as a guide, Raytheon and its university partners — the Institute for Soldier Nanotechnologies and the Ortiz Laboratory at MIT — have been studying nature to provide unique solutions to meet our customer’s requirements and even go in new directions that may exceed customer expectations.

Although it is commonly acknowledged that nature inspires much of art, nature also has enormous potential to serve as inspiration for engineered processes, substances, devices and systems. Biological materials, such as musculoskeletal and exoskeletal tissues, have developed amazingly complex, hierarchical, heterogeneous nanostructures over millions of years of evolution in order to function properly under the mechanical loads they experience in their environment.

In addition to this, researchers have found that it is possible to amplify a material’s properties in different ways just by creating structural differences at the nanoscale. Then, starting with more obtainable or perhaps even stronger materials, a better, lighter weight, more robust material or structure can be fabricated.
One example of such a natural material that has helped fabricate new forms of armor is nacre. Nacre — also known as mother-of-pearl — is essentially the strong part of a seashell and is primarily composed of calcium carbonate. Yet in a seashell the nacre has roughly 100X the fracture toughness and 5X the strength of most calcium carbonate samples. The secret to this strength is the multilayered structure, which the animal forms as the shell. These structural models have been used to fabricate similar mechanisms with stronger materials. Although research has yet to obtain the same strength amplification as that found in nature, researchers have demonstrated 10X increase in fracture toughness and 3X increase in strength in the same sample with no increase in density. This was accomplished merely through a nanoscale change in the material structure.

In an ongoing collaboration with the Institute for Soldier Nanotechnologies and the Ortiz Laboratory at MIT, Raytheon has been examining this and other natural systems. Another of the new systems being examined may help to save soldiers from improvised explosive device (IED) blast injuries. These injuries result from the aftereffects of an explosion that causes enormous pressures to hit the soldier and compress the brain, producing in some cases damage that can never be repaired. These brain injuries can lead to life-long afflictions.

Nature has found a way to solve this problem, an approach which may prove useful to researchers attempting to mitigate this threat.

The bombardier beetle offers a unique unexplored opportunity — particularly for lightweight, soldier-protection applications such as blast shields — and a new direction in fire-retardant materials for first responders.

This type of beetle possesses a defense mechanism which involves ejecting a spray from the tip of the abdomen. The spray, which contains p-benzoquinones (a known chemical irritant) at elevated temperatures (100°C), is ejected in a controlled direction and is accompanied by loud audible detonations. The quinones are generated explosively — completely within the interior of the beetle’s body — by mixing two reactants: hydroquinones, hydrogen peroxide which are stored in two millimeter-sized reservoir chambers and then released by a valve into a reaction gland containing enzymes such as catalases and peroxidases, depending on the sub species of bombardier beetle. Oxygen is liberated (which acts as a propellant) from the hydrogen peroxide, and the hydroquinones are oxidized by the freed oxygen.

The reaction chamber and exit nozzles clearly have been designed over millions of years of evolution to protect the internal organs of the beetle from the resulting blast wave, heat and toxic chemicals during the defensive microexplosions. Currently, very little is known about the material structure and properties of this explosion-resistant pygidial chamber. The goal of the proposed research is to use new materials science and nanotechnological methodologies to investigate the detailed morphology and properties of this fascinating material. The fundamental materials design principles learned through this proposed research could likely be employed to develop a new class of fire-retardant materials, improved blast-protective equipment, and ultimately much lighter soldier loads.

The research in this area is ongoing. We are continuing to work with universities in an attempt to garner large, revolutionary breakthroughs in materials technology, not merely iterative performance increases. Engineers with ideas or thoughts relating to this ongoing research area are encouraged to contact either author with these for consideration.

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When you must quickly detect and fix defects, hold a peer review and close the resulting issues, and collect and analyze metrics — and do all of these tasks within a tight budget — you may believe that only a diverse mix of custom-built and COTS products can help you. Yet a solution exists that does all of the above and much more: Raytheon’s iTracker™. iTracker is a Web-based tool suite used across the company by program 1, software, system and hardware engineers, and by our subcontractors and customers as well.

What Is It?
iTracker is an integrated, Web-enabled tool suite that provides common but high-value applications for use by a single program, a set of programs or an organization. iTracker easily accommodates programs ranging from a single user to thousands of users in different parts of the country — or the world.

Developed in 1995, iTracker was one of the first enterprisewide tools deployed as a Web application. Currently, more than 650 active programs throughout the company use one or more iTracker tools. Because most of the suite’s support and development costs are funded by Raytheon Integrated Defense Systems (IDS), Intelligence and Information Systems (IIS) and Network Centric Systems (NCS), iTracker is available free to programs within these businesses. Customized iTracker versions have been created to meet each business’s needs. For example, the NCS version contains fields and menus that support the implementation of the Common Process Architecture (CPA).

iTracker can be deployed standalone or as a component within the Raytheon Electronic Collaborative Environment (ECE) iCenter security infrastructure to provide Internet–extranet access. Roles and permissions schemes — by user, project and control component — are embedded into the database and the application to restrict access to particular fields and forms on a need-to-use basis.

What Does It Do?
An iTracker project can include any combination of the following tools:

- **iTracker Change Request (CR)** enables a project to record, manage and track technical changes to its products (program engineering, software, hardware and system issues) or its process. Changes may result from bug fixes or enhancements. CR also enables users to run customized or standard metrics reports derived from change request content.

- **iTracker Inspection Process Report (IPR)** provides a mechanism and process for setting up, announcing and conducting a peer review (also known as an inspection). IPR is used to record the issues generated during the peer review and to track them to resolution. Users can also upload issues into IPR that were captured in Microsoft Excel spreadsheets or that reside in commercial tools such as PleaseTech’s PleaseReview™.

- **iTracker Action Item (AI)** provides a mechanism for programs to record and track simple tasks, such as, “Contact the customer to arrange a demo.” Often during a meeting action items are discussed — and perhaps even assigned — but if there is no follow-up, some tasks may not be done. A popular AI tool option is a “nag” feature that reminds users of their overdue action items.

- **Hazard Tracking System (HTS)** is a closed-loop system that identifies, tracks and documents resolution of Environment, Safety and Occupational Health (ESOH) hazards and associated risks. HTS identifies ways to mitigate hazardous conditions, and it reduces all unacceptable risks through standard (Mil-Std 882D, “System Safety” [10 Feb 2000]) mitigation preferences.

- **iTracker Metrics Management System (iTMMS)** allows projects to set up report configurations to enable scripts to run during off hours to collect, calculate and transfer project metrics data to various repositories (such as iMetrics, IDS Data Repository, iTracker Program Metrics and DataDrill®).

- **Service Request Tracker (SRT)** (anticipated release Q1 2009) allows programs or organizations to create and track help-desk issues to closure. If you provide customer support for a tool or application you produced, you know that reducing problem-resolution times and increasing customer satisfaction are important. SRT can help. Because solutions and lessons learned are preserved in the SRT knowledge database and are easily retrievable, the support staff is less likely to waste time researching a problem that has already been solved. Customers also benefit because a proven solution can be provided quickly.

Other Benefits
No license or client software are required, so no license-key-management costs are incurred. Users only need a simple Web browser (Microsoft Internet Explorer®, Netscape Navigator® or Firefox®) and network access to start using iTracker tools for a given program or organization.

The back-end database is the industry-standard Oracle® RDBMS (Relational Database Management System), for which Raytheon has a corporate agreement authorizing companywide use. The freely available Apache Web Server provides all the necessary Web services.

Continued on page 34
The 2008 Electro-Optical Systems Symposium, held in Tucson, Ariz., was the third major Raytheon technology event this year, marking the third technology network (TN) to announce a shift in its core focus. Now the Multifunction Electro-Optical Systems Technology Network (MEOSTN), this TN has begun its transformation to better align its strategy with Raytheon’s core markets.

Themed “EO technologies: Key Elements of Innovative Mission Solutions,” this year’s event brought two new track sessions to the table — novel sensors and systems, and EO manufacturing technology — both key pieces to expanding EO’s role as a multifunction network. These new sessions emphasized innovation in both design and product delivery to the customer.

In one of the opening sessions, Bob Lepore, vice president of Engineering at Raytheon Missile Systems, addressed the challenges of technology innovation in the EO arena as well as the challenge to deliver affordable, producible, testable products to our customers. “The products we come up with have to fall into those [challenge areas], or we’re not going get those products out to the warfighter.” Lepore added that we currently look at affordability, producibility and testability in the production phase of a project — too late in the process to effect change without significant effort and cost. These challenges need to be introduced early in the design phase to minimize redesign and rework.

In addition to refocusing its annual symposium tracks, the MEOSTN will respond to emerging strategic challenges by adding new technology interest groups (TIGs) over the next few months. “Since the new [track] sessions were successful, we feel there is critical mass to launch TIGs in Novel Sensors and EO Manufacturing Technology,” said Brian Perona, MEOSTN chair. “Additionally, our LADAR/LASER TIG will have the most influence on where EO multifunction systems go from a hardware standpoint. I would expect extra emphasis in that area.”

So what lies ahead for the MEOSTN? As technology needs change, so will the TIGs — the heart and soul of the technology networks — continue to evolve, retire or combine to implement new technologies into Raytheon’s products. Joint efforts between the hardware networks will also continue to grow as new technologies span traditional boundaries. The MEOSTN’s role going forward will be to help focus the talent in the EO community on the challenges ahead. That is the TNs’ strength: access to talented people and their ideas.  
The fourth Raytheon Mission Assurance Forum was held June 11–13 at the Gaylord National Resort and Convention Center, outside Washington, D.C.

Organized around the theme, “It Takes a Team,” the forum brought together more than 500 Raytheon employees, leaders, customers and industry partners to focus on supporting and encouraging the attributes of good teams to deliver NoDoubt™ Mission Assurance.

Over the course of three days, the attendees increased their knowledge and understanding of Mission Assurance through panel discussions, breakout sessions, exhibits and networking opportunities. The program also featured a diverse range of voices — customers, warfighters, Raytheon leadership and coworkers.

The forum was one of the largest ever, as for the first time the Raytheon Six Sigma™ Awards were integrated into the program. They joined the Excellence in Operations and Quality Awards as evening events to recognize achievements in productivity, process excellence and Mission Assurance.

Keynotes From the Customer Community
Attendees heard about the importance of Mission Assurance directly from leading customer voices during keynote addresses from:
- Lt. Michael E. Thornton (ret.), U.S. Navy, Medal of Honor Recipient
- Lt. Mark G. Stainbrook, Los Angeles Police Department
- Randolph R. Stone, director of Safety, Quality and Mission Assurance for the MDA

Panel Discussions
Panel discussions led by Raytheon leaders and warfighters allowed attendees to gain a better understanding of Mission Assurance and what it means to the work we do everyday.

Members of the Raytheon leadership panel included Raytheon Vice President and CIO Rebecca Rhoads, Raytheon Intelligence and Information Systems President Mike Keebaugh, and Raytheon Technical Services Company President Rick Yuse. The leaders shared their personal perspectives on Mission Assurance, the important aspects of a team, and how to manage risk, as well as and their thoughts on organizational health.

Additionally, a warfighter panel that four officers comprised fielded questions from the audience and told personal stories about the role that Mission Assurance plays when they are in the field.

Hearing From Day-to-Day Mission Assurance Practitioners
Detailed track sessions gave participants firsthand experience and actionable information about the role that Mission Assurance plays in Raytheon businesses for the benefit of customers. The 25 track sessions represented an enterprisewide dedication and commitment to educating Raytheon employees on their role in process excellence.
Recognizing and Rewarding Accomplishment

Raytheon Chairman and CEO Bill Swanson, along with Raytheon Missile Systems President (and former Vice President of Raytheon Engineering Technology and Mission Assurance) Taylor W. Lawrence, acknowledged 18 Raytheon Six Sigma projects on June 11 with the prestigious Raytheon Six Sigma President’s Award for top projects within a business that achieved overall project excellence — each business’s and corporate’s “Best in Business.” Swanson and Lawrence also unveiled the four CEO Award Winners; these were chosen from the 18 President’s Award winners as “Best in Class” in four focus areas: Customer-Focused Company, Mission Assurance, Mission Systems Integration and CEO’s Choice.

On June 12, Lawrence acknowledged 21 teams and one individual with the Excellence in Operations and Quality award. Each recipient contributed to Raytheon’s growth by helping ensure our customers’ mission success. The award recognizes those who demonstrate a constant pursuit of excellence, dedicated leadership and a commitment to customers by providing the best solutions.
People

Eighteen Raytheon Six Sigma President’s Award teams were honored at the 2008 Mission Assurance Forum, including four CEO Award winners, one of which is highlighted below. To view all award-winning teams and projects visit: http://home.ray.com/feature/ray08_r6s_awards

Raytheon Six Sigma CEO Award

Trust and Respect Behavioral Assessment Tool (NCS)
Joe Adams, Mike Allgeier, Katrina Beers, Rick Grady, Vince Hrenak, Ed Johnson, Christy Lee, Ana Marrero-Cosme, JD McCarty, Ed McFarlane, Sabrina McReynolds Pargo, Joe Paone, Glynn Raymer, Alyson Schneller

The Network Centric Systems (NCS) Trust and Respect project focused on top drivers of low Trust and Respect scores in the Employee Opinion Survey and creating concrete deliverables to improve these results. A cross-functional team was formed with representatives from all functions across the major sites in NCS.

The team identified 10 specific behaviors that define Trust and Respect across the five Raytheon Pillars of Respect which are: Valuing One’s Opinion, Acknowledging One’s Presence, Explaining Why We Do What We Do, Providing Ongoing Feedback, and Showing Appreciation. These behaviors were then built into a Trust and Respect Behavioral Assessment Tool that can be utilized by NCS employees to receive feedback from their leaders, direct reports and peers on how well they demonstrate Trust and Respect to each other. This tool enables identification of strengths and areas for improvement, and allows for targeted training. The tool is being rolled out to all NCS employees to improve the culture of Trust and Respect within NCS.

Twenty-one teams and one individual received the Excellence in Operations and Quality Award at a recognition celebration at the 2008 Mission Assurance Forum this past June. Two of these teams are highlighted below. To view all award-winning teams and projects visit: http://home.ray.com/feature/ray08_eioq07

2007 Excellence in Operations and Quality Awards

Raytheon Enterprise Energy Team (Accelerating Knowledge Transfer Award)
John T. Steele (Intelligence and Information Systems), Randy Taylor (Technical Services), Kimberley S. Rasile (Network Centric Systems), Lang L. Lawrence (Missile Systems), Jack M. Holt (Space and Airborne Systems)

The Raytheon Enterprise Energy team achieved Raytheon’s two-year goal to reduce energy consumption, decreasing total companywide energy consumption by 17 percent during 2006–2007, compared with a 2005 baseline adjusted for business impacts. It also avoided 104 million kWh in 2007, which is equivalent to 10,000 homes. Additionally, it obtained 11,500 “Change a Light” pledges in 2007, and continued the Energy Champion program, growing it to 1,500 participants. Raytheon saved $10 million in energy costs in 2007. Since energy constitutes 90 percent of the greenhouse gases emitted by Raytheon, the company is expected to meet a year early its goal of reducing greenhouse gases by 33 percent for each $1 billion in revenue.

Missile Systems Convergence With Corporate Integrated Product Development System (IPDS) Team

The Missile Systems (MS) Convergence with Corporate IPDS team led MS’ adoption of the corporate IPDS architecture and layer content. All new MS programs and contract awards will use the new system for tailoring and program execution. The team reviewed and rewrote all of MS’ method and enabler content and loaded the information into Raytheon’s process asset library. The rewrite removed non-value-added methods, identified Lean processes to reflect best practices, identified gaps aligned with process requirements, and unified efforts that streamline activities and question bureaucracy. The team also filled the gap between information and user requirements with directive documentation aligned with requirements and shared across Raytheon’s businesses. By using Raytheon’s IPDS, MS infrastructure funds can be redirected to cost-saving projects to reduce time-executing processes.
Suzanne P. Hassell
Senior Principal Systems Engineer
Network Centric Systems

Suzanne Hassell is a Raytheon Certified Architect at NCS in Largo, Fla., currently researching information assurance architectures for the Information Assurance Emerging Technologies campaign and an Identify–Develop–Exposé–Action (IDEA) project.

Hassell joined Raytheon three years ago with 23 years of experience in systems engineering, systems and software architecture, and software development in the communications industry. Hassell holds seven U.S. patents in the communications area.

Hassell got her start as an architect in 1983 at Bell Labs, when she was on the system architecture team that developed the Datakit Virtual Circuit Switch, an early packet switch. “Looking back now,” she said, “I see that working on such a cutting-edge, successful architecture early in my career really inspired me to continue to remain technical and focused on architecture.”

At the time, Bell Laboratories was at the forefront of networking and architecture development and methods. Hassell focused on software, systems and network architecture for all aspects of networking protocols and architectures, both at AT&T and later at E-Systems (acquired by Raytheon in 1995) for the Data Distribution System (now CEC).

At Raytheon, Hassell has met with customers on the Red Switch programs and at trade shows and demonstrations as principal investigator for VoIP internal research and development efforts. “One of the things that impresses me the most about Raytheon is how everyone in the company is totally focused on the customer,” she said. “Listening to customers is the most important thing.”

Hassell believes that one of the key challenges that Raytheon faces is continuing to leverage One Raytheon initiatives to streamline processes and to enable better communications and reuse across business areas. “Raytheon employees are very willing and happy to work across business unit boundaries,” Hassell stated. “But the separate business unit charging structure and tools sometimes puts up barriers in cross-business initiatives that constrain collaboration in areas such as research or process improvement.”

Hassell said she is impressed with the wide range of opportunities available within Raytheon and has enjoyed moving into areas beyond communications, such as performing enterprise architecture for border security, command and control, and information assurance projects.

Hassell cites many reasons for her career success. “Working with and learning from excellent colleagues and customers and seeking out a wide variety of assignments are very important,” she said. “My degree in physics and mathematics and taking additional psychology, sociology, speech and research-writing courses has really helped me in enterprise architecture.”

Hassell became a Raytheon Certified Architect in 2007, and she praises the RCAP program. “It is a tremendous program. It provides a common architecture discipline framework across Raytheon and between Raytheon and our customers. This allows us to communicate more effectively and leverage work done in other areas, both inside and outside Raytheon.”

Jagannath (CJ) Chirravuri
Chief Technologist, Northeast Region
Network Centric Systems

As a lead architect working for a telecommunications provider, Jagannath (CJ) Chirravuri was setting up a network operations center for managing IP services. At that time, a mentor gave him some advice that he has carried with him: Architecture should present business value to executives (sponsors) while providing enough detail to the engineer and driving requirements.

After receiving a Ph.D. in physics from Purdue University, CJ began his 28-year technical career in research and development, working primarily on optical and optoelectronic components. After 40 publications and 12 patents, he took on the challenge of working on projects to implement broadband (optical) networks with particular focus on reducing operational costs while providing the requisite quality of service. This led to several business process reengineering projects — all of which reinforced his mentor’s advice.

CJ joined Raytheon in May 2005 as a lead systems engineer, developing collateral for optical communication proposals, mentoring systems engineers, and supporting manufacturability of optical components, including support of potential technology licensing opportunities. Eager to immerse himself in the Raytheon culture, in 2007 he took on the role of chief technologist for the Northeast region. There he received a “crash course” on the breadth of projects within Network Centric Systems business: from large ship-based satellite communications systems to next-generation air traffic management solutions.

The importance of mission systems integration cannot be overemphasized, according to CJ. Architecture, he believes, provides the means to capture customer needs and define a systems solution. “The diversity of skill sets in this organization; from networking protocols to service-oriented architecture needs to be channeled to provide MSI solutions to core and adjacent markets,” he said. Learning from large MSI projects such as Perimeter Intrusion Detection System, he is working on public-safety network architecture to address the critical need for interoperability among first responders, including the systems and business processes in an emergency operations center.

According to CJ, we are a critical point in the evolution of public safety where public safety personnel have to be on the mark all the time and there is little room for error. “ ‘No doubt’ means that communications systems provide timely and accurate decision support information,” CJ said. “This keeps me up at nights and at the same time challenges me.”

The Raytheon Certified Architect Program (RCAP) is the culmination of Raytheon’s systems architecting learning curriculum. RCAP focuses on providing our customers with the expertise needed to support their long-term transformational goals. In recognition of their certification, we continue to highlight our Raytheon certified architects.
The Net-Centric Software and Systems Consortium

When involved in IRAD or CRAD capture activities, you sometimes find yourself in the position of having the right competencies in place to do the work, but not the capacity. In other cases you may identify technical gaps in your organization which, if you could fill them quickly, might open up new business opportunities. One approach to solving capacity issues is to identify a “force multiplier” from which expertise can be drawn to help achieve your project’s technical objectives. In the North Texas region of Network Centric Systems (NCS), this issue is being addressed in part with the formation of a Net-Centric Software and Systems Consortium (NCSS) advocated by the Office of the Under Secretary of Defense and sponsored by the National Science Foundation (NSF).

The NCSS is a planned NSF Industry/University Cooperative Research Center (I/UCRC) created to collectively undertake and promote research and workforce development of service-oriented, network-centric systems. The consortium currently includes the four major universities in the Dallas–Fort Worth metropolitan area: University of North Texas, University of Texas at Arlington, University of Texas at Dallas, and Southern Methodist University. Lockheed Martin Aeronautics and Raytheon have participated in consortium formation activities since 2006 and other industrial partners, including Rockwell-Collins, Texas Instruments and EDS (now HP) have announced their plans to support the consortium as well.

The NCSS will provide a primary source for fundamental systems research of modeling, analysis, design, implementation, verification and validation, deployment, and evolution of net-centric systems. The consortium will enable coordinated hardware–software systems engineering research and development, as well as education and training of students to meet future software and systems workforce needs of the industrial members. The universities are already taking direction from the consortium’s industrial partners on how to shape technical curricula in ways that maximize student exposure to net-centric technical skills.

The consortium will also establish a leading research alliance capable of conducting significant research projects for the federal government and industrial customers. By joining the forces of the participating academic institutions and high tech companies, the consortium will significantly enhance the research capabilities of the participants and revolutionize our national research competence. The consortium can earn national fame as a leading technology innovator, technology incubator, and center for technology commercialization.

An NSF planning grant proposal, seeking support to further develop and transform the existing industry–university consortium into an NSF I/UCRC, was approved in August 2007. The consortium held an industry open house in February 2008, which was attended by more than 20 academic and industrial partners seeking information on present research directions and membership. The current academic partners each have until August 2008 to identify $150,000 from supporting industry partners to meet the I/UCRC formation requirements imposed by the NSF. Once these financial commitments are met, other NSF, federal and state funding opportunities become available.

Benefits of membership in the consortium to industry partners such as Raytheon include the opportunity for constructive collaboration and directed research efforts with a team of customers, partners, suppliers and competitors on basic and applied research of mutual benefit. For NCS, this includes Service Oriented Architectures as applied to software dependability verification, architecture selection as a function of dependability requirements, mathematical modeling, and dynamic adaptation of services — to name only a few.

There are also opportunities for focused incubation of net-centric technologies, directed by a business partner, and targeted to specific product line enhancements. Technologies to be exploited using the consortium include model-driven architectures, agile processes, automated testing and regression testing, scalable multi-threaded systems, optimized partitioning of applications across fixed core vs. FPGA-based systems, networking strategies and protocols, and others. Research packages targeting software safety and video data compression, for example, are already in work.

Joint research with universities, industries and customers (e.g., DoD, NSF, DARPA) is also enabled by the consortium. Its resources augment potential CRAD/IRAD projects by providing evidence of, and access to, collective consortium capabilities, skilled personnel, and past research project performance. Novel concepts emerging from collaborative industry, customer, and academic research provide opportunities to move ideas from theory to practice.

Access to university research is a “force multiplier” for generating new business opportunities, growing existing competencies, and filling technical gaps. Curricula of member academic institutions target key net-centric enabling technologies, providing potential employees with focused skill sets and minimal learning curves — an economical alternative to in-house development and deployment of new courseware to address net-centric concepts. Students trained in technologies supporting net-centric software applications provide a relevant, desirable, and domain-specific resource pool.

As one of the industry sponsors committed to its success, NCS North Texas is looking forward to the Net-Centric Software and Systems Consortium becoming a full-fledged NSF I/UCRC in August 2008. As of this writing, the university partners are fully engaged in their drive for industry sponsorship and have signed a Memorandum of Understanding to jointly pursue research and educational activities in the area of net-centric software and systems engineering.

David Struble
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Raytheon will be the title sponsor of the 2009 MATHCOUNTS National Competition to be held May 7–10 at Walt Disney World’s Swan and Dolphin Resort in Orlando, Fla. MATHCOUNTS® is a national math enrichment, coaching and competition program that promotes middle school mathematics achievement in every U.S. state and territory, and is one of the most successful education partnerships involving volunteers, educators, industry sponsors and students in America.

“With the generous support of Raytheon and its employees and volunteers, MATHCOUNTS will continue to provide students with the tools they need for a foundation for success in science, technology, engineering and mathematics careers at a critical time in their education,” said Lou DiGioia, executive director of MATHCOUNTS. “Our generous sponsors help us prepare middle school students for higher education and to take their place as leaders in a changing technological global economy. With Raytheon’s help we are looking forward to our 26th National Competition and celebrating the achievements of our dedicated and talented Mathletes.”

Raytheon has partnered with MATHCOUNTS to increase middle school mathematics achievement for the past 13 years, and has donated significant financial contributions to help middle school students become creative problem solvers and develop the skills needed to become the math and science leaders of the future. In addition to financial support, Raytheon assists MATHCOUNTS through volunteerism and community involvement from Raytheon employees.

In the continuing commitment to encourage students to remain interested in programs in math and science, Raytheon also touts its MathMovesU™ program, an initiative that features interactive learning programs, fun contests, live events, scholarships, tutoring programs and much more.

Middle-school age is the time when critical thinking skills are being honed and a change in attitudes toward mathematics can occur. The MATHCOUNTS Competition program capitalizes on this pivotal point in a child’s development by exposing students to more math in a fun and exciting way. By offering teachers, kids and parents terrific free materials to aid them in math enrichment, MATHCOUNTS prepares kids for a high-tech future that will require mathematics-related skills to achieve success. During the last 25 years, more than 7 million students have used MATHCOUNTS materials and over 41,000 middle schoolers from all 50 states and U.S. territories compete in local and regional MATHCOUNTS competitions each year. The final 228 students will advance to the Raytheon MATHCOUNTS National Competition to vie for the top spot as the National Math Bee Champion.

For its 25th anniversary year, MATHCOUNTS introduced the innovative new Club Program, creating non-competitive math clubs by providing free materials and guidance to any middle school in the U.S. The Club Program was initiated to help foster enthusiasm for mathematics in all students, and to further engage those who prefer not to participate in the competitive aspect of MATHCOUNTS. Materials and information are available by registering free-of-charge on the website at www.mathcounts.org.

Registration for the MATHCOUNTS 2008–2009 school year runs through Dec. 12. Concurrently, more than 50,000 copies of the MATHCOUNTS School Handbook have been distributed to middle schools across the country. Thousands of teachers currently use the free materials every year to supplement classroom materials or as an extracurricular activity.
Support for these tools is easily accessed. Because servers can crash, hardware can fail, and data can be contaminated, backup and recovery are rigorously supported. These features give programs confidence that data will not be lost and that their project will always be available.

A Dozen Reasons Why Raytheon iTracker Is Unique

• It’s a single tool suite that performs the common, but critical tasks described above.
• It’s an integrated tool suite that allows you to quickly find what you are looking for in one place, rather than accessing and searching various tools. The iTracker graphical user interface lets a user move from one tool to another easily and quickly, and it even provides a shortcut — “my work” — to the user-specific information.
• Because Raytheon has a corporate agreement with Oracle, and all the other iTracker software is either open-source or Raytheon-owned, programs need not worry about maintenance and license-key issues.
• Each server is large enough to support hundreds of projects. This eliminates the need for many project servers and reduces the resources required for maintenance, backup and recovery.
• Each member in a family of projects, such as a product line, can propagate items to others in that family. This is a time-saving feature when a new project is being created based on an existing project in the same domain, or when similar changes must be made in more than one project that have the same baseline.
• A set of fields in selected items can be bulk-updated, saving users the time and effort of updating them one by one.
• A customizable watchlist for tracking personalized items is available to each project user.
• An application programming interface is available to allow projects to capture data in a variety of formats (XML, comma separated fields, text, tab delimited, etc.)
• Customization is a snap. Users who have the iTracker Admin role can tailor fields (hide; specify defaults; change labels, field values or help definitions; make mandatory) to meet project and customer needs.
• Tool-embedded rules enforce business processes.
• External access is available through integration with the ECE iCenter and OneIDE (integrated development environment) (future) security infrastructures.
• iTracker’s open approach does not tie it to one vendor’s suite of projects. For example, it can work with ClearCase® (IBM) and DOORS® (Telelogic) products.

Why Not COTS?

An out-of-the-box solution seems straightforward, but it is also simplistic and generic. Raytheon program requirements, however, are often complex and specific. COTS products can also be expensive. In addition to initial licensing and yearly maintenance costs, there is the cost of learning and tailoring the tool for each project adopting it. COTS support and training can also be expensive. Significant resources and cycle time are needed to add a new capability, tailor the product, or fix a bug. Factor all this effort for each program. Then multiply it not only for additional programs, but for additional tools because no one tool is likely to do everything you want.

iTracker, however, does more, and does it more efficiently, than a diverse mix of COTS products. iTracker provides a fully supported, integrated, proven and ready-to-use solution to handle program change requests, peer reviews, action items, hazard tracking, service requests and metrics.

For more details, visit our home page at http://itracker.app.ray.com, or contact our help desk directly at 508.490.1020.

Tim Niesen

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Contributor: Christina LaCroix

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1 In this article, a program is defined as the organizational entity (such as a project management office) responsible for a product. The term project is defined as an iTracker entity to be used by a group of people who work together to create a product.

2 Change Request (initial caps) is the tool’s name. Lowercase change request is an individual change request handled by the tool.
Congratulation to Raytheon technologists from all over the world. We would like to acknowledge international patents issued from June 2008 through August 2008. These inventors are responsible for keeping the company on the cutting edge, and we salute their innovation and contributions.

Titles are those on the U.S.-filed patents; actual titles on foreign counterparts are sometimes modified and not recorded. While we strive to list current international patents, many foreign patents issue much later than the corresponding U.S. patents and may not yet be reflected.

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CLIFTON QUAN
RAQUEL Z. ROKOSKY
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