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Raytheon's Culture of Innovation Providing Leading-Edge Customer Solutions



Raytheon

Customer Success Is Our Mission



Raytheon's Innovations in Sensor Systems

Raytheon has a long history of applying and integrating innovations to produce world-class sensor solutions for our customers. One area where this is readily apparent is in our state-of-the-art systems. Today's sensor systems have become more capable, affordable and reliable through an evolution fueled by constant and consistent innovation. For example, systems such as the Cobra Dane and Pave Paws radar systems were leading-edge radar sensors when developed 30 years ago, and with 21st-century enhancements, these early-warning systems continue to play a key role in missile defense.

Numerous innovations are required to realize each of these systems. During World War II, radar systems were enabled by innovations such as mass production of the magnetron, which Raytheon pioneered in the 1940s. Future sensor systems will benefit from some innovative new technologies:

- Gallium nitride (GaN), which will provide radio frequency (RF) sensors with increased power and advanced capabilities, where needed
- Compound Semiconductor Materials on Silicon (COSMOS) to achieve revolutionary semiconductor performance
- Advanced electro-optical (EO)/infrared (IR) detection and imaging devices for applications in the x-ray, visible, infrared, terahertz and millimeter-wave regions of the electromagnetic spectrum
- Advanced materials and mechanical structures that not only provide support and environmental protection, but also remove heat, all while maintaining the critical tolerances necessary for optimal performance
- Supercomputing technologies that execute advanced signal processing algorithms
- Systems that maintain the nanosecond timing tolerances required for success

This wealth of experience and portfolio of technologies enable Raytheon to provide solutions that are scalable, affordable, reliable and highly capable in response to our customers' operational needs.

Four of Raytheon's state-of-the-art complex sensor systems are described below:

- AN/APG-79 AESA, which makes the U.S. Navy's F/A-18 E/F Super Hornet more lethal and less vulnerable
- X-Band Radar, the largest, most sophisticated phased array, electro-mechanically steered X-band radar in the world
- SPY-3, the U.S. Navy's first shipboard active phased array multifunction radar
- ARTEMIS, a sophisticated hyperspectral imaging sensor that was designed and built in less than 15 months

AN/APG-79 AESA Radar System

The AN/APG-79 AESA radar system is a significant advance in airborne radar technology. Entirely new — from front-end array to back-end processor and operational software — the system substantially increases the power of the U.S. Navy's F/A-18 E/F Super Hornet, making it more lethal and less vulnerable than ever before.

With its active electronic beam scanning, which allows the radar beam to be rapidly steered as it searches the surrounding airspace, the APG-79 optimizes situational awareness and provides superior air-to-air and air-to-ground capability. The agile beam enables the radar's air-to-air and air-to-ground modes to interleave in near-real time, so that pilot and crew can use both modes simultaneously, an unprecedented technological leap.

Now in flight test with the Navy, the APG-79 demonstrates reliability, image resolution, and targeting-and-tracking range signifi-

cantly greater than that of the current F/A-18 radar. With its open systems architecture and compact, commercial-off-the-shelf (COTS) parts, it delivers dramatically increased capability in a smaller, lighter package. The array is composed of numerous solid-state transmit and receive modules to virtually eliminate mechanical breakdown. Other system components include an advanced receiver/exciter, ruggedized COTS processor, and power supplies.

X-Band Radar

The nine-story-high XBR is the world's largest X-band radar, weighing four million pounds. The sea-based X-band (SBX) platform that it sits on stands more than 250 feet and displaces more than 50,000 tons. It consists of a semi-submersible oil production platform, topped with the XBR. XBR is the primary payload on the semi-submersible platform supporting the Ground-Based Midcourse Defense phase of the Missile Defense Agency Ballistic Missile



Defense System. SBX's floating platform, a modified oil-drilling vessel, was designed for exceptional stability in high winds and storms. Measuring 240 feet wide and 390 feet long, the vessel includes a power plant, bridge and control rooms, living quarters, storage areas, and enough floor space and infrastructure to support the X-band radar.

The X-band radar itself, which sits on top of the floating platform, is the largest, most sophisticated phased array, electro-mechanically steered X-band radar in the world. It consists of thousands of elements driven by transmit/receive (T/R) modules. In the X-band radar, they provide the full fire control sensor functions for the Ground-Based Midcourse Defense system, including search, acquisition, tracking, discrimination and kill assessment.

Continued on page 8

Continued from page 7

SPY-3

The AN/SPY-3 Multi-Function Radar (MFR) is the U.S. Navy's first shipboard active phased array multifunction radar. It is an X-band active phased array radar designed to meet all horizon search and fire control requirements for the Navy in the 21st century. MFR is designed to detect the most advanced low-observable anti-ship cruise missile (ASCM) threats and support fire-control illumination requirements for the Evolved Sea Sparrow Missile, Standard Missiles, and future missiles that will be required to support engagement of the most stressing ASCMs. MFR combines the functions provided by more than five separate radars currently aboard Navy combatant ships and also supports new ship-design requirements for reduced radar cross-section, significantly reduced manning (no operators), and total ownership cost reduction.

The radar performs such functions as horizon search, limited above-the-horizon search, and fire control track and illumination. One of the most significant design features of the radar is to provide automatic detection, tracking and illumination of low-altitude threat missiles in the adverse environmental conditions routinely found in coastal waters.

SPY-3 uses three fixed-face arrays, each containing around 5,000 T/R elements. These elements are connected to T/R integrated multi-channel modules, each of which drives eight elements. Individual modules are designed to slide into the array structure and provide a high-conductivity thermal path to the cooling-array manifold without having any connection to the T/R module itself.

ARTEMIS

ARTEMIS is a sophisticated hyperspectral imaging sensor for the Operationally Responsive Space Office's flagship Tactical Satellite (TacSat) program. The U.S. Air Force selected Raytheon to research and develop the primary surveillance sensor for the TacSat-3 mission. This groundbreaking space sensor was designed and built in less than 15 months as a rapid development project.

ARTEMIS makes extensive use of COTS components and industry-standard interfaces to create an affordable, high-performance space-based surveillance option. It also realizes the operationally responsive space vision of fast, flexible launch and use capability.

As defined by the joint Operationally Responsive Space Office at Kirtland Air



ARTEMIS baffle mirror assembly

Force Base, N.M., the responsive space approach seeks to "assure space power focused on timely satisfaction of Joint Force Commanders' needs." Under one envisioned scenario, warehoused satellite components would be rapidly assembled, configured, and transported to nearby sites for quick launch into low Earth orbit — some 200 miles overhead. The TacSat-3 program will test the feasibility of launching a payload such as ARTEMIS within as few as seven days after receiving the request.

Once in orbit, ARTEMIS's quick-reaction optics will enable it to see otherwise hidden targets, such as disturbed earth.

When operated by a military commander in the field, ARTEMIS is able to provide data

ENGINEERING PROFILE



Katherine Herrick
Deputy to the
Technology
Director, RMS

A fresh face at Raytheon Missile Systems (RMS), Dr. Katherine Herrick arrived

in Tucson, Ariz., in April 2008 from Raytheon Integrated Defense Systems' Advanced Technology Directorate. She brought her extensive experience in cutting-edge RF semiconductor technology, but Herrick sees her current work as deputy to RMS' technical director as drawing less upon her background in solid state III-V devices, and more upon her experience as a yoga instructor and cellist.

"RMS is a bit like the human body, or an orchestra," Herrick said. "It's an extraordinarily complex system of systems that's capable of amazing performance, but you can't get the best out of it unless you view it holistically and determine the optimal way for its elements to work together in a dynamic environment.

"We work across RMS, and enterprise-wide, to develop strategic technology road maps at multiple levels, from basic technological innovation to Supply Chain to Business Development," she explained. "We evaluate capability gaps against internal technology investment efforts aimed at an array of technology solutions. What we bring into the equation is an integrative approach that treats RMS as a whole, preparing it for agility and success in a complex environment of

developing customer needs and technological possibilities."

After receiving her Ph.D. in 2000 and conducting post-doctoral work at the University of Michigan, Herrick joined the Advanced Technology Department at Raytheon RF Components with a focus on high-frequency semiconductor circuits and integrated arrays. After transferring to Raytheon IDS' Advanced Technology Directorate, Herrick led the capture of, and served as Raytheon's principal investigator for, the DARPA COSMOS (Compound Semiconductor Materials On Silicon) program. That effort, she recalled, was one of the most exciting and rewarding experiences of her professional career. "COSMOS truly enables a new paradigm in circuit design through the innovative

heterogeneous integration of semiconductors via direct epitaxial growth. It's easy to be passionate about your work when it's this transformational."

Herrick received the 2007 IDS President's Award as the driving force behind Raytheon's path-breaking COSMOS effort. Her other recent awards include: the 2008 Outstanding Young Engineer Award from the IEEE Microwave Theory and Techniques Society, 2008 RMS Technical Honors Award, and selection to the 2008 National Academy of Engineers Frontiers' of Engineering Symposium. Herrick has published more than 40 technical papers, and holds several patents in the areas of antennas, RF MEMS packaging, and microwave circuits.

in a user-friendly format, greatly reducing critical response times and enhancing battle assessment capabilities.

The Future of Sensor Systems

Raytheon continues technological advances that improve sensing capabilities at different wavelengths. As these sensors improve in performance with reductions in size and cost, wideband/multispectral/multiband sensors are becoming powerful, practical solutions for many applications. These sensors integrate multiple phenomenologies to exploit the unique characteristics of the target and environment, for improved performance against the most challenging targets in the most challenging environments.

Polarization: A natural discriminant.

Electromagnetic waves may be resolved into orthogonal oscillating electric fields. If there is a significant difference in the amplitude of one of the fields compared to the other, the light is said to be polarized. Polarization is of interest because manmade objects that contain sharp edges and flat surfaces tend to polarize light, while naturally occurring objects do not.

Multiband: Detection can be optimized by employing many segments of the spectrum. Targets appear different across the spectrum because of their composition. Components are designed to operate across a limited range of the spectrum, driven by system requirements and physical parameters. By using sensors that employ multiple portions of the spectrum, selected for the best sensor performance in that range, sensing can be optimized.

Multispectral: A color-based discriminant. Objects are not typically blackbodies — they emit or reflect some wavelengths preferentially to others. This is obvious in the visible, when we see the rich diversity of color in the world. We can far more easily separate objects from their surroundings in a color image than a black-and-white one. Yet we only sense three primary colors. All other sensed colors are mixtures of these. This is the idea of multispectral systems that are two or three infrared colors.

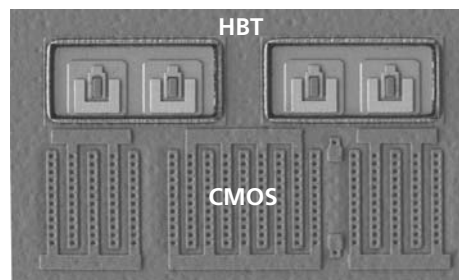
Hyperspectral: Exploring color as a multidimensional discriminant. Hyperspectral systems use tens to hundreds of colors at each pixel. Using this technology, we can identify individual chemicals through their line emissions. Thus, we can discriminate

painted vehicles from foliage, and even identify gas emission from factories or gas clouds. Raytheon has been a pioneer in this technology for space applications.

Wideband: System range resolution is driven by its operating bandwidth. Wideband is a relative term used to describe a broader range of operating frequencies enabled by the use of improved component designs.

Ultra-Wideband: Ultra-wideband yields higher range resolution. This is also a relative term used to describe a significantly broader frequency range; octaves or even decades wider in operating frequencies.

Under DARPA's COSMOS program, Raytheon offers the designer the "best junction for the function" without compromising the yield and scale of complementary metal oxide semiconductor (CMOS) or the speed and breakdown of compound semiconductors (CS). COSMOS's unique technology enables the micron-scale placement of CS (GaAs, InP, and eventually GaN) in arbitrary locations on a CMOS wafer, while maintaining co-planarity with the CMOS for simple, high yield, monolithic integration. This monolithic integration approach is akin to the move from hybrids to MMICs, which enabled compound semiconductor insertions into systems over the last decade. The figure below shows InP heterojunction bi-polar transistors (HBT) integrated onto a silicon-on-lattice engineered substrate to enable InP performance while maintaining CMOS affordability.



Today's multifunction systems integrate sensing functions with communications and electronic warfare functions by sharing the aperture, processing and power to minimize weight, volume and total lifecycle costs.

Two additional constraints are also driving innovations in future sensor systems. First, the available surface area or volume on a platform may not accommodate multiple unique sensors, each optimized for a specific

application. Second, if platforms operate independently, this results in larger and more expensive sensor systems. Thus, the next generation of sensor systems will use the techniques described, to enable multiple simultaneous functions out of a common aperture and to operate as nodes in a network, sharing information with other sensors.

Sensor netting is a powerful capability that provides an interoperable plug-and-fight architecture with networked multimission sensors that are tasked by "mission managers." Acting as a network, the sensors can provide persistent surveillance while supporting multiple simultaneous missions. Additionally, network performance exceeds what is achievable by any individual sensor because multiple sensors are viewing objects from multiple angles and potentially with greater spectral diversity (RF, millimeter wave, terahertz, IR, visible regions, ultraviolet, etc.) to dramatically improve our ability to detect, track and identify objects. Raytheon is a world leader in sensor networking with products such as the Cooperative Engagement Capability (CEC), deployed by the U.S. Navy, and the Tactical Component Network (TCN) which provides a bandwidth-efficient composite tracking capability.

Summary

The four systems described in this article are examples of how Raytheon's culture of innovation has resulted in providing unmatched capabilities for our customers and warfighters. As we address next-generation systems, we continue to extend the performance envelope while reducing cost and increasing reliability. Raytheon is extending its technological expertise and integration skills to provide key sensor technologies in a joint environment: joint in the sense of the services working together, joint in the sense of space, air, surface and subsurface, and joint in the sense of allies working together. We are developing the architecture, the connectivity, the software, the sensors and the electronics to help choreograph how today's joint task force commanders integrate and employ their assets. ●

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