Technology Today

HIGHLIGHTING RAYTHEON'S TECHNOLOGY

2007 Issue 4

Raytheon's University Relations Program

Collaborative Research to Advance State-of-the-Art Technologies for Our Customers

Raytheon

Customer Success Is Our Mission

A Message From Dr. Taylor W. Lawrence

Vice President of Engineering, Technology and Mission Assurance

Technology companies like Raytheon thrive on close partnerships with academia. For Raytheon, these partnerships are a source of innovation, discoveries and most importantly our people — the lifeblood of the company.

University research laboratories contribute valuable outside perspectives and approaches in solving difficult problems our customers face. Their applied research can provide immediate benefits to Raytheon programs and pursuits, while their basic research can provide disruptive innovations through the exploration of new frontiers.

This University Research issue of *Technology Today* leads off with an overview of Raytheon's university programs to develop new technologies and talent. This largest issue of the year highlights ongoing research activities with eight of our university partners — projects that are providing breakthroughs in our core market technologies and our enterprise research and development projects.

You'll also read about Raytheon's MathMovesU™ initiative which is evolving to further engage middle school students who will become a new generation of university graduates and researchers.

In this issue's Leaders Corner, Dick Johnston, vice president of corporate Operations, discusses his function's role in the company's success and how it collaborates across the enterprise to tackle important challenges like transition to production, utilization and energy conservation.

Lastly, I would like to thank the entire ET&MA community for their many contributions in 2007. We can be proud of improving the way we innovate, reaping the first fruits of our Enabling Technology Projects, celebrating our world-class people and embracing stewardship as never before. In the year ahead, I look forward to building on the groundwork we laid in 2007.

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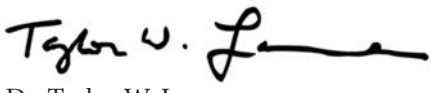
Until next time …



Dr. Taylor W. Lawrence

Do you have an idea for an article?

We are always looking for ways to connect with you — our Engineering, Technology and Mission Assurance professionals. If you have an article or an idea for an article regarding technical achievements, customer solutions, relationships, Mission Assurance, etc., send it along. If your topic aligns with a future issue of *Technology Today* or is appropriate for an online article, we will be happy to consider it and will contact you for more information.

Send your article ideas to techtodayeditor@raytheon.com.

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INSIDE THIS ISSUE

EDITOR'S NOTE

As I reflect on Raytheon's success in 2007, the depth and breadth of knowledge and expertise of our engineering community is nothing short of inspiring. That's not by accident — Raytheon continually recruits the best and brightest talent while fostering strategic relationships with colleges and universities to develop innovative, cutting-edge technologies.

This issue, featuring Raytheon's University Research Program, highlights some of the next-generation technologies currently in development by Raytheon and their university partners like secure geospatial semantic Webs, advanced lightweight, high-temperature missile airframes and shape memory polymers, to name a few. This groundbreaking research is helping to pave the way for future technologies to become a reality for our customers and our world.

Enjoy!

Lee Ann

Lee Ann Sousa

University Relations at Raytheon

Helping to Develop Talent and Technologies

Photo courtesy Georgia Tech

Research and Membership

To stay on top of the aerospace industry, Raytheon must continually develop new talent, technologies and business opportunities. From a talent perspective, Raytheon hopes to increase the interest young people have for the math and science fields through innovative programs like MathMovesU™.

Our aim through research and technical memberships is to find specialized talent, provide educational opportunities for Raytheon employees, and enable access to key laboratories to conduct research in areas critical to our technology needs.

The Engineering University Relations Program and Enterprise University Programs organization in corporate Human Resources work together to ensure the collaboration of research and recruiting needs for Raytheon. The University Relations Program provides funding to universities across the nation, allowing professors, students and Raytheon engineers to work together on specific projects that advance state-of-the-art products for future customers.

The *Technology Today* feature for this quarter highlights some of our ongoing research activities at eight strategic schools. Currently, there are 27 research projects underway at 24 universities, but space limitations prevent us from including all projects in this issue.

This program has been active at Raytheon since 1998. Since that time, 289 projects have been funded at 81 schools working with engineers within Raytheon's businesses.

University Technical Memberships allow Raytheon engineers to work with professors and other industry partners in consortia relationships to collaborate on common issues facing government and industries.

Recruiting at Universities and Colleges

Raytheon created an initial framework for college recruiting by defining a vision, objectives and strategies. Acquiring entry-level talent from recent college graduate pools demands a very different approach. The "filling the empty chair" recruiting approach, which is common for recruiting more experienced professionals, simply won't do.

A much longer talent acquisition cycle is needed when planning for entry-level hiring. Needs in August cause us to target the very best graduating seniors during the fall semester. Many candidates will not be available until the following spring or summer.

The ensuing vision was one that included strategic alignment with businesses and a long-term focus for building the workforce of the future. Raytheon sought to have a program that was stable from year-to-year and used its line resources in a partnership with the

businesses to assist with campus recruiting. It also wanted to maintain an equitable level of quality and diversity in hires, and build synergy with other university relationships centered around technical memberships, research, grants and donations. University programs chartered a centralized infrastructure and developed key roles for business representatives.

The university programs (UP) organization establishes a One Company approach, enterprisewide branding, and processes that are common across the company. As a result, Raytheon fundamentally looks, sounds, and conducts itself the same at the University of Washington as it does at the University of Florida, or any of the more than 100 schools where it recruits. UP comprises three regions, each with a manager and scheduling coordinator assigned to manage the relationships and campus teams at colleges and universities within his/her region. UP also assigns a campus manager from the line organization, whose primary role is to lead each campus recruiting team. Campus managers understand and exploit the unique opportunities at that school to drive student and faculty recognition of Raytheon's opportunities. Raytheon identified 25 "strategic schools" and is committed to building long-term, strategic relationships with these selected university partners in four key areas: recruitment, education, diversity and technology development. UP then assigned a senior leader to serve as a "campus executive" to drive the development of these four key areas.

Recruitment is rather straightforward. Raytheon provides experiential learning opportunities to students through co-op/intern assignments. Hiring these graduates in entry-level positions helps build the life blood of the company's future workforce.

Raytheon partners with universities on education to ensure that course work continues to meet their needs. This is accomplished in part by actively participating on curriculum advisory and industrial affiliate boards for critical disciplines, and enthusiastically sponsoring campus student groups and outreach programs. Raytheon employees serve as guest lecturers, technical seminar leaders and adjunct professors. Universities, in turn, contribute to the continuous learning environment of Raytheon via advanced degrees and courses that keep engineers technically current.

A diverse and inclusive culture gives Raytheon a definite competitive advantage. Our company consistently performs beyond all expectations by recognizing the uniqueness of each individual, empowering one another, and truly valuing one another's input. In short, it's right for people, and it's right for business. We make diversity an element of everything we do to recruit — from selecting the schools where we recruit, to the activities and relationships that we develop.

Raytheon funds research grants that match our business needs and technology development road maps. We also team with schools in pursuit of new business opportunities, which enable us to continue to develop technology to support our customers and enrich us all with an exchange of ideas.

It's through these key initiatives that Raytheon will continue to develop talent, as well as grow new businesses and technologies within the aerospace industry. We hope you enjoy the research detailed in this issue. ●

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Some of Raytheon's Additional University Relationships and Projects	Raytheon Point of Contact
Cal Berkeley (Berkeley Sensors & Actuator)	Carl Kirkconnell
Cal Poly (Direction of Arrival Estimation using PRIME Algorithm)	Thomas W. Miller
Cal Poly (SAR ATR)	Jeffrey Hoffner
Cornell University (High Temperature Dielectrics for GaN-based mm-Wave HEMTs)	Eduardo Chumbes
University of California (Development of Wide Bandwidth Push-Pull Amplifier Modules)	Robert Leoni
University of Colorado (Unmanned Vehicle Management and Control)	Mark H. Johnson
University of Florida (Center for High Performance Reconfigurable Computing)	Sam Estess/Rich Crowley
University of South Florida (Wireless and Microwave Information Systems Center)	Al Nauda
Indiana/Purdue University (C3I Domain Knowledge Capture and Representation)	James L. Jacobs
University of Maryland (CALCE Super Membership)	Bill Rollins, Anthony Rafanelli
Massachusetts Institute of Technology (Soldier Nanotechnology)	Tim Imholt
University of Massachusetts (Quantum Dot/Polymer Based IR Detectors)	Mark Meisner
Ohio State (USA Satellite Cons, RF Arrays)	Yeuh-Chi Chang/Robert Yaccarino
Ohio State (Electromagnetic Range)	Jacob Kim
Ohio State (Connection One)	Billy Saeki
University of Rochester (Optics Center)	Todd Johnson/Clayton Shannon
Stanford University (Stanford Photonics Research Center)	Richard Ackerman
Virginia Tech (Mobile Portable Radio Group)	Steve Seidel/Martt Harding

The Georgia Institute of Technology

Raytheon and the Georgia Institute of Technology have collaborated for many years. Our relationship with Georgia Tech is beneficial for several reasons.

First, it provides Raytheon with advanced research — theoretical and applied — toward improving our systems for the defense and commerce of our country. Second, we are able to attract very capable graduate candidates with relevant experience in our areas of need. Finally, we are able to participate in the university's industrial advisory boards, giving us firsthand access to both students and professors.

The Georgia Institute of Technology research, funded by Raytheon, spans a variety of advanced topics covering RF packaging, RF devices, cryogenic cooling and memory materials. Raytheon also has a very productive relationship with the Georgia Tech Research Institute, which supports numerous Missile Defense Agency and Department of Defense programs.

The research in advanced packaging is focused on improving the cost and performance of RF circuits for our sensor products. The advanced RF devices research supplements our development of new materials to improve power and efficiency. Research in the miniaturization of cryogenic cooling is an important step in improving a broad class of optical and electronic circuit assemblies. Finally, the research in memory materials provides Raytheon with firsthand insight into a new class of reconfigurable mechanical assemblies that may revolutionize the way we design and build everything from missiles to robots. ●

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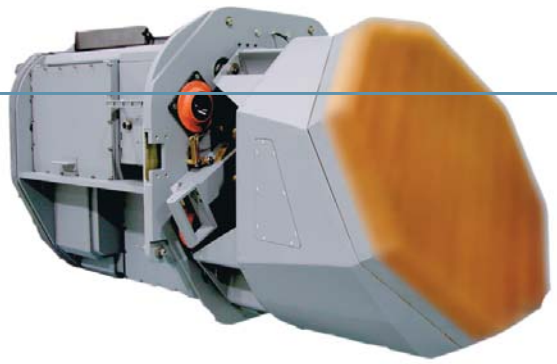
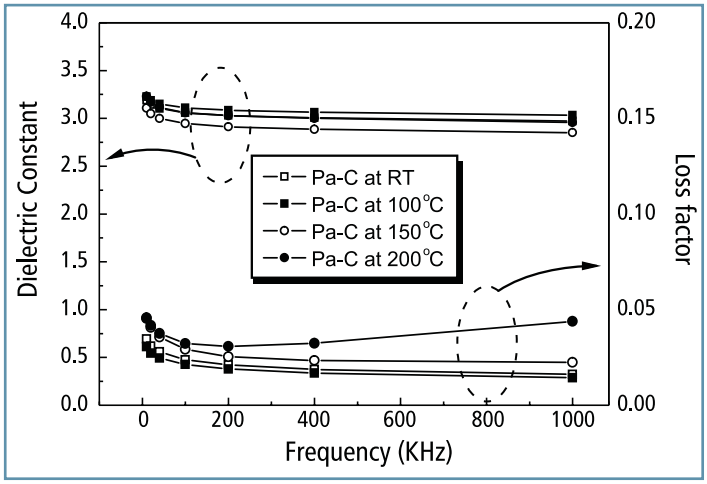


Coatings for Module-less AESA Applications

The elimination of hermetic enclosures for transmit/receive modules can substantially reduce system cost and weight, and enable high-frequency performance for module-less Active Electronically Scanned Array (AESA) and other microelectronic applications. The elimination of hermetic enclosures requires the development of coatings at the device, assembly and/or system level. The coatings must demonstrate good electrical and environmental performance and be compatible with assembly processes. A number of candidate coating materials have been evaluated independently and in conjunction with other materials. Parylene materials are frequently used where dielectric and conformal coating materials are required to have high dielectric strength, a low dissipation factor and a low dielectric constant.



Parylene N is primarily used as a dielectric; parylene C is used where low permeability to moisture and corrosive gases are required; parylene D can be used where slightly higher operation temperatures are required; and parylene F is used where UV and high temperature stability (up to 450-500°C) are required. Parylene F also has a lower dielectric constant than parylene N, C and D (2.3-2.4). Due to the uniqueness of the vapor phase deposition, the parylene polymers can be formed as structurally continuous films from several hundred angstroms to 75 microns in thickness.

When vapor is deposited, these materials produce (1) quality conformal coatings for circuit board assemblies for protection against moisture and corrosive environments; (2) surface passivation and environmental protection of semiconductor devices; and (3) conformal coatings for biomedical device electrical insulation requirements.

The typical parylene deposition processes for parylene N is as follows. The [2,2] paracyclophane dimmer is transformed into para-xylylene monomer at ~650°C and 0.5 torr. Poly [para-xylylene] is deposited at 25°C and 0.1 torr. Therefore, the parylene deposition process is room temperature and solvent-free, which is a very attractive encapsulation and interlayer dielectric materials and process, especially for temperature-sensitive, low glass transition temperature substrate materials.

Adhesion in parylene coatings is frequently problematic for several reasons. Due to the non-polar nature of these materials, often, they do not adhere well to inorganic substrate materials. This problem is evident when using these materials to passivate polar substrates such as SiO_2 and Si_3N_4. Adhesion problems between polymer films and substrate materials become even more significant when fluorinated materials such as parylene F are used as low dielectric passivation layers. Even when using silane coupling agents as adhesion promoters, adhesion problems are encountered, especially when coating with parylene F. New methods and techniques are needed to improve adhesion of these polymers to substrate materials and ensure long-term environmental protection.

Substantial progress has been made with respect to the intended objectives of this project. Specific accomplishments include:

1. Development and application of a quantitative adhesion measurement technique for testing the adhesion of thin polymer films
2. Surface chemistry studies resulting in identification and improvement of fundamental adhesion mechanisms for parylene
3. Determination of the influence of deposition materials and techniques on parylene adhesion before and after exposure to accelerated humidity conditions
4. Characterization of dielectric loss and constant versus frequency, before and after exposure to humidity.

Surface chemistry studies resulted in the development of a surface bonding model. X-ray photoelectron spectroscopy was used to identify the chemically bound interfaces and to develop a novel and improved adhesion promoter. Long-term environmental characterization was completed and demonstrated an adhesion promoter and coating process that did not degrade in extended humidity testing. Characterization of RF properties of parylene is continuing. ●

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Alternative Dielectrics for GaN HEMTs

Gallium nitride-based transistors are actively being pursued as power devices for high-power electronic systems. As a wide bandgap semiconductor, GaN can operate at much higher voltages than standard GaAs or Si transistors. The higher voltage and high currents allow GaN to provide five to 10 times the power density of traditional GaAs-based technologies with similar efficiencies.

This higher level of power performance will enable improved sensitivity for future state-of-the-art radars. Substantial development efforts at Raytheon RF Components (RRFC) have produced devices with excellent RF performance and industry-leading reliability. The process is currently being transitioned to production at RRFC.

The unique nature of GaN-based technologies provides substantial challenges to realizing the full potential of the devices. The strong polarization effects that provide the active charge make these devices particularly sensitive to both surface effects and the local stress fields in the device. To further improve the performance and reliability of next-generation GaN devices, Professor Brent Wagner at the Georgia Tech Research Institute is developing alternative passivation layers using an ion-assisted physical vapor deposition (IAD) in a commercially available deposition system.

The technique can deposit dielectrics with minimal heat loading of the substrate or at higher temperatures by heating the sample, which can be used to control the strain induced by the deposition. IAD has been used to deposit a wide variety of materials, including oxides (such as SiO_2, SiON, SiO_x, Al_2O_3, $SiAlO_x$ Y_2O_3, TiO_2, $Ta_2Zn_3O_8$, $BaTa_2O_6$, Ta_2O_5) and nitrides (such as SiN, AlN, BN), which allows for a wide variety of possible passivations to be tested. By tailoring the material, as well as the deposition conditions, Prof. Wagner and the team at RRFC will be optimizing these unique passivations to enhance performance and reliability for the next generation of higher voltage GaN devices. ●

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Development of LCP-Compatible System on Package With Integrated RF Passives and Actives

The primary objective of the Raytheon-funded Georgia Tech University Program is to explore the performance of liquid crystal polymer (LCP) as the next-generation organic material for application ranges from 2 to 75 GHz, where conventional low-cost organic materials such as epoxies and polyimides do not perform.

The key advantages of LCP, in comparison to other microwave organic dielectrics, are low loss (tan = 0.002-0.005) up to mm-wave frequency range, near hermetic nature (water absorption < 0.04%), lower cost ($5–$7/sq. ft.), and a coefficient of thermal expansion that can be matched closely to silicon or GaAs, as well as printed wiring board materials. LCP is also a flexible material which allows for the realization of conformal RF modules in non-orthogonal and non-planar surfaces. In addition, multilayer circuits are possible with LCP due to two types of LCP material with different melting temperatures. Thus, vertically integrated designs may be realized, increasing the functionality and space savings.

Nevertheless, there are numerous issues in processing LCP multilayer structures — and most have not been resolved yet for successful commercialization of the LCP materials for multilayer 3-D structures. This effort is uniquely positioned to address the design, simulation and fabrication of multilayer LCP structures which would perform in the wide frequency domain from X-band to W-band. It is also a strategic effort in that it may trigger early marketing opportunities through a collaborative teaming effort between the School of Electrical and Computer Engineering at Georgia Tech and Raytheon.

The breadth of work completed by the Georgia Tech team specifically centers around: 1) the RF design, simulation, characterization and processing of single layer LCP; 2) the deposition of thin resistive layer on LCP by laminated foil transfer process, as well by direct electroless plating, surface activation for bonding to copper with good peel strength; and 3) the transition from one layer LCP to three layers LCP with embedded resistors, attenuators, power dividers and MMICs encompassing X, Ka, V and W bands.

Below is a summary of some key accomplishments that can be adopted into manufacturing.

- Design of Wilkinson power dividers from X to W Band
- Design, simulation and measurement of resistors on LCP up to 40 GHz
- Electroless plating of copper on LCP with good peel strength
- Surface activation of LCP with plasma for good LCP/Cu bonding
- Electroless plated thin film resistors on LCP with good adhesion
- Integration of MMICs

The fabrication of multilayer prototypes encompassing electroless plated thin film resistors; Wilkinson Power Dividers in X, Ka, V and W-bands; laser ablated vias; metallization through electroless; and electroplated copper are currently in progress. Once completed, this potentially would be the first-time accomplishment of multilayer LCP laminated 3-D package with embedded RF components performing up to 70 GHz application domain.

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Miniaturization of Pulse Tube Refrigeration Systems

Pulse tube cryocoolers (PTC) are well known as rugged and reliable cryogenic coolers for many military applications, primarily focal plane cooling for space-based and tactical infrared sensors. The miniaturization of pulse tube cryocoolers is of great interest to reduce overall sensor mass and volume.

Low-cost, very small PTCs utilizing micro electro-mechanical systems (MEMS) fabrication techniques have been conceptualized, which could broaden applicability to envelope a host of other applications, such as personal computer processor cooling. However, there are numerous known significant challenges complicating their miniaturization, including:

- **Surface friction.** The surface-to-volume ratio increases with miniaturization, rendering surface effects more prominent.
- **Thermal effects caused by large temperature gradients.** Strong axial heat conduction in the solid structures may provide for direct heat transfer between hot and cold ends of the pulse tube, decreasing PTC performance.
- **Periodic flow in miniature components.** For the pulse tube cooler to function, the thermal boundary layers that form periodically must remain thin in comparison with component diameters. It is also necessary that periodic gas displacements are small in comparison with component lengths. These restrictions will require very high frequency operation for miniaturized PTCs.

Improved analysis techniques are required to quantify these effects. Georgia Tech is approaching the problem in two phases. First, existing one-dimensional cryocooler system design models are going to be exercised at progressively smaller physical scales to obtain estimates of the potential performance characteristics of miniature PTCs. The expectation is that these results will be increasingly inaccurate as size is reduced, because the macro empiricisms upon which they are based break down. Thus, the second phase will employ full-blown computation fluid dynamics (CFD), which can fully and accurately represent the physics of the problem down to very small (micron) scales. The CFD models are expected to provide the design parameters for future experimental reduction to practice of a miniature PTC. In addition, a comparison of the CFD results to the one-dimensional model results is expected to provide a strong indication of the sizes at which the miniaturization effects described above become prominent relative to the overall system losses.

At present, the one-dimensional modeling work has been completed. The results indicate excellent performance is possible for PTCs with characteristic working dimensions in the sub-millimeter range — but as previously stated, these results are suspect. The CFD phase of the modeling recently commenced. We expect the CFD results to provide a much more accurate picture of what is possible with miniature PTC technology, and point us in the right direction regarding how to best realize that potential. ●

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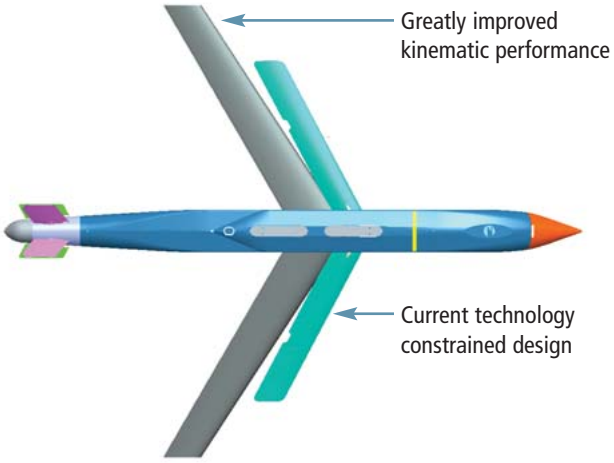
Dr. Carl Kirkconnell is a nationally recognized expert in cryogenics and thermodynamic optimization of space systems. Currently, he is the product line manager for Raytheon Space Cryocoolers. In this capacity, Kirkconnell leads all major initiatives within the product line, including the manufacture of long-life cryocoolers, the development of high capacity Stirling/pulse tube hybrid cryocoolers for Air Force Research Lab, and several university research programs.

Kirkconnell has extensive experience working with Stirling, pulse tube, Joule-Thompson, Gifford-McMahon and various hybrid cryocooler systems. He was the lead track sensor thermal engineer and cryogenic system integration lead on the SBIRS (Space Based Infrared System) Low Flight Demonstration System. He was also the lead cryogenics engineer and thermal system designer for the Joule-Thompson cryogenic cooling system on the Exo-Atmospheric Kill Vehicle (EKV). More recently, he served as technical director for two mission-critical programs: a Stirling cryocooler program and the experimental demonstration of a two-stage turbo Brayton cryocooler.

Kirkconnell received a doctorate in mechanical engineering from the Georgia Institute of Technology in 1995.

Shape Memory Polymer Characterization
for Advanced Air Vehicle Technologies

As Raytheon customer needs have evolved in recent years, the dividing lines between "missile" and "UAV" (unmanned aerial vehicle) have begun to blur. There is a growing interest in missiles that can perform UAV-like missions before reaching the target, as well as a demand for both missiles and tube-launched UAVs that have range and endurance efficiencies on par with conventional aircraft. In other cases, multispeed air vehicles are needed to perform advanced missions — something that may require morphing airframes. But these advanced missions all require large increases in wing area, and this poses a challenge for missiles and tube-launched UAVs.



Next-generation subsonic missiles and tube-launched UAVs will need more than twice the wing area found on conventional missiles.

Large-scale morphing tail fins would make commercial aircraft more fuel efficient, and would also make takeoffs and landings for passenger aircraft safer.

Lack of room to stow adequate wing area has meant that conventional missiles and tube-launched air vehicles have historically been "under winged" relative to conventional aircraft. To match the performance of conventional aircraft, the subsonic missile wing area must more than double, yet these larger wings must stow with about the same weight and volume as the existing wings. It will also be necessary to build ailerons into these larger wings for flight control. Realizing such highly compact, stowable wings will require advanced material systems and actuators that are not yet commercially available.

One way of providing highly compact, stowable wing structures, which may also morph, is to use shape memory polymer (SMP) and shape memory polymer foam (SMF) nanocomposites. SMP and SMF nanocomposites are an emerging class of materials with potentially broad applications in both aerospace and biomedical technology. SMPs can theoretically tolerate extremely large strains over indefinite time frames without taking a permanent set. This will make it possible to fold up, compress or otherwise stow much larger wings in about the same volume that conventional missile and tube-launched UAV wings fit in. SMP and SMF nanocomposites are already enabling deployable space structures, by allowing large antenna dishes and similar structures to be folded into compact shapes, lifted into space, and then deployed to full size.

Raytheon is funding basic research at Georgia Institute of Technology to investigate and characterize SMP and SMF nanocomposites. Most currently available SMPs are heat activated. As such, the research at Georgia Tech has already uncovered essential aspects of heat-activated SMP-based materials, including key insights into proper material activation temperatures and a pioneering study of their mechanical failure. Novel, low-energy airframe heating systems for in-flight activation of SMP matrix composites are also under development.

SMP and SMF nanocomposites can provide flexible skin materials that could enable highly compact, stowable and morphing wings, helping to turn today's science fiction into tomorrow's reality. Ultimately, the resulting advances in airframe technology will not only improve the performance of military air vehicles, they will also improve the overall efficiency and safety of commercial aircraft by allowing them to morph into safer, more efficient shapes during takeoff and landing. ●

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Contributor: Ken Gall (Georgia Tech)

Pennsylvania State University

Penn State University has a long history in information fusion research focused on the human and cognitive aspects. They are a key partner in the DoD-sponsored National Center for Multisource Information Fusion Research led by the Calspan-University at Buffalo Research Center.

Dr. David Hall, associate dean for Research at Penn State's College of Information Sciences and Technology, and Dr. James Llinas, director of University at Buffalo's Center for Multisource Information Fusion (CMIF), are founders in the field of multi-source data fusion and each have coauthored pioneering books on the subject.

Their work focuses on basic and applied research which results in the creation of advanced information fusion-based tools and systems. These tools and systems can be applied across a number of application domains, including defense, intelligence, homeland security and medical informatics. The Penn State-University at Buffalo team leads the only academic center among all U.S. universities conducting integrated, coordinated research on information fusion for defense and military applications. ●

ENGINEERING PROFILE

Alexander Nauda
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Dr. Al Nauda is an Engineering fellow at Raytheon Network Centric Systems in St. Petersburg, Fla. He facilitates technology planning, coordinates university interaction on advanced technology initiatives, supports strategic proposal efforts, manages the Independent Research and Development program, and serves as the Patent Committee chair.

Nauda has been at Raytheon or its legacy companies for 27 years, beginning as a part-time systems engineer while teaching at Penn State University. He has written over 40 papers on digital signal processing, systems analysis, modeling and simulation, and technology management and communication. A registered professional engineer, he has consulted for Singer, NASA, Alcoa, PPG Industries and the Technology Training Corporation. Nauda has taught signal processing, communication theory, and circuit and systems engineering at Bucknell University and Penn State University.

Nauda received his doctorate in electrical engineering from the University of Pittsburgh in 1977.

GeoDiscoverer: A Search Engine to Integrate Social Networks With Geospatial Information

Part of the focus of the ongoing Raytheon Intelligence and Information Systems research program in Knowledge Management and Knowledge Discovery is developing new ways to enhance exploitation of unstructured text data. One of the research program's goals is to team with academia to provide cutting-edge research supporting various aspects of text data enrichment.

One such activity involving Pennsylvania State University combined the disciplines of information sciences and geographic visualization to automatically discover and display social network information that is embedded in text documents. The principal investigators from Penn State are the College of Information Science and Technology's Dr. Lee Giles, an ACM fellow who directs the CiteSeer search engine project (http://citeseer.ist.psu.edu/), and the College of Earth and Mineral Sciences' Dr. Alan MacEachren, the director of the North-East Visual Analytics Center (http://www.geovista.psu.edu/NEVAC/index.html), which is part of the NVAC consortium led by the Pacific Northwest National Laboratory.

Combining and integrating social network discovery techniques with geographic information retrieval, indexing and visualization techniques will enable the discovery of new location-based social networks. Such methods can reveal more of the semantic structure of social networks enhanced by the topology of communication. By crawling the Web of communicated messages (or documents) or using Web logs of people, geospatial information and their relationships, significant and novel social connections and their geographic patterns can be discovered.

A core goal for the GeoDiscoverer application is to develop and implement search methods for collecting and recognizing information about people, geospatial contents and purposes from a message pool, using the CiteSeer search engine as a platform of testing. It enables geo-referencing and mapping of social networks and their geo-semantics using visual-analytics tools that support knowledge analysts' efforts to discover new evidence of social interactions and their geographic characteristics.

The CiteSeer search engine has a large collection of academic documents obtained from the Web using an automatic crawler. A tool has been developed for segmenting, recognizing and disambiguating the text in these documents into meaningful author profiles. Geospatial information is then extracted from these author profiles and ingested into a newly-developed, Web map services-based visualization tool. CiteSeer can be considered a data gather that acquires data based on a need-to-know basis. The CiteSeer data is a good analog for a range of other real-world data; data included are flawed and imperfect, like that obtained from search engines such as Google and Yahoo. Dates of acquisition for publications, for example, should be interpreted as found dates, not dates of publication.

The tool developed for author profiling consists of several components, including (1) header segmentation; (2) refined field recognition; and (3) disambiguation. For header segmentation, an easy and fast tool based on keyword match and heuristic rules has been implemented. Heuristics are used to determine tokenizing and extraction points in the text, where such terms as "introduction," "abstract," "keywords," etc. denote important text structure. For refined field recognition, the headers are segmented into fields to fill in the predefined ontology of documents and authors. A typical author ontology includes individuals' names, affiliations, addresses, etc. Several support vector machine (SVM) classifiers are trained from the part-of-speech tags provided by a natural language processing (NLP) software component, word text features, position features, surrounding text features, etc. The classifiers determine whether a word is within the boundary of a field and which field that is, yielding the mapping between the text pieces and the predefined ontology fields.

The fields obtained so far can be very ambiguous, especially for the author names. We have developed various methods for author disambiguation. On the disambiguated text fields, we run a regular expression recognizer to extract e-mails and zip codes, which are later used for visualization.

To support analysis of the retrieved and extracted information, we are developing and implementing client-server, Web services-based tools that support the application of geovisual analytics strategies to analysis and presentation. The methods incorporate a particular focus on handling the complex interactions among place, time, person, organization and attribute components of information as these relate to social networks of interest.

The parts of GeoDiscover directed to analysis of information extracted from CiteSeer by the methods discussed above build upon on a range of open source and (for the geospatial information) Open Geospatial Consortium–compliant tools and methods. In particular, the multilayer base maps displayed in the interface are generated with a Web-map service (WMS) request and the filtered publications that are drawn on the client are accessed with a Web-feature service (WFS) request.

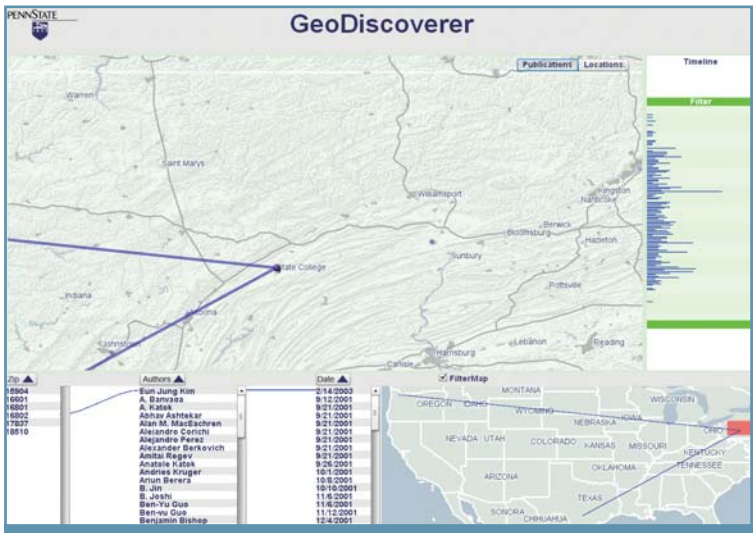
WFS filters are also used extensively to query the geographic data based upon user selections. For example, identifying locations of all co-authors for individuals at any location selected on the map is supported through WFS filter requests. Geographic data of various kinds can be integrated into the Web client view using Geoserver and Mapserver WMS and WFS requests. Postgresql/PostGIS is used to store local geographic data and MySQL is used as the backend database for the CiteSeer author/publication data.

The focus of the user interface and display components of the GeoDiscover application is on presenting and exploring cross-connections for the author networks in a geographical-temporal context. The functionality being implemented in the GeoDiscover application includes:

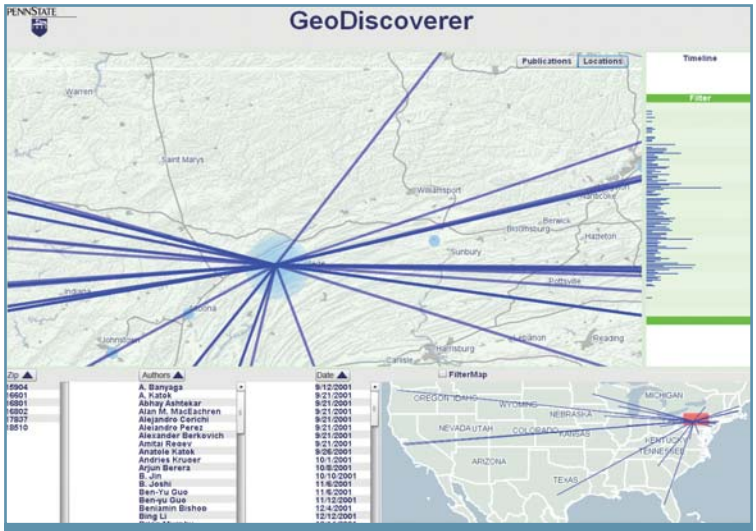
- Geographic coordinate retrieval for locations extracted from documents. The initial implementation is focused on zip codes for places in the United States, but is being extended to support text-geography matching using a gazetteer approach implemented to be flexible on the source of geographic names information.
- Display of overview information in linked map and table forms. The tables include the following information extracted as outlined above: location (zip codes in the example shown), author names and publication dates.
- Compound filtering on data subsets and multiple forms of result display. Filtering can be on place, person or time.

The following analysis scenario illustrates a subset of developed tool functionality:

An analyst is interested in determining when a particular individual has published one or more documents. Her goal is to determine when others had access to the information, thus when it had the potential to make an impact. To pose this question, she simply scrolls to the author name, clicks on it, and views a display of publication dates associated with this author (reference top Figure). If she is interested in a particular publication, she can click on it to determine (by highlighting in the list) who the co-authors are and (by viewing the map) where the co-authors are in relation to the main author.



The user drills down to individual publications by clicking on the Author list. Connections are displayed between lists for that author's location and publication dates. By filtering the map to show individual publications and then clicking the desired publication, the user can see the geographic connections between the lead author of that publication and all collaborators at different locations (in this case there is one collaborator). The inset map zooms to an extent that includes all relevant locations.



The user selects the Locations layer to display a map with graduated symbols showing total publication counts at each location. By clicking on the desired location, geographic connections between lead authors at the location and all remote collaborators with those authors are displayed on both the detail map and the overview map.

A second analyst notices a series of publications of interest being generated from one institution/location. He is curious about who the authors are collaborating with. To find out, he uses the geographic view into the data and selects a place by clicking its location on the map (reference bottom Figure). The map display shows the number of publications (represented by circle size) and the locations of all collaborators from other locations (shown in both the main map and context map with the lines emanating from the selected location).

For future work, we intend to perform other intelligent analysis of the text document data with special focus on the author social networks. First, we will investigate the temporal dimensions in addition to the geographical locations in the distribution of documents and authors. We will use and propose topic analysis techniques on CiteSeer documents to show how topics and actors move over time. We will also examine how the underlying social networks correlate with the observed movements of topics covered in papers. These correlations will be modeled using statistical learning techniques (e.g., Bayesian networks). Social networks of entities at different levels will be studied including authors, conferences and institutes.

Finally, we propose to evaluate the importance of authors and their documents based on their heterogeneous relationships. CiteSeer has used citation counts for ranking documents and accumulated citation counts for ranking authors. This ranking method can be undermined due to the lack of domain categorization and insufficient considerations of social networks. We intend to improve the ranking in CiteSeer by combining the various topological relationships among those entities. As a result, we can discover the major players with respect to certain topics in the social network embedded in the document space. This will enable us to see the flow of topics and authors in geospace describing what topics are created, which authors are prominent and how a discipline changes over time. ●

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Transforming Data Into Knowledge: The Use of Advanced Visualization and Cognitive Aids to Support Improved Level 2 and Level 3 Data Fusion

In today's modern battlefield environment, commanders and warfighters have become inundated with vast amounts of unprocessed data from large arrays of sensors and remote data sources. This ever-increasing load of tactical and operational data creates a stressful operator environment that can significantly reduce effective decision making.

A comprehensive computational process is required for the management, processing, distribution and visualization of this information. This process is called data fusion — the integration of information from multiple sources, the management of information and knowledge derived from the aggregated data, and the visualization and presentation of the information to the end user.

Figure 1 depicts the data fusion process model and taxonomy for data fusion levels 0 through 4 which have been formally recognized by the Joint Director of Laboratories (JDL) Data Fusion Working Group. Only recently has level 5 fusion, *Cognitive Representation,* been considered as part of the formal process model. The six levels of fusion span the "sensor-to-screen" processing spectrum from the conversion of received energy from an active sensor (level 0: target detection process) to the visualization of all the processed information as displayed to the end user (level 5: visual representation).

Recently, Raytheon Joint Sensor Networks (JSN) in St. Petersburg, Fla., has teamed with leading data fusion academic research experts, including Penn State University's College of Information Sciences and Technology (IST), to apply PSU's level 2 (*Situation Assessment*) and level 3 (*Impact Assessment*) data fusion expertise for a global maritime domain awareness application.

The level 2 fusion process, *Situation Assessment*, is the process by which aggregations of detected objects are placed in context in their environment and relationships among objects and sets of objects are defined. Level 3 fusion, *Impact Assessment*, is the process where future operational impacts and situations are predicted based on the current estimated situation state. Level 3 fusion incorporates automated processes by which courses of action are recommended to the warfighter. These data fusion processes are key functions that bring actionable knowledge to the warfighter, as they estimate the contextual meaning of objects in their surrounding environment and the predicted intentions associated with these objects.

Led by Professor John Yen, the principle investigator for PSU's cognitive decision aid research with JSN, PSU's IST research efforts have included development of state-of-the-art level 2 and 3 data fusion processes — specifically, the development of collaborative agents to assist decision makers faced with intense operational tempos and large volumes of unprocessed data. PSU has applied their Recognition Primed Decision (RPD)–enabled Collaborative Agents Stimulating Teamwork (R-CAST) model to provide situational assessment and impact assessment aids to the warfighter.

The R-CAST technology research extends CAST agent architecture, which was initiated in 1998. The fundamental goal of PSU's R-CAST technology is the development of an information-sharing cognitive agent system that facilitates distributed understanding across multiple communities of interest, increasing situational awareness across multiple users, and reducing human-in-the-loop data processing load.

As shown in Figure 2, R-CAST is a complete level 2 and level 3 decision-making process and consists of several components. The main components of R-CAST consist of an active knowledge base, the RPD model, and several management functions that facilitate information processing, distribution and resource management tasking.

One of the main components of R-CAST is the active knowledge base. It is a forward-chaining rule-based system that facilitates the links between observations and information that can be deduced from them. Its primary feature is the representation of information dependency and relations — key for assessing situations as aggregates of observations of objects or events. This knowledge base is active in the sense that it keys on missing information and attempts to acquire needed information to fulfill the perceived knowledge gaps that would otherwise be facilitated by humans in the loop.

At the heart of R-CAST is the RPD model. It is a decision-making model that supports human-to-agent and agent-to-agent collaboration, enabling the end user to more effectively make tactical decisions collaboratively based on R-CAST's current assessment of the situation. This model uses a knowledge structure that represents knowledge about decision-making experiences based on RPD (refer to Figure 2, "experiences" process function). There are several functional areas associated with the RPD process including situational analysis, recognition, evaluation and execution (course of action implementation), and expectancy monitoring.

Data Fusion Level	Data Association Process	State Estimation Process	Product
Level 0: Sub-object Data Association/Estimation	Assignment (observation-to-feature)	Detection	Estimated signal state
Level 1: Object Refinement	Assignment (observation-to-entity)	Kinematic/ attributive state	Estimated entity state (ID and track)
Level 2: Situation Assessment	Pattern recognition/ relationship (entity-to-entity)	Relation/identified pattern	Estimated situation state
Level 3: Impact Assessment	Evaluation (situation to actor's goals)	Prediction/estimate intent/COA analysis	Estimated situation utility
Level 4: Process Refinement	Resource management/ library refinement (task-to- resource)	Optimization/control/ a-priori state estimation (patterns, etc.)	Action/library update
Level 5: Cognitive Representation	Information discovery - multi-expert collaboration - (entity/situation/action-to-information representation)		Shared understanding/ collaborative decision making

Figure 1. Six levels of data fusion

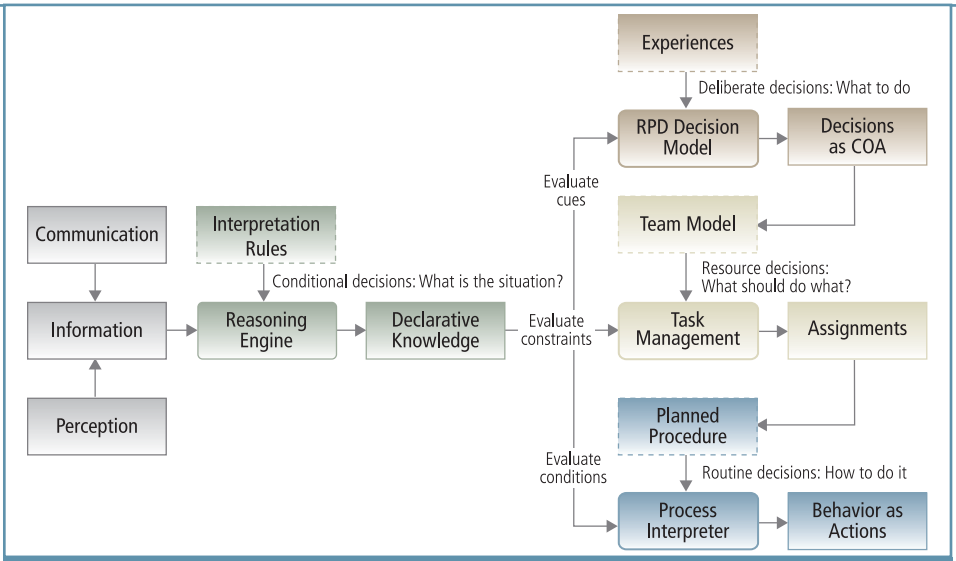

Figure 2. R-CAST decision-making process model

Without automating this processing capability, the warfighter would be challenged to consistently recognize (and remember patterns for) complex situations and could possibly by overloaded and misinterpret tactical situations.

There are several management functions associated with R-CAST that facilitate the end-to-end collaborative decision-making process. The process manager recommends courses of action and presents them to the end user based on R-CAST's situational assessment. The information manager manages supply and demand of information to and from multiple agents and has the ability to anticipate information needs. The communications manager facilitates information exchange and has the ability to handle heterogeneous message exchanges. The task manager facilitates and oversees the completion of assigned tasks (a resource management function). Finally, the configuration manager is responsible for making the R-CAST tool flexible enough to be used across many different applications and it enables the R-CAST tool to be reconfigurable both on and offline.

The R-CAST level 2 and 3 data fusion functionality provides state-of-the art situational assessment and course of action recommendation tools to the decision maker. To fully make use of these tools' products, the fused information must be presented to the end user in order for them to quickly comprehend and take action — a significant challenge for level 5 fusion (*Cognitive Representation*). Traditionally, two-dimensional displays with geographic reference overlays have been used to present situational data. Today, representation of other kinds of data such as situational context of threats, textual and time-sensitive data necessitate alternative visual presentations of this fused contextual data. PSU, under the leadership of Professor David Hall, is developing several state-of-the-art visualization technologies including three-dimensional immersive displays, as shown in Figure 3. These visualization technologies further enhance the end user's situational understanding and quickly facilitate the transformation of information to knowledge.

The complexity of the warfighter's information domain will undoubtedly increase as net-enabled technologies grow and mature. The combination of these state-of-the-art data fusion technologies ultimately enables the warfighter to collaborate more efficiently and effectively across many communities of interest, meaning higher mission success for the warfighter. The development and implementation of state-of-the-art data fusion technologies, such as those being developed collaboratively between Raytheon and academic research centers of excellence like PSU, is key for the transformation of information to actionable knowledge. ●

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Dr. John Yen and Dr. David Hall are leading information fusion research scientists from PSU IST supporting this IRAD effort. They are contributing both their expertise and their data fusion products (R-CAST) for this IRAD. Dr. Yen is an IEEE fellow and his research focus is agent-based/team collaboration information fusion research and applications, including the agent-based system R-CAST currently being used in this IRAD. Dr. Hall is an internationally recognized research expert in multisensor data fusion. He is currently supporting this IRAD in several areas, including data fusion architecture and visualization.

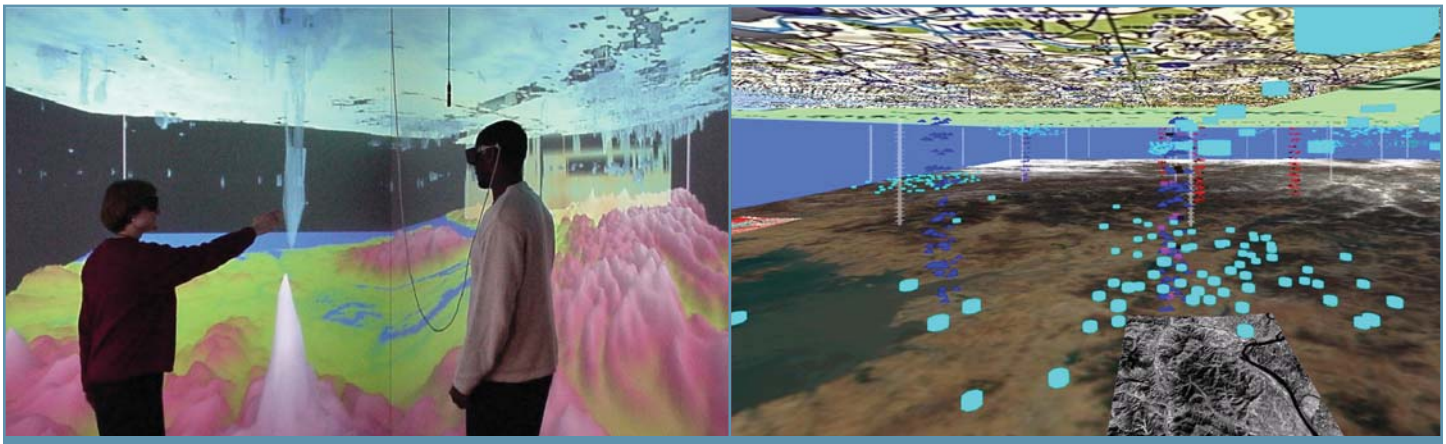

Figure 3. Three-dimensional immersive and hierarchical displays

The University of California, Los Angeles

The University of California, Los Angeles (UCLA) research, funded by Raytheon during the current school year, encompasses materials research to artificial dielectric structures for use in SiGe BiCMOS integrated circuits. Raytheon and UCLA have collaborated since 2001 in numerous endeavors. The university's professors have provided collaborative research opportunities in wafer bonding, MEMS and tunable filters. Our relationship will continue to grow as Raytheon advances research toward improving defense systems.

University Collaboration Projects With UCLA on Advanced Lightweight, High-Temperature Missile Airframes

Raytheon Missile Systems (RMS) has embarked on a series of university collaboration projects with the University of California, Los Angeles (UCLA) to integrate titanium foils between layers of high-temperature composites to strengthen and stiffen supersonic missile airframes envisioned for future programs.

Titanium graphite (TiGr) hybrid composites coupled with advanced organic materials currently under development in commercial industry have great potential to enhance future evolution of existing production programs, as well as proposed, high-speed interceptors. TiGr-configured airframes promise to provide a lightweight, low-cost alternative to refractory metal components such as control surfaces, wings, nosecones, ramjet inlets and fuselages. RMS has funded three university collaboration phases to date, and is looking forward to coupling TiGr technologies with Small Business Innovation Research (SBIR) efforts currently underway to further enhance maturity and application developments.

Titanium graphite hybrid laminates have been evaluated as a high-temperature structural material for high-speed civil transport (HSCT). The hybrid laminate is composed of a thin sheet of titanium adhesively bonded together with a high-temperature resin that contains intermediate or high modulus carbon fibers. The polymer matrix used was primarily polymerization of monomeric reactants (PMR) type polyimide thermoset resin materials. However, the issues with microcracking and thermal oxidative stability and the presence of methylenedianiline (MDA), which is a known animal and suspect human carcinogen, has limited the use of PMR-15 resin for high-temperature applications.

Many alternative resins have been developed to replace PMR-15. One of the highest performing PMR type of resins is Avimid N. This resin demonstrates excellent thermal oxidative stability without microcracking issues. However, the processing of Avimid N is very difficult due to the need for extremely high pressures and temperatures.

More recently, a new high-temperature polyimide resin system containing no MDA was developed. This new polyimide has

been demonstrated to possess excellent thermal oxidative stability with no observations of microcracking; it can also be processed in standard high-temperature/high-pressure autoclaves. The combination of ease-of-processing with high-glass transition temperature (Tg) and good retention of mechanical properties following extended thermal aging has led to a resin which is well suited for a wide range of high-temperature applications.

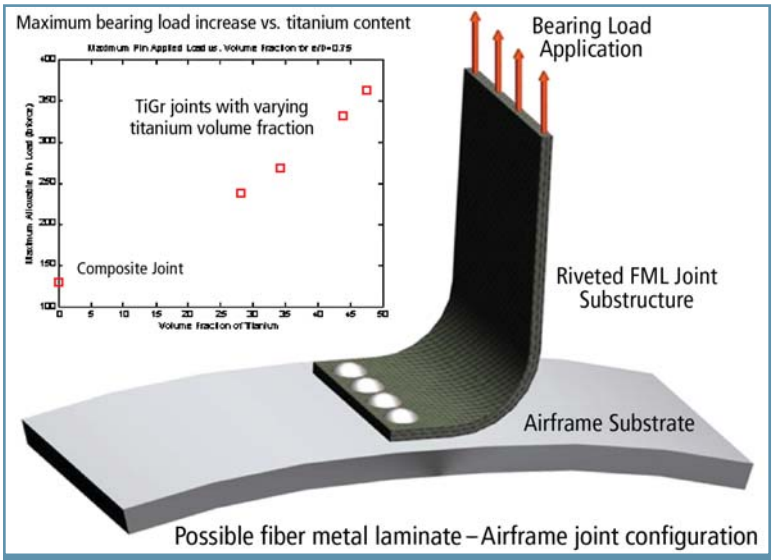

Figure 1. Sample joint configuration and TiGr bearing strength increase

The leading edge of a supersonic/hypersonic missile wing can easily exceed 650°C, far exceeding the capability of the polymer composite used in typical composite applications. A hybrid laminate with the combination of titanium and carbon fiber/polyimide resin will be excellent materials for supersonic/hypersonic missile airframes with the capability to withstand extended exposure to the aerodynamic heating encountered during flight. The main objective of this proposed research is to develop a new generation of titanium graphite hybrid laminate for supersonic/hypersonic missile airframes and control surfaces.

In order for TiGr fiber metal laminates to be considered a candidate material for next-generation high-temperature missile airframes and aerosurfaces, their structural advantages with respect to existing carbon fiber composites and titanium alloys must be demonstrated.

Collaborative Raytheon research at UCLA has produced numerical and analytical models to predict the mechanical behavior and to guide the structural design of such hybrid laminate. Finite element (FE) models of a typical bolted or riveted joint were created at UCLA to analyze the relative merits of TiGr laminates in an airframe structural joint. The validity of these models was ensured by comparing the FE-predicted ultimate bearing strength, defined as stress level at joint failure, against test results for commercially available materials such as monolithic titanium and GLARE ("GLAss-REinforced") fiber metal laminates.

Excellent correlation was observed between the finite element modeling and experimental values, with the metal bearing strength prediction within 0.4 percent of the tested values, while the GLARE bearing strength predictions were within 2.0–8.1 percent.

Both the analytical and finite element models were then applied to several TiGr configurations designed for high-temperature missile aerosurfaces. As expected, for identical geometries, TiGr fiber metal laminates exhibited improved specific (ratio of property value to material density) properties compared to carbon fiber composites and metals. Figure 1 shows a sample airframe joint with comparative strength increase values. In regions of the airframe which require fasteners, hybrid titanium graphite laminate showed 40.3 percent and 19.5 percent improvements in specific ultimate bearing strength over composite and monolithic titanium joints respectively.

The finite element modeling results indicated that the high anisotropy of carbon fiber composites, which contributes to their low joint efficiency, can be offset with the inclusion of titanium foil plies, while still maintaining the tremendous weight savings associated with composite materials. For areas of the airframe which are sufficiently removed from the joint, the titanium plies can be phased out in a step-wise manner, resulting in a composite structure with an improved joint strength and a nominal increase in airframe weight.

To supplement the finite element strength calculations, a local failure prediction model was developed to further demonstrate the advantages of titanium graphite fiber metal laminate joints. In a bolted or riveted composite joint, failure typically occurs in either a shear-out mode, where the bolt rips through the material, or in a bearing mode, where local material failure around the bolt-hole results in a loss of joint strength. The latter failure mode is preferred, since it occurs at much higher stress levels, and does not result in a full loss of structural integrity.

To determine the joint failure mode, a progressive composite failure subroutine was used to relate local component failure, such as fiber buckling, to the global failure mode. Examples of composite and metal failure in a sample 3-D FE joint model are provided in Figure 2. Preliminary results indicate that incorporation of titanium plies into the bolt-region results in as much as a 241 percent decrease in the minimum joint size required for failure to still occur in a bearing mode. This joint area reduction means that less material is required to secure the joint, resulting in a lighter, stronger aero structure. Further refinements of these analytical and numerical methods are in progress.

Currently, we are working closely with a SBIR contractor to (1) establish a robust

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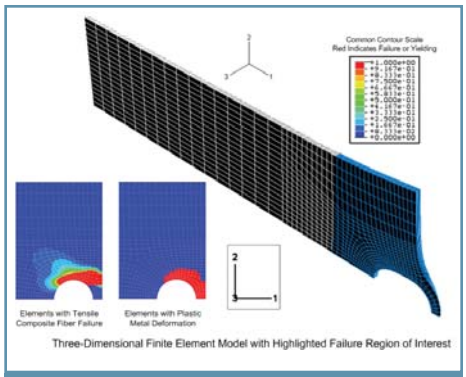

Figure 2. Finite element modeling and damage progression in a typical FML joint

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processing approach for processing/manufacturing of titanium graphite hybrid laminates; and (2) study the durability of titanium graphite hybrid laminates under rapid heating, thermal cycling and hot-wet environmental exposures. The successful implementation of such advanced materials and processes onto the missile airframes and aerosurfaces will undoubtedly enhance the competitive edge for RMS.

Three collaborative research projects between Raytheon and UCLA Henry Samueli School of Engineering and Applied Science have been underway since 2005. The RMS project originator and technical point of contact is Andrew Facciano of the Advanced Systems Design Department in Tucson, Ariz.

As a UCLA alum, Facciano established a collaborative relationship with professors Jenn-Ming Yang and H. Thomas Hahn, and graduate student Jacob Hundle in the pursuit of advanced airframe technologies, including smart structures, high-temperature ceramics, thermal protection systems, and designer knowledge databases. UCLA has been a very proactive research partner with Raytheon for many years, and has again proven their resourcefulness in maturing titanium graphite hybrid technologies. ●

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Dr. H. Thomas Hahn is the Raytheon Distinguished Professor of the Mechanical and Aerospace Engineering department and serves as the editor-in-chief of the Journal of Composite Materials. In 2006, he was designated as a Centennial Fellow of the department of Engineering Science and Mechanics, Penn State University, and received the Faculty/Staff Partnership Award at UCLA. He was president of the American Society for Composites, 1996-1997, and is the current president of the International Committee on Composite Materials for the 2005-2007 term.

Dr. Jenn-Ming Yang is the vice chair of Undergraduate Studies at UCLA and a recipient of the NSF Presidential Young Investigator, Alcoa Foundation and Ford Foundation Awards.

UCLA Develops **New Artificial Dielectric Technology** to Reduce Microchip Size While Adding Tunability

UCLA, working on a Raytheon university grant, has developed an artificial dielectric structure for use in SiGe BiCMOS integrated circuits at military frequencies. Millimeter-wave circuits and systems are dominated by GaAs or InP compound-based HBTs because of their high-frequency performance, low noise, and low loss on-chip transmission lines and passive components. However, these HBT technologies are more costly and less available than mainstream CMOS. It is thus beneficial to achieve high levels of integration, low-cost communication and radar systems using modern CMOS technologies.

Two major challenges in CMOS millimeter-wave IC designs are (1) device noise, which is typically one or two orders higher than that of compound or SiGe HBTs; and (2) signal attenuation due to the skin effect and substrate losses, which inevitably result in low performance on-chip lumped passive components. These issues hinder the development of key radar transceiver building blocks such as the VCO.

An artificial dielectric is formed by embedding metal obstacles in a periodic pattern, as shown in the upper part of Figure 1. When an external electric field E is applied, the charges induced on the obstacles result in a dipole field with polarization density P. The artificial dielectric constant boost-factor is given by $\kappa=C'/C$, where C′ and C are the respective unit volume capacitance with and without the artificial dielectric. We can implement the artificial dielectrics in commercial CMOS with a 2-dimensional metal strip array. The lower part of Figure 1 shows a coplanar strip line $\lambda/4$ standing wave resonator with underlying artificial dielectric in CMOS technology.

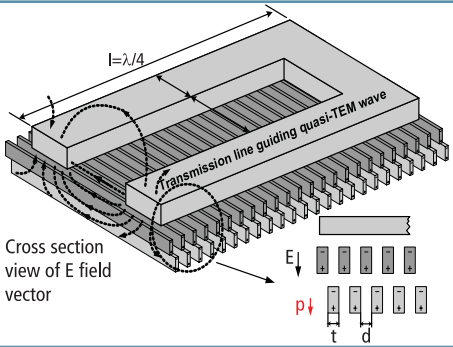

Figure 1. Artificial dielectric and on-chip λ/4 resonator

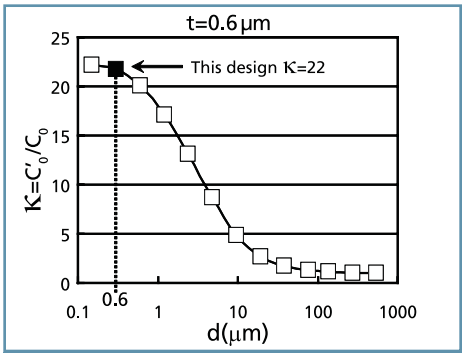

Figure 2. κ vs. metal horizontal spacing d

Several advantages exist for this artificial dielectric medium. First, a large dielectric constant boost-factor leads to small size and low loss resonators. The plot in Fig. 2 of k versus conducting strip horizontal spacing d, shows the size reduction of a resonator designed with and without the embedded artificial dielectric. For our design with d=0.6μm and $\kappa=22$, the $\lambda/4$ resonator was reduced from 700μm, without artificial dielectric, to 150μm — almost a factor of 5 reduction in resonator size due to this new technique. Second, since the current flow of the resonator is perpendicular to the conducting strips, conductive loss for the artificial dielectric is low. Third, the conducting strips shield the electromagnetic field from penetrating into the conductive substrate, and hence dramatically reduce the substrate loss.

A 60GHz VCO was designed and implemented in a 90nm CMOS to verify the effects of the embedded artificial dielectric on resonator size, loss and noise reduction. Compared to resonators without artificial dielectrics or those using conventional spiral inductors at this frequency, a much lower loss resonator can be accomplished by using embedded artificial

dielectric. The artificial dielectric resonator has reduced the resonator area by 79 percent, as compared to a resonator without the artificial dielectric. Additionally, 120 metal strips are individually connected to varactors, each made up of back-to-back NMOS pairs. In order to block signal leakage from the frequency tuning path, the control voltage V_{ctrl} is externally applied through a bias-T, and all of the varactor common ends are connected together at the symmetrical plane of the differential resonator where the differential signal "sees" a virtual ground (Figure 3).

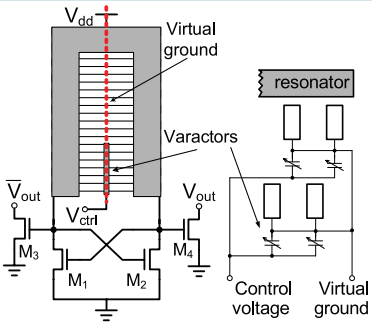

Figure 3. VCO using embedded artificial dielectric

Frequency tuning is obtained by altering the electric length of the resonator through capacitance variation of the varactors. The tuning range for the VCO, Δf/f, can be estimated from

$$\frac{\Delta f}{f} = -\frac{1}{2}\frac{\Delta C'}{C'} = -\frac{1}{2}\frac{\Delta C_v}{\kappa C + C_v} \quad (2)$$

where κC is the equivalent capacitance introduced by the artificial dielectric, C_V is the total capacitance of the varactors, and ΔC_V is the available varactor tuning range. Another method of frequency tuning may be accomplished by inserting MOS switches at the virtual ground position of metal strips to connect/disconnect metal strips of the artificial dielectric. Preliminary measurement results show that it achieves broad and linear frequency tuning range and steps (over several GHz).

Phase noise	-94dBc/Hz @ 100kHz -107 dBc/Hz @ 1MHz
Figure-of-merit	-207dBc/Hz @ 100kHz -200 dBc/Hz @ 1MHz
Operating frequency	60 GHz
Tuning range	100 MHz
Supply voltage	1V
Power dissipation	1.9 mW
Chip area	0.015 mm^2

Table 1. Performaance summary

With the total current of 1.9mA from the 1V supply, the phase noise at 1MHz frequency offset is -107dBc/Hz. Table 1 summaries the VCO performance and Table 2 compares the performance of this VCO at 1MHz offset to recent published results of HBT and CMOS at around 60GHz. Note that the FOM of -200dBc/Hz is 19dB lower than that of the prior arts in SiGe and GaAs HBTs, and is the lowest FOM reported for V-band VCOs. These improvements can be attributed to the use of on-chip artificial dielectric for size, loss and noise reduction.

Reference	Process	f_0(GHz)	V_{DD} (V)	P_{DC} (mW)	PN@1MHz (dBc/Hz)	FOM	Die area (mm^2)
This work	90 nm CMOS	60	1	1.9	-107	-200	0.015
J.Kim[1] MTT-S,2003	InGaP/ GaAs HBT	60	3.5	158	-93	-167	0.78
B.A. Floyd[2] RFIC,2004	SiGe HBT	67	3	25	-98	-181	-
Y. Cho[3] RFIC,2005	0.18 μm CMOS	53	2.1	27	-97	-177	0.20
R. Liu[4] ISSCC,2004	0.25 μm CMOS	63	1.8	119	-85	-160	0.32
P. Huang[5] ISSCC,2005	0.13 μm CMOS	57	1.2	8.4	-70	-136	0.20

Table 2. Performaance comparison

In summary, we have realized a 60GHz CMOS VCO with a measured phase noise of -107dBc/Hz and a record low F.O.M. of -200dBc/Hz at 1MHz frequency offset. This VCO dissipates only 1.9mW from a 1V power supply and occupies a chip area of 0.015mm^2, which is less than 10 percent of the prior arts (Table 2). ●

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Contributors: Terry Cisco, Tim LaRocca, Glenn Sakamoto (Raytheon), Daquan Huang (UCLA)

ENGINEERING PROFILE

Andrew Facciano
Senior Principal Systems Engineer

Extended Area Protection and Survivability Systems

Raytheon Missile Systems

Andrew Facciano has been an Interceptor or Vehicle Design Integrated Product Team (IPT) Lead for 15 years on a number of programs at Raytheon Missile Systems. He recently began as the Interceptor Lead for EAPS (Extended Area Protection and Survivability Systems), transferring from KEI (Kinetic Energy Interceptor), where he worked since 2002. At KEI, he was the Interceptor then the Payload Design IPT Lead as the program expanded.

Prior to that, Facciano worked as the Interceptor Lead for ESSM (Evolved SeaSparrow Missile) for five years, and AIT (Atmospheric Interceptor Technology) for two years. He also worked as the Guidance Section IPT Lead for the SM-3 (Standard Missile 3) Block II.

"I consider myself lucky to have worked with such talented and capable educators, mentors, management and design team leaders," said Facciano. "They've influenced me to accept new challenges, broaden my multidisciplinary capabilities, and build on my task assignments and experiences."

Facciano received a master's degree in mechanical engineering from the University of California, Los Angeles (UCLA) in 1987.

The University of Texas at Dallas

Building a Secure Geospatial Semantic Web

Semantic Web technologies enable machine-understandable Web pages. A number of research projects around the world have recently begun to focus on developing a geospatial semantic Web. A research collaboration between Raytheon Intelligence and Information Systems in Garland, Texas, and the University of Texas at Dallas aims to develop a secure geospatial semantic Web for applications including crime analysis and border control.

Crime Analysis

We are particularly interested in police blotter crime analysis. A police blotter is the daily written record of events in a police station, such as arrests and thefts. These records, available publicly on the Internet, provide a wealth of information for analyzing crime patterns across multiple jurisdictions. What's needed is a tool that will integrate multiple police blotters, extract semantic information from them, and provide a seamless framework for queries with multiple granularities.

Geospatial Semantic Web

Following the semantic Web vision of Tim Berners-Lee at the Massachusetts Institute of Technology, we have defined a layered architecture. At the bottom are communication protocols. Next we have the Geography Markup Language (GML) and GML schemas layer. We have developed Geospatial RDF (GRDF) to specify the semantics, where the GRDF layer lies on top of the GML layer. On top of GRDF we have developed geospatial ontologies and query facilities. In Example 1, we have defined a City class that identifies the boundary of a particular city.

For demonstration, we have created a system called DAGIS (Discovery of Annotated Geospatial Information Services) that reasons with ontologies to answer queries (see Figure 1). DAGIS is an integrated platform that provides the mechanism and architecture for building geospatial data exchange interfaces using the OWL-S Service ontology. Data encoded in GRDF provides the ability for DAGIS or client agents to reason about the payload data to provide intelligent inferences.

```
<owl:Class rdf:id=http://127.0.0.1/grdf_voc#City />
  <rdfs:subClassOf rdf:resource="http://127.0.0.1/grdf_voc#tplace"/>
  <rdf:Property rdf:about="http:// 127.0.0.1/grdf_voc#boundary">
    <rdfs:domain rdf:resource="http://127.0.0.1/grdf_voc#  CRS_EPSG:6.6:4326/>
  </rdf:Property>
</rdfs:Class>
```

Example 1. City class defined

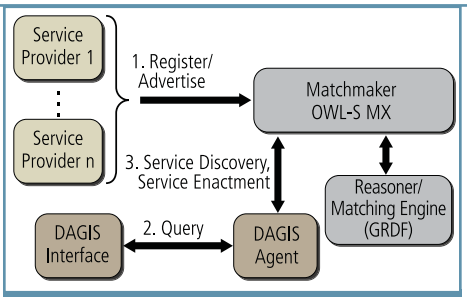

Figure 1. DAGIS demonstration

Geospatial Data Mining

We use a multistep approach for geospatial data mining. Our initial research has focused on developing data mining techniques for classification of remote sensing data used to determine if there are suspicious activities in particular regions.

Land cover information can be derived from various remote sensing systems, such as images from Landsat 7 ETM+, SPOT HRV/HRVIR, Terra ASTER and AVIRIS. These images can have different spatial resolutions and spectral resolutions. Classification on the pixel level cannot reveal semantic concepts at higher levels — and semantic concepts at high levels can be crucial for security protection, environment evaluation and urban open space research.

For instance, if a pixel or a few neighboring pixels are classified as a body of water, the location could be a pool in a residential area, a pond in an urban area, or a lake in a park or open rural area. Similarly, a group of buildings could be for public service in an urban area, for residential purpose in a residential area, or for highly confidential military use in a desert. We develop high-level concepts to distinguish these so the semantic meanings of pixel classes are clear.

Our approach (Figure 2) uses support vector machine (SVM) classifiers (see Tables 1 & 2) to classify data of different resolutions that are used to form high-level concepts by grouping and re-evaluating classes of pixels. To generate high-level concepts for a group of neighboring pixels, we have developed domain-dependent ontologies to provide specification of fine-grained concepts, while generic ontologies provide concepts in coarser grain.

Secure Interoperability

Geospatial data protection in a distributed environment presents many challenges beyond providing or denying access. Geospatial data is unique in that the same piece of data has varying levels of granularity, depending on context. Raster images can be processed in different resolutions, scale and accuracy. Even vector data is available at differing scales. Further, access control of data integrated from multiple agencies may be highly sensitive.

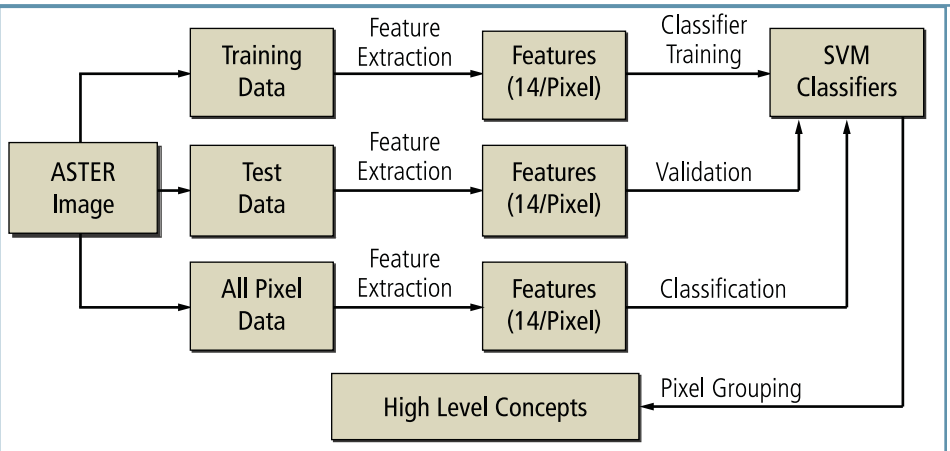

Figure 2. Support vector machine classifiers

	Water	Barren Land	Grass	Tree	Building	Road	House	Total	Accuracy (%)
Training	1175	1005	952	887	1041	435	1584	7079	99.8
Test	1898	1617	1331	1479	768	648	1364	9105	89.25

Table 1

Class	Predicted						
	Water	Barren Land	Grass	Tree	Building	Road	House
Water	1898	0	0	0	0	0	0
Barren Land	0	1225	216	0	143	33	0
Grass	0	15	1175	54	69	0	18
Tree	0	0	0	1454	0	0	25
Building	0	1	0	0	578	189	0
Road	0	0	0	0	143	500	5
House	0	0	0	0	9	59	1296
Accuracy (%)	100.00	75.76	88.28	98.31	75.26	77.16	95.01

Table 2

We have thus far defined two types of constructs. The first type provides alternative abstract elements for vector data. The second type constitutes ontology for subject classifications and action roles. Currently defined top-level classes for various categories of subjects are: Administrator, GISAdmin, System Admin, Manager, Regular Professional, Facility Personnel and Guest. The actions defined so far are Read, Write, Save and Execute.

In an ideal situation, all parties in a distributed system have an agreed-on set of measures to combine their policies, or resolve them in case of a failure. However, this is not always possible, and in such cases, our security constructs would allow a semantic access control processor to interpret the role and action definitions and combine the corresponding policies. We have defined our ontology for policy integration using the SWOOP ontology editor. Example 2 (following page) gives a snapshot of the ontology hierarchy.

Summary

Thus far, our major contributions to initial research on developing a secure geospatial semantic Web include:

- Development of geospatial RDF for specifying geospatial semantics and ontologies
- Geospatial data mining for classification of remote sensing data
- Policy integration for geospatial data interoperability

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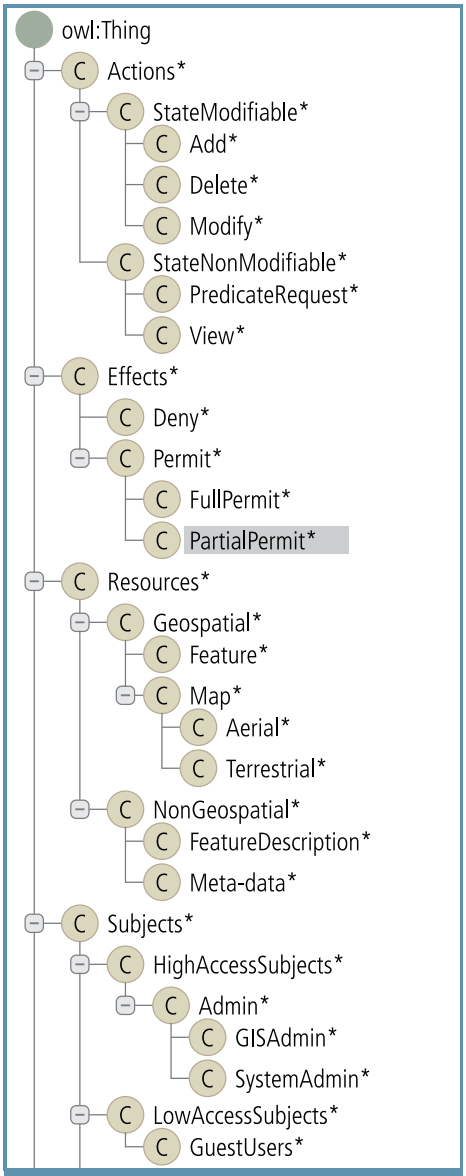

Example 2. Ontology hierarchy snapshot

While we continue with our collaborative research on building a secure geospatial semantic Web, we will also enhance the DAGIS system into a fully functional prototype that will answer complex queries and help in decision making. Our prototype will include the following components:

- Semantic search browser for police blotters
- Tools for generating crime analysis concepts from blotters
- Map-based visualizing tools and semantic dashboard

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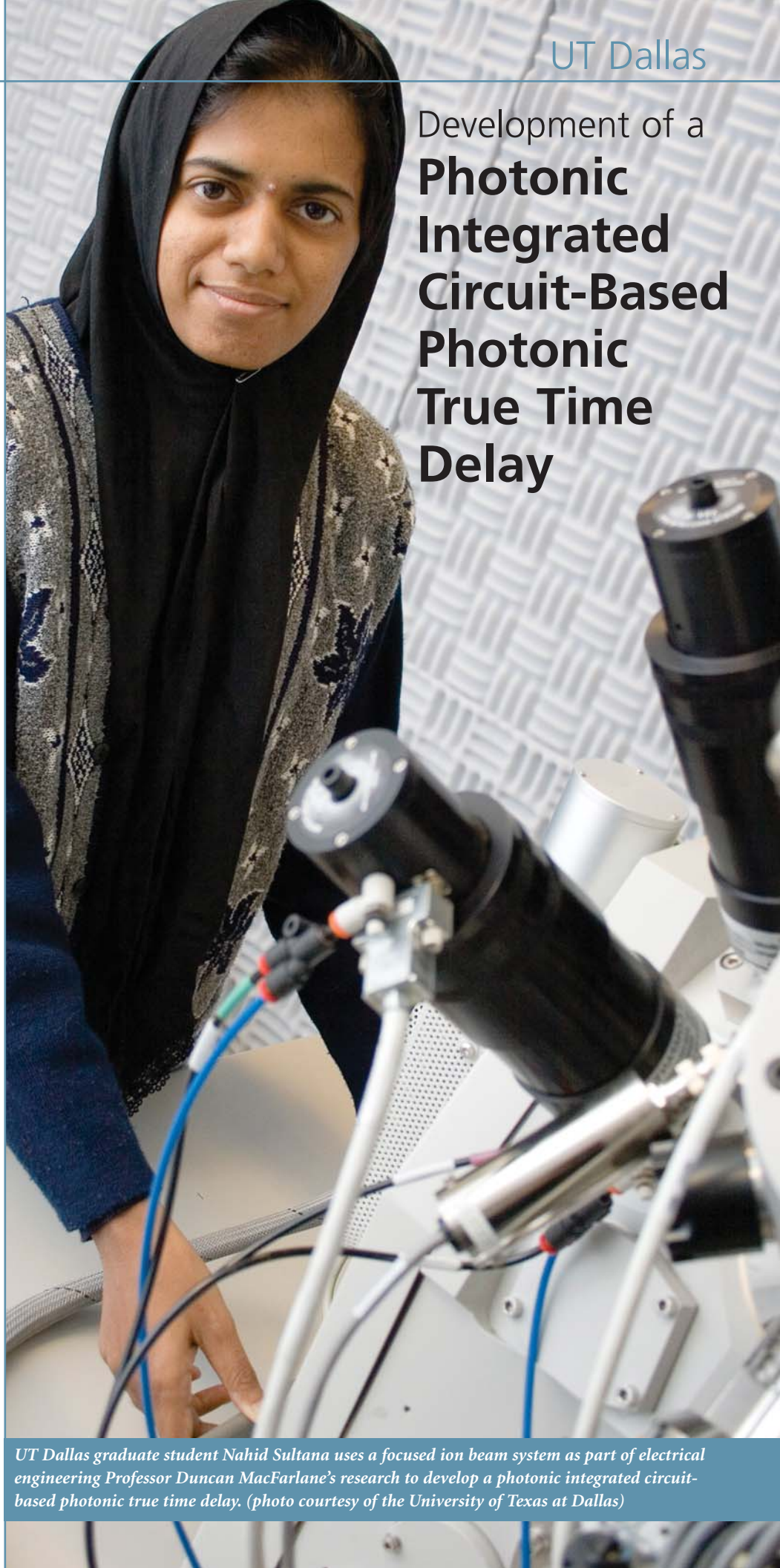
Contributor: Dr. Bhavani Thuraisingham, Prof. Latifur Khan (UT Dallas)

Development of a **Photonic Integrated Circuit-Based Photonic True Time Delay**



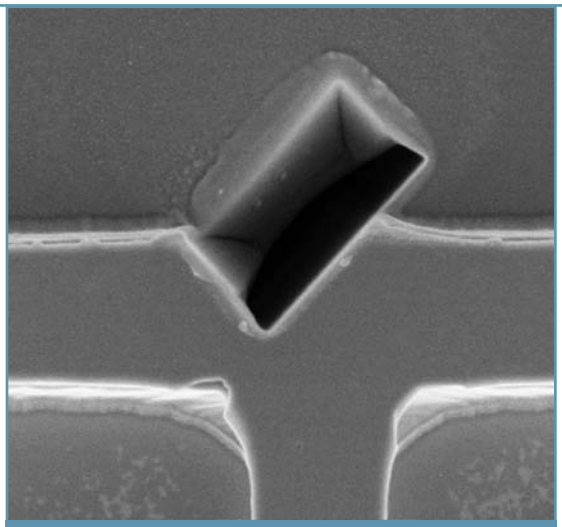
UT Dallas graduate student Nahid Sultana uses a focused ion beam system as part of electrical engineering Professor Duncan MacFarlane's research to develop a photonic integrated circuit-based photonic true time delay. (photo courtesy of the University of Texas at Dallas)

The cornerstone building block of any phased-array antenna technology for radar, communications, signal intelligence and other applications is the time delay function. For narrow band applications, this function is approximated by phase shifters. However, for wider band applications such as SAR, a unique phase shift is required for each spectral component. This is the principle used in the channelized or subbanding beamformer. A true time delay function realization using RF components requires large RF manifolds and large waveguide or coaxial time delays. Raytheon Company and its Network Centric Systems business are jointly sponsoring research at the University of Texas at Dallas (UTD) to develop a photonic true time delay (PTTD) module incorporating nanophotonic couplers and semiconductor optical amplifiers.

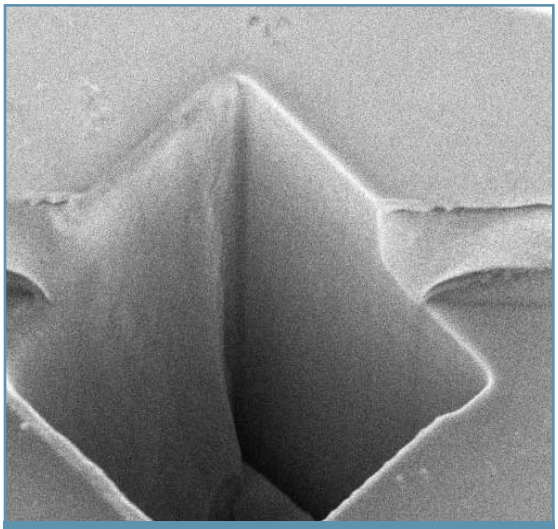
The PTTD is a novel-enabling device that will dramatically enhance the operation of phased-array antennas. It's also a forbearer of a new age of highly integrated photonic systems based on nanotechnology and active elements. Optical circuits based on nanophotonic couplers will allow standardized photonics that may be user-programmed for a vast number of different signal processing, filtering and coding tasks.

This programmable philosophy, along with its inherent economic advantages, will be a watershed in photonics in particular, and modern information engineering in general. The photonic integrated circuit proposed is a versatile, programmable, scalable architecture that will process photonic signals, and provide a sophisticated and practical interface with existing electronics.

This photonic-integrated device leverages the researcher's expertise in nanophotonic technology and semiconductor processing of III-V compounds with the latest focused ion beam (FIB) technology at the University of Texas at Dallas. In addition to a compact, reliable, lightweight, low-cost and easily manufactured package, the architecture offers the potential to integrate electronic to optical (E/O) and optical to electronic (O/E) conversions for very high signal fidelity and very low noise figures, and to integrate programmable optical signal processing into the module. The goal of this project with UTD is to develop the next generation of devices and to further advance the design and fabrication of photonic chips for system-level integration.



The proposed active optical filter is fabricated using a multiple quantum well (MQW) epitaxial growth with ridge waveguide processing. The active region consists of 5x85Å compressively strained AlInGaAs quantum wells, which are designed for 1550nm wavelength operation and provide gain for TE polarized light. Patterned p-type electrodes facilitate individual addressing of the SOA gates. The ridge waveguide formed with reactive ion etching (RIE) is 2.5 um wide and 1.3 um high, which supports single transverse mode operation.



Total internal reflection (TIR) mirrors are fabricated in a two-step procedure using focused ion beam (FIB) micromachining. A 4 um deep trench is first directly milled, and cross section cleaning is then applied to remove the redeposition during FIB milling. An SEM of the obtained TIR mirror as shown is optically smooth, and the sidewall angle is less than 1 degree.

In 2005, UTD demonstrated the feasibility of a photonic true time delay circuit using a 2-bit breadboard circuit. The advantage of achieving gain along with switching demonstrated in the approach enables fabrication of monolithically integrated PTTD circuits. In 2007, UTD developed a photonic true time delay (8 bits) using an array of fast switching semiconductor optical amplifiers (SOAs) integrated onto a chip with nanophotonic couplers and optical waveguides. The use of SOAs overcomes high losses generally associated with integrated photonic chips. Lower losses, in turn, allow for large area high-density integrated photonic chips. Higher level of integration allows for more complex functions on a single chip that have been traditionally carried out on tabletop setups.

This research will result in a completely new class of photonic components that will have a revolutionary impact on information engineering. This development of the active optical filter is an advance that is analogous to bringing a transistor to an electric circuit comprising inductors, capacitors and resistors, and promises to provide the same revolutionary impact to photonics.

In October of this year, Photonic Analog Signal Processing Engine with Reconfigurability (PhASER) — the UTD proposal that was based on this research — was selected by the Defense Advanced Research Projects Agency (DARPA) for funding. ●

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Contributor: Dr. Duncan MacFarlane (UT Dallas)

ENGINEERING PROFILE

Steven Seida

Sr. Principal Engineer

Science and Technology

Raytheon Intelligence and Information Systems

A trusted leader within Raytheon Engineering, Steven Seida has extensive hands-on experience in the development and implementation of complicated systems and technologies for solving analysis issues.

Seida is now helping to lead the company forward through a plethora of technologies sometimes referred to as Knowledge Management and Knowledge Discovery (KM/KD). "You just have to stay focused," said Seida. "Knowledge management and discovery is all about being a man-power multiplier, substantially helping the analyst in accessing the knowledge of his enterprise."

Seida's 20 years of experience in image processing has exposed him to numerous evolving technologies and initiatives. He has tamed technology for autonomous land vehicles, air-bag deployment robotics, advanced image processing architectures and analysis systems for imagery. In addition to leading a group of KM/KD developers, Seida directs research at three universities, a commercial research laboratory, and a consultant firm to further the goals of the KM/KD program.

Before joining Raytheon in 1997, Seida developed advanced machine vision capabilities at Southwest Research Institute. He received his master's degree in engineering from the University of Texas at Austin in 1985.

Feature

New Mexico State University

Measuring the Security Measures the Southwest

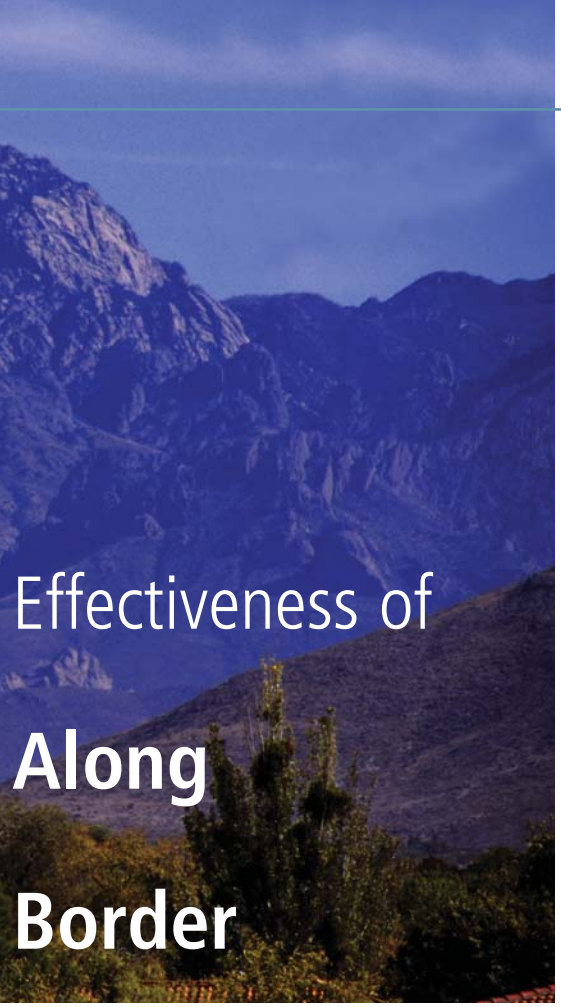
To date, virtually all attempts to create useful measures of effectiveness for understanding and evaluating security measures along the southwest border of the U.S. have fallen short of the mark. The end result is an insufficient and sometimes unrealistic border operational security picture. While each U.S. agency having border law enforcement/security missions publishes reports, there is no single centralized location/agency pulling together the collective information and looking at the border as a whole system. As such, intelligent grist for thorough border policy decision-making is not reasonably available.

The problem of border security is further exacerbated when viewed as primarily a law enforcement issue, when in reality it's a system of economic, foreign policy, national security, intelligence, social and public health-related issues.

Arguably, with the exception of the conflict in Iraq, there are few topics today that surpass border security and illegal immigration in importance, especially as related to the border between the United States and Mexico. Paradoxically, the plethora of impassioned information flooding the airwaves and print media reveals a dearth of dispassionate data from which one can draw sound facts for determining causality and setting the stage for decision making and implementing security measures of effectiveness.

Working through a grant from Raytheon, the New Mexico State University (NMSU) Open Source Intelligence Laboratory is completing what could well be a groundbreaking approach to creating an operational template for evaluating security on the southwest border and possibly elsewhere.

The team chose Open Source Intelligence (OSINT) as the vehicle with which to do the border security assessment. OSINT is an intelligence-gathering discipline that involves collecting information from open sources and analyzing it to produce usable intelligence. In the intelligence community, the term "open" refers to overt, publicly available information sources (as opposed to covert or classified sources), that any member of the public could lawfully obtain by request or observation, as well as other



Effectiveness of Along Border

unclassified information that has limited public distribution or access. OSINT makes use of "gray" literature, regardless of media; this may include research reports, technical reports, economic reports, trip reports, working papers, discussion papers, unofficial government documents, proceedings, preprints, research reports, studies, dissertations and theses, trade literature, market surveys, newsletters and more. Such material cuts across scientific, political, socio-economic and military disciplines.

The NMSU team took a somewhat progressive approach to creating the assessment. Rather than explain how such work might be done and hand off a report to that effect, the NMSU team actually stood up a small model Intelligence Center directed toward southwest border activities. The model functions in a similar manner to a "real-world" southwest border intelligence center. Additionally, the OSINT "products," upon which the center's measures of effectiveness are based, are also "real world."

Prior to creating its Target Collection Plan, the team sought to identify existing information sources that might reflect on the border security issues. Not surprisingly, they found no single or collective body of knowledge that portrays a fully comprehensive, operational security picture of the border.

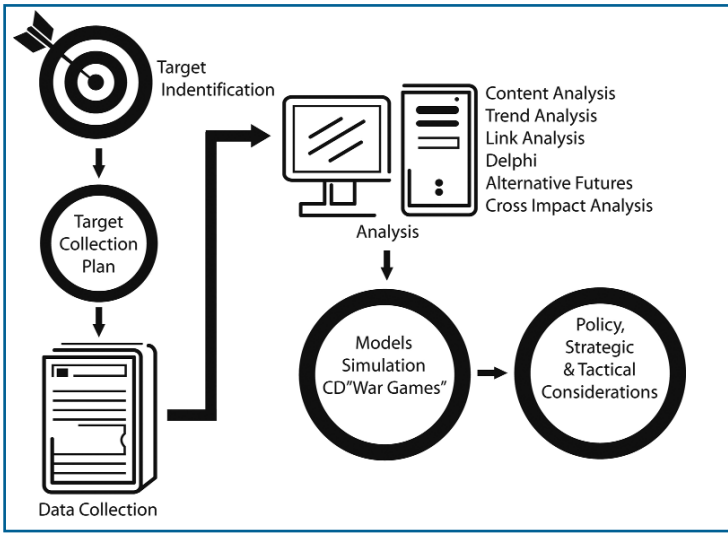
The collection plan identified and sought to gather information from the drug-producing countries of northern South America to the primary illegal alien-producing states in Mexico, as well as a range of sources that might provide realistic information about potential terrorists crossing the southwest border.

Particular emphasis was placed on the collection of subject matter around two border-related notions unique to the southwest: "La Frontera" (The Frontier) and "La Linea" (The Line). Rather than a definitive line separating two countries, La Frontera hints at a state of mind by the people of an area that stretches for 50 to 100 miles on either side of the border. Its magnitude is awesome in scope and sometimes impossible to comprehend in operational terms. It is an area in which the law on both sides has often been ignored, and government authorities are seen as the traditional enemy. Vast and deceptively open, it has been the place of smugglers and contrabandistas for centuries.

In the case of La Linea, the term represents that often intangible territory of the border, which when successfully crossed, means a step toward the hope of a better life. Contrary to popular belief, this line is little more than a poorly maintained three-strand fence that rambles from the Gulf of Mexico to the California coast. With the exception of heavy fencing in a few places such as El Paso, Texas, Nogales, Ariz., and San Ysidro, Calif., the border is easily traversed illegally. The question is not whether it can be crossed, rather where it is safest to cross, considering the dangers of bandits and the climate, and the possibility of detection by the border patrol.

Considerable effort was made to identify, monitor, collect, analyze/synthesize and create products that reflected on the nature and impact of illegal immigration and drug trafficking across Mexico. Specific collection was directed to the present situation in Mexico in which the narcotraficantes (drug runners) have declared open warfare on the government, which in turn has taken off the gloves in its new counter-drug policy.

In designing and operating the Target Collection Plan, the team identified specific information sources, each of which provides data from a range of sectors and all of which reflect elements that accurately portray events on the southwest border and related areas. When woven into an intelligent mosaic, the OSINT products provide the basis for sound measures of effectiveness.



The assessment is a carefully crafted product that incorporates a number of facets:

- The impact of increased U.S. law enforcement presence on the southwest border
- The implications of possible new U.S. immigration policies
- The potential issues that the government of Mexico has to address in the near and immediate future
- An accurate understanding of issues dealing with the southwest border and terrorism.

The end result of the assessment is a template, built around appropriate measures of effectiveness, which will provide great operational utility to a real-world southwest border intelligence activity, and in turn, provide consolidated, complete and reliable information for effective regulation, enforcement and policy. ●

Robert Silver, Jim Holden-Rhodes, New Mexico State University

Adaptive Multi-Channel Access Protocols for **Raytheon Advanced Frequency Agile Radio**

In 2006 Raytheon Missile Systems (RMS) began work on the Raytheon Advanced Frequency Agile Radio (RAFAR) system. RAFAR is a very small form-factor, inexpensive, software-defined radio that is intended for use in tactical scenarios, including unmanned systems, sensor networks and missiles (expendable data links).

To keep the hardware size to a minimum, RAFAR's architecture was based on a half-duplex front-end. This allowed for the removal of bulky circulators from the design, as well as the reuse of significant portions of the RF chain for both receive and transmit functionality. The radio provides ample adaptivity in spectrum management, rate control and transmission power adjustment. To exploit this flexibility and enable the system to operate efficiently in a multi-user (ad-hoc network) environment, novel channel access (MAC) protocols are needed.

To develop an appropriate MAC protocol for the RAFAR system, RMS utilized Raytheon's University Research Program (URP) funding and contracted with Marwan Krunz, a professor in electrical and computer engineering at the University of Arizona (UA). Dr. Krunz and his team investigated various design alternatives. The goal was to come up with a design that exploits RAFAR's unique features, which include the ability to transmit over one of 10 possible frequency channels (spectrum adaptiveness), the ability to receive over two channels simultaneously, the ability to adjust the transmission power on a per-packet basis, and the ability to choose from eight possible transmission rates.

One key challenge was related to the "transmitter deafness" phenomenon, which is caused by the half-duplicity of the radios. Specifically, while transmitting a data packet over a given channel, a RAFAR node is unable to monitor traffic over the control channel. This results in outdated channel assignment information at that node, ultimately leading to packet collisions.

The UA team converged into a novel MAC design that extends the popular single-channel CSMA/CA (carrier sense multiple access with collision avoidance) approach, often used in wireless LANs, to a multi-channel, multirate, power-controlled RAFAR network. The design calls for dedicating a channel for control purposes, including the exchange of customized RTS/CTS (ready-to-send/clear-to-send) packets to allow a pair of RAFAR nodes to agree on a common

channel, without causing harmful interference to ongoing transmissions. The sender-receiver rendezvous also allowed the pair to negotiate the best attainable transmission rate using the least amount of required transmission power.

The UA team, with input from RMS, simulated the behavior of the RAFAR MAC using up to 80 nodes under various traffic scenarios and channel conditions. Early results indicate impressive spatial reuse improvement compared with state-of-the-art approaches.

The results also expose the key bottlenecks of the system and demonstrate how they affect the overall network throughput. For instance, because of the large difference between the maximum transmission rate (5 Mbps) and minimum transmission rate (40 kbps) that the RAFAR system supports, using the minimum rate to transmit control information (typically done to extend the range of the control transmissions) leads to a control-channel bottleneck. A higher rate for control information is then needed to increase the system throughput, but this comes at the expense of reducing the range and, hence, increasing the likelihood of collisions (due to hidden terminals) over the control channel. By identifying the system bottlenecks, various updates to the protocol and to the underlying radio network architecture can be made.

Current research goals include: (1) extending the design to a more general multihop setting, which also requires accounting for notorious "hidden terminal" effects; (2) designing an intelligent scheme for dynamic selection of the control channel (i.e., not requiring pre-assignment of the control channel); (3) allowing for load-dependent rate adjustment for transmissions of control packets; and (4) exploring routing solutions for a multihop RAFAR network.

Exhaustive simulation-based evaluations are currently underway, with the purpose of evaluating the protocol performance under various path loss exponents and mobility scenarios. One reason for these simulations is that early results show some interesting tendencies in the protocol's selection of data rates that seem to be tied to the value of the path loss exponential.

This ongoing URP funded research is complemented by Dr. Krunz's ongoing research on cognitive radio networks (CRNs), which is being funded through a grant from Connection One, a National Science Foundation/state/industry consortium that includes Raytheon. The Connection One effort focuses on channel/rate/power optimizations in CRNs subject to "primary-radio" (PR) power masks and transceiver constraints. The RAFAR system can be viewed as a preliminary version of a CR with limited transmission capabilities. (A CR is typically capable of transmitting simultaneously over a variable number of channels and must also be able to account for CR-to-PR and PR-to-CR interference constraints.)

Due to the fact that RAFAR is software definable, additional CR capabilities will be integrated into the system as time progresses. As increased CR capabilities are brought on line, the UA team will address these new capabilities in their modeling. ●

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ENGINEERING PROFILE

Eduardo Chumbes
Principal Electrical Engineer

RF Components – Advanced Device Group

Raytheon Integrated Defense Systems

Eduardo M. Chumbes graduated from the Massachusetts Institute of Technology (MIT) in 1992 with a bachelor's degree in physics. Prior to his graduate work, he worked in Japan for two years at Matsushita Electric Works, developing automated tools (software and hardware) for device characterization.

In 2001, he received his doctorate in electrical engineering from Cornell University for research work involving device processing and testing of novel GaN HEMTs. During this time, he was involved (as a recipient) in a University Directed Research (UDR) program funded by Raytheon for two years to work on GaN HEMT structures. This led to his employment with the company starting in 2001.

Today, he manages two UDR programs — one with Cornell and one with MIT. He has been involved with the Cornell program since 2001 and began managing the MIT program in September 2007. Both programs complement Raytheon's microwave and millimeter-wave GaN MMIC technology development for next generation systems.

Low-Cost IR Dome Material Characterization

Zinc sulfide (ZnS) is an important infrared (IR) material used in many of Raytheon's products, from missile domes to targeting pod windows. Recent product requirement trends have necessitated a revised look at the cost and properties trades in ZnS processing. Raytheon is leveraging the University of Arizona's characterization capabilities to distinguish among similar materials that behave differently during processing. The University of Arizona (UA) has certain microscopy and optical test capabilities that Raytheon deems useful for additional insight into ZnS.

The collaborative work between Raytheon and UA is a component of a broader program to gain a fundamental understanding of the processing and property relationships in ZnS that give rise to the desired optical and mechanical properties. Professors in the Department of Materials Science and Engineering are engaged in this project along with the resources of the Arizona Materials Laboratory in collaboration with engineers at Raytheon.

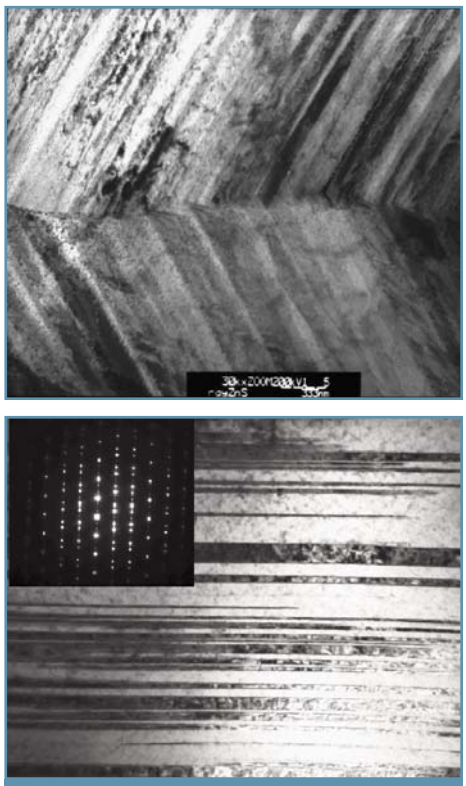
Zinc sulfide has shown unequaled utility for infrared windows that require longwave infrared (8-12μm) transparency, mechanical durability and elevated temperature performance. Its unique set of properties lends itself also to electroluminescent phosphors, optical thin films for anti-reflection and various other opto-electronic applications.

The materials community realized that ZnS was an important optical material for infrared windows over 40 years ago. Chemical vapor deposition (CVD) quickly became the method of choice for producing large ZnS windows and domes due to the ability to grow large uniform parts. Once grown by CVD, the optical "blanks" are consolidated in a hot isostatic press (HIP) at a temperature near the hexagonal to cubic structural transition (1020 °C) for a period of time to achieve high transparency and low scatter. High optical quality ZnS windows several millimeters thick produced in this manner transmit visible light and so have received attention as candidates for multispectral windows for applications using both visible and thermal infrared sensors.

At present, the processing-property relationships for CVD ZnS have not been firmly delineated. Optical quality remains highly variable among CVD grown materials, and common characterization techniques have thus far been unable to uniquely fingerprint materials that exhibit different optical properties. Photoluminesence (PL), which measures the electronic effects of atomic defects, has been able to differentiate among materials with seemingly similar bulk optical properties, but which behave differently when hot isostatic pressed. Additionally, transmission electron microscopy (TEM) has provided insight into the nanoscale structure of ZnS, which is determined by mechanisms of crystal growth during deposition and recrystallization during subsequent heat treatments. This joint Raytheon-University of Arizona project is focused on the characterization of CVD ZnS produced under different deposition conditions using photoluminescence and transmission electron microscopy with the objective of establishing clearer processing-property relationships for CVD ZnS.

Photoluminescence spectroscopy typically involves two primary processes: (1) optical excitation of the electronic states of a material system in thermal equilibrium into higher-energy allowed states; and (2) the collection of emitted light as the electronic states spontaneously relax back to lower energy ground states via radiative mechanisms.

Analysis of the spectral (transition energy) and temporal behavior of the radiative processes provides important insights into the nature of the electronic states and their associated structures. Photoluminescence is often used, for example, in the identification of defect states in insulator and semiconductor materials. In this case, structural point defects (disruptions in stoichiometry, elemental composition, or structure at lattice sites within the perfect crystal) often result in localized energy states within the band-gap of the material. Radiative decay, within these defect energy levels, will result in emission peaks and relaxation dynamics whose characteristics (e.g., transition energy, lifetime) can be uniquely associated with elemental impurities or structural defects. In conjunction with complementary techniques such as absorption and excitation spectroscopy, photoluminescence can be used to develop an experimental understanding of the electronic structure of a material, and therefore of the number and type of defects.



Transmission electron microscopy images show structures at the atomic level that may impact optical and mechanical properties.

TEM offers the unique possibility to observe defects in crystals at the atomic level as defects scatter and diffract electrons differently from their surrounding matrices. Electron diffraction patterns can be used to gain quantitative information on the following: (1) the identity of phases and their orientation relationship to the matrix; (2) habit planes of precipitates and slip planes in materials; (3) exact crystallographic description of crystal defects; and (4) order/disorder, spinodal decomposition, magnetic domains and similar phenomena.

Planar defects such as twin boundaries, platelets and crystallographic shear planes have been studied, and detailed computer simulations have been used to confirm the interpretation of micrographs obtained by TEM. Characterizing these types of defects is important because they play a dominant role in kinetic processes such as growth and recrystallization. In addition, because their structures deviate from the perfect crystal, they often have unique electronic states associated with them that can contribute to the optical and electrical properties of the material.

Preliminary TEM and PL measurements are encouraging. Insights gained through this Raytheon–University of Arizona program will be used to develop fundamental understanding of the processing, property and structural relationships in chemical vapor deposited zinc sulfide in order to tailor material properties to meet the needs of Raytheon's systems. ●

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IED Detection by THz Spectroscopy of Relevant Explosives

For several years, Raytheon Missile Systems (RMS) has collaborated with the University of Arizona terahertz (THz) Radio Astronomy Group directed by Prof. Chris Walker. Much of the effort was to develop THz radiation sources for the detection of explosive materials.

Many military explosives can be detected by very specific lines in the absorption spectrum in the THz region. One of the major difficulties was the absence of an intense source of THz radiation. Prof. Walker's R&D efforts to construct a traveling wave tube (TWT) THz amplifier for the improvement of interstellar cloud imaging presented a technology leverage opportunity for the science of improvised explosive device (IED) detection. Through the Raytheon-University of Arizona collaboration, several million dollars have been directed to the TWT amplifier program. Initially, Raytheon Innovation funding was provided to Dr. Delmar Barker in RMS Advanced Programs to study the problem of explosive detection by THz spectroscopy. Raytheon University Research funding was combined with corporate matching funds to extend the work at the university. Prof. Walker's small company received SBIR funding. Finally, JIEDDO (the Joint IED Defeat Office) in collaboration with the U.S. Air Force, began to contribute at the million dollar funding level.

The TWT will be integrated into a system that will detect IEDs by differential heterodyned imaging. Detection sensitivity is expected to increase by several orders of magnitude above the broadband techniques now in use. RMS has been asked to design and field-test a system that can aid our troops in combat situations.

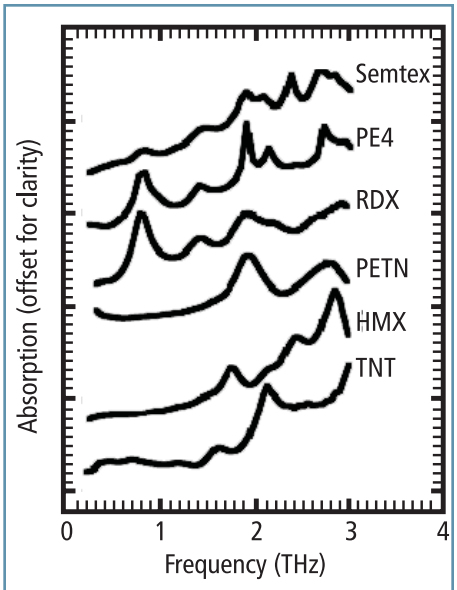


Figure 1. The THz-TDS generates and detects picosecond THz pulses by a coherent and time-gated method using near infrared femtosecond laser pulses (Woolard, et. al 2005).

More Details

Over the past decade, experimental and theoretical studies have demonstrated that complex molecules like explosives can be identified by their unique absorption line signatures at far-infrared wavelengths (Woolard, et al. 2005; Globus, et al. 2003). These absorptions arise from the interaction of an applied electromagnetic field with phonon (lattice vibrations) within the molecules. These resonances are common at THz frequencies (0.1 – 10 THz), making this an excellent spectral regime for the identification of complex molecular species (see Figure 1).

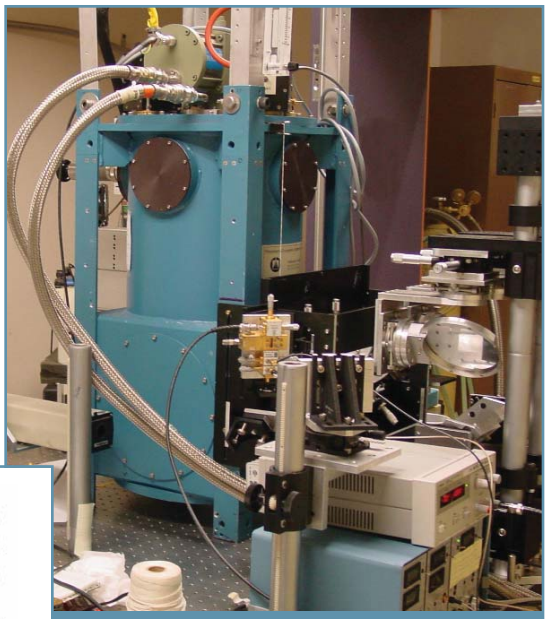
For remote sensing applications, the low end of this frequency range (< 1.5 THz) is particularly important since it is less susceptible to absorption by atmospheric water vapor. At these wavelengths it is also possible to see through a variety of dielectrics (e.g., clothes, paper and ceramics) which are opaque in the optical and infrared.

The key to the successful operation of an explosive detection system based on THz absorption line spectroscopy is the availability of a powerful signal source for illuminating targets. The reflected signal contains the absorption line used to identify the explosive.

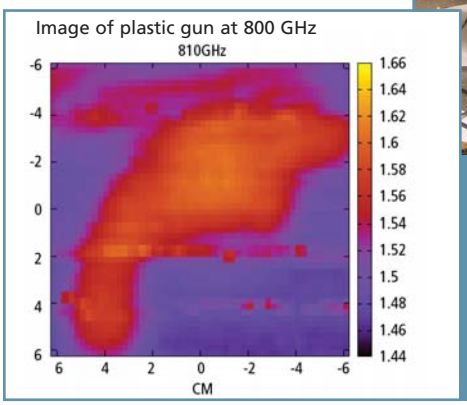
Continued on page 30

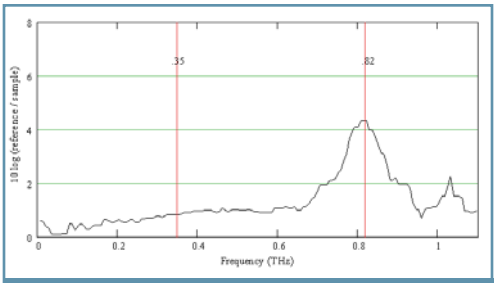
Continued from page 29

A strong source is needed for two reasons 1) to overcome the absorption due to atmospheric water vapor and intervening materials; and 2) because the molecules being identified couple only weakly to the incident radiation. A powerful signal source increases both the ability of detection and the effective range of the system. In addition, by using heterodyne techniques to target specific known explosive absorption lines, many orders of magnitude increase in sensitivity can be achieved compared to broadband techniques, such as time domain spectroscopy (TDS).



The THz imaging spectrometer was constructed by Prof. Walker's radio astronomy group for interstellar cloud imaging from a location at the South Pole. It was then sent back to a Raytheon Advanced Programs laboratory where it was reconfigured for explosive detection and imaging studies.





Absorption peak from RDX measured with the THz spectrometer.

This 'targeted frequency' differential absorption approach in itself reduces the confusion associated with clutter in urban environments and actively discriminates against false detections. Over the past two years, the Univ. of Arizona, Raytheon and, more recently, AFRL/DEHE, have been collaborating on the development of THz TWT amplifiers. Coupled with existing, tunable solid state sources, these THz TWT amplifiers will provide the strong, coherent signal sources needed to realize the power of THz spectroscopy to identify IEDs at safe distances.

After several years of exploratory research, the THz TWT project is beginning to show results. Initial results on the detection of explosive materials will be presented by the U.S. Air Force sponsors at a classified meeting of the Military Sensing Symposium in early 2008. Development of a fieldable system in the next phases of the effort will involve an even higher level of Raytheon participation.

The THz TWT collaboration of RMS with the Univ. of Arizona is an excellent example of how industry and the academic community can combine their respective talents to improve our safety in an effort that would otherwise not happen nearly so quickly or efficiently. This development work has been partially funded through a Phase I NSF STTR grant, IRAD/IDEAS/Cooperate Matching funds from Raytheon and (since September 2006) an award from JIEDDO. ●

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Additional Raytheon University Research Work

University of Massachusetts, University of Oklahoma, Colorado State University, and University of Puerto Rico, Mayaguez

Raytheon is an industrial partner with the University of Massachusetts (UMass), which leads the center for the National Science Foundation's $100 million grant to the Collaborative and Adaptive Sensing of the Atmosphere (CASA) project. The four partner universities are UMass, the University of Oklahoma, Colorado State University and the University of Puerto Rico, Mayaguez. The center focuses on the development of a distributed sensor network aimed at improving the forecasting and warning for severe weather events (tornadoes, flooding, etc.).

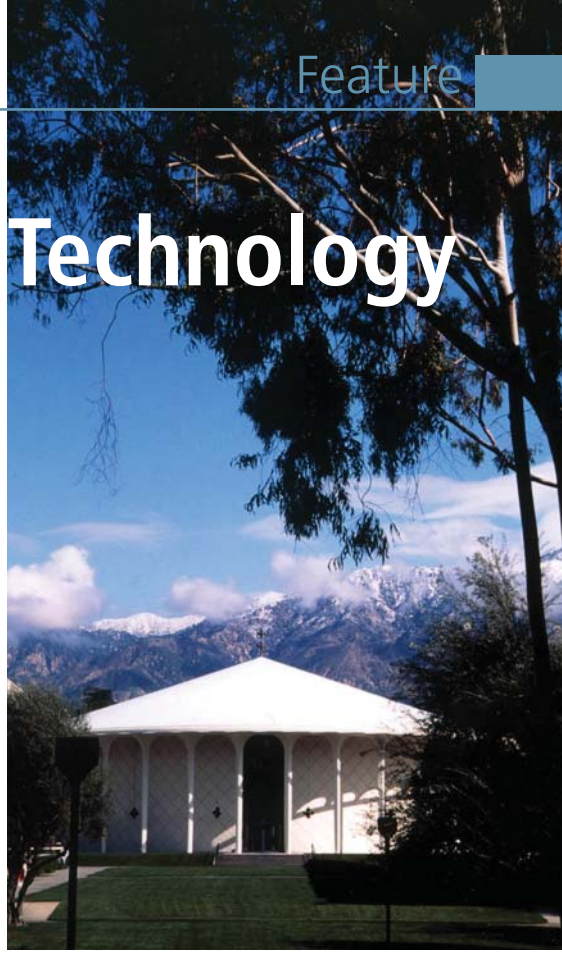
University of Illinois, Purdue University, Georgia Institute of Technology, Lehigh University

Raytheon is a strategic member in the Industrial Affiliates Program of the IMPACT (Investigative Multi-physics Modeling and Performance Assessment-driven Characterization and Computation Technology) Center for the Advancement of MEMS/NEMS VLSI. The program is led by the University of Illinois.

The IMPACT Center is sponsored by the Defense Advanced Research Projects Agency (DARPA). The work focuses on accelerating and expanding the understanding of micro/nano-electromechanical systems (M/NEMS). This evolving technology plays an important role in future RF and mechanical systems, because it enables a new class of control electronics for a variety of sensors.

Our close relationships with professors and students provide us with valuable insight, which in turn allows us to focus much of the research toward our needs and problems. It also provides early access to breakthrough solutions. The IMPACT member universities include the University of Illinois, Purdue University, the Georgia Institute of Technology and Lehigh University.

The California Institute of Technology



Raytheon supports the **Caltech Microelectronics Center** in the research of RF CMOS circuits for microwave and millimeter wave applications. Professor Ali Hajimiri and his staff are developing novel approaches that leverage the strengths of silicon while supporting mixed signals to provide more affordable solutions for sensor applications.

A 60 GHz RF-combined 4-element phased array front end is implemented in silicon using a novel hybrid parallel/series-fed approach which reduces on-chip phase shifter requirements. The array, which includes amplitude control as well as continuous phase adjustment, provides for simultaneous illumination of two angles of incidence.

We combine the series-fed and parallel-fed array architectures to further relax the RF phase-shifter requirements to enable RF signal-combining. As shown in the simplified block-diagram of Figure 1, discrete phase shifters (DP) in every element choose one of two phase-shift settings (e.g., 0° or 180° in Element 2). The DPs can be configured to provide different values of phase shift in each mode of operation, thereby reducing the variable phase shift requirement in the BVPs. The signals are then fed into bidirectional series phase shifters, each of which provides a certain amount of phase shift.

The important point is that the signals on the series phase shifters travel in both directions, yielding the following signal summations at the two outputs providing for two concurrent receive beams. The input to each element is first amplified by a four-stage 60 GHz LNA that has variable gain to compensate for downstream gain variation. The fourth stage of each LNA provides variable gain by current steering. The output of the LNA is provided to a DP that can choose between two phase-shift settings.

The front end has a noise figure lower than 6.9 dB at 60 GHz and array achieves full spatial coverage with better than 20 dB peak-to-null ratio. The four-element 60 GHz front end consumes 270 mW and occupies 4.6 mm^2 of die area. Figure 2 shows a die photo of the array, which was implemented in a SiGe process with BJT cut-off frequency of 200 GHz. ●

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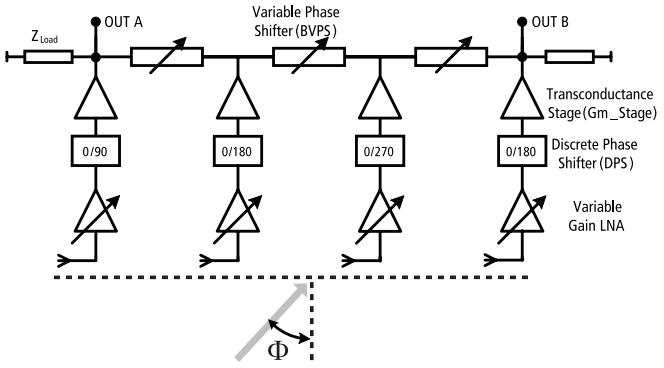

Figure 1. Block diagram of 60 GHz phased-array front end

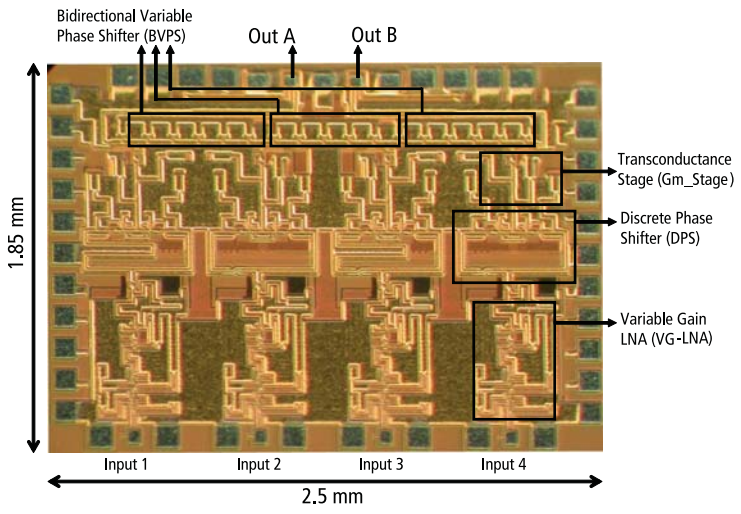

Figure 2. Die photograph of 60 GHz phased-array receiver front end

Raytheon and the Institute for Soldier Nanotechnologies at MIT: Survivability and Success of the U.S. Warfighter

The history of design and manufacturing is as old as people fashioning sticks for crude tools like clubs and spears. As these tools evolved over time, so too did the manufacturing technologies. The fabrication techniques and product designs interacted in unique ways to provide the products that we have utilized in all aspects of our lives. As fabrication methodologies matured over time, people specialized into a multiplicity of trades and crafts. These early efforts where characterized as a single point (zero dimension) methodology as one person produced one item in time.

Then in 1908, Henry Ford started the modern assembly line and a new paradigm was launched. Parts entered into the factory in one area and were built in a long continuous line by specialized individuals at each point, launching the one-dimension or linear manufacturing technique. In 1955, this one-dimensional approach to manufacturing was altered by a new two-dimensional manufacturing technology that allowed new designs and technologies to emerge.

These semiconductor fabrication technologies fundamentally transformed both the design and the manufacturing approach enabling a whole new class of products. The world is now entering into a new three-dimensional fabrication capability. The change is being driven by the development of new micro- (10_{-6} m) and nano- (10_{-9} m) scale technologies. 3-D stacked packages and new nano technologies are very recent examples of this new trend that promises to also radically change both the design and manufacturing approach to products. Nowhere is this transformation more evident than in the university partnerships that Raytheon has formed to explore and exploit these brand new technologies.

The Institute for Soldier Nanotechnologies (ISN) at MIT is an interdepartmental research center founded in 2002 by a $50 million, five-year contract with the U.S. Army Research Office. Raytheon, along with DuPont and Partners Healthcare, is one of

three founding industrial partners for the ISN. Now in its second five-year contract, the mission of the ISN is straightforward: Develop and exploit nanotechnology to dramatically improve the survivability of warfighters. The ultimate goal is to help the Army create a 21st-century set of technologies that combines high-tech capabilities with light weight and comfort.

MIT Leaders for Manufacturing

Raytheon is an industry partner to MIT's "Leaders for Manufacturing" (LFM) program. Currently, 13 LFM graduates hold leadership roles in numerous organizations across Raytheon, including Supply Chain, Operations, Engineering and Business Development. At the core of the program is a six-month internship with a partner company. Raytheon provides learning opportunities for up to six LFM interns annually at various businesses.

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Imagine a bullet-resistant jumpsuit, no thicker than ordinary spandex, that monitors health, eases injuries, communicates automatically, and reacts instantly to chemical and biological agents. It's a long-range vision for how fundamental nanoscience can make warfighters less vulnerable to enemy and environmental threats.

Picture yourself as a U.S. soldier running down a street in a potentially hostile area. Now add up to 140 pounds of gear and assume that it is more than 100 degrees Fahrenheit outside and people are shooting at you. That is the situation that soldiers are facing today and one that Raytheon along with its partners at the ISN at MIT are determined to solve.

Today's dismounted infantry warfighter carries a back-breaking load, and still has incomplete ballistic protection, insufficient defense against chemical and biological weapons, and too many pieces of equipment that do not work well together. An ISN challenge is to help transform today's cotton/nylon fatigues and bulky equipment to a sleek, lightweight battle suit that provides everything from responsive armor to medical monitoring to communications in one integrated system. This battle suit is the ultimate goal, but many of the more immediate pieces of developing technology can apply to vehicles, sensors and other products produced by Raytheon today.

Nanotechnology fits into this vision in two important ways. First, it offers the potential for miniaturization, a key part of reducing weight and bulk. Today's hefty radio worn on a harness might be reduced to a button-sized tab on the collar. A waterproof poncho could be replaced by a permanent nano-thin coating applied to everything the warfighter carries. Second, because nanotechnology operates at length scales where classical Newtonian physics breaks down, it offers engineers the potential for creating unprecedented new materials properties and devices. Nanotechnology can solve problems that scientists have been struggling with for decades.

As part of the formation of the ISN, funds were made available through the U.S. Army Research Office in the form of 6.2 applied research programs. Raytheon has two current awards shared with and based on research done at the ISN prior to Raytheon's involvement — and there are other submissions planned in the future. The current Raytheon ISN programs are in novel infrared detectors and transparent conductors. Raytheon has planned submissions in lightweight materials and blast wave mitigation.

The ISN's vision for the warfighter of the future is part of a larger transformation going on today in the U.S. Army. Faced with new threats and challenges, the Army is redesigning itself as a lighter, faster, more agile force that can be deployed quickly where warfighters are needed. The ISN supports the Army's Future Force Warrior program, which aims to achieve a soldier-centric force enabled by an integrated individual combat system. Raytheon is proud to be a member of the ISN and in helping to ensure the survivability and success of the U.S. warfighter. ●

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ET&MA
OPERATIONS

Richard B. Johnston
Vice President
Corporate Operations

Recently, *Technology Today* talked with Dick Johnston, vice president of corporate Operations. Johnston discussed the function's unsung role in Raytheon's success, the power of cross-functional partnerships and why the company is taking on the challenge of environmental responsibility.

TT: *In 2006, corporate Manufacturing was renamed Operations. Can you explain the significance of this change, and what is the underlying message here?*

DJ: The cornerstone of Operations is still very much manufacturing. The name change was intended to reflect the breadth of the responsibilities. First of all, as part of Operations, we manage Raytheon's facilities, that is to say, the physical buildings and the properties. We're the day-to-day managers of those sites, and so we work closely with corporate real estate.

When it comes to the people who take care of those buildings, take care of the utilities, and plan for the future to support business growth and business needs, that's done by Operations professionals across the company and around the world.

Clearly, there's a lot of overlap between Operations and other functions. Environmental, Health and Safety (EHS) is not part of Operations at corporate, but if you look at a lot of things we do, they certainly affect the EHS area, so we team with them. Rob Moore and I consider each other partners. He has responsibility for EHS and corporate real estate. I have responsibility for Operations. I think we would both tell you that neither function would be successful without the other.

TT: *What are the priorities for Operations?*

DJ: Our number one priority is *people* and supporting an injury-free, safe and healthy lifestyle — as opposed to just a safe work place. Since we make decisions as to what the facilities will look like, we believe we play a very important role. Consider the process of ordering desks. Are they ergonomically proper? EHS will help us pick them out. We're the people who actually implement. We decide what the work environment will look like. That's important when you think of generational diversity, like Generation Xers and Millennials. They have different expectations than Baby Boomers, like me. So, we're trying to ensure we team with Human Resources to meet those needs.

Mission Assurance is another one of our main objectives. We're the people who actually build and test the hardware, and define the processes. So our manufacturing engineering and planning processes, working with Engineering and Performance Excellence, are fundamental to achieving Raytheon's goal of no doubt.

TT: *How do you foster that collaboration between functions outside of Operations? How do you accomplish that throughout all the sites and facilities?*

DJ: There are several ways. We have representatives from other functions on the Operations Council: Performance Excellence, EHS, corporate real estate, Engineering, Supply Chain and Mission Assurance. We are all in tune to what the other's objectives are — strategic, tactical or otherwise. We recognize that we cannot accomplish anything without total cooperation. We do a lot of collaboration outside the Operations Council to make sure we understand the businesses' needs and strategies. We look for areas of common ground that we can leverage to make the company more successful.

The common denominator is people. We reach out to identify what the people are interested in, and we try to tie those to the company's objectives in a meaningful way. We probably have the opportunity to do that as an organization more than some others because Operations spans all the way from leadership to the person on the factory floor. By the very nature of our assignments, we have multilevel communications going on all the time. We know, particularly in manufacturing, you cannot be successful if you do not understand what the needs of the people are, and how you can leverage those to achieve the company's goals.

TT: *One recent example of effective cross-functional, multisite collaboration is in the area of energy conservation. Tell us how this employee momentum was achieved?*

DJ: First, we looked to Raytheon's Integrated Defense Systems business leadership on this front. We liked what they were doing, and asked, "How can we leverage this across the company?" We often do that. Many times a different business will become the de facto leader and the corporate function will look at ways to leverage what they have already done.

Also, we have very strong support from our presidents. Looking at September's enterprisewide Energy Conservation Summit, you saw a great number of the presidents making personal commitments and having all-hands meetings where they talked about the importance of energy conservation. This helps us get that broader base of support. And candidly, in areas like energy and the environment, most of us want to leave the planet a better place for our grandchildren. It's good stewardship and something that's easily supported by many people on a personal level because we all live where we work.

TT: *Why is energy conservation becoming such a priority for Raytheon?*

DJ: In addition to the personal reasons I just mentioned, we're taking a proactive approach to energy conservation for business and workplace reasons. From a business standpoint, Wall Street expects leading companies to act as accountable stewards of the environment. There is an intrinsic value to stockholders who expect the companies in which they invest to demonstrate high performance and responsible behavior throughout all business operations.

It makes good business sense when you think about it, because of our priority on having a healthy workplace and an injury-free work style. Part of that is the environment; it's the air you breathe. You only have to look at the recent fires in California to see that because they could visualize the dirty air. We want our employees to be attracted to clean and healthy places to work and create a very diverse and productive workforce that will drive the innovation that has been the history of Raytheon and certainly will be the future of Raytheon.

TT: *Can you comment on the recent Energy Conservation Summit?*

DJ: Our biggest impact to our environment is our use of energy. That was the reason for the Energy Conservation Summit — most of our emissions are from energy, almost 90 percent.

We've seen a lot of employee engagement to date and in 2008 we want to take that to the next level. We're issuing a new energy policy and included in that will be LEED (Leadership in Energy and Environmental Design) certification of new buildings by the U.S. Green Building Council, and the U.S. Environmental Protection Agency green building standards. The policy requirement will list this as one of the factors for consideration when you do major renovations, lease or build new buildings. There have been four LEED projects at Raytheon to date. The idea is to make energy conservation part of everyday business.

TT: *We've discussed energy conservation. Can you discuss other focus areas?*

DJ: Another Operations priority is transition to production. This is our ability to take an innovative concept from the technology area and turn it into a profitable product. This is a focus area for Operations in partnership with Heidi Shyu [VP Technology], Peter Boland [VP Engineering], and Greg Alston [VP Mission Assurance]. Our role is to make sure they understand our requirements up front, we understand their requirements and we blend those together. For years we've heard about "technology readiness levels" and more recently "manufacturing readiness levels," and they're not necessarily the same. Technology can be ready to be leveraged, but if manufacturing processes aren't available to leverage it, you won't have effective product realization.

TT: *Optimizing capacity, that's part of Operations as well?*

DJ: Yes. We leverage the industrial engineering skill set that is available in Operations to conduct capacity modeling for our factories, so we know how much we can handle. We look at a lot of variables. What's the capacity of our equipment? What's the capacity and skill set of our people? We look at various factors, including our current backlog and projected bookings, and then we can determine how much of the capacity we're using. That will help us determine whether or not we have the capacity and capability, or if that work needs to done someplace else.

On our corporate Operations portal, there is a link to every factory, what they do, who the contact people are, and what kind of products they build. This is available for anyone at Raytheon. So, for instance, if I was considering building a harness, I could go to the Operations website, click on "harnesses," and see every site that builds harnesses. I would also find subject matter experts to contact for more information. You can do that for any technology and it will tell you which factories are involved.

TT: *One thing we've not talked about is PRISM – the enterprise Process Reinvention Integrating Systems for Manufacturing.*

DJ: PRISM is now in its sixth year since we started planning, and it's probably the most significant single initiative Operations is overseeing. That may be hard to believe when you consider our utilization and environmental/energy conservation efforts, which are huge. PRISM will affect virtually everybody involved in the production of hardware, regardless of function. So it's much bigger than Operations, and a very significant game changer for Raytheon.

TT: *How exactly is it a game changer?*

DJ: Implementing PRISM is a recognition across the company that we did not have an enterprise system that allowed us to leverage the size of the company. It's important in many dimensions. It lets us aggregate our spend on the material side. It lets us aggregate demand and achieve a higher utilization rate of our factories. But it also lets us leverage our people because when you have common processes across the company, the ability to rotate people and develop their careers is improved.

There are many real advantages and they include things other than material resource planning. It is often called "the next generation MRP system." Virtually, PRISM is every process, from the release of the engineering file up to and including shipment. You can imagine the leverage across a company of 73,000 people, when our basic core processes become common across the company. I don't know of another company that has achieved that to date.

It's going to require intense focus to complete that transition. I estimate we will be about two-thirds of the way there by the end of 2008.

TT: *With all these focus areas, you must have quite a large corporate staff.*

DJ: Actually, it's just the opposite. The success is a tribute to the teamwork of the businesses and their operations leaders! I have three staff members and their titles will tell you where my priorities are. Yuliya Frenkel is manager of Operations initiatives. She looks at how we drive utilization through the company and improve our return on investment. Mark Edmondson is director of lean strategy, and that's how we lean out the entire value stream, and Aaron Shin, is director of transition to production. Everything we've talked about falls under one of those areas. Operations is successful because of the greater Operations team and the collaboration with the other functions.

Basically, the fundamental principle is lean. People often associate it with lean manufacturing, but if you understand lean, it needs to be a lean product life cycle — all the way from innovation to delivery — because you have to tie in that customer on both ends. The transition is self-explanatory, and Aaron is bridging across all those areas to make sure that we do make that connection. Yuliya is looking at our footprint and investments to make sure we're doing it wisely across a complex company.

TT: *So Operations is much broader than most employees realize?*

DJ: I think most people recognize we do those things. We're a function that wants to be there when we're needed. Ideally, we don't want to be noticed. You want have a nice facility to come to work. You want to be safe at that facility. Customers want products delivered on time that work every time. You want the business to continue even in the event there is a hurricane. It's a function that, in a perfect world, people may never recognize what we do, because we're taken for granted. And that's one of our goals. We don't want people to worry about basic needs. ●

COSMET: A Powerful System Engineering Development Tool

The performance analysis of complex radio frequency platform communication systems have always been a challenge. The traditional approach captured platform performance with linked spreadsheets and Matlab scripts. The shortcoming of this approach was that it was static (i.e., a single scenario at a single point in time). With this approach, changes to the requirements or "what-ifs" were difficult to accommodate within a reasonable time and the consistency of the results were in question. This approach was also susceptible to subjective evaluation —. e.g., what assurance is there that the worst-case performance has been identified?

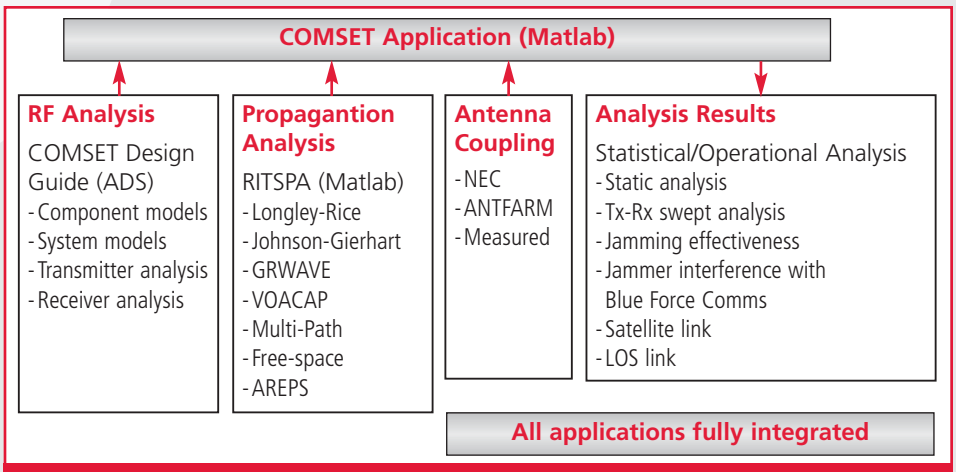


Figure 1. COMSET is a fully integrated tool set.

In 2001 Raytheon received a contract for the communications system on rotary wing Army Airborne Command and Control System (A2C2S). This contract had a system requirement stating there shall be no degradation to the platform performance with the inclusion of the new command and control (C2) elements. The contract was accepted with the understanding that Raytheon would be allowed to define what "no degradation" meant. Raytheon took this position because known platform interference would be present; therefore, there was a need to define in measurable terms precisely what constituted "no degradation."

The outcome of this effort was an analysis tool called RAYCIPT (Raytheon Cosite Interference Performance Tool). This tool integrated system performance from Agilent Advanced Design System (ADS) and full frequency path loss models with multiple Matlab scripts and integrated graphical user interface–based applications to define the statistical performance of the system, not just the worst-case performance. The tool enabled the introduction of concepts of operations (CONOPS) so actual mission scenarios were used in defining "no degradation" at the operational level.

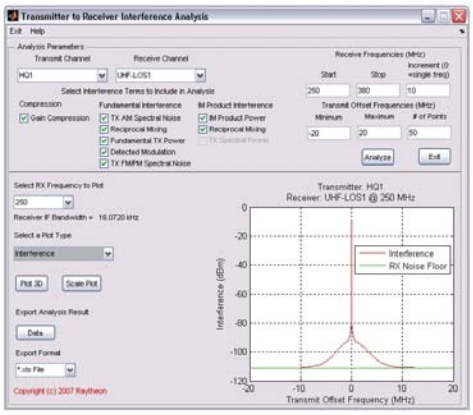
In 2006 RAYCIPT was upgraded to COMSET (Communication System Engineering Tool). The upgrade provided more efficient, faster simulations for large platforms, improved accuracy and improved graphic user interface (GUI) to make the tool easier to use. Figure 1 illustrates the integrated applications that can support multiple platform mission analyses. COMSET is not limited to communication systems alone, but can also be used to analyze jamming systems and combinations of jamming and co-located communication systems.

COMSET is a fast, repeatable, easy-to-use system performance design tool that evaluates and allocates system performance requirements within the platform communication system in an operational environment. Design performance requirements can be easily evaluated from the proposal stage through the final design stage of the program. The platform interference sources can be individually selected to examine their individual contributions to the platform interference performance. This allows the system engineer to isolate specific interference sources from which hardware and system requirements can be generated or accepted. An example is the Transmit/Receive (TX/RX) swept analysis for any receive port and any transmitter port. This feature allows instant observation of the platform interference performance.

The tool has been successfully applied to various platforms and operational scenarios (see Figure 3). Detailed platform performance analyses have been performed on platforms including complex maritime platforms (DDG, CVN, LHA, LHD and SSN), complex airborne platforms (AC-130U, E-2D, AV-8, A-10, E-8, E-10, ASTOR, Apache, Chinook, Blackhawk and A2C2S) and fixed sites (PAX River NAS, Polk AFB, Langley AFB, M2C2 and MBC).

The tool can easily evaluate CONOPS impacts on the platform communication 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 10 percent operational problem, is it worth the cost to correct the problem?"

These analyses can be performed at the preliminary design phase of the program to



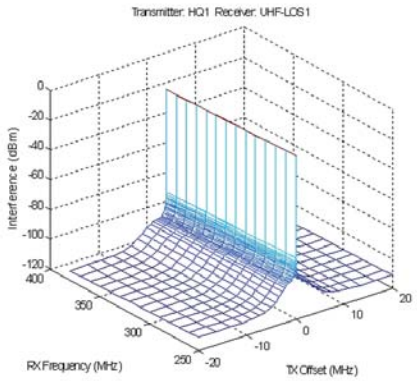


Figure 2. Transmit/Receive Swept Analysis – select analysis frequency from 3-D data

refine the system requirements for cost and performance impacts. COMSET is not limited to any specific frequency range or to any specific platform or operational scenario. Mission Systems Integration, Homeland Defense, C2 systems and command centers are candidate applications that would benefit from COMSET.

The COMSET database has more than 200 performance models that can be assembled into a platform communication or jamming architecture. These models include specific nomenclatured radios, filters, power amplifiers, multi-couplers, cable types, antennas, LNA, diplexers, etc. If required, new models can be easily introduced to the tool. Waveform parameters and modulations are also included in the database. Platform architectures can be created and evaluated in days vs. weeks and months as demonstrated on the ASTOR program. What-ifs can easily be accommodated in a reasonable time frame. The tool supports analysis report generation with consistent data result formats and a flexibility in generating specific platform performance result presentations. Finally, the tool provides to the RF systems engineer a set of measurable cosite performance characteristics against which the actual implementation can be formally evaluated — a capability that was not available until the introduction of COMSET. ●

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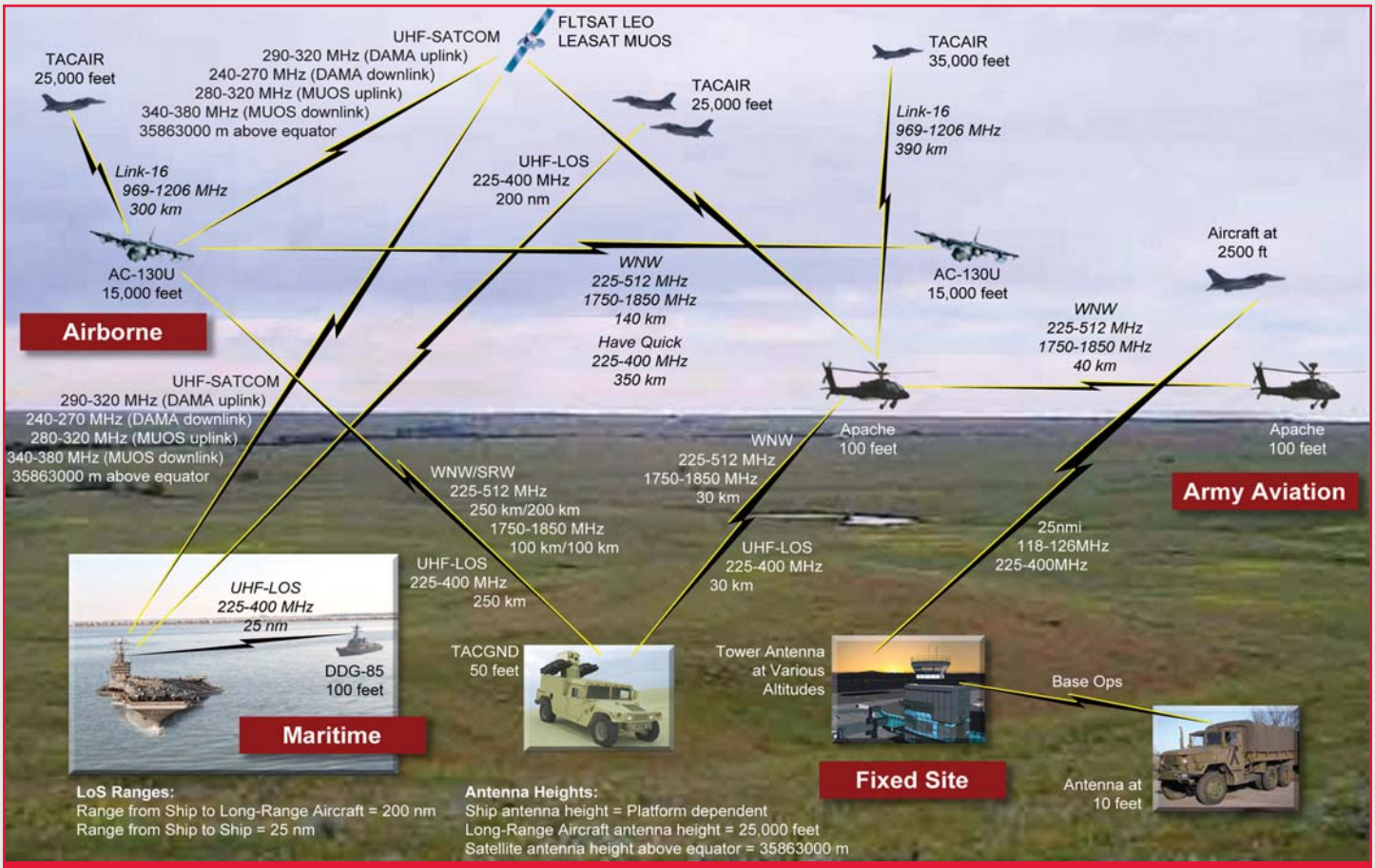


Figure 3. COMSET simulates operational performance.

Tapping Into University Research to Fuel Raytheon's Disruptive Technology

All six of Raytheon's Technology Networks have been issued the following challenge from Taylor W. Lawrence, vice president of Engineering, Technology and Mission Assurance, and Heidi Shyu, vice president of Technology and Research: "Bring new Raytheon products and solutions to our customer by leveraging disruptive technology across the businesses." This is a tall order and one the members of the Electro-Optical Systems Technology Network (EOSTN) do not take lightly.

Disruptive technology is the application of new technology into products that "disrupt" the market leaders, create new customers or even create new markets. The study and effects of disruptive technology have been pioneered by author and scholar Clayton Christensen of Harvard University. Christensen explores disruptive technology in detail in his two celebrated books, *The Innovator's Dilemma* and *The Innovator's Solution.*

Ongoing and emerging research at America's universities can provide the basis for infusing new and potentially disruptive technology into our products and services. The Raytheon Engineering and Technology Council, along with the corporate technology office, has both the monies and the infrastructure in place to help do just that. Called the Engineering University Research Program, it is accessible to all engineers and scientists at every level and business here at Raytheon. Leveraging the capabilities of universities through the development of Raytheon-University partnerships in research and other engineering activities is vitally important to our future growth.

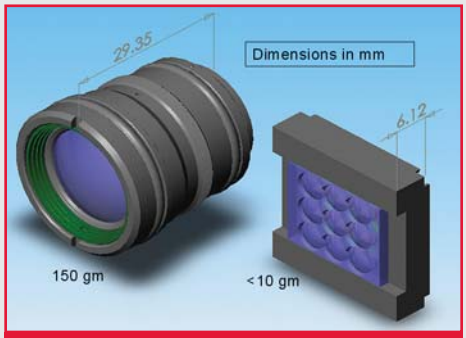
The program is composed of two key elements: (1) directed research, which focuses on sponsoring directed research projects; and (2) technical memberships, which focus on sponsoring memberships in organizations at universities usually consisting of industry/university consortiums. For both types, research reports and results are available through the University Project Library.

Initial target grant sizes are fairly small, usually under $25,000. The target technology is typically in the Technology Readiness Level (TRL) range of two to four. The thrust is to mature the technology within the university system by providing funding, target maturity plans and performance, while continually looking at developing its insertion into our current or emerging products.

The advantage of using the university system for maturation is cost-effectiveness and focus on the technology. Small corporate grants can go a long way in funding labor and materials when working with graduate and doctoral students. Additionally, their college departments forge a company alliance with Raytheon, and Raytheon gains firsthand knowledge of a top-notch engineering talent pool.

One strategy for identifying candidate technologies is to not only envision where our current products fulfill missions effectively, but also where they can be significantly improved with a technology infusion (performance, speed, weight, power, etc.). Our customer would receive a system that performs the mission of the current product with a substantial advantage. This follows the basic definition of disruptive technology — just like the Apple iPod displaced the Sony Walkman®.

Imagine a solder-mounted EO product where the optics could be reduced in size by 4x, along with a reduction in weight of 15x, while having improved optical image quality. Such is the promise of the field of computational optics that is being pioneered by Duke University and sponsored by Raytheon Network Centric Systems in North Dallas. Engineering Fellow Alan Silver defines computational optics thusly: "As the name implies, computational optics is the melding of optics and computers. Up until very recent times, the optical image was an analog image, formed on either a human eye or photographic film. We now have a fully digital image of the external scene, which opens up the potential to combine the digital image and computer processing to improve or even redefine the camera."



Optical system improvements possible using computational optics: >15x reduction in weight, >4x reduction in thickness

An example of an improvement that is being matured in a DARPA Phase 3 contract is the smaller, lighter camera sensor with broader depth of focus having narrower bandwidth and wider dynamic range. It's everything you would want for an EO system that is either solder-mounted or at the front end of a missile, for example.

Imagine a new class of optical fibers that efficiently transmits multimode infrared (IR) laser energy from the source into the transmission optics of a Directed Energy Infrared Countermeasure System (DIRCM).

Such is the promise of work being performed at Clemson University under the sponsorship of Raytheon Missile Systems in Tucson and chief scientist James Mills. This type of technology in IR fibers allows for radically new packaging designs of these types of systems. This in turn allows for reductions in weight, packaging volume and cost. These improvements would enable the integration of DIRCM systems onto additional platforms, thus providing many more applications and market opportunities for Raytheon.

As a member of the Raytheon Technology Networks leadership team, I encourage all technologists from every Raytheon business to get involved. Through participation in the Engineering University Program, you can help Raytheon achieve its vision of creating world-class partnerships with strategic universities and making Raytheon an employer of choice.

To learn more about university research at Raytheon, visit the ET&MA website at http://homenet.ray.com/univ_rel/. ●

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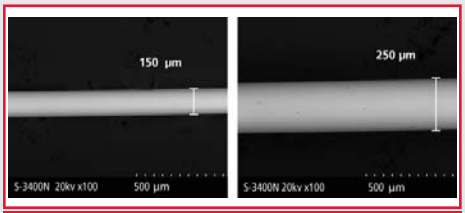

SEM images of the $As_{20}Se_{80}$ fiber. The surface of the fiber is smooth and uniform. Some black spots can be seen at the surface of the fibers. The composition analysis using EDS has shown that these black spots correspond to SiO_2 contamination, probably from the combustion tube.

R-CDL Communication Closes the NT-ISR Information Gap

ISR and Non-Traditional-ISR

Current enemy tactics present a considerable challenge for the traditional Intelligence, Surveillance and Reconnaissance (ISR) constellation, as Maj. Jason Brown[1] of the U.S. Air Force has observed. Currently, the available ISR assets are not adequate to monitor the mobile targets in the battlespace. The military strategy to develop a more capable ISR constellation is to give ISR capabilities to tactical platforms that are not currently used for traditional and dedicated ISR purposes, and integrate these assets into the overall ISR picture. The strategy is called Non-Traditional-ISR (NT-ISR).

Gen. Ronald Keyes has directed the development of the NT-ISR paradigm[2]. The NT-ISR concept is that joint ISR and NT-ISR assets operating throughout the battlespace will be upgraded with robust information collection capability that will be tasked as needed. Additionally, the collected information will be moved off-board the collecting platform for processing, exploitation and dissemination. Moving the collected traditional ISR information will be done with Common Data Link (CDL) waveforms. On the other hand, moving the NT-ISR information off-board will be done with new communication waveforms that were developed from the Radar-CDL (R-CDL) program initiated recently by AFRL[3]. The waveforms are called Pulsed-Common Data Link (P-CDL). Thus, P-CDL can provide the bridge that links legacy tactical ISR capabilities to future integrated tactical ISR capability. Figure 1 illustrates the NT-ISR paradigm along with the concept of NT-ISR producers and consumers.

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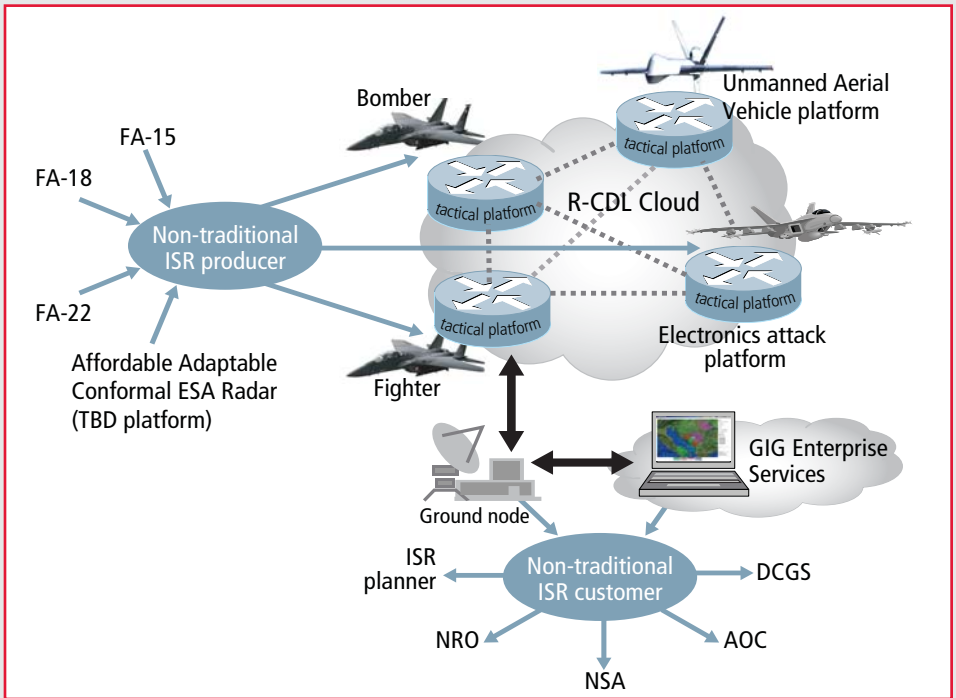

Figure 1. R-CDL communication technology links NT-ISR producers with NT-ISR consumers.

[1]Maj. Jason M. Brown, Capt. Max Pearson, "Non-Traditional Intelligence, Surveillance, and Reconnaissance White Paper," C4ISR Summit 2004.
[2]Gen. Ronald E. Keys, "NTISR Functional Concept," HQ ACC/IN, 209 Thornell Ave, Langley AFB, VA 23665.
[3]Air Force Research Laboratory, AFRL/PKSE, Sensors Division, Broad Agency Announcement Titled "Radar Common Data Link (R-CDL)," BAA-06-2-PKS, CFDA) Number: 12.800 AF.

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Raytheon advanced sensors are capable of producing large volumes of ISR and NT-ISR data. For instance, the Raytheon Integrated Sensor Suite (ISS) enables traditional ISR assets, such as Global Hawk, to scan large geographic areas and produce outstanding high-resolution reconnaissance imagery, and provide night vision and radar detection capabilities. ISS combines a cloud-penetrating synthetic aperture radar (SAR) antenna with a ground moving target indicator (GMTI), a high-resolution electro-optical (EO) digital camera and an infrared (IR) sensor.

For an NT-ISR asset such as F/A-18, Raytheon's Advanced Targeting Forward Looking Infrared (ATFLIR) pod provides pinpoint accuracy and NoDoubt™ reliability for air-to-air and air-to-ground mission support. Raytheon's ATFLIR integrates advanced EO and IR sensors with one of the most powerful lasers on the market. ATFLIR provides air crews with unparalleled performance, including a substantial increase in target detection/recognition range, pinpoint accuracy and assessment from longer standoff ranges, advanced laser designation capability and superior EO/IR imagery.

Multi-Function RF Systems Concept for NT-ISR Applications

The Multi-Function RF Systems (MFRFS) concept applies the reuse concept. In other words, if an NT-ISR platform needs a wideband communications link function and it already has a radar that operates at 2 GHz or above, the radar electronics should be upgraded to implement the communications link through the radar aperture. By contrast, the old approach would encourage procuring and installing a complete new RF system on the platform.

Reuse also minimizes new system development costs for the DoD. The R-CDL system was conceived with "wideband CDL channels and above 2 GHz operation" in mind. Carrier frequencies above 2 GHz allow wide data bandwidths, so R-CDL is the wireless networking "fat pipe" infrastructure to service network centric operations (NCO). In that role, it cooperates with and complements other notable DoD communications efforts such as JTRS, TTNT and QNT.

The Air Force R-CDL Program

The Air Force's R-CDL program was created to implement the R-CDL communications utilizing the MFRFS concept. The R-CDL program develops wideband Pulsed-CDL (P-CDL) waveforms, which are IP-capable, directional communications capabilities currently targeted for application with X-band AESAs. The program is technically and contractually monitored by AFRL/IFGD and AFRL/PKSE, respectively. The program consists of three phases:

- **Basic Effort:** Comprised of Waveform Development, SoS Analysis (CONOPS), R-CDL specifications and lab test/demo
- **Option 1:** Limited flight test/demo of (point-to-point) R-CDL capability
- **Option 2:** Targeted for a multi-platform JEFX08 experiment

The industry team of Raytheon Company, L-3 Communications and The Boeing Company won the contract to perform the basic effort. Figure 2 shows the Raytheon Team spiral approach for R-CDL network architecture maturation. Three phases are shown for tactical networks:

- Short-Term R-CDL Capability: NT-ISR Point-to-Point Data Links (P2P-DL). Figure 2 shows NTISR Tactical platform architecture attributes associated with P2P-DL.
- Mid-Term R-CDL Capability: Wide Area Networking (WAN). Figure 2 shows NT-

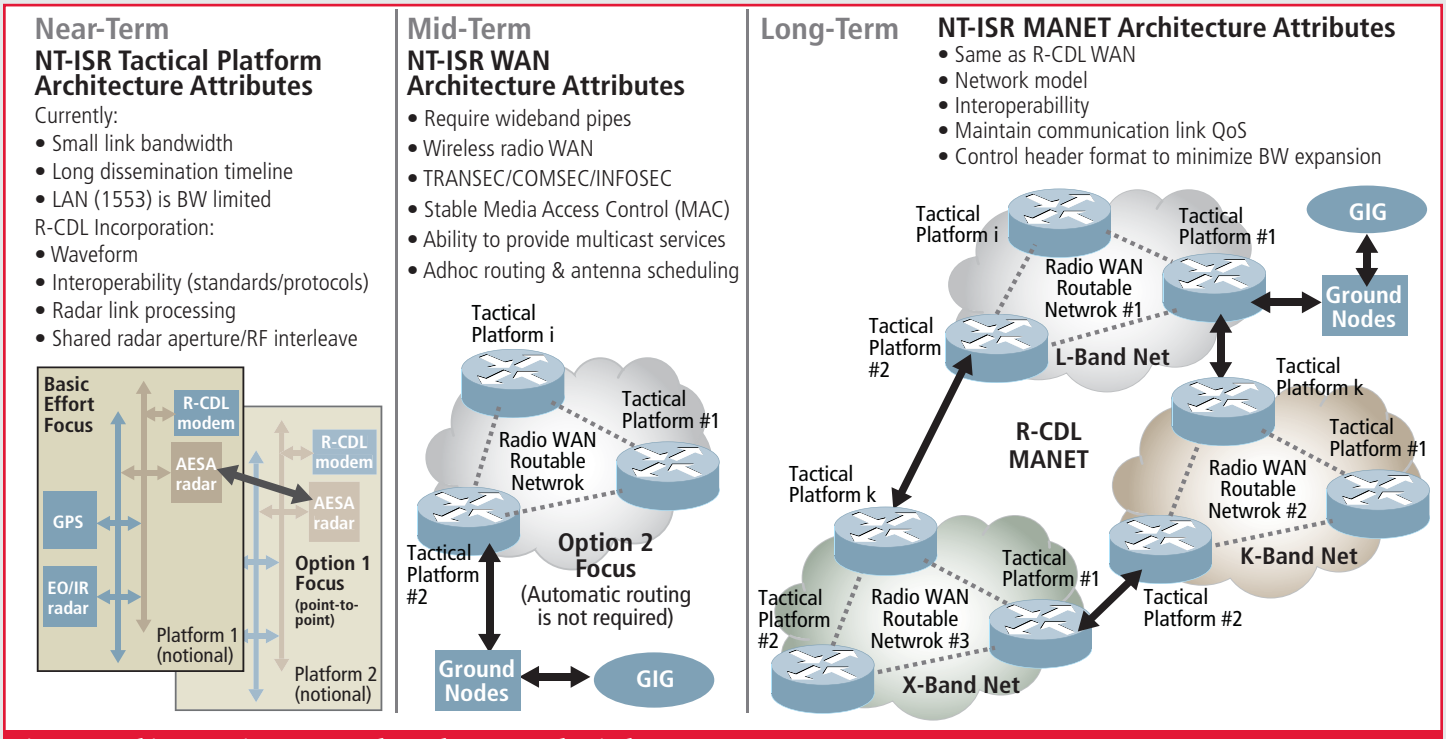

Figure 2. Architecture views, R-CDL three-phase network spirals

ISR Tactical platform architecture attributes associated with WAN.

- Long-term R-CDL Capability: Mobile Ad Hoc Networking (MANET). Figure 2 shows NT-ISR Tactical platform architecture attributes associated with MANET.

The Raytheon team has successfully completed the Basic Technical Effort with a lab test demonstration at L3's facility in Salt Lake City, and a ground demonstration in El Segundo, Calif. The ground test was conducted across a densely populated business park. L3's portable ground station was set up on top of a parking structure, and a Raytheon AESA antenna was set up on the roof of a Raytheon building about two kilometers distant. The AESA radar transmitted live IR camera video to the ground station at the modem's basic rate of 274 Mbps at 33 person duty cycle, and received streaming video from the ground terminal. The bit error rate (BER) performance of the communication link is presented in Figure 3.

In summary, the primary objectives of the Basic Technical Effort are (i) developing P-CDL waveform specifications, including hardware and software application programming interfaces for wideband routable IP that are appropriate for MFRFS, (ii) conducting a lab test and ground demonstrations of the waveforms, and (iii) validating the key performance parameters (KPP) of the P-CDL waveforms. The follow-on options lead to a JEFX08 demonstration with F/A-18Es.The P-CDL waveform KPP is summarized in Table 1.

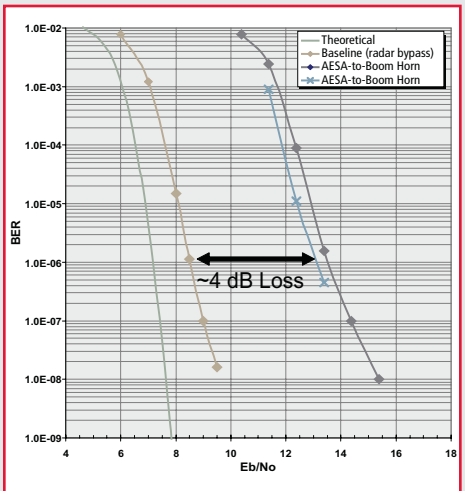

Figure 3. R-CDL communication performance of the El Segundo ground test

Table 1. P-CDL key performance parameters

Modulation	Offset QPSK (OQPSK)
Forward error correction	Reed-Solomon (137 and 274 rates) Viterbi (10.71 and 44.73 rates)
Digital data pulse shaping	Square-root raised-cosine
Bit-error rate	10-6 with encryption (uTDD, mTDD) 10-8 with encryption (mTDS)
Pulse period (T)	30 microsec < T < 380 microsec
Pulse width (W)	10 microsec < W < 130 microsec
Pulse duty factor (d)	10% < d < 35%
Time division duplex/simplex variants	μTDD (micro TDD) mTDD (macro TDD) m TDS (macro TDS)
Instantaneous data rates	274.176 Mbps, 137.088 Mbps, 44.73 Mbps, 10.71 Mbps
Datagram format (OSI layer 3)	Internet protocol v4 & v6 (dual stack support)
Protocol stack support	UDP/TCP/FCS-MANET (i.e. W-NAMA)
Datalink COMSEC	Type 1 cryptography

Raytheon Technology Demonstrations and Instantiations

Prior to R-CDL demonstration, the R-CDL waveform concept was also demonstrated through Raytheon-funded lab demonstrations in El Segundo — namely, the Pearl and AACER-MFRFS Communication Demos.

The Pearl Demo configuration is similar to the R-CDL Demo configuration, except using L3-Modem emulator COTS equipment (instead of actual R-CDL hardware and software), radar received continuous waveform for the Pearl Demo (instead of Pulsed waveform), and the transitions from transmit to receive do not use the radar T/R Gate. The Pearl Demo has successfully demonstrated the capability to transmit and receive NT-ISR products at an instantaneous data rate of 274 Mbps using Raytheon AESA aperture as a transmit and receive element.

The AACER-MFRFS Communication Demo employs a Ka-band carrier and L3 R-CDL modem. The two multi-function RF systems in this demonstration were AACER (Affordable, Adaptable, Conformal ESA Radar) and Cobra.

AACER is an airborne Ka-band ESA radar providing multi-mode operation with time multiplexed GMTI/SAR/Communication/Data Link and Cooperative Combat Identification in a common set of time multiplexed hardware. The processing system and radar control employs the Preprocessor and Common Integrated Signal Processor (CISP) of Raytheon's APG-79 F/A-18 AESA Radar. The AACER system employs a Ka-Band ESA that enables the time multiplexed operation, a confined and highly direction radar/communication beam and consequently low probability of signal intercept. The AACER is being developed by DARPA and the Army Research Lab with support from ASA (ALT).

Cobra is a Raytheon internally developed Ka-band ESA radar with certain modes similar to those of the Multi-Function RF System (MFRFS). MFRFS is a Ka-band ESA system being built by Raytheon for the Army FCS ground vehicles.

Digital pictures were encoded into differential I/Q formats by the L3 modem and input to the AACER Exciter, which modulated the data onto a Ka-Band carrier and transmitted it to the Cobra at 48 Mbps on an R-CDL waveform with a 25 percent duty cycle. The 48 Mbps data rate was consistent with the Cobra ground vehicle radar bandwidth. The AACER is capable of transmitting at 300 Mbps.

In the MFRFS implementation, the communication waveforms can be interleaved with the self-protection system, so that the self-protection function remains fully operational while supporting communications. ●

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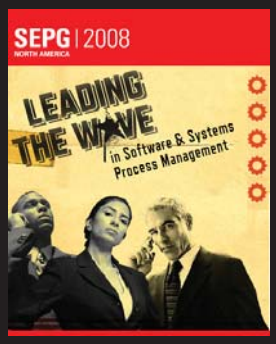
Upcoming Engineering and Technology External Events



SEPG 2008
Leading the Wave in Software & Systems Process Management
March 17–20, 2008
Tampa Convention Center
Tampa, Florida
http://www.sei.cmu.edu/sepg/2008

20th Annual Systems and Software Technology Conference
Technology: Tipping the Balance
April 29–May 2, 2008
Las Vegas Hilton
Las Vegas, Nevada
http://www.sstc-online.org

INCOSE 2008
Systems Engineering for the Planet
June 15–19, 2008
Netherlands
http://www.incose.org/symp2008

Enterprise Modeling and Simulation Knowledge Transfer

As a distinguished provider of customer-focused solutions, Raytheon develops, operates and maintains many of the highest-fidelity models and simulations of our nation's defense, intelligence and environmental systems. The Enterprise Modeling and Simulation (EMS) Enabling Technology initiative provides access for the composition and application of selected models and simulations developed and maintained at sites across Raytheon.

As part of this year's effort, EMS established a collaborative resource that combines the newly updated EMS home page with a collaborative wiki (based on Wikipedia®) and a configuration-managed software and document repository. The resource enables knowledge transfer by providing information on which Raytheon Modeling and Simulation (M&S) capabilities and tools are available, past and present activities they have been used on, and how to reuse and extend them.

The EMS website (http://home.ray.com/ems) is the main portal for Raytheon M&S reuse. It provides an interactive overview of Raytheon site-specific M&S capabilities through the Google Earth®-based EMS Virtual Tour. It also provides access to a standardized and configured M&S environment from any computer through a virtual private network (VPN) hosted over Raytheon's global intranet via the EMS Global Grid. Finally, it enables the ability to search the wiki for relevant M&S artifacts such as Department of Defense Architecture Framework (DoDAF) views of Raytheon Distributed Experiments (RayDX) and enterprise campaigns, as well as tool description and usage guidelines.

The EMS wiki (http://openwiki.app.ray.com/Enterprise_modeling_and_simulation) provides valuable M&S information for use by any Raytheon employee. It can be accessed and edited by all internal Raytheon personnel and offers easy techniques for finding relevant material. For each reusable artifact, a wiki page is created that contains a description of the artifact, point of contact information, and a link to the artifact. The wiki links to the internal EMS repository as well as external repositories such as eRoom and Docushare, so data contained in these repositories is not moved or duplicated. ●

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Raytheon Technology Network Fall Symposia

Breaking its long-standing tradition of joining forces with the Software Systems Symposium, the Systems Engineering Technology Network (SETN), along with the Systems Engineering Council, sponsored their second independent technology symposium in 10 years. This year's **2007 Systems Engineering Symposium**, held at the Disneyland Hotel in Anaheim, Calif., was themed *Customer Solutions Through Innovative Technology Integration.*

The event afforded systems engineers the opportunity to focus on issues unique to their discipline, and to share their experiences and lessons learned. More than 100 presentations were given over the four-day event on topics pertaining to architecture, Mission Systems Integration (MSI), SE innovation and specialty engineering.

One key message this year was how much Raytheon has accomplished in the last 60 years in SE. To wit, standard processes, tools and architectures are now used companywide, as are expanded training programs for systems engineers and architects.

However, there is still more to accomplish if Raytheon is to be recognized as an industry leader in SE and MSI. To that end, Raytheon has established initiatives to identify, propagate and reward its best systems engineers, create virtual teams of SE experts, and revolutionize the way it teaches systems engineering.

To see what your peers discussed at this year's event, view the symposium presentations online at: https://dace.sas.ray.com/ren/technetworks/library/protect/se2007.htm.

To collaborate with system engineers enterprisewide, join a Technology Interest Group or become part of the Systems Engineering Technology Network, visit: http://home.ray.com/rayeng/technetworks/setn/setn.html. ●

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Much is made these days about innovation. One way to find out where the truly innovative ideas are coming from is to attend a Raytheon Technology Network engineering symposium. The recent **2007 Mechanical and Materials Technology Network (MMTN) Systems Symposium** fit the bill perfectly. Held in Los Angeles, the seventh annual event spanned three activity-filled days in October.

Expanding on its traditional array of technical sessions, this year the MMTN added a track on "Process, Tools and Training" to help emphasize the importance of discipline in driving quality into all of Raytheon's products and services. The network is also looking for ways to move the culture forward by more closely aligning engineers with the company's various strategies and missions.

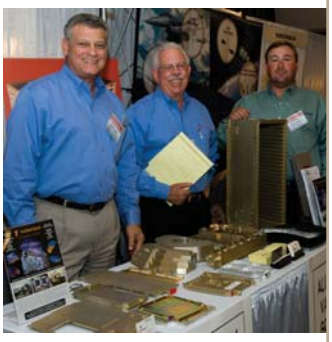
One of the major factors driving our new culture of innovation is the current conflict in Iraq. The dynamic environment in the Middle East has created a demand for the rapid turnaround of new products that integrate the technology of commercial products. The customer is looking for ways to implement cutting-edge ideas on the ground quickly and reliably — without a lot of wasted time and effort. And they're counting on Raytheon to provide the technical leadership to deliver NoDoubt™ solutions every time.

A key takeaway from this year's event was an unwavering dedication to quality, performance and execution on every program, even if it requires taking a hard stand on doing the right thing. Attendees were strongly encouraged to apply that message to their everyday tasks and become courageous self-leaders.

A true benefit of attending these symposia is that engineers receive firsthand exposure to technology strategies and road maps from our company's leaders, which, largely, are outside of our everyday jobs. It's also important that engineers bring back the energy and excitement that these events generate in the areas of teaming, motivation and technology.

To see what your peers were discussing at this year's MMTN Symposium, view the presentations online at: http://docushare1.app.ray.com/docushare/dsweb/View/Collection-216751.

To collaborate with mechanical engineers enterprisewide, join a Technology Interest Group or become part of the Mechanical and Materials Technology Network, visit: http://home.ray.com/rayeng/technetworks/mmtn/mmtn.html. ●



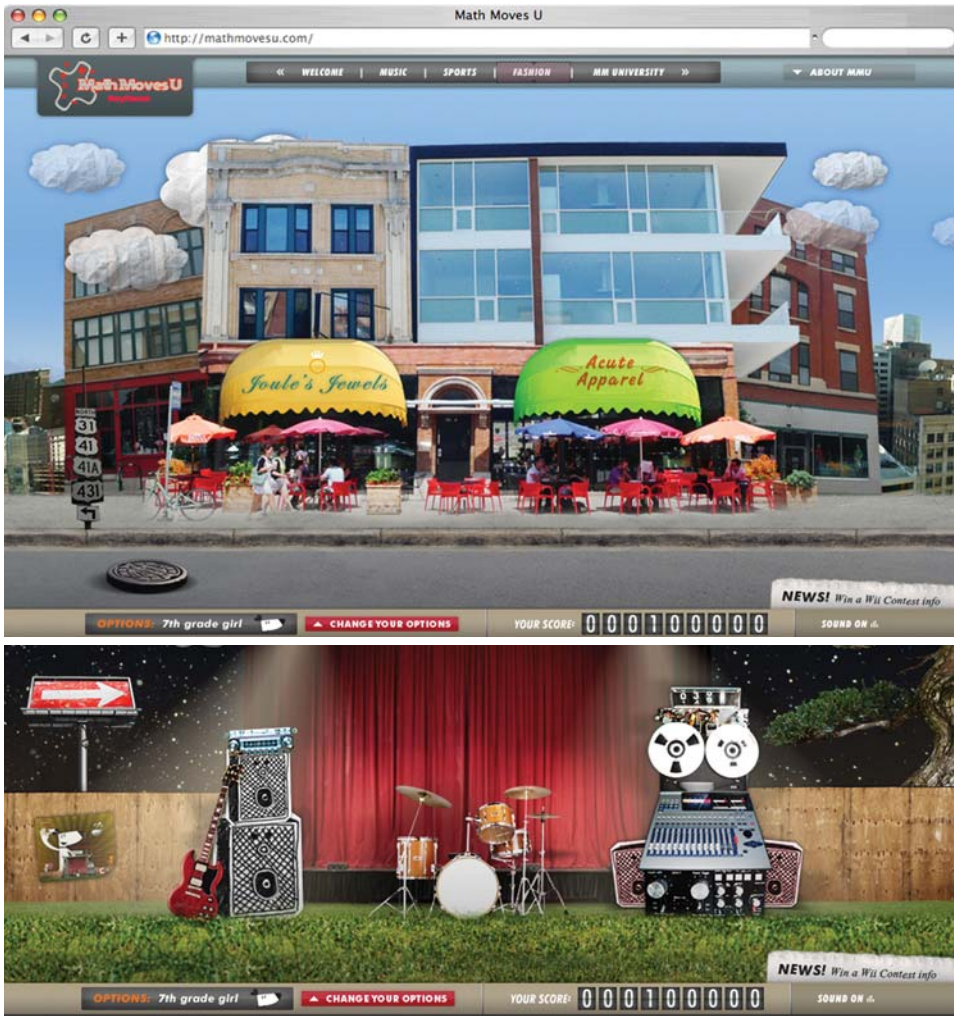
MathMovesU Raytheon to elevate community math and science initiatives

Math and Science Programs

While children in America's education system continue to lag far behind students of other nations, corporations are seeing the need to play a larger role in providing resources, programs and assistance to students and teachers. Raytheon and its employees are responding with involvement in a variety of math and science education outreach programs across the country.

"We are very pleased with the employee and public response to our MathMovesU initiative," said Kristin Hilf, Raytheon's vice president of Community Relations. "But we also want employees and constituents to know that we have many other math and science programs they can get involved in."

Raytheon is involved in educational initiatives like MATHCOUNTS, FIRST Robotics, MathMovesU, tutoring, mentoring and much more. Employees can volunteer their time or make donations to educational institutions, which Raytheon will match. For a complete list of Raytheon's educational assistance programs and information on how you can get involved, contact your local community relations representative.



New MathMovesU Website

In the fall of 2007, Raytheon created a new MathMovesU.com website and conducted a soft-launch using employees' children as "test pilots" of the new site. After talking to several middle school students in focus groups, Raytheon overhauled the MathMovesU.com site with the type of media and interactivity this age group is accustomed to using.

When you log onto the new site, you'll notice a lot of movement, engaging content and neat sounds. The "cool" characters, or avatars, take you through math games and contests and give kids the opportunity to invite friends to join them. The new MathMovesU.com website will be officially launched to the public in January. Be sure to tell any students you know about this incredible resource, which includes a homework helper and math dictionary.

MathMovesU was created to instill interest and excitement in math among U.S. middle school students by showcasing how math connects with music, fashion and sports. Studies show that American students' math scores decline significantly during their middle school years. By engaging students in math and showing them how math relates to their interests, Raytheon hopes to help students stay interested in math during the critical middle school years.

Increased Scholarships and Grants

Currently, Raytheon awards $1 million in grants and scholarships to students and teachers each year. "Instead of cutting that money into a lot of smaller awards, we want to give more incentive by awarding larger scholarship amounts," said Hilf. "We plan to announce our redesigned scholarship program early in 2008."

The influx of technology jobs in the U.S. coupled with the decline of American students pursuing these areas will likely cause a large percentage of unfilled engineering jobs by 2010. Now is the time to help our students see how important math and science is to their everyday lives and their future. ●

Rick Ramirez
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Raytheon: A Proud Industrial Partner of the NOAA CREST Center

The National Oceanic and Atmospheric Administration (NOAA) first established the Cooperative Remote Sensing Science and Technology (CREST) Center in 2001. The center's goal is to create a framework to recruit and train graduate students — especially underrepresented minorities — for professional opportunities within NOAA and related industries. Raytheon has been NOAA-CREST Center's industrial partner since its inception.

CREST supports tuition and research internship opportunities at NOAA and participating universities such as the City University of New York (City College of New York), the lead institution, as well as Hampton University, the University of Puerto Rico at Mayaguez, the University of Maryland at Baltimore County, Bowie State University and Columbia University. Many students have used their valuable experience as stepping stones to permanent jobs in remote sensing science and engineering at NOAA, NASA and Raytheon.

More than half of the graduating Hispanic master's and doctorate remote sensing students in the nation originate from the CREST program. In the first five years of operations, CREST recruited, mentored and trained increasing numbers of graduate students in NOAA-relevant science, engineering and technology areas — with a special emphasis on underrepresented minorities — while developing a high-school-through-college recruitment pipeline. In all, 137 students (12 doctorate degrees; 43 master's degrees; 82 bachelor's degrees) have graduated since 2001.

At the same time, CREST has built and demonstrated an institutional capacity for conducting cutting-edge remote sensing research in line with NOAA's mission goals. CREST conducts collaborative research with NOAA's National Environmental Satellite, Data and Information Service (NESDIS), and is developing the unique capacity to be the nation's center for urban air quality. The center and its partners form a broad-based research team in remote sensing applied to atmospheric, environmental and marine sciences. Their research and training focuses on all aspects of remote sensing, including sensor development, satellite remote sensing, ground-based field measurements, data processing and analysis, modeling and forecasting.

Raytheon Information Solutions COO Pete Janke (right) presents a ceremonial check to CREST Principal Investigator and Director Reza Khanbilvardi during the Advanced Weather Interactive Processing System (AWIPS) open house.

As CREST's industrial partner, Raytheon helps develop the strategy for the subsequent five-year period (2006–2011). Raytheon scientists and technologists have assumed key administrative roles in support of the program, and have served as teachers and mentors to students. Phil Ardanuy, a chief scientist at Raytheon Information Solutions, serves as the Raytheon liaison to the program, while Jeff Puschell, director of Technology at Raytheon Space and Airborne Systems, serves in the chair of the CREST External Advisory Board. Raytheon provides an annual stipend for a partial Ph.D. fellowship and administrative expenses. Additionally, the company seeks summer internship opportunities for CREST scholars.

CREST enjoys considerable congressional support. Among its backers are New York senators Hillary Clinton and Charles Schumer, and U.S. representatives José Serrano and Charles Rangel.

"I am pleased to be collaborating with NOAA, and the hosts of this forum — the NOAA CREST at City College of New York and their sector-partner, Raytheon — to provide opportunities for students to be a part of improving the quality of life for the communities within which they live," said Serrano, who represents the Sixteenth Congressional District of New York in the Bronx.

Raytheon's partnership with NOAA through CREST gives us the opportunity to strengthen our relationship with a key customer while supporting future leaders of the climate and earth science community.

For more information about the CREST Center, visit: http://earth.engr.ccny.cuny.edu/noaa. ●

Philip Ardanuy
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Contributor: Roela Santos

CREST students and faculty from the City College of New York, a CREST institution, enjoy a light moment at the Arecibo Observatory. The observatory supports research in radio astronomy, planetary radar and terrestrial aeronomy.

U.S. Patents
Issued to Raytheon

At Raytheon, we encourage people to work on technological challenges that keep America strong and develop innovative commercial products. Part of that process is identifying and protecting our intellectual property. Once again, the U.S. Patent Office has recognized our engineers and technologists for their contributions in their fields of interest. We compliment our inventors who were awarded patents from September through November 2007.

CARL S KIRKCONNELL
KENNETH D PRICE
GERALD R PRUITT
7263838 Pulse tube cooler with internal MEMS flow controller

C V BAKER
JAMES G SMALL
7265360 Magnetron anode design for short wavelength operation

REZA TAYRANI
7265619 Two stage microwave class E power amplifier

GIB F LEWIS
7265713 Overlapping subarray architecture

WENDY A CONNOR
7265727 Top loaded disk monopole antenna

JAY M OCHTERBECK
BYRON E SHORT JR
7268744 Method and apparatus for controlling temperature gradients within a structure being cooled

WILLIAM T JENNINGS
7269261 Key escrow systems

JASON R FOX
JASON J JERALD
HOWARD E NEELY
PETER A TINKER
7269623 System and method for distributed multimodal collaboration using a tuple-space

JOHN R STALEY
7269920 Weapon sight with ballistics information persistence

GABOR DEVENYI
7270022 Temperature-compensated structure with force multiplier for the temperature compensator

STEVEN P DAVIES
7272681 System having parallel data processors which generate redundant effector date to detect errors methods and apparatus for processor system having fault tolerance

THOMAS K DOUGHERTY
JOHN J DRAB
7273942 Water-soluble group III polyether acid salt complexes and thin films from same

CYRUS E CLARK
GREGORY D MCINTIRE
7274328 Transmitting and receiving radio frequency signals using an active electronically scanned array

GABOR DEVENYI
BLAISE ROBITAILLE
CONRAD STENTON
7274507 Two-mirror telescope with central spider support for the secondary mirror

FRANK N CHEUNG
RICHARD CHIN
7275174 Self-aligning data path converter for multiple clock systems

CLIFTON QUAN
STEPHEN M SCHILLER
YANMIN ZHANG
7276989 Attenuator circuit comprising a plurality of quarter wave transformers and lump element resistors

KWANG M CHO
LEO H HUI
7277042 Compensation of flight path deviation for spotlight SAR

VINH N ADAMS
WESLEY H DWELLY
7277046 Single transmit multi-receiver modulation radar, multi-modulation receiver and method

JOSEPH A ROBSON
GARY SALVAIL
CHAD M WANGSVICK
7283103 Compact broadband antenna

BORIS S JACOBSON
7285876 Regenerative gate drive circuit for power MOSFET

MOHINDER S GREWAL
PO-HSIN HSU
7286082 Method and apparatus for wide area augmentation system having geo uplink subsystem with enhanced clock steering

DANIEL CHASMAN
STEPHEN D HAIGHT
MICHAEL A LEAL
7287725 Missile control system and method

THEAGENIS J ABATZOGLOU
FREDERICK A DOMINSKI
RAQUEL E MADERAZO
JESSICA E SWANSON
7289060 Super high range resolution amplitude and range principal scatterer (sharp) classifier

JOHN W BOWRON
REGINALD JONAS
7289272 Optical system including an anamorphic lens

DARYL B ELAM
7289541 Method for locating and tracking communication units in a synchronous wireless communication system

MICHAEL B SCHOBER
7292180 System and method for passively estimating angle and range of a source using signal samples collected simultaneously from a multi-aperture antenna

MICHAEL A MOORE
JAMES S WILSON
7292439 Thermal management system and method for electronic assemblies

DELMAR L BARKER
WILLIAM R OWENS
7292740 Apparatus and method for controlling transmission through a photonic band gap crystal

JON-MICHAEL C BROOK
RANDALL S BROOKS
MATTHEW C RIXON
TROY D ROCKWOOD
7293238 Graphical user interface for an enterprise intrusion detection system

ABRAM ALANIZ
KEN J CICCARELLI
CARL S KIRKCONNELL
7296418 Multi-stage cryocooler with concentric second stage

DAVID R SAR
JERRY D WITHROW
7297055 Vacuum-insulating system and method for generating a high-level vacuum

DAVID B HATFIELD
7297753 Reduction of permeation through a polymer

JOHN S ANDERSON
CHUNGTE W CHEN
7297951 Two F-number, two-color sensor system

MICHAEL G ADLERSTEIN
VALERY S KAPER
7298217 Phased array radar systems and subassemblies thereof

HAROLD S FENGER
MARK S HAUHE
CLIFTON QUAN
KEVIN C ROLSTON
TSE E WONG
7298235 Circuit board assembly and method of attaching a chip to a circuit board with a fillet bond not covering RF traces

KAPRIEL V KRIKORIAN
ROBERT A ROSEN
7298325 Technique for accurate estimate of large antenna inertial two dimensional orientation using relative GPS spatial phase

KENNETH W BROWN
7298344 Series FED amplified antenna reflect array

JOHN S ANDERSON
CHUNGTE W CHEN
CHENG-CHIH TSAI
7298484 Dual-band sensor system utilizing a wavelength-selective beamsplitter

THEAGENIS J ABATZOGLOU
KWANG M CHO
LEO H HUI
7301495 Interrupt SAR implementation for range migration (RMA) processing

JAMES FLORENCE
CLAY E TOWERY
7292262 Electronic firearm sight, and method of operating same

International
Patents Issued to Raytheon

Congratulations to Raytheon technologists from all over the world. We would like to acknowledge international patents issued from September through November 2007. 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.

AUSTRALIA

FERNANDO BELTRAN
ANGELO M PUZELLA
2002334695 Slot coupled, polarized, egg-crate radiator

REZA M DIZAJI
RICK MCKERRACHER
ANTHONY M PONSFORD
2003213763 Noise suppression system and method for phased-array based systems

REZA M DIZAJI
ANTHONY M PONSFORD
2003220063 System and method for spectral generation in radar

ROBERT C ALLISON
RON K NAKAHIRA
JOON PARK
2003295553 Micro electro-mechanical system device with piezoelectric thin film actuator

MICHELLE K ESTAPHAN
FREDERICK J FRODYMA
GUY T RAILEY
DANIEL M VICCIONE
2004206560 Sonar array system

KHIEM V CAI
SAMUEL D KENT III
LLOYD F LINDER
2004207960 Mixed technology MEMS/SiBG BICMOS digitizing analog front end with direct RF sampling

CANADA

F O HARA
C HUNT
DOMINIC V RESTAGNO
K TURNER
PIETRO VENTRESCA
1341541 Dual mode seeker (microwave front end)

JAMES R BENDER
PIETRO VENTRESCA
1341542 Dual mode seeker (broadband mixer)

J HOPSON
GEORGE R SPENCER
1341543 Dual mode seeker (seeker)

DANIEL B GOLDSTEIN
NEIL F LACEY
MALCOLM E SKINNER
1341544 Correlation receiver (sampling circuit)

FRANCE, GERMANY, GREAT BRITAIN, ITALY

MICHAEL R BORDEN
0919069 Environmentally resistant, infrared-transparent window structure

TOVAN L ADAMS
NORMAN LANGE
ERIC C MAUGANS
1508019 Method and apparatus for energy and data

FRANCE, GERMANY, GREAT BRITAIN, ITALY, SPAIN

GEORGE F BARSON
MICHAEL D KOEHLER
RICHARD M WEBER
1528619 Method and apparatus for cooling heat-generating structure

FRANCE, GERMANY, GREAT BRITAIN

ROBERT W BYREN
ALVIN F TRAFTON
1362226 System and method for effecting high-power beam control with outgoing wavefront correction utilizing holographic sampling at primary mirror, phase conjugation, and adaptive optics in low power beam path

STEPHEN H BLACK
JAMES A FINCH
ROGER W GRAHAM
JERRY A WILSON
RICHARD H WYLES
1421628 IR FPA ROIC with dual TDM reset integrators and sub-frame averaging functions per unit cell

PHILLIP I ROSENGARD
1466430 Compressing cell headers for data communication

LACY G COOK
1488269 Compact four-mirror anastigmat telescope

ROBERT W BYREN
DAVID S SUMIDA
1493214 Solid-state devices with radial dopant valence profile

MILTON BIRNBAUM
KALIN SPARIOSU
1658664 Gain boost with synchronized multiple wavelength pumping in a solid-state laser

KALIN SPARIOSU
1684392 Ultra-low heat laser

ANDREW K BROWN
KENNETH W BROWN
JAMES R GALLIVAN
PHILIP D STARBUCK
1704546 Millimeter-wave area-protection system and method

JOHN S ANDERSON
CHUNGTE W CHEN
CHENG-CHIH TSAI
1723464 Dual-band sensor system utilizing a wavelength-selective beamsplitter

KENNETH W BROWN
1723698 System and low-loss millimeter-wave cavity-backed antennas with dielectric and air cavities

GREAT BRITAIN

MICHAEL Y JIN
MICHAEL E LAWRENCE
1410066 System and method for processing squint mapped synthetic aperture radar data

ISRAEL

JOHN R ARCHER
ROY P MCMAHON
147681 Arc-fault detecting circuit breaker system

JAPAN

CHUNGTE W CHEN
RONALD G HEGG
WILLIAM B KING
3999129 Light-weight head-mounted display

DEAN L SHOLLENBERGER
4008046 Radar System

JOHN J FIJOL
4008818 Liquid crystal device and manufacturing method

OSCAR J BEDIGIAN JR
JACK J SCHUSS
THOMAS V SIKINA
4009063 Phased array antenna calibration system and method using array clusters

SINGAPORE

LLOYD F LINDER
1153031 Mixed technology MEMS/BIMOS LC bandpass sigma-delta for direct RF sampling

SOUTH KOREA

REZA TAYRANI
759659 Miniature broadband switched filter bank

Raytheon's Intellectual Property is valuable. If you become aware of any entity that may be using any of Raytheon's patented inventions or would like to license our patented inventions, please contact your Raytheon IP counsel: Leonard A. Alkov (SAS) , Horace St. Julian (MS & RTSC) , Robin R. Loporchio (NCS) Edward S. Roman (IDS), John J. Snyder (IIS).

Raytheon

Customer Success Is Our Mission