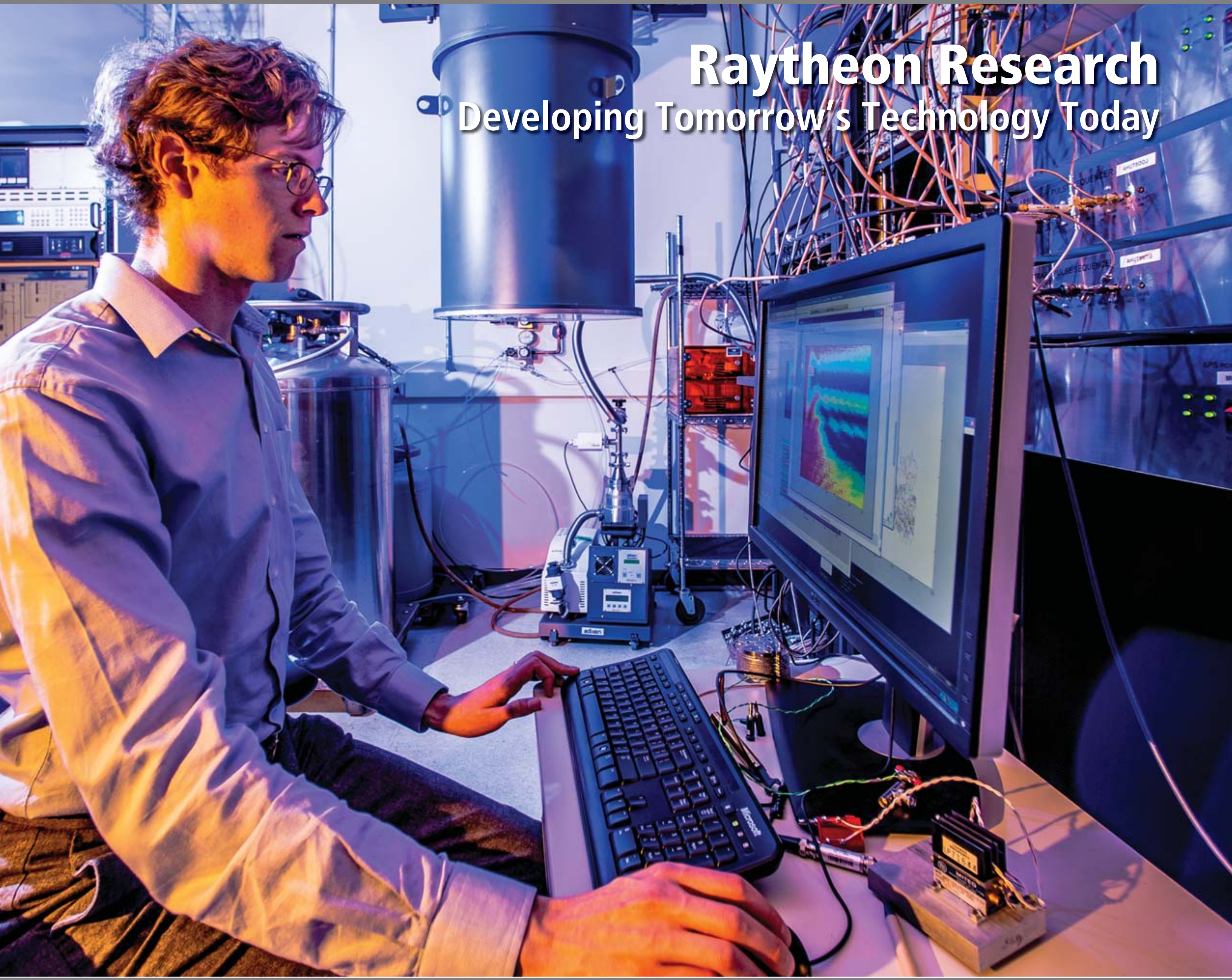
# Technology Today

HIGHLIGHTING RAYTHEON'S TECHNOLOGY

2014 ISSUE 1



## Raytheon Research
### Developing Tomorrow's Technology Today

Raytheon

*Customer Success Is Our Mission*

# A MESSAGE FROM Mark E. Russell

Vice President of Engineering, Technology and Mission Assurance

Raytheon has always valued a focused research portfolio that both continuously improves our products and offers revolutionary new capabilities. Best performing, affordable solutions are important in today's fiscally constrained environment, and Raytheon's research provides a mechanism to identify and nurture technologies that help develop best-in-class solutions.

Raytheon's research approach is multifaceted where Raytheon laboratories enterprise-wide perform research that impacts our core sensing, effects, C3I (command, control, communications and intelligence), mission support and cyber markets. Collaboration and partnerships with universities, small businesses and other contractors are critical elements of our approach. As part of a formal process, research topics and results from across the company are integrated and continuously assessed against Raytheon products and customer mission needs to ensure focus on the most promising and needed areas.

This issue highlights the depth and breadth of Raytheon research, including our more than 30-year commitment to multifunction, wideband and high-power active electronically scanned array (AESA) technologies and longer range research areas including quantum computers. While it may take years to realize the benefits in a particular area, conducting research is nonetheless a critical part of maintaining excellence for our future products. Our development of gallium nitride semiconductor device technology began nearly 15 years ago and today provides the foundation for our most advanced radar, communication and electronic warfare development programs.

In our Leaders Corner, Raytheon Chief Technology Officer Bill Kiczuk and the other Technology Leadership Council members discuss their roles as technology leaders and how Raytheon collaborates and nurtures research across the company. In our Eye on Technology section, Raytheon Australia's sapphire resonator oscillator technology, developed by recently acquired Poseidon Scientific Instruments, is presented.

Our special interest section highlights two of Raytheon's university partnerships; our partnership with the Franklin W. Olin College of Engineering, where a team of engineering students work for a year with Raytheon engineers on real-world engineering projects, and our collaboration with Worcester Polytechnic Institute that includes science, technology, engineering and mathematics (STEM) education, course development and research.

Mark E. Russell

On the cover: The Raytheon BBN Technologies quantum computing lab where employee Colm Ryan analyzes results from a recent experiment.

# Raytheon Enhances Its Sensor Technology Portfolio With the Acquisition of Poseidon Scientific Instruments

## Introduction

Raytheon is committed to the success of our global radar customers through our technological leadership in radio frequency (RF) sensor systems. Our ability to provide next generation capabilities has increased with the acquisition of Australian technology company Poseidon Scientific Instruments (PSI), developers of the world's highest-performance microwave signal generators. PSI expands Raytheon's brand in world-class sensor systems by providing expertise in ultra-low-phase-noise signal generation and companion measurement technologies. These technologies provide new levels of system performance and mission capabilities for the U.S. warfighter and our international coalition partners.

## Radar Oscillator Background

Radar systems consist of several major subsystems, including a receiver-exciter, transmitter, signal data processor and power system, each of which performs a specific role in radar operation. For the receiver-exciter subsystem, a master oscillator (MO) is used to provide the phase reference for transmit, receive and radar timing functions. It is the spectral purity of the MO, measured as power spectral density and conventionally expressed as amplitude modulation or phase modulation noise, that, in part, establishes the receiver-exciter noise and in turn, the radar's detection sensitivity. In the presence of large clutter, MO noise can mask small targets and thus limit a radar's detection sensitivity. Moreover, at the heart of every MO is a narrow-bandwidth, high-stability, resonator technology that is critical to establishing and sustaining oscillation.

High-performance, low-phase-noise microwave MO technology evolved over the decades from klystron oscillators in the 1950s, to frequency-multiplied quartz crystal oscillators, to frequency-multiplied surface acoustic wave (SAW) oscillators in the 1990s. This technology evolution has enabled radar systems to achieve higher levels of sensitivity.

*Figure 1. High performance sapphire resonator oscillator solutions: the Sapphire Loaded Cavity Oscillator (SLCO) (left) and Shoebox Oscillator® (SBO) (right) — Setting the bar for superior sensor sensitivity.*

Furthermore, Raytheon's novel SAW resonator and oscillator technologies have delivered outstanding radar system performance for several decades. However, the emergence in the mid-1990s of new threats drove even more demanding radar sensitivity requirements that pushed the limits of SAW-based exciters.

## PSI Technologies

Raytheon and the warfighter needed a leap-ahead technology to achieve the increased radar sensitivity necessary to combat new emerging threats. Enter PSI and their ultra-high-performance sapphire resonator technology. Founded in 1987, PSI is recognized worldwide by international and U.S. defense and commercial industries as a leader in generating and subsequently analyzing ultra-low-phase-noise microwave signals for high sensitivity radar and communications systems. By the early 1990s, PSI's compact sapphire resonator was a reality. It employed a single synthetic sapphire resonator that offered orders of magnitude reduction in microwave oscillator noise over our SAW-based solutions.

From the mid-1990s to 2000, Raytheon and PSI engineers independently developed and demonstrated a sapphire-based MO, built around PSI's patented sapphire resonator technology. Raytheon's proof-of-concept MO and related exciter architecture were used to demonstrate a new level of radar performance. At the same time, PSI had fully productized their compact sapphire-based oscillator into a shoebox size

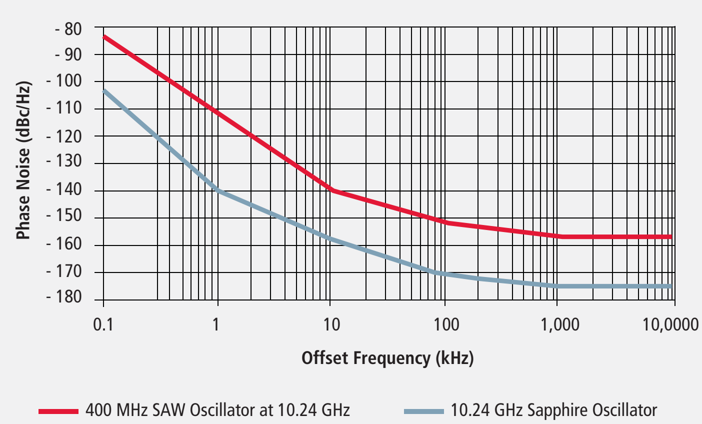



*Figure 2. Sapphire technology performance comparison: -20 dB better phase noise performance opens new doors for radar performance.*

*Figure 3. The Oscillator Development INstrument (ODIN®) phase noise analyzer — Designing and delivering state-of-the-art sources requires a commensurate state-of-the-art noise measurement capability.*

form factor suitable for radar applications. This new sapphire-based exciter forms the foundation of many of our current, high-performance radar systems and continues to provide Raytheon radar systems with industry leading levels of performance.

Raytheon Australia's PSI Sapphire Loaded Cavity Oscillator (SLCO) and Shoebox Oscillator® (SBO) are shown in Figure 1. The SBO design represents a groundbreaking productized capability for use in tactical defense systems. These microwave oscillators are used today in premier Army, Navy and Air Force sensor systems and are used as laboratory standards at the National Institute of Standards and Technology (NIST) and the U.S. Naval Surface Warfare Center, Crane Division. Figure 2 shows the superior performance of the Raytheon Australia sapphire oscillator.

For less demanding applications, PSI's dielectric resonator oscillator (DRO) product line provides lower-cost solutions. PSI also has a family of low noise, regenerative frequency dividers that can be used to derive additional, lower-frequency signals.

PSI's sapphire source and noise degeneration technology has its roots in the field of gravity wave detection, which required a unique, high-performance measurement system offering many dual use and technology transition opportunities into radar and sensor programs. However, it is the innovation and vision of PSI's founder and managing director Jesse Searls who, early on, saw the potential and value in transitioning the cryogenic sapphire resonator technology from his gravity wave work at the University of Western Australia (UWA) in Perth, into a product for commercial and defense applications.

During the development of its sapphire oscillators, PSI needed measurement tools that were not limited by conventional semiconductor performance. To meet this need, PSI developed ODIN® (Oscillator Development INstrument) – a sophisticated phase noise analyzer (Figure 3). ODIN was developed out of necessity to support measurement of their low-noise sapphire sources, but it evolved into a standalone, commercially competitive product line.

## Raytheon-PSI Today

PSI technologies are currently being integrated into Raytheon products in the U.S. The integration of these technologies with Raytheon technologies and architectures opens doors to new commercial and defense opportunities, in particular in the area of communications where ultra-high stability (i.e., low phase noise/jitter) clock oscillators are essential. The importance of precision timing continues to increase to support higher speed communications protocols and to support an ever expanding wireless environment that continues to be constrained by fixed operational bandwidth allocations.

In addition to PSI's resonator technology, their RF engineering design and test skills provide Raytheon Australia with enhanced engineering expertise. Recently, PSI delivered 16 receiver systems for the Murchison Widefield Array (MWA) telescope system. Figure 4 shows portions of this system. The receiver components were designed at different universities and other research organizations worldwide as part of an international scientific consortium that sponsors the MWA telescope project. PSI designed the receiver node enclosure, integrated all of the components into their enclosure, tested each node and delivered them to the MWA team to support system integration and testing.

During the PSI and Raytheon integration process, opportunities to grow and expand PSI's footprint in commercial and international markets for low-noise products will continue to be explored as well as opportunities to enhance current and future Raytheon products with PSI technologies. •

*Robert E. Desrochers II, Mark Koehnke and Jesse Searls*


*Figure 4. Murchison Widefield Array equipment: 4 x 4 antenna tile (left) and Raytheon Australia PSI integrated receiver node (right). Each receiver node supports eight tiles for a total of 128 dual-linear-polarization antenna elements.*