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## Features

### 14 SPECIAL REPORT

#### **Radar keeps a surveillance eye on the battlefield**

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### 24 TECHNOLOGY FOCUS

#### **Test and measurement: the right results at the right time**

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## Columns

### 2 TRENDS

### 4 NEWS

### 11 IN BRIEF

### 29 RF & MICROWAVE

### 32 UNMANNED VEHICLES

### 37 ELECTRO-OPTICS WATCH

### 41 PRODUCT APPLICATIONS

### 46 NEW PRODUCTS

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# U.S. military forces are neglected, too small, and worn-out, warns new Heritage Foundation report



BY John Keller  
EDITOR IN CHIEF

The U.S. military is in dire need of money, effort, and resources to reverse a trend toward mediocrity and obsolescence in the face of aggressive world adversaries like Russia, China, Iran, and North Korea, according to a report released last month from the conservative Heritage Foundation think tank in Washington.

The report, 2023 Index of U.S. Military Strength, says the U.S. Air Force is very weak, the Navy and Space Force are weak, and the Army is marginal in their abilities to fight effectively in future two-front wars. Only the U.S. Marine Corps and nuclear forces are considered to be strong.

The key question is why. The answer involves a years-long failure to introduce new weapon systems to replace old ones, upgrade existing systems effectively, and provide adequate funding for war-fighter training.

“The common theme across the services and the U.S. nuclear enterprise is one of force degradation caused by many years of underinvestment, poor execution of modernization programs, and the negative effects of budget sequestration (cuts in funding) on readiness and capacity,” the report says.

“Because of the rising costs of fuel, munitions, and repair parts, and the lack of qualified maintainers and maintenance facilities, much of the progress in regaining readiness that had been made in 2020 and 2021 has been lost in 2022,” the report continues. “The forecast for 2023 is likewise gloomy, given a proposed defense budget for 2023 that will not be sufficient to keep pace with ongoing and dramatic increases in inflation.”

Of all the military services, the Air Force is the worst off, rated as very weak in its ability to meet

national military goals. Poor mission readiness and the physical location of combat aircraft would give the service a difficult time responding rapidly to a crisis, Heritage Foundation analysts say.

The service “is short 650 pilots, the average age of its fighter aircraft fleet is 32 years old, and pilots are flying barely more than once per week across all types of aircraft,” the report states. New aircraft like the F-35 and KC-46 are being introduced, but the pace is too slow.”

The Navy, meanwhile, is more than 100 ships short of an ability to fight a two-front war. “The Navy needs a battle force of 400 manned ships to do what is expected of it today,” the report states. “The Navy’s current battle force fleet of 298 ships and intensified operational tempo combine to reveal a service that is much too small relative to its tasks.”

The Army is in slightly better shape. “Though the Army has sustained its commitment to modernizing its forces for great-power competition, its modernization programs are still in their development phase, and it will be a few years before they are ready for acquisition and fielding,” the report says.

In sum, the Army is aging faster than it is modernizing, and has only 62 percent of the force it should have, analysts say. The good news: 25 of its 31 regular brigade combat teams are at the highest state of readiness.

“The U.S. military is a growing risk of not being able to meet the demands of defending America’s vital national interests,” the report concludes.

The executive summary of the 2023 Index of U.S. Military Strength is available online at <https://www.heritage.org/military-strength/executive-summary>. ←





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# Raytheon, Northrop Grumman team on hypersonic cruise missiles

BY John Keller

EGLIN AIR FORCE BASE, Fla. – U.S. Air Force guided missile experts are asking a team of Raytheon Technologies Corp. and Northrop Grumman Corp. to develop one of the first hypersonic cruise missiles to be in the U.S. inventory.

Officials of the Air Force Life Cycle Management Center's Armament Directorate at Eglin Air Force Base, Fla., announced a \$985.3 million task order to the Raytheon Missiles & Defense segment in Tucson, Ariz., to design and develop the Hypersonic Attack Cruise Missile (HACM).

▲ **A team of Raytheon and Northrop Grumman will develop the Hypersonic Attack Cruise Missile (HACM) for U.S. combat aircraft.**

This air-launched hypersonic cruise missile, which initially will be carried on the jet fighter-bomber aircraft like the Boeing F-15EX and F-15E Strike Eagle aircraft, is a scramjet-powered hypersonic weapon

designed to hold high-value targets at risk in contested environments from standoff distances, Air Force officials.

Hypersonic munitions fly through the air at speeds of at least Mach 5, which is 3,836 miles per hour. Some hypersonic munitions under development are expected to fly much faster. Raytheon and the Northrop Grumman Defense Systems segment



in McLean, Va., will deliver operationally ready HACM hypersonic cruise missiles to the Air Force.

The hypersonic operating environment involves heavy exposure to shock, vibration, heat, and thermal shock, so its guidance and navigation technologies must be specially hardened to withstand such severe operating conditions.

The task order calls for Raytheon and Northrop Grumman to use model-based critical design review, qualification, integration, manufacturing and testing in developing and deploying the HACM hypersonic cruise missile.

The Hypersonic Attack Cruise Missile will have scramjet engines, which use high vehicle speed to compress incoming air forcibly before combustion, which enables sustained flight at hypersonic speeds.

By traveling at these speeds, hypersonic weapons like HACM can reach their targets more quickly than similar traditional missiles, and potentially evade air defenses.

Raytheon and Northrop Grumman have worked together since 2019 to develop, produce, and integrate Northrop Grumman's scramjet engines onto Raytheon's air-breathing hypersonic weapons.

In 2020, the U.S. Air Force joined Australia in a multi-year project called the Southern Cross Integrated Flight Research Experiment (SCiFiRE) to develop air-breathing hypersonic cruise missile prototypes.

The Air Force awarded three 15-month SCiFiRE contracts in June 2021 to Boeing Co., Lockheed Martin Corp., and Raytheon to complete preliminary designs of a hypersonic cruise missile.

The HACM program will bring the Raytheon SCiFiRE prototype design into production for fighter aircraft integration, and deliver two leave-behind assets with operational utility.

Through SCiFiRE, the U.S. and Australia will continue collaborating on HACM design and development, including using Australian test sites for the initial all-up-round flight tests. The Air

Force plans to deliver a HACM capability with operational utility by 2027. ←

On this task order Raytheon will do the work in Tucson, Ariz., and should be finished by March 2027. For more information contact Raytheon Missiles & Defense online at [www.raytheonmissilesanddefense.com](http://www.raytheonmissilesanddefense.com), Northrop Grumman Defense Systems at [www.northropgrumman.com](http://www.northropgrumman.com), or the Air Force Life Cycle Management Center at [www.aflcmc.af.mil](http://www.aflcmc.af.mil).

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## BY John Keller

▲ The Environment-driven Conceptual Learning (ECOLE) project seeks to analyze large amounts of data automatically, but also cooperate with humans to resolve ambiguities and improve performance over time.

ECOLE will create AI agents able to learn from linguistic and visual input to enable humans and computers to work together to analyze image, video, and multimedia documents quickly in missions where reliability and robustness are essential.

System interaction with human intelligence analysts is expected to be symbiotic, with the systems augmenting human cognitive capabilities while simultaneously seeking instruction and correction to achieve accuracy.



Industry proposals should specify how symbolic knowledge representations will be acquired from unlabeled data, including the specifics of the learning mechanism; how these representations will be associated and reasoned within a growing body of knowledge; how the representations will be applied to human-interpretable object and activity recognition; and how the framework will permit collaboration with several analysts to resolve ambiguity, extend the set of known representations, and provide greater recognitional accuracy and coverage.

The four-year ECOLE project with three phases; this solicitation concerns only the first and second phases. The first phase will create prototype agents that can pull relevant information out of unlabeled multimedia data, supplemented with human interaction.

These prototypes will demonstrate not only the ability to learn new concepts, but also to recombine previously learned attributes to recognize never-before-seen objects and activities. Systems also will be able to reason over similarities and differences in objects and activities.

The second phase of the ECOLE project will scale-up the framework to include several AI agents and human analysts to help deal with uncertain or contradictory information.

Computer interaction with human analysts will enable the system to learn to name and describe objects, actions, and properties to verify and augment their representations, and to acquire complex knowledge quickly and accurately from potentially sparse observations.

Humans and computers will work together primarily through the English language — including words with several different meanings — in a way that is readily understandable. The ECOLE project also will have two technical areas: distributed curriculum learning; and human-machine collaborative analysis.

Distributed curriculum learning involves multimedia data, and will use human partners provide feedback on the learning process. human-machine collaborative analysis will involve a human-machine interface (HMI) to improve ECOLE representations and analyze data such as multimedia and social media. ←

Companies interested were asked to upload proposals by 14 Nov. 2022 to the DARPA BAA website at <https://baa.darpa.mil>. Email questions or concerns to DARPA at [ECOLE@darpa.mil](mailto:ECOLE@darpa.mil). More information is online at <https://sam.gov/opp/fd50cb65daf5493d886fa1ddc2c0dd77/view>.

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# Wanted: ionosphere computer models to enhance HF radio propagation

BY John Keller

ARLINGTON, Va. – U.S. military researchers are asking industry to develop new ways to model the ionosphere in real time to help predict the propagation of high-frequency (HF) radio waves for improved communications and sensing.

Officials of the U.S. Defense Advanced Research Projects Agency in Arlington, Va., issued a solicitation in August (HR001122S0028) for the Ouija TA-2 project to develop real-time modeling for assimilative ionospheric and HF radio propagation.

The ionosphere is the ionized part of the upper atmosphere of Earth, from about 30 miles to 600 miles above sea level, which is ionized by solar radiation. It influences radio propagation to distant places on Earth by reflecting HF signals.

▲ **Military researchers are asking industry to create new models of the ionosphere to help find better ways of propagating high-frequency radio communications signals.**

HF radio uses signals in relatively long wavelengths of between 10 and 100 meters. HF radio bands lie between the commercial AM and FM broadcast bands, and operate from 3 to 30 MHz. HF radio waves are notable for their ability to propagate signals for long distances by bouncing signals off the ionosphere.

HF radio also is notorious for static from thunderstorms and other radio frequency interference. The ionosphere is constantly changing, and can influence HF radio signals from minute-to-minute, and from season-to-season.

One goal of the Ouija TA-2 project is to develop near-real-time assimilative ionospheric computer models that can mimic ionospheric disturbances at scales of 100 kilometers and below.



These models must assimilate ionospheric measurements taken with the scientific instrumentation packages to be flown on the Ouija TA-1 CubeSats in very low-Earth orbit (VLEO), in addition to standard vertical and oblique sounder data. The scientific instrumentation on the Ouija spacecraft will include Langmuir probes and similar devices to measure electron density and other quantities of interest.

The objective is to predict the characteristics of the ionosphere at unprecedented resolution and fidelity in near-real-time, DARPA researchers say.

The second goal is to develop high-fidelity HF radio propagation models to help predict ground-to-VLEO radio wave propagation, which will be validated using on-orbit measurements taken from the Ouija spacecraft HF payload, which will receive test signals from cooperative terrestrial transmitters.

Researchers expect industry to develop HF radio propagation models by linking ionospheric models using on-orbit measurements to an HF propagation prediction model that will provide high-fidelity predictions of ground-to-space HF radio propagation.

The scientific payload will measure ionospheric characteristics in near-real-time using Langmuir probes, magnetometers, and global navigation satellites system (GNSS) devices to estimate

electron density profiles using radio occultation. The HF payload will consist of an HF antenna and receiver to receive test signals from terrestrial transmitters.

One objective is the ability to predict the ionosphere at using high-fidelity models that update at a rate of 10 seconds per update, rather than minutes per update, which should be sufficient to predict HF radio propagation for ground-to-space HF links.

The project's nine-month first phase will begin modeling before data from the Ouija VLEO satellites is available. Instead, it will use sounder measurements from a terrestrial HF radio transmitter to low-Earth orbit (LEO) satellites equipped with an HF receive payload.

The one-year second phase will assimilate data from one VLEO satellite and produce electron density distributions. The 16-month third phase will assimilate on-orbit data from six Ouija satellites. DARPA researchers say they expect to award several contracts. ◀

Companies interested were asked to upload unclassified proposals by 23 Sept. 2022 to the DARPA BAA Website at <https://baa.darpa.mil>. Email questions or concerns to DARPA at [HR001122S0028@darpa.mil](mailto:HR001122S0028@darpa.mil). More information is online at <https://sam.gov/opp/33f627f25a5d48a19f73539e0c73f307/view>.

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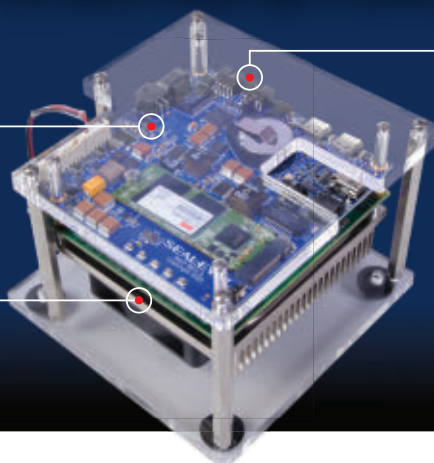
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# Industry to develop miniature optical beam steering for laser communications and lidar

BY John Keller

ARLINGTON, Va. – U.S. military researchers are asking industry to develop miniature optical beam steering for applications like free-space laser optical communications and light detection and ranging (lidar).

Officials of the U.S. Defense Advanced Projects Agency (DARPA) in Arlington, Va., have issued a microsystems exploration topic (DARPA-PA-21-05-01) for the Steerable Optical Aperture Receivers (SOAR) project.

SOAR will identify promising new approaches to optical beam steering in miniature form factors, and experimentally demonstrate their operation in receive mode with small aperture sizes.

Today, optical beam steering primarily is mechanical, using a gimbal or motor to point optical lenses. The size weight of gimbal-based beam steering systems, however, typically is too big for small and autonomous vehicles that need onboard laser communications and lidar capability.

The rise of integrated photonics, in which microscopic devices on chips replicate the functions of discrete optics. This offers not only dramatic size reduction, but also the potential for new and complex optical system architectures until now have been impractical at the macroscopic scale. The SOAR project seeks to answer key questions about optical receiver performance, scalability, and integration.

SOAR seeks to develop optical interfaces that can receive light from any direction without knowing the incoming angle

▲ **SOAR will identify promising approaches to optical beam steering in miniature form factors, and demonstrate their operation in receive mode with small aperture sizes.**

by steering the angle of acceptance to acquire and couple the input beam into a common output mode, or detect the optical signal within the receiver interface.

The first phase of SOAR will focus on lidar and laser communications receiver design and process development. The second phase will fabricate the receiver, and include a transceiver design study on aperture scalability and system integration.

DARPA researchers want steering components to be significantly smaller than 100 cubic centimeters, and be able to steer light beams at high speed, with pointing time faster than 100 microseconds, and with modest power consumption.

SOAR is technology-agnostic and open to any concept that meets program goals. Researchers would consider, for example, two-dimensional optical parametric amplification (OPA), non-planar integrated photonics, optical metasurfaces, directional optical scattering techniques, and discrete micro-optics. Researchers also are interested in the ability to generate several simultaneous beams. ◀

Companies interested were asked to upload unclassified proposals by 13 Oct. 2022 to the DARPA submission website at <https://baa.darpa.mil>. Email questions or concerns to Jonathan Hoffman, the DARPA SOAR program manager, at [SOAR@darpa.mil](mailto:SOAR@darpa.mil). More information is online at <https://sam.gov/opp/c0bda073553047b1803c11518eae78fc/view>.



## Honeywell and Reaction Engines collaborate on advanced thermal management for aircraft

Honeywell in Phoenix and Reaction Engines Limited, an aerospace company in Oxfordshire, England, have signed a memorandum of understanding to collaborate on the development of thermal management technologies as an enabler to reduce aircraft emissions, regardless of the fuel type used in the aircraft. Honeywell and Reaction Engines will adapt the unique microtube heat exchanger technology from Reaction Engines and apply it across a broad range of Honeywell systems for sustainable aviation thermal management solutions. Reaction Engines develops unique heat exchange technology that can reduce weight by more than 30%, which translates to less fuel consumption and longer range or higher capacity of aircraft. The potential for this technology is wide-ranging across all segments of the aerospace industry. Heat exchangers are important components of many of the aircraft mechanical systems that Honeywell manufactures. Today, Honeywell heat exchangers are being used on various platforms, from extremely compact spacecraft to large, wide-body airliners. They are critical in assisting aerospace heating and cooling

and have a direct impact on aircraft fuel efficiency. Future generations of aircraft powered by sustainable fuels will require much more efficient and lightweight thermal management than what is available today. Advancements of this technology will help aircraft manufacturers deliver on sustainability commitments and meet government sustainability regulations while increasing operational efficiencies.

## Seven emerging technological trends shaping aviation in 2022

Technological aviation trends have changed the aviation sector over the past few years. In addition, this is to make operations more seamless. Moreover, when the pandemic hit, there was an urge for new technology to make air travel easier due to the restrictions. Since the Wright Brothers first took flight, aircraft have been the proving ground for many nascent technologies. With air travel bouncing back from the COVID pandemic in a big way, Mwangi's piece for Travel Radar notes how emerging technologies are being embraced by carriers and how existing services are being improved by advances. The seven tech trends Mwangi chose include

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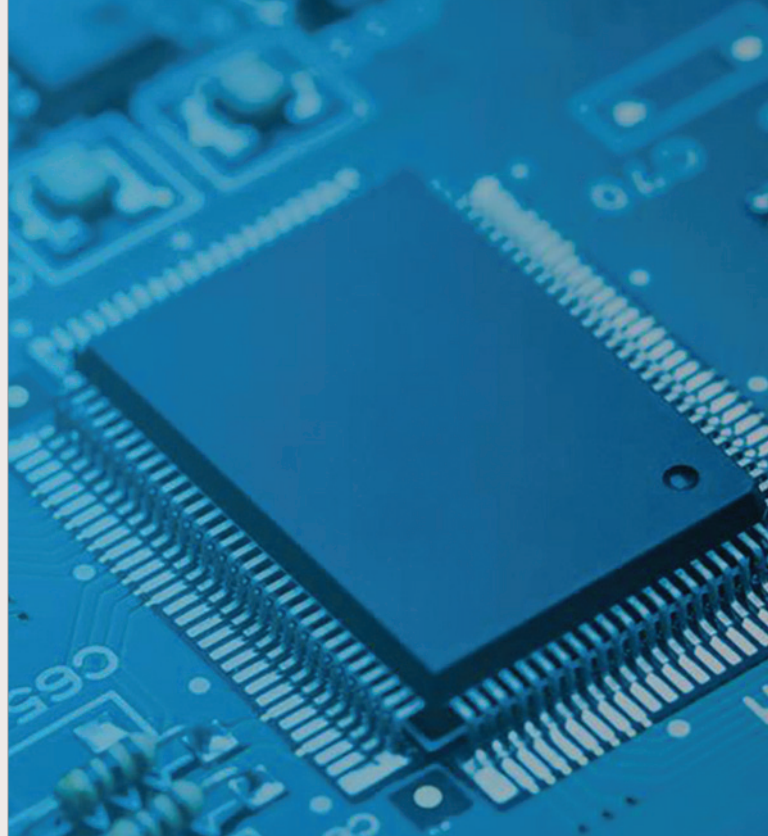




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### **Boeing to procure final 51 mission computer systems for EA-18G EW aircraft**

Military avionics experts at the Boeing Co. will provide the final 51 Advanced Mission Computer (AMC) retrofit kits for the U.S. Navy EA-18G Growler electronic warfare (EW) aircraft under terms of a \$51.7 million contract. Officials of the Naval Air Systems Command at Patuxent River Naval Air Station, Md., are asking the Boeing Defense, Space & Security segment in St. Louis to provide 51 AMC systems, which are designed and manufactured by the General Dynamics Corp. Mission Systems segment in Bloomington, Minn. The contract calls for Boeing to procure 49 AMC kits for EA-18G aircraft and two kits for software integration labs. The latest version of the F/A-18 mission computer is the AMC Type 4, which first was flight tested in 2012. Type 4 AMC increases computing power and accelerates image and mission processing functions, Boeing officials say. Those advances will support new systems and future systems aboard the aircraft, including a distributed targeting system, infrared search and track, and a new high-definition touch-screen display. The AMC is the nerve center of the Navy Super Hornet. The commercial off-the-shelf (COTS)-based, open-systems architecture product is configurable to many operating environments. The flight and mission computer is designed to handle mission processing; sensor processing; display processing; stores management; and information management. The AMC is a rugged avionics embedded computer that performs general-purpose, I/O, video, voice, and graphics processing. Communication is over several buses, including 1553, Fibre Optic Fibre Channel, and Local PCI. Single-board computers and other modules in the AMC fit in an industry standard 6U VME backplane, and the I/O configuration may be tailored with PCI mezzanine card (PMC) modules. An Ethernet interface supports software development and system maintenance. On this contract Boeing and its partners will do the work in Bloomington, Minn.; St. Louis; and Linthicum Heights, Md., should be finished by September 2025. For more information contact Boeing Defense, Space & Security online at [www.boeing.com/company/about-bds](http://www.boeing.com/company/about-bds), General Dynamics Mission Systems at <https://gdmissionsystems.com>, or Naval Air Systems Command at [www.navair.navy.mil](http://www.navair.navy.mil).



## **Air Force mulls 10-year half-billion-dollar computer anti-tamper program**

BY John Keller

**WRIGHT-PATTERSON AFB, Ohio** – U.S. Air Force anti-tamper experts are asking industry to comment on a potential 10-year half-billion-dollar program to develop anti-tamper enabling technologies to protect U.S. weapons and military systems from attempts at reverse-engineering.

Officials of the Air Force Life Cycle Management Center's Anti-Tamper Executive Agent Program Office (ATEA PO) at Wright-Patterson Air Force Base, Ohio, have released a draft request for proposal (AT2022DraftRFP) for the Anti-Tamper Executive Agent Program Office Multiple Award Indefinite Delivery/Indefinite Quantity Contract (MAC ID/IQ) project.

Air Force officials seek acquisition approval to issue a \$499 million 10-year contract solicitation to procure anti-tamper product and technology development of anti-tamper solutions in secure processing; volume protection and sensors; and cryptographic protection.



The objective is to deter, prevent, delay, or respond to reverse-engineering attempts that may compromise critical program information, and prevent adversary countermeasure development, unintended technology transfer, or alteration of a system due to reverse-engineering.

◀ **The U.S. Air Force is developing anti-tamper enabling technologies to safeguard sensitive electronics components from unauthorized reverse engineering.**

The purpose is to obtain contractor support from large and small businesses in developing unique anti-tamper technologies, integrated anti-tamper technologies.

Secure processing will develop products and technologies to establish and maintain secure processing in single-board computers, custom microelectronics, commercial microelectronics, or modified commercial processing

devices, and to extend security from one device to another related to physical hardware, intellectual property (IP), or software that manages security.

This will involve a secure physical boundary around critical components in products to prevent non-privileged users from gaining access to the critical components or information in line-replaceable units (LRUs) and shop-replaceable units (SRUs).

Cryptographic protection, meanwhile, will protect critical information in products and technology through encrypted algorithms, cryptographic key-generating methods, key storage products, or ways to discourage an adversary from gaining access to key material. ◀

Companies interested were asked to email comments and questions by 9 Sept. 2022 to the Air Force's Sara Smith-Custer at [sara.smith-custer@us.af.mil](mailto:sara.smith-custer@us.af.mil), and Jonathan Mashburn at [jonathan.mashburn.3@us.af.mil](mailto:jonathan.mashburn.3@us.af.mil). More information is online at <https://sam.gov/opp/7a7c65049adb4032b991dc6c68dc675c/view>.

## **Qatar Airways CEO says political upheaval is the biggest threat to the airline industry**

When it comes to challenges facing the airline industry, inflation, fuel prices and labor shortages take a backseat to politics, according to the CEO of the state-owned airline of Qatar. "The biggest challenge to the industry, of course, is political upheaval," Qatar Airways CEO Akbar Al Baker told an audience at the IATA World Financial Symposium in Doha. Al Baker is also Secretary-General of Qatar Tourism. As part of the same panel discussion on Tuesday, Al Baker also said that the Covid pandemic was "the biggest challenge to aviation in our living memory," before running through a litany of other obstacles. "And then there is the oil price, then there is shortage of manpower, there is no investment because of the climate issues that is happening in the world in infrastructure," he said. Al Baker was most pointed in his criticism about restrictions imposed upon airlines in the name of climate change. "And then governments unnecessarily putting restrictions on aviation to sustain political gains in many of the countries around the world, to show that they are looking after the environment and that aviation is the biggest emitter of CO2, misleading the public who depend so much on aviation for trade, for tourism, for sustaining jobs," he said. ◀

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# Radar keeps a surveillance eye on the battlefield

RF energy of various frequencies, coupled with advanced digital signal processing, helps U.S. and allied forces detect the enemy, pick out targets, and create an interactive picture of the war zone.

BY John Keller

**R**adar, short for radio detection and ranging, has been one of the most influential military technologies since World War II. It can detect and track objects as small as insects and as large as ocean-going ships and giant aircraft by bouncing radio waves of different frequencies off these targets and receiving the reflected signals. Its uses are not limited just to detecting and tracking enemy ships, aircraft, satellites, and land vehicles, but also for detailed mapping of terrain, guiding

smart munitions to their targets, identifying and imaging targets, detecting and monitoring threatening weather, and even tracking flocks of migrating birds.

Radar systems designers can digitize analog RF return signals and apply sophisticated computer processing to find the most important targets in large formations of aircraft, create detailed images of distant objects to determine if they're serious threats, unveil stealthy targets designed to evade or spoof radar, separate





incoming ballistic missile warheads from decoys, and give the most warning time possible in case of enemy attack.

In the last year alone, the U.S. military has undertaken many projects to develop and refine radar systems for airborne, land, and sea applications. These radar systems can defeat enemy attempts to jam them, and help guide missiles reliably to their targets. Advances in high-performance embedded computing are enhancing radar pictures like never before help safeguard U.S. and allied warfighters and civilians from sophisticated threats. This special report takes a look at some of the most important U.S. and allied radar development and deployment programs over the past year.

## Land systems

Perhaps the most important radar story of the past year involves U.S. Air Force Lockheed Martin Three-Dimensional Expeditionary Long-Range Radar (3DELRR), which is to be the principal Air Force long-range, ground-based radar sensor for detecting, identifying, tracking, and reporting aerial targets.

The Lockheed Martin Corp. Rotary and Mission Systems segment in Liverpool, N.Y., won a \$75 million order last April from the Air Force Life Cycle Management Center at Hanscom

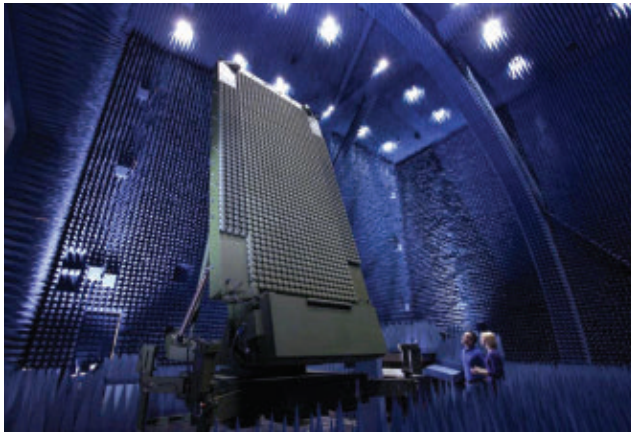
▲ **Lockheed Martin is building seven retrofit advanced radar processor systems for the E-2D Advanced Hawkeye tactical airborne early warning (AEW) aircraft.**

Air Force Base, Mass., to build and deliver the initial two 3DELRR radars. The 3DELRR radar is to replace the Air Force's Northrop Grumman AN/TPS-75 transportable 3-D passive electronically scanned array air search radar for enabling U.S. and allied invasion forces to protect themselves from airborne threats after establishing beachheads.

A long-established land-based air-defense radar is the Long Range Discrimination Radar (LRDR) near Fairbanks, Alaska, which helps the U.S. from ballistic missile attack. The Lockheed Martin Rotary and Mission Systems segment in Moorestown, N.J., won a \$784.3 million contract from the U.S. Missile Defense Agency (MDA) in 2015 to build and operate the LRDR at Clear Space Force Station, Alaska. LRDR keeps pace with evolving ballistic missile threats and increases the effectiveness of ground based interceptors, Lockheed Martin officials say. In September the U.S. Space Operations Command at Peterson Space Force Base, Colo., announced a \$31.1 million four-year order to InDyne Inc. in Lexington Park, Md., to operate and maintain the LRDR. With options the contract should be worth \$316.9 million.

The LRDR combines proven solid-state radar technologies with proven ballistic missile defense algorithms on an open-architecture designed for future growth. The solid-state





**The Air Force Lockheed Martin Three-Dimensional Expeditionary Long-Range Radar (3DELRR) enables U.S. and allied invasion forces to protect themselves from airborne threats after establishing beachheads.**



**The Multi-Mission Explorer (MDX) counter-unmanned aerial system (C-UAS) from Liteye Systems is a man-portable sensor package that uses 3D radar combined with medium-wave infrared (MWIR) and visible-light sensors.**

GaN-based radar uses Lockheed Martin's Open GaN Foundry model, which leverages relationships with strategic GaN suppliers, company officials say. The LRDR provides a persistent mid-course ballistic missile defense system (BMDS) discrimination capability as part of a layered defense of the U.S. from ballistic missile attacks of all ranges in all phases of flight.

Last summer the U.S. Army announced a \$280.1 million order to General Dynamics Land Systems in Sterling Heights, Mich., for kits to install the Trophy expedited active protection system aboard M1A2 Abrams SEPv2 and SEPv3 main battle tanks.

The Trophy system uses radar and computer processors to locate incoming anti-tank missiles and rocket-propelled grenades, and detonate the incoming munitions away from the tank. General Dynamics is working with the Leonardo DRS Land Systems segment in St. Louis to procure the Trophy active-protection system for the Abrams tank. DRS is adapting technology developed by Rafael Advanced Defense Systems Ltd. in Haifa, Israel, to help shield M1A2 Abrams main battle tanks from rocket-propelled grenades and anti-tank guided missiles.

The Trophy system isn't the only ground-based radar protecting warfighters and their equipment from anti-personnel munitions. Last April the army announced a \$3.3 billion five-year contract to Lockheed Martin Rotary and Mission Systems for full-scale production of the AN/TPQ-53 counter-fire radar to detect, classify, track, and pinpoint enemy drones and incoming artillery shells without posing a risk to nearby aircraft and military forces. The so-called Q-53 is a solid-state phased array radar that detects, classifies, tracks, and determines the location of enemy indirect fire weapons like rockets, artillery shells, and mortars in either 360- or 90-degree modes. This system is replacing the aging U.S. Army AN/TPQ-36 and AN/TPQ-37 medium-range radars.

The Q-53 radar is deployed on an Army 5-ton FMTV truck, and can go into battle with heavy, medium, and light forces. A second tactical truck carries a control shelter, backup power generator, and two additional soldiers to operate the system. Lockheed Martin started developing the Q-53 counter-fire radar in 2007. The AN/TPQ-53 is designed to detect the firing points of enemy mortars, artillery shells, and rockets with sufficient accuracy to enable counter-fire artillery to destroy the enemy launcher with one shot. The Q-53 is deployable as part of the Counter-Rocket Artillery and Mortar (C-RAM) system of systems (SoS) to provide a sense and warn capability for deployed U.S. and allied forces. The system is small enough to move aboard C-130 and C-17 aircraft.

Countering UAVs has become a top priority for tactical radar systems designers. Last summer Liteye Systems Inc. in





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Centennial, Colo., introduced the Multi-Mission Explorer (MDX) counter-unmanned aerial system (C-UAS) for force protection, expeditionary base defense, port and shoreline security, and border security. The MDX is a man-portable sensor package that uses 3D radar combined with medium-wave infrared (MWIR) and visible-light electro-optical cameras to provide air and ground surveillance, target acquisition, and tracking. The full MDX system capability offers RF surveillance and detection, 3D radar systems, HD EO/IR optical surveillance, target tracking, laser target designation, and omnidirectional and directional electronic attack in a small package that can be remotely operated and controlled by one operator.

### Aerial radar

Radar aboard aircraft has become an indispensable tool for reconnaissance, surveillance, and target acquisition (RSTA). In September the Air Force Life Cycle Management Center at Wright-Patterson Air Force Base, Ohio, announced a \$184 million five-year contract to the Raytheon Intelligence & Space segment in El Segundo, Calif., for the Advanced Synthetic Aperture Radar System-2 — better-known as ASARS-2.



**The Lockheed Martin AN/TPQ-53 counter-fire radar detects, classifies, tracks, and pinpoints enemy drones and incoming artillery shells.**

The imaging radar is a multimode real-time, high-resolution reconnaissance system carried on the U-2 Dragon Lady high-altitude reconnaissance jet with all-weather, day-night, long-range mapping capabilities. ASARS-2 detects and locates stationary and moving ground targets with precise range in search and spotlight imagery modes. It gathers detailed information, formats the data, and transmits it via wideband data link for display of fixed or moving ground objects. The imaging radar can produce extremely high-resolution images from long stand-off ranges and provides the highest resolution radar ground maps available today, experts say.

A year ago Lockheed Martin Rotary and Mission Systems started signal-processing upgrades to the U.S. Navy E-2D carrier-based radar early warning aircraft. Lockheed Martin is building seven retrofit advanced radar processor systems for the E-2D Advanced Hawkeye tactical airborne early warning (AEW) aircraft that operates from aircraft carriers. The E-2D uses Lockheed Martin's AN/APY-9 radar for Navy carrier surveillance and theater air and missile defense missions. radar provides the enhanced airborne command and control and expanded surveillance for the E-2D. The radar detects small maneuverable targets in difficult coastal-water and overland environments.

The AN/APY-9 radar for the E-2D surveillance aircraft features advanced radar signal processing subsystems to enable flexible radar beam management and enhanced target processing to help the radar pinpoint and track enemy aircraft and missiles, and reject clutter and radar interference. It has mechanical and electronic scanning modes, providing the warfighter with 360-degree situational awareness around the aircraft, and the ability to augment mechanical scanning with electronic scanning to dedicate extra resources to challenging targets or 90-degree sectors in any direction. The AN/APY-9 Radar detects air and sea surface targets simultaneously with its space-time adaptive processing (STAP) architecture, which suppresses clutter, jamming, and other sources of electromagnetic interference to focus on the target.

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November 2021 also saw a \$770 million U.S. Air Force contract to Georgia Tech Applied Research Corp. in Atlanta to build the Advanced Radar Threat System - Variant 1 (ARTS-V1) — a mobile advanced radar system to help combat aircraft pilots learn to operate safely in hostile areas guarded by modern radar-guided surface-to-air missiles. The ARTS-V1 system is for U.S. military training ranges to help pilots of several different aircraft types — especially for 5th generation aircraft like the F-35 joint strike fighter.

The ARTS-V1 has five operators, tracks and engages several targets simultaneously, and reacts to aircrew and aircraft defensive measures. The weapon systems are integrated on a transportable and ruggedized system able to go over all range terrain. The system simulates threats at full radiated power, and replicates threat signals, antenna patterns, operational modes, and threat capabilities. It sends real-time radar data to the range control center or live missions operations center together with the range's digital integrated air defense system-controlled threat environment for processing and analysis. The ARTS-V1 system includes antenna; transmitters; command, control, and communications (C3) equipment; power-generation equipment; and other ground support equipment.



**The Raytheon Advanced Synthetic Aperture Radar System-2 (ASARS-2) is a multimode real-time, high-resolution reconnaissance system carried on the U-2 Dragon Lady high-altitude reconnaissance jet.**

In October 2021 the Air Force awarded an \$80.7 million order to the Lockheed Martin Missiles and Fire Control segment in Grand Prairie, Texas, to build five Advanced Radar Threat System - Variant 2 (ARTS-V2) systems, and for ARTS-V2 production option two. The ARTS-V2 is a ruggedized mobile system designed to emulate radar-guided surface-to-air missile threats. Lockheed Martin will build the ARTS-V2 to provide threat-representative radar tracking and reaction such as

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## WHO'S WHO IN RADAR SYSTEMS DESIGN

**BAE Systems Electronic Systems**

Nashua, N.H.  
<https://www.baesystems.com/en-us/our-company/inc-businesses/electronic-systems>

**DRS Laurel Technologies**

Johnstown, Pa.  
<https://www.leonardodrs.com/locations/naval-electronics-laurel-technologies-johnstown-pa/>

**Echodyne Corp.**

Kirkland, Wash.  
<https://www.echodyne.com>

**Elta Systems Ltd., a division of Israel Aerospace Industries (IA)**

Ashdod, Israel  
<https://www.iai.co.il/about/groups/elta-systems>

**General Dynamics Land Systems**

Sterling Heights, Mich.  
<https://www.gdls.com>

**Georgia Tech Applied Research Corp.**

Atlanta  
<https://gtcr.gatech.edu/gtar>

**InDyne Inc.**

Lexington Park, Md.  
<https://www.indyneinc.com/corporate/>

**Liteye Systems Inc.**

Centennial, Colo.  
<https://liteye.com>

**Leonardo DRS Land Systems**

St. Louis  
<https://www.leonardodrs.com/who-we-are/our-segments/land-systems/>

**Lockheed Martin Missiles and Fire Control**

Grand Prairie, Texas  
<https://www.lockheedmartin.com/en-us/who-we-are/business-areas/missiles-and-fire-control.html>

**Lockheed Martin Corp. Rotary and Mission Systems**

Liverpool, N.Y.  
<https://www.lockheedmartin.com/en-us/who-we-are/business-areas/rotary-and-mission-systems.html>

**Northrop Grumman Mission Systems**

Linthicum Heights, Md.  
<https://www.northropgrumman.com/who-we-are/business-sectors/mission-systems/>

**Rafael Advanced Defense Systems**

Haifa, Israel  
<https://www.rafael.co.il>

**Raytheon Intelligence & Space**

El Segundo, Calif.  
<https://www.raytheonintelligenceandspace.com>

**Raytheon Missiles & Defense**

Tewksbury, Mass.  
<https://www.raytheonmissilesanddefense.com>

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**Maritime radar**

It's common to think of air traffic control (ATC) radar for coordinating aircraft at large airports, but U.S. Navy aircraft carriers need the same kind of radar to keep carrier operations moving smoothly. In September Saab Inc. in East Syracuse, N.Y., won a \$31.7 million Navy order for AN/SPN-50(V) 1 shipboard air traffic control radar systems to replace the Navy's AN/SPN-43C radar aboard aircraft carriers and amphibious assault ships.

The AN/SPN-50(V) 1 radar enables shipboard air traffic controllers to identify, marshal, and direct aircraft within a 50-nautical-mile radius of the ship. The order includes two on-board repair kits, and two depot spares kits. In recent years, the top 25 percent of the AN/SPN-43C frequency band has been reallocated to the fixed wireless access community prohibiting air traffic control and air search radar operation within 50 nautical miles of the coast, Navy officials say. The AN/SPN-50(V)1 radar is one of the U.S. versions of Saab's Sea Giraffe agile multi beam radar, functions as the primary air traffic control surveillance radar for manned and unmanned aviation aboard the Navy's nuclear-powered aircraft carriers and large-deck amphibious assault ships.

Just last month the Navy awarded an \$8.7 million order to the DRS Laurel Technologies segment of Leonardo DRS in



Johnstown, Pa., to build AN/SPQ-9B radar systems and support equipment. DRS in April 2018 displaced Northrop Grumman Corp. as the Navy's AN/SPQ-9B shipboard radar contractor. The AN/SPQ-9B is an X-band pulse-Doppler frequency-agile radar that scans out to the horizon and performs simultaneous and automatic air and surface target detection and tracking of low flying anti-ship cruise missiles, surface threats, low-and-slow-flying aircraft, unmanned aerial vehicles (UAVs), and helicopters.

Above decks, the radar uses a mechanically rotating, electronically stabilized antenna. The 1,500-pound antenna consists of dual planar arrays mounted back-to-back, each connected to independent transmitters and receivers. Below decks, the radar consists of processor, receiver/exciter, and transmitter cabinets; radar set control; and motor generator. The processor cabinet performs signal processing, tracking, and interface functions. The receiver/exciter has three receivers, and generates system frequencies and clocks. The transmitter cabinet receives the RF pulses from the receiver/exciter and amplifies them for output to the antenna.

Two of the most influential maritime radar projects involve the Dual Band Radar (DBR), and the Enterprise Air Surveillance Radar (EASR) from Raytheon Missiles & Defense. The DBR surface-search radar system for large U.S. Navy warships combines the benefits of S-band and X-band radar capabilities for a range of environments, while its open architecture software design enables automatic operation with

minimal human intervention. Unfortunately, Navy leaders have deemed DBR to be too expensive, and are switching large-deck surface warships to the EASR. Its only installation is aboard the aircraft carrier USS Gerald R. Ford.

Last April Raytheon won a \$19.1 million order to support the expensive DBR until EASR comes online for the aircraft carrier USS John F. Kennedy — the second ship of the Ford class — to replace the discontinued DBR. The America-class

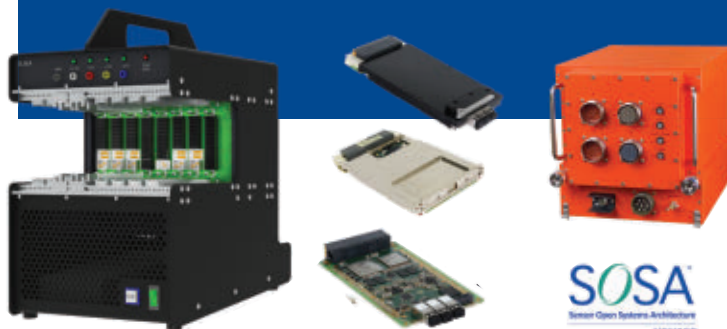


**The Trophy system uses radar and computer processors to locate incoming anti-tank missiles and rocket-propelled grenades, and detonates the incoming munitions before hitting their targets.**



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amphibious assault USS Bougainville (LHA 8), under construction in Pascagoula, Miss., is expected to be the first ship that will take EASR to sea. Raytheon's EASR capitalizes on an existing radar modular assembly (RMA) architecture matured on the company's Air And Missile Defense Radar (AMDR).

EASR is for different ship classes for ship self-defense, situational awareness, air traffic control, and weather monitoring. The Radar Modular Assembly (RMA) affords EASR the scalability for a variety of ship sizes across diverse missions for advanced capabilities and affordable costs, company officials say.

The Raytheon AMDR will be integrated into late-model Arleigh Burke-class (DDG 51) Aegis destroyers. Raytheon won a \$650.7 million Navy order last March for AN/SPY-6(V)

shipboard radar hardware. The Raytheon AN/SPY-6(V) AMDR will improve the Burke-class destroyer's ability to detect hostile aircraft, surface ships, and ballistic missiles, Raytheon officials say. The AMDR will supersede the AN/SPY-1 radar, which has been standard equipment on Navy Aegis Burke-class destroyers and Ticonderoga-class cruisers. The radar will provide greater detection ranges, increased discrimination accuracy, higher reliability and sustainability, and lower costs, compared to the AN/SPY-1D(V) radar onboard today's Burke-class destroyers. The system is built with individual building blocks called radar modular assemblies (RMAs), Raytheon officials say. Each RMA is a self-contained radar in a two-cubic-foot box; RMAs can stack together to form any size array to fit ship mission requirements. ◀

### The digital signal processing requirements of advanced radar systems

Modern military radar systems use synthetically steered radar beams that operation in many different RF frequencies that not only detect potential targets of interest, but also can identify these targets through sophisticated radar imaging.

Making this possible today are advanced embedded computing systems for digital signal processing that capitalize on the today's most advanced general-purpose processors (GPPs), field-programmable gate arrays (FPGAs), general-purpose graphics processing units (GPGPUs), real-time software, and innovative architectures.

Signal processing is just as important for advanced radar as it is for electronic warfare (EW) systems, says Denis Smetana, senior product manager at the Curtiss-Wright Corp. Defense Solutions Division in Ashburn, Va.

"Radar has its own unique system needs that differ from EW applications. When it comes to the front end of the system, which typically is some type of FPGA device, one key difference is the importance of latency," Smetana explains. "Receiving and responding to data in an EW system, because you are trying to spoof, or in some way modify the signal coming in so your adversary doesn't detect what you are doing. Minimizing latency is more important in EW than it is in radar."

Radar, on the other hand, is more uni-directional than EW systems. Although radar may be less interrupt-driven than radar, today's military radar systems increasingly are using a growing number of radar transceivers in different locations to produce a high-fidelity picture of the battlefield, as well as to use stealth techniques to confuse the enemy.

"In radar you have signals from many to hundreds of sensors coming in, and you can have fiber optics coming from front-end sensors to an FPGA device that will do that first level of processing and filtering, and then you pass that on to more of a general-purpose processor," Smetana says. "An FPGA could have 100 different streams of data coming in, and the FPGA says here's five of that 100 signals that warrants a deeper look and requires more processing."

This kind of processing can give analysts deeper information into what targets are and what they are doing, Smetana says. It can compare the radar signals of contacts with profiles of known targets to start making judgments of the potential intentions of those targets.

Artificial intelligence (AI), machine learning, and parallel-processing capabilities of today's signal processing architectures also can relieve analysts of differentiating targets, and also can help humans by making some preliminary decisions and eliminating many possibilities without human intervention.

The new Ice Lake D processor from Intel Corp. in Santa Clara, Calif., is expected to have a major influence on radar signal processing in the near future, Smetana says. "Ice Lake D has capability that helps radar processing; its floating point engine can do twice as many floating point operations in parallel than it could do before.

The Ice Lake D also has optimizations that improve its AI and machine learning by an order of magnitude over the previous generation of the Intel Xeon D processor family, Smetana points out. the Curtiss-Wright Champ XD3 embedded computing systems uses the Ice Lake D devices, aligns to the Sensor Open Systems Architecture (SOSA) industry standard, and is optimized for signal processing in RF and electro-optical sensors. ◀





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# Test and measurement: the right results at the right time

Today's test systems technologies for aerospace and defense applications are helping enhance the reliability of increasingly complex computer systems, sensors, software, and power electronics.

BY Jamie Whitney

**T**here are no do-overs in life, and warfighters must have confidence that their equipment will work as intended the first time. On top of this requirement for rock-solid systems, warfighters need their technology to be ready at a moment's notice. To ensure everything is ready, test and measurement equipment is invaluable.

Retired U.S. Air Force Maj. Gen. Stephen Sargeant, who is the CEO of Marvin Test Solutions in Irvine, Calif. says his company shines in assuring arms are tested and mission ready.

"In military-aerospace, mission readiness is key, and readiness requires comprehensive, accurate testing of the complex systems that warfighters rely on to accomplish their objective the first time," Sargeant says. "With lives on the line, maintainers must have the resources to deliver an aircraft that is completely checked out and fully mission capable. The risk of failure is too high, and the consequences of failure are too great, to rely on even educated guesswork when it comes to readiness."

One representative challenge for test and measurement equipment involves complicated precision-guided munitions of the U.S. military.

In 1975, the U.S. Department of Defense (DOD) Long Range Research and Development Planning Program (LRRDPP) and, a year later, a defense science board study, opined that the United States should pursue precision guided munitions as a matter of policy.

When Operation Desert Storm began in 1990, the American people at home and warfighters on the ground got a look at just what precision-guided munitions were capable of and the DOD never looked back.

"Precision-guided munitions have become the weapons of choice for militaries around the world. For those weapons to be truly reliable — to ensure that a missile fires every time when it's supposed to, and never when it's not supposed to — the test sets must be up to the challenge," says Marvin Test's Sargeant. "And given the increasing complexity of these mission-critical systems, the need for comprehensive accurate testing becomes more acute. For example, the emerging concept of collaborative combat aircraft requires a team of aircraft, both crewed and uncrewed, working together to accomplish a mission. Every element of this complex and dynamic system of systems must be fully capable of reliable communications and successful weapons employment."

## Harsh environments

Precision-guided munitions and other sensitive military equipment often are expected to perform flawlessly in challenging conditions including at supersonic speeds in extreme temperatures. In that end, Reyes Cortes, who is the manager of electrical testing for Dayton T. Brown in Bohemia, N.Y. explains how accurate test and measurement equipment helps achieve mission success.

"The products we test need to survive in very harsh environments," says Dayton T. Brown's Cortes. "When testing for space, electronic components and systems must survive the trip from Earth and the extreme shock, vibration, and acoustic effects of



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the launch. Then, they must perform reliably and according to specifications. This requires careful inspection and precise testing, making measurements under conditions that mimic an operating environment beyond the atmosphere of Earth, such as operating over temperature ranges from -100 to 200 degrees Celsius.

Cortes continues, “Having the right equipment that is properly calibrated is a critical step. Combining the right tools with MIL STD specifications leads to success. There have been clients’ products that pass during internal testing but then fail during our independent testing. We review the test plan and setup procedures as well as the calibration data of the equipment used during test to discover this critical step was missed during their internal testing.”

Rodger Hosking, co-founder of Pentek and now a vice president at Mercury Systems in Upper Saddle River, N.J., explains that because defense equipment is largely reliant on real-time signal processing, the testing process is essential to ensure everything is ready and reliable in the extreme environments they’re expected to operate in.

“Using these devices to test these systems is essential for many critical reasons,” Hosking says of real-time signal processing reliant systems. “Protecting a pilot in a fighter jet during combat requires effective electronic countermeasures that must precisely and instantly deceive enemy equipment or help evade enemy fire. For targeting and fire control systems, accuracy of determining target position, speed and trajectory assures hitting targets and minimizing collateral damage.”

Hosking continues, “For SIGINT systems, detecting and extracting information from small signals in the presence of noise and interference can help warfighters improve the effectiveness of offensive and defensive measures. All these systems must be



**Anritsu's now supports the PCI Express 6.0 Base Specification Receiver Test and has been further enhanced with an SKP function to filter SKP packets to support separate clock architecture.**



**The Tektronix 2 Series MSO includes TekDrive, a test and measurement data workspace in the cloud where engineers can upload, store, organize, and share any file from a connected device.**

precisely characterized with test and measurement equipment under a wide range of situations using complex simulations and challenging scenarios, and then rigorously tested during production to ensure consistent and reliable operation over time.”

### To the core

Part of making sure that sensitive equipment works in harsh environments every time it is called into action, experts need to be able to inspect the disparate components that make up today’s technologies to ensure each link in the chain is reliable.

“All mil-aero electronics — circuit cards, subassemblies and LRUs — require a certain level of functional test to ensure they are operating properly before being issued to the fleet,” Marvin Test’s Sargeant says. “Most test systems include several core subsystems including power, digital, switching, DC measurements, signal generation and AC and RF measurements which are used to generate stimulus and measure response. Testing avionics, radar, EW and similar LRU’s operating at high frequencies -typically GHz — where the use of instrumentation such as spectrum analyzers essential. Additionally, the use of software-defined instrumentation may provide a way to utilize a single device for multiple different measurement types, potentially reducing footprint and logistical demands.”

Sargeant says the overall technological trends of size, ease of use, rugged, and easy to deploy is enabled by accurate test equipment.

“Test equipment commonality streamlines maintenance and sustainment, providing the capability to support multiple aircraft platforms or even an entire fleet with a smaller number of test sets and fewer personnel,” says the Marvin Test Solutions



CEO. “As we worked with maintainers in the field and learned about the kinds of test sets that would make them more effective, we designed those desired features into our test sets. And it turns out that maintainers were pretty smart about the characteristics of the test sets they would need to achieve their objectives.”

### Trends in test

Marvin Test’s Sargeant says the U.S. Air Force has adopted the mantra of Chief of Staff of the Air Force Gen. Charles Q. Brown, Jr. to “Accelerate Change or Lose” and recently has released an operational concept called “Agile Combat Employment (ACE)”, which calls for smaller, tailorable force packages and multi-capable airmen.

“ACE puts a premium on easy to use, easy to sustain, easy to deploy, high-performance, small footprint, and rapid test time equipment,” Sargeant explains. “Our rugged, portable flightline test sets represent real-world solutions, available today, to help the services successfully execute the ACE operational concept. So, we’re not driving the trends, but in some ways we’ve been ahead of the curve.”

Dayton T. Brown’s Cortes says he and his company are seeing a lot of demand for services in the electric propulsion sector.

“We see growing demand for engineering, test, and technical services in electric propulsion and power storage within the space, aerospace, and transportation industries as companies strive to achieve carbon neutrality by 2050,” Cortes explains. “We’re doing a lot of battery testing for example for electric vehicles — cars, buses, ships, as well as ground equipment for aerospace applications. It’s estimated that 30% of emissions come from aerospace ground equipment. Additionally, we’re seeing a growing demand for testing for space including satellites, cubesats, and lunar landers. We perform several types of testing including environmental, shock and vibration, and acoustic.”

Mercury’s Hosking says that his company’s customers have expressed a need to generate challenging test signals to signals



**The F-16 System Program Office (SPO) also declared that the SmartCan O-Level Armament Test Set is a fully qualified and approved solution for the F-16 Fighting Falcon and assigned SERD #75A77.**

to verify proper operation of the most advanced electronic equipment. “This means RF signals with higher frequencies and wider bandwidths,” Hosking informs. “They also want to be able to verify that signals generated by these defense systems meet their specifications, like high power outgoing radar pulse waveforms, for example. Receive and transmit signals are increasingly sophisticated with new complex modulation and frequency hopping schemes to avoid detection, decoding or decryption.

He continues, “We design and manufacture software radio products that acquire and generate RF signals across a wide range of frequencies and bandwidths. These products rely on powerful FPGAs and processors to handle the complex real-time digital signal processing.”

### In the field

Hosking says that Mercury’s recently introduced model 5560 3U VPX Xilinx Versal HBM adaptive compute acceleration platform (ACAP) processor, which was recently introduced, is ideal for spectrum processing applications.



**The Mercury Systems model 5560 offers 16 gigabytes of Versal high-bandwidth memory, which delivers memory bandwidth as quickly as 820 gigabytes per second. This is eight times the bandwidth of DDR5 memory at 63 percent lower power consumption.**

“Incorporating powerful Versal FPGA fabric, advanced scalar and vector processors, on-chip high-bandwidth memory, the ACAP easily adapts to a diverse range of compute-intensive signal processing tasks, ideal for the challenging signals found in the latest defense systems,” Hosking says.

The model 5560 offers 16 gigabytes of Versal high-bandwidth memory, which delivers memory bandwidth as quickly as 820 gigabytes per second. This is eight times the bandwidth of DDR5 memory at 63 percent lower power consumption.

“We also offer RF signal recorders and generators capable of capturing live RF signals in the field, such as in a UAV flying over an area of conflict,” Hosking says. “These signals can later be analyzed to help our warfighters know what equipment they can expect to encounter during combat. The signals can also be played back in real time as test signals to challenge



## WHO'S WHO IN TEST AND MEASUREMENT

**Abaco Systems**

Huntsville, Ala.  
www.abaco.com

**Anritsu**

Morgan Hill, Calif.  
www.anritsu.com/en-us/

**Astronics Corp.**

East Aurora, N.Y.  
www.astronics.com

**Behlman Electronics**

Hauppauge, N.Y.  
www.behlman.com

**Bloomy Controls**

South Windsor, Conn.  
www.bloomy.com

**Curtiss-Wright Defense Solutions**

Ashburn, Va.  
www.curtisswrightds.com

**Data Device Corp. (DDC)**

Bohemia, N.Y.  
www.ddc-web.com

**Dayton T. Brown, Inc.**

Bohemia, N.Y.  
www.dtb.com

**Diversified Technical Systems Inc. (DTS)**

Seal Beach, Calif.  
www.dtsweb.com

**Great River Technologies**

Albuquerque, N.M.  
www.greatrivertech.com

**Kaman Precision Products**

Middletown, Conn.  
www.kamansensors.com

**Keysight Technologies**

Santa Rosa, Calif.  
www.keysight.com

**Marvin Test Solutions**

Irvine, Calif.  
www.marvintest.com

**Meggitt Sensing Systems**

Irvine, Calif.  
www.meggitt.com

**North Atlantic Industries**

Bohemia, N.Y.  
www.naii.com

**Rohde & Schwarz**

Columbia, Md.  
www.rohde-schwarz.com

**Saelig Co. Ltd.**

Fairport, N.Y.  
www.saelig.com

**Tektronix**

Beaverton, Ore.  
www.tek.com

**VIAVI Solutions Inc.**

San Jose, Calif.  
www.viavisolutions.com

**Vishay Precision Group**

Malvern, Pa.  
www.vpgsensors.com

The Marvin Test Solutions MTS-3060A SmartCan is an example of the Air Force's ACE concept as it embraces the call for ease of use, a small footprint, ruggedness, cyber security, and deployability, Sargeant says.

"It is capable of testing all legacy and Smart weapon systems on any fighter aircraft, enabling multi-capable Airmen to ensure the highest levels of readiness for sortie generation. The SmartCan is globally deployed and supports testing of JDAM, SDB, AIM-9, AIM-120, AGM-65, and AGM-114 for F-35, F-22, F/A-18, F-16, F-15, TA-50, FA-50, F-5, Hawk, RPA and more. It uses weapons emulation and active testing methodologies to comprehensively test launchers, pylons, bomb racks, and their associated interfaces and subassemblies — all in a hand-held package that weighs about four pounds. The Air National Guard has acquired the SmartCan to support flightline armament test for their F-15, F-16, and A-10 aircraft and will soon begin using them. The intuitive operation of the SmartCan enables readiness for the service that is 'Always Ready. Always There.'

Sargeant continues, "Additionally, the SmartCan was recently awarded Support Equipment Requirements Document (SERD) certification for F-16 armament test, signifying that the SmartCan is safe, operable, and effective for testing F-16 armament systems including launchers, bomb racks, pylons, fuel tanks, and the gun. Lockheed Martin certified the SmartCan in support of one of its Foreign Military Sales (FMS) customers. The F-16 System Program Office (SPO) also declared that the SmartCan O-Level Armament Test Set is a fully qualified and approved solution for the F-16 Fighting Falcon and assigned SERD #75A77."

Last month, Anritsu in Morgan Hill, Calif., announced that its Signal Quality Analyzer-R MP1900A now supports the PCI Express 6.0 Base Specification Receiver Test and has been further enhanced with an SKP function to filter SKP packets to support separate clock architecture (SRNS). As a result, one MP1900A supports PCI Express 3.0 to PCI Express 6.0 and can calibrate stressed test signals and measure jitter tolerance using a real-time oscilloscope to provide engineers with an efficient solution to verify their high-speed interconnect designs for 5G data centers and services.

The Signal Quality Analyzer-R MP1900A is a high-performance bit error ratio tester (BERT) for testing high-speed computing and data communications interfaces, including PCI Express, USB, Thunderbolt, and 400/800 Gigabit Ethernet. Link training status state machine (LTSSM) functions are supported by a level PAM4/NRZ PPG for waveforms, high-sensitivity input ED, high-accuracy jitter generation source (SJ, RJ, SSC, BUJ), and vertical noise generation source (CM-I/DM-I and white noise), facilitating various applications, including compliance and margin tests, as well as troubleshooting. ◀

our receivers with actual signals generated by the adversary in the field. This allows designers of defense hardware to modify system capabilities accordingly to improve effectiveness."

Last summer Tektronix in Beaverton, Ore., unveiled its 2 Series Mixed Signal Oscilloscope (MSO) that can go from the bench to the field and back. It offers benchtop performance and the Tektronix user interface. Weighing less than four pounds and 1.5 inches thin, the 2 Series MSO can fit into a small backpack. The built-in capabilities of the optional arbitrary function generator (AFG), pattern generator, voltmeter and frequency counter enable versatility built into one "Our team worked closely with engineers to deeply understand their unique needs. We cannot wait to see how the 2 Series MSO improves the way our customers work," Tami Newcombe, Tektronix President says.

Natively integrated software tools enable engineers to collaborate, troubleshoot, and debug designs across time zones. The 2 Series MSO includes TekDrive, a test and measurement data workspace in the cloud where engineers can upload, store, organize, and share any file from a connected device. Users can also perform analysis on a waveform and save it back to the cloud for immediate viewing and feedback from peers.





# Army taps Raytheon for radar-guided surface-to-air missiles

BY John Keller

**REDSTONE ARSENAL, Ala.** — U.S. Army air- and missile-defense experts needed advanced surface-to-air missiles for anti-aircraft and missile defense. They found their solution from Raytheon Technologies Corp.

Officials of the Army Contracting Command at Redstone Arsenal, Ala., announced a \$183.3 million contract to the Raytheon Intelligence & Space segment in Tewksbury, Mass., for National Advanced Surface-to-Air Missile Systems (NASAMS).

NASAMS is an adaptable mid-range air-defense system that consists of the Raytheon Sentinel radar, Advanced Medium Range Air-to-Air Missile (AMRAAM), and the Fire

▲ **NASAMS consists of the Raytheon Sentinel radar, Advanced Medium Range Air-to-Air Missile (AMRAAM), and the Fire Distribution Center from the Kongsberg Gruppen Defense & Aerospace segment in Kongsberg, Norway.**

Distribution Center from the Kongsberg Gruppen Defense & Aerospace segment in Kongsberg, Norway.

The AN/MPQ-64 Sentinel is an X-band electronically steered pulse-Doppler 3D radar system used to alert and cue short range air defense weap-

ons to the locations of hostile approaching targets.

Last year the Raytheon Missiles and Defense segment in Tucson, Ariz., unveiled a medium-range air and missile-defense radar for NASAMS called GhostEye MR. GhostEye MR is a 360-degree surveillance and fire-control sensor designed to detect, track, and identify cruise missiles, drones, fixed-wing aircraft, and helicopters.



GhostEye MR can operate as a stand-alone radar, or as a future sensor for NASAMS, which Raytheon has produced and supported in partnership with Kongsberg for more than 30 years.

GhostEye MR will provide increased range and altitude coverage for NASAMS. GhostEye MR's extended range also maximizes the capabilities of the AMRAAM Extended Range (AMRAAM-ER) variant.

NASAMS provides air defenders with a tailorable defense system that can identify, engage, and destroy current and evolving enemy aircraft, unmanned aerial vehicles (UAVs) and emerging enemy cruise missiles.

NASAMS is owned by 12 countries and has been integrated into the U.S. National Capital Region's air defense system since 2005. In addition to the U.S., Norway, Finland, Spain, The Netherlands, Oman, Lithuania, Indonesia, Australia, Qatar, Hungary, and one undisclosed country use NASAMS for

homeland defense and the defense of critical assets, Raytheon officials say.

Built on a modular, distributed, open-hardware and software architecture, NASAMS continuously can accept new and evolving enabling technologies, in partnership with Kongsberg, Raytheon officials say.

Continuous upgrades can provide one of the most technologically advanced and combat-ready system in the world, Raytheon officials say. On this contract Raytheon will do the work in Tewksbury, Mass., and should be finished by August 2024. ◀

For more information contact Raytheon Intelligence & Space online at [www.raytheonintelligenceandspace.com](http://www.raytheonintelligenceandspace.com), Raytheon Missiles & Defense at [www.raytheonmissilesanddefense.com](http://www.raytheonmissilesanddefense.com), Kongsberg Defense & Aerospace at [www.kongsberg.com/kda](http://www.kongsberg.com/kda), or the Army Contracting Command-Redstone at <https://acc.army.mil/contractingcenters/acc-rsa>.

## Air Force orders more advanced F-16 jet fighter SABR AESA radar avionics

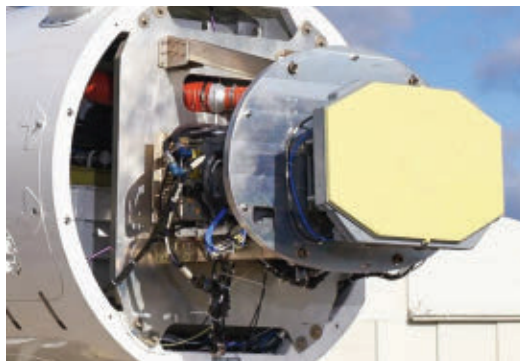
BY John Keller

WRIGHT-PATTERSON AFB, Ohio – U.S. Air Force aerial warfare experts are ordering additional modern active electronically scanned array (AESA) radar for F-16 jet fighter aircraft under terms of an \$88.2 million order.

Officials of the Air Force Life Cycle Management Center, Fighter Bomber Directorate, F-16 Division, at Wright Patterson Air Force Base, Ohio, are asking the Northrop Grumman Corp. Mission Systems segment in Linthicum Heights, Md., for 31 production radars and spare parts.

The APG-83 AESA fire-control scalable agile-beam radar (SABR) integrates within the F-16's structural, power, and cooling constraints without Group A aircraft modification, Northrop Grumman officials say. The company leverages technology developed for the APG-77 and APG-81 radar systems on the U.S. F-22 and F-35 combat aircraft.

In a 2013 competition, Lockheed Martin Corp., the F-16 manufacturer, selected the APG-83 as the AESA radar avionics



**Northrop Grumman will provide 31 new APG-83 AESA fire-control scalable agile-beam radar (SABR) systems for U.S. Air Force F-16 jet fighters.**

for the F-16 modernization and update programs of the U.S. Air Force and Taiwan air force.

The bandwidth, speed, and agility of AESA radars enable legacy fighter aircraft like the F-16 to detect, track, and identify many targets quickly and at long ranges, and to operate in hostile electronic warfare (EW) environments.

Northrop Grumman is building APG-83 radar systems for global F-16 upgrades and new aircraft production, as well as for the U.S. Air

National Guard. Northrop Grumman also has installed a production APG-83 SABR on a U.S. Marine Corps F/A-18C Hornet jet fighter-bomber, company officials say.

On this order Northrop Grumman will do the work in Linthicum Heights, Md., and should be finished by July 2025. For more information contact Northrop Grumman Mission Systems online at [www.northropgrumman.com](http://www.northropgrumman.com), or the Air Force Life Cycle Management Center at [www.aflcmc.af.mil](http://www.aflcmc.af.mil). ◀



### **Navy orders AN/ARC-210 avionics radio components from Collins Aerospace**

U.S. military radio communications experts needed components for AN/ARC-210 avionics radios across several military radio systems. They found their solution from Collins Aerospace, a Raytheon Technologies company in Cedar Rapids, Iowa. Officials of the Naval Air Warfare Center Aircraft Division at Patuxent River Naval Air Station, Md., announced a \$9 million order to Collins for several pieces of AN/ARC-210 radio equipment. The AN/ARC-210 Gen V programmable digital aircraft radio from Collins Aerospace provides two-way, multi-mode voice and data communications over frequencies from 30 to 512 MHz, covering UHF and VHF bands with AM, FM, and satellite communications capabilities. The Navy is ordering 105 MT-4935 mounting bases; 95 MX-12366 low noise amplifier triplexers; 95 AM-7642 high power amplifiers; 34 C-12561B control, radio sets; 20 Gen 6 reprogramming kits; and three additional training courses in support of multiple platforms across the Navy, Air Force, Marine Corps, and U.S. allies. The ARC-210 radio also includes embedded anti-jam waveforms, including Have Quick and SINCGARS, and other data link and secure communications features for battlefield interoperability and transfer of data, voice, and imagery. The radios communicate with other avionics over a MIL-STD-1553 data bus. The AN/ARC-210 Gen V programmable digital communication system conforms to software-defined radio (SDR) tenets and architectures, and transfers networked or point-to-point data, voice, and imagery. For more information contact Collins Aerospace online at [www.collinsaerospace.com](http://www.collinsaerospace.com).

### **Lockheed Martin to repair and recertify Patriot PAC-3 radar-guided missiles**

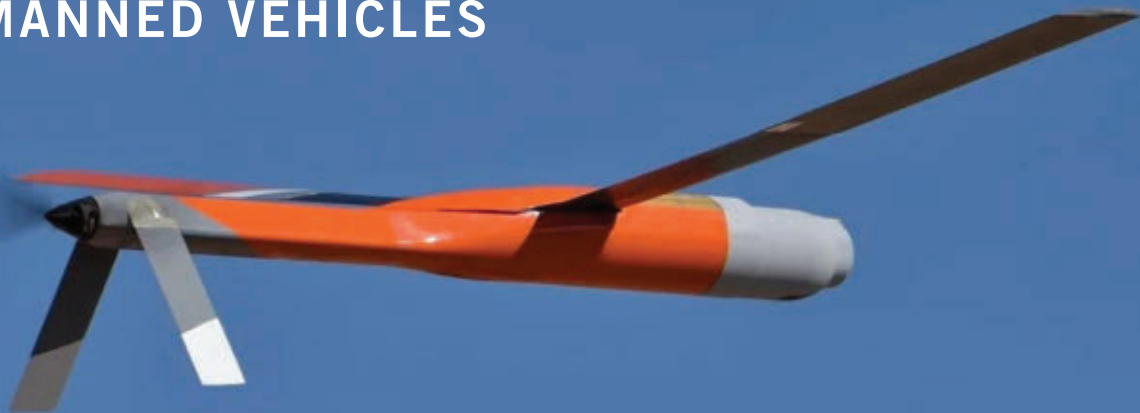
Ground-to-air missile experts at Lockheed Martin Corp. will repair and recertify the Patriot PAC-3 air-defense missile under terms of a \$307.1 million contract. Officials of the U.S. Army Contracting Command at Redstone Arsenal, Ala., are asking the Lockheed Martin Missiles and Fire Control segment in Grand Prairie, Texas, to repair and upgrade the Patriot PAC-3 missile. The full-name of the weapon is Phased Array Tracking Radar to Intercept on Target Advanced Capability-3. The PAC-3 is a hit-to-kill missile designed to defeat tactical ballistic missiles, cruise missiles, and aircraft. It is a high- to medium-altitude long-range air defense missile that defends ground combat forces and high-value military equipment.

The PAC-3 missile is a high velocity interceptor that defeats incoming targets by body-to-body direct impact. PAC-3 missiles, when deployed in a Patriot battery, provide 16 PAC-3s on a Patriot launcher. Lockheed Martin also handles the PAC-3 missile segment upgrade, which consists of the PAC-3 missile, PAC-3 missile canisters in four packs, a fire solution computer, and an enhanced launcher electronics system. The PAC-3 missile uses a solid propellant rocket motor, aerodynamic controls, attitude control motors, and inertial guidance to navigate. The missile flies to an intercept point specified prior to launch by its ground-based fire solution computer, which is embedded in the system's engagement control station. The PAC-3 system can update target trajectory data during missile flyout with a radio frequency uplink and downlink. For more information contact Lockheed Martin Missiles and Fire Control online at [www.lockheedmartin.com](http://www.lockheedmartin.com), or the Army Contracting Command-Redstone Arsenal at <https://acc.army.mil/contractingcenters/acc-rsa/>.

### **Raytheon to continue providing parts for upgrades to counter-radar missiles**

U.S. Navy electronic warfare (EW) experts are asking Raytheon Technologies Corp. to continue providing parts for upgrading the obsolescent AGM-88 High-speed Anti-Radiation Missile counter-radar weapon with improved precision. Officials of the Naval Air Systems Command at Patuxent River Naval Air Station, Md., announced a \$67.3 million order to the Raytheon Missiles & Defense segment in Tucson, Ariz., to continue to provide HARM guidance section and control section repairs and refurbishments for the U.S. Navy, Air Force, and U.S. allies. HARM is designed to suppress or destroy surface-to-air missile radars, early warning radars, and radar-directed air defense artillery systems. Over the last decade Raytheon has provided HARM guidance upgrades that add a GPS receiver and an improved inertial measurement unit (IMU) for precision navigation. The HARM control section has a digital flight computer that merges targeting solutions from navigation and seeker systems. The enhancements improve the probability of hit, while controlling where the missile can and cannot fly. The upgrades improve HARM's anti-radar capability to defeat counter-HARM tactics, while reducing the risk of fratricide and collateral damage. For more information contact Raytheon Missiles & Defense online at [www.raytheonmissilesanddefense.com](http://www.raytheonmissilesanddefense.com), or Naval Air Systems Command at [www.navair.navy.mil](http://www.navair.navy.mil). ←





# Special Operations Command orders small UAVs from Area-I for covert reconnaissance

BY John Keller

MacDILL AIR FORCE BASE, Fla. — U.S. military special operations experts needed small unmanned aerial vehicles for reconnaissance, surveillance, and target acquisition. They found their solution from Area-I LLC in Marietta, Ga.

Officials of the U.S. Special Operations Command at MacDill Air Force Base, Fla., announced a \$30.5 million contract to Area-I for the Agile-Launch Tactically-Integrated Unmanned System (ALTIUS) unmanned aircraft.

The ALTIUS covert UAV family comes in three variants: the ALTIUS-500 that launches from A-size sonobuoy launch canisters aboard Navy helicopters and fixed-wing aircraft; the tube- and air-launched ALTIUS-600; and the high-endurance ALTIUS-900 can be launched from military aircraft bomb racks.

This contract includes reconnaissance mission payloads, training, logistics, engineering, test and measurement, and other services in support of U.S. Special Operations Command's Aviation Integration Directorate Contracting Office.

The ALTIUS-500 agile-launched UAV can be delivered as all-up-rounds and available on-demand and operational within

▲ **The ALTIUS covert UAV family comes in three variants: the ALTIUS-500 that launches from A-size sonobuoy launch canisters aboard Navy helicopters and fixed-wing aircraft**

minutes. It is designed to store and launch from A-size sonobuoy launch canisters from anti-submarine warfare (ASW) aircraft and helicopters, and can perform high-altitude ASW because it can deploy a magnetic anomaly detector to detect the

magnetic signature of a submarine.

The ALTIUS-600 is a tube-launched UAV that can be launched from the air, sea, and ground from systems like the Common Launch Tube (CLT), Pneumatically Integrated Launch System (PILS), and other launch systems. It has a sensor or payload package, and can launch from C-130A, AC-130J, and P-3 fixed-wing aircraft; the UH-60 ASW helicopter, civilian aircraft, and ground vehicles.

The ALTIUS-900 is similar to the ALTIUS-600, but with increased endurance, next generation power system, and interfaces with 14-inch, 1,000-pound class bomb racks where the UAV falls away from its launch aircraft. ◀

On this contract Area-I will do the work in Marietta, Ga., and should be finished by July 2027. For more information contact Area-I LLC online at <https://areai.com>, or U.S. Special Operations Command at [www.socom.mil](http://www.socom.mil).



# Six companies to study building large unmanned surface ship for cargo, sensors, and weapons

BY John Keller

**WASHINGTON** – U.S. Navy autonomous marine vessel experts are asking six shipbuilding companies to study different concepts for a large unmanned surface vessel (USV) able to carry cargo, sensors, and weapons to augment the Navy's manned surface force.

Officials of the Naval Sea Systems Command in Washington have announced contracts collectively worth \$62.1 million to the six companies for separate conceptual designs of the Large Unmanned Surface Vessel (LUSV).

Companies receiving LUSV concept design awards are Huntington Ingalls Inc. in Pascagoula, Miss. (\$13.1 million); the Lockheed Martin Corp. Rotary and Mission Systems segment in Baltimore (\$11.3 million); Marinette Marine Corp. in Marinette, Wis. (\$10.2 million); Bollinger Shipyards Lockport LLC in Lockport, La. (\$9.4 million); Austal USA LLC in Mobile, Ala. (\$9.1 million); and Gibbs & Cox Inc. in Arlington, Va. (\$9 million).

This kind of unmanned surface ship is expected to carry as much as 40 tons of personnel and cargo, and operate in 8-to-13-foot waves for as long as 90 days without a human crew.

The LUSV would use technology developed under the Sea Hunter project of the U.S. Defense Advanced Research

Projects Agency (DARPA) and the Office of Naval Research in Arlington, Va.

Initial phases of LUSV development will involve a prototype unmanned ship with a range of 4,500 miles amid waves as high as 13 feet, and the ability to generate as much as power as 75 kilowatts of 450-volt, 60 Hz, three-phase power for on-board electronic payloads.

At this early stage, Navy experts envision a LUSV about 200 to 300 feet long — about a third the size of a future Navy frigate.

Other details, dimensions, and performance specifications of the LUSV are classified. With a large payload capacity, the LUSV will be designed to conduct a variety of warfare operations independently or with manned surface combatants.

The LUSV will be capable of semi-autonomous operation, with operators controlling the vessel remotely, or through autonomous operations. U.S. Marine Corps leaders, for example, plan to use the future LUSV for long-range resupply missions, and troop transport, says Lt. Gen. Eric Smith, commander of the Marine Corps Combat Development Command at Quantico Marine Base, Va.

The future Navy LUSV could rendezvous with Navy amphibious assault ships offshore to move Marines and supplies quickly where needed, at perhaps lower costs and less risk to human ship crews than is possible today.

In addition to the Marine Corps desired cargo, transport, and surveillance missions, the future LUSV also might be able to carry payloads for electronic warfare, anti-surface warfare, and land-strike warfare. The six companies should complete their concept design work on the future LUSV by September 2024. ◀



**The U.S. Navy is asking six shipbuilding companies to study building a large unmanned surface vessel (USV) to carry cargo, sensors, and weapons.**

For more information contact Huntington Ingalls online at <https://huntingtoningalls.com>; Lockheed Martin Corp. Rotary and Mission Systems at [www.lockheedmartin.com](http://www.lockheedmartin.com); Marinette Marine Corp. at <https://fincantierimarinegroup.com/about-us/us-shipyards/marinette-marine>; Bollinger Shipyards Lockport at [www.bollinger-shipyards.com/locations/bollinger-lockport](http://www.bollinger-shipyards.com/locations/bollinger-lockport); Austal USA at <https://usa.austal.com>; Gibbs & Cox at <https://www.gibbscox.com>; or Naval Sea Systems Command at [www.navsea.navy.mil](http://www.navsea.navy.mil).





# Army orders soldier-carried unmanned surveillance aircraft from AeroVironment

BY John Keller

REDSTONE ARSENAL, Ala. — U.S. Army unmanned aircraft experts needed soldier-carried unmanned aerial vehicles (UAVs) for battlefield surveillance applications. They found their solution from AeroVironment Inc. in Simi Valley, Calif.

Officials of the Army Contracting Command at Redstone Arsenal, Ala., announced an \$11.2 million order to AeroVironment for RQ-20B Puma 3 AE unmanned aerial systems.

The AeroVironment Puma 3 AE is a soldier-carried unmanned aircraft system designed for land and maritime operations. The hand-launched Puma 3 AE has a wingspan of 9.2 feet, weighs 15 pounds, can operate for as long as 2.5 hours, and has a range of as far as 12.4 miles.

The Puma 3 AE UAV has a standard antenna, and can extend its operation range to as far as 37.2 miles with AeroVironment's Long-Range Tracking Antenna (LRTA).

Capable of landing in water or on land, the all-environment Puma, with its Mantis i45 EO/IR sensor suite, gives the operator

▲ **The AeroVironment Puma 3 AE is a soldier-carried unmanned aircraft system designed for land and maritime operations.**

extended flight time and a high level of imaging capability.

The third-generation all-environment Puma 3 AE delivers mission critical intelligence, surveillance, and reconnaissance (ISR), and features a reinforced airframe with an optional underwing transit bay for secondary payloads and third-party applications.

Multi-mission capable, operators can swap between Mantis i45 and the enhanced night variant Mantis i45 N, for day, night, and low-light operations. The UAV is launchable by hand, bungee, rail, or vehicle, and recoverable by deep-stall landing.

AeroVironment's family of tactical UAS use a common ground control station and software, allowing for improved interoperability and decreased training and logistics costs for NATO forces. ◀

For more information contact AeroVironment online at [www.avinc.com](http://www.avinc.com), or the Army Contracting Command-Redstone at <https://acc.army.mil/contractingcenters/acc-rsa>.



### Army orders UAV for Nigeria for reconnaissance and electronic warfare (EW)

U.S. Army unmanned aerial vehicle (UAV) experts needed a relatively small unmanned aircraft for communications and reconnaissance applications. They found their solution from Textron Systems Corp. in Hunt Valley, Md. Officials of the Army Contracting Command at Redstone Arsenal, Ala., have announced a \$9 million order to Textron for an Aerosonde Mk 4.7 small UAV for Nigeria. The Aerosonde small UAV is for multi-mission expeditionary land- and sea-based operations. Aerosonde weighs 80 pounds, has an 11.9-foot wingspan, can carry a 20-pound sensor payload, can fly as high as 15,000 feet, has a maximum range of 75 nautical miles, and can fly for as long as 14 hours. It for simultaneous day-and-night full-motion video, communications relay, and intelligence missions. The Aerosonde MK 4.7 unmanned aircraft is designed for expeditionary land- and sea-based operations and equipped for simultaneous day and nighttime full-motion video, communications relay, signals intelligence (SIGINT), and a sensor payload in one flight. The Textron Aerosonde small unmanned aircraft system (SUAS) has a Lycoming EL-005 heavy-fuel engine; and can accommodate multi-intelligence sensors, electronic warfare (EW), and communications payloads. The Aerosonde MK 4.7 uses a hydraulic pneumatic launcher and net recovery system, and can launch from ground sites or from surface vessels. On this order Textron will do the work in Hunt Valley, Md., and should be finished by September 2023. For more information contact Textron Systems online at [www.textron-systems.com](http://www.textron-systems.com), or the Army Contracting Command-Redstone at <https://acc.army.mil/contractingcenters/acc-rsa>.

### Rugged DC-DC converters for unmanned vehicles introduced by TDK Lambda

TDK-Lambda Americas Inc. in San Diego is introducing the 250-Watt RGA series of ruggedized non-isolated DC-DC converters for harsh-environment applications such as robotics, automated guided vehicles, communications, and industrial and portable battery-powered equipment. Capable of operating from an input voltage of 9 to 40 volts or 9 to 53 volts, the step-down converter delivers output voltages that are adjustable from 3.3 to 15 volts, 3.3 to 24 volts, or 3.3 to 40 volts, with output currents as strong as 20 amps. The 1/16th brick form factor power electronics device measures 35.6 by 25.6 by 13 millimeters, and is encapsulated to provide high resistance to shock and vibration. The five-sided aluminum case reduces

radiated electromagnetic interference and enables conduction cooling to a cold-plate for fanless operation. The rugged RGA models consist of three voltage and current combinations to support operation from 12-, 18-, 24-, 36-, and 48- power sources. The wide input ranges can assist with inventory reduction programs with one part number covering several nominal voltages. With efficiencies to 98 percent, power losses are minimized to enable the products to operate in temperatures from -40 to 110 degrees Celsius case temperatures. The need for external output capacitance is reduced due to an optimized dynamic voltage response, thus reducing board space requirements. The basic feature models include an output voltage adjustment pin, negative logic remote on-off, remote sense, input under-voltage, over-current and thermal protection. Full feature models are equipped with a power good signal, output voltage sequencing and the ability to synchronize the operating frequency to minimize system noise. For more information contact TDK-Lambda Americas online at [www.us.lambda.tdk.com](http://www.us.lambda.tdk.com).

### Federal law enforcement orders tethered unmanned helicopters from Zenith

Leaders of a U.S. law-enforcement agency in Washington needed heavy-lift tethered unmanned aerial vehicles (UAVs) for surveillance applications. They found their solution from Zenith AeroTech in Afton, Va. Zenith AeroTech has completed delivery of two Quad 8 tethered UAVs to a federal law enforcement agency for command overwatch during emergency response missions. The Quad 8 can lift as much as 20 pounds of customer-defined payloads. That's more than enough capacity to carry a long-range EO/IR camera, a communications relay, and two 17,000-lumen, weather-resistant LED panels. The Quad 8 is a long-endurance tethered unmanned quad copter able to carry infrared and visible-light video cameras, a communications relay, and overhead high-intensity lights. The tethered UAVs can stay in the air for days at time. "These high-powered lights are ground-controlled for intensity and on/off functions," says Doganc Kucuk, lead designer for Zenith AeroTech. "When they are activated, it becomes like daytime on the ground." Hovering at altitudes of 200 to 400 feet, the Quad 8 tethered UAV draws its power from its ground power unit, which converts AC voltage into high-voltage DC power. The power unit also runs an automated management system that works in inclement weather conditions. For more information contact Zenith AeroTech online at <https://zenithaerotech.com>. ◀





# Wanted: enabling technologies for submarine and UUV propulsion

BY John Keller

ARLINGTON, Va. — U.S. military researchers are asking industry to develop enabling technologies for next-generation propulsion for crewed submarines and unmanned underwater vehicles (UUVs) that will be quieter and more efficient than ever before.

Officials of the U.S. Defense Advanced Research Projects Agency (DARPA) in Arlington, Va., issued a solicitation (HR001122S0046) for the Advanced Propulsor, Experimental (APEX) project.

Areas of interest include enabling technologies in hydro-dynamics, hydro-acoustics, mechanical engineering, naval submarine architecture, electro-mechanical, and other disciplines. Details are classified.

U.S. military experts constantly are looking for new propulsion technologies for manned and unmanned submersibles to operate in dangerous areas amid ever-more-sophisticated enemy sonar systems.

Today's submarines are quieter than ever before, and are difficult to detect and track even with the most advanced sonar systems. Still, it's a cat-and-mouse game for submarine designers to

▲ **Researchers are interested in hydro-dynamics, hydro-acoustics, mechanical engineering, naval submarine architecture, and electro-mechanical propulsion for submarines and UUVs.**

keep their vessels quiet enough to evade current- and next-generation sonar technologies.

DARPA researchers are looking for submarine propulsion technologies related to efficiency, signature, mechanical design and limits, and operational considerations.

The project's phase 1A base will last for one year, and will consider theoretical propulsion designs and identify knowledge gaps. Phase 1B option will last for nine months, and will work toward defining one APEX design approach, then refine the design. The three-month phase 1C option will refine the design. ◀

DARPA researchers are asking each interested company to submit one full proposal for phases 1A, 1B, and 1C. Companies were asked to upload unclassified proposals in September to the DARPA BAA website at <https://baa.darpa.mil>. Email questions or concerns to the DARPA APEX BAA coordinator at [HR001122S0046@darpa.mil](mailto:HR001122S0046@darpa.mil). More information is online at <https://sam.gov/opp/20f87528a2b54aceb4a4469d5ffb20df/view>.





# Industry asked for infrared imaging sensors based on optomechanical technology

BY John Keller

ARLINGTON, Va. — U.S. military researchers are asking industry to develop new kinds of thermal imaging and infrared (IR) detection based on optomechanical sensors — or those that can modulate light propagation.

Electro-optical scientists at the U.S. Defense Advanced Research Projects Agency (DARPA) in Arlington, Va., have issued a broad agency announcement (HR001122S0055) for the Optomechanical Thermal Imaging (OpTIm) Technical Area (TA) 1 project.

The OpTIm program seeks to demonstrate a new class of room-temperature integrated optomechanical medium- and long-wave IR detectors that could bridge the gap between room-temperature microbolometers and cryogenic quantum-limited IR photodetectors.

The project will explore intrinsic infrared-sensitive materials, nano-assembled metamaterials and heterostructures that combine

▲ **DARPA wants industry to develop a new class of room-temperature integrated optomechanical medium- and long-wave IR detectors.**

enhanced IR-absorption, multispectral or polarization-sensitive IR capabilities with high-Q optomechanical resonator integration and quantum-limited optical readout.

OpTIm will validate the essential elements

of this IR detection concept, which consist of three elements:

- spectrally tailored narrowband, multispectral, or polarization-sensitive IR absorption in high-Q thin-film resonators or heterostructure membrane resonators;
- IR-induced frequency shifts in the resonator eigenmodes that can be determined rapidly because of high intrinsic quality factors, low thermomechanical noise, low thermal mass, and low fractional frequency instability of these resonators; and
- all-optical detection of these frequency shifts at or near quantum-limited precision by harnessing visible or near-IR photodetection technology.



Such all-optical protocols potentially can circumvent issues of readout integrated circuit (ROIC)-induced noise sources, fabrication incompatibilities, or related issues that have hampered conventional microbolometer technology. OpTIm also aims to establish fundamental sensitivity, bandwidth, noise, and performance limits of this new modality of IR detection.

Infrared detectors involve applications like night vision, biochemical spectroscopy, automation, and climate science.

Current IR detection techniques rely either on photodetection or thermal detection. While IR photodetectors can achieve quantum levels of sensitivity, they require cryogenic cooling to mitigate dark current and other noise sources.

In contrast, thermal detectors such as microbolometers can operate at room temperature but offer far lower performance levels than IR photodetectors, resulting in a significant performance gap in IR detection technology between uncooled thermal detectors and cryogenically cooled photodetectors.

OpTIm is a 60-month program broken into two 30-month phases. The first phase will focus on the validating the OpTIm device concept by developing sensor materials that combine low-noise, high-Q optomechanical properties with tunable, narrowband, or multispectral IR-sensitive absorption characteristics.

The project's first phase also will demonstrate IR-induced modification of resonator eigenmodes in a single-pixel detector with effective area smaller than 100 square microns, and characterize the detector's IR sensitivity and IR-spectral characteristics.

The second phase, which will depend on a successful first phase, will demonstrate all-optical interrogation of the optomechanical detector and optical readout of IR signals from the single-pixel detector developed the project's first phase.

It also will tune, optimize, and characterize detector sensitivity, dynamic range, signal bandwidth, spectral and polarization characteristics, Allan variance of the optomechanical resonator spectrum, and performance metrics for the optical readout.

This broad agency announcement addresses technical area one (TA1) of the OpTIm program, which focuses on IR sensitivity, signal bandwidth, and the spectral characteristics of medium- and long-wave detectors. ←

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Companies were asked to submit full proposals by 1 Nov. 2022 to the DARPA BAA Website at <https://baa.darpa.mil>. Email questions or concerns to DARPA at [OpTIm@darpa.mil](mailto:OpTIm@darpa.mil). More information is online at <https://sam.gov/opp/ad090fdd991d4478b72efd30f37d89d0/view>.

### Electro-optical near-infrared LED illuminator introduced by Opto Diode

Opto Diode Corp. in Camarillo, Calif., is introducing the OD-663-850 near-infrared LED illuminator with total power output from 300 to 425 milliwatts for high-power, near-infrared illumination tasks. The narrow-angle-of-emission OD-110L and the wide-angle-of-emission OD-110W are ultra-high-power aluminum gallium arsenide (GaAlAs) near-infrared emitters with uniform optical beams and peak emission wavelengths of 850 nanometers. These devices are designed to operate in extreme temperatures and rugged conditions. Other infrared LED products, such as the narrow-angle OD-110LISOLHT and the wide-angle OD-110WISOLHT operate at 880 nanometers with a spectral bandwidth of 55 nanometers (typical). These high-power infrared emitters feature wide temperature ratings and convenient two-lead TO-39 cans with isolated cases for high-temperature lighting tasks. The company recently introduced the highest output power available OD-669 GaAlAs IRLED illuminator with an extremely wide angle of emission. The electro-optical device is in

a TO-66 package for heat sink attach, and is designed with nine chips connected in series. The device has an electrically isolated case to covert aircraft lighting and covert anti-collision lighting in aviation applications. For more information contact Opto diode online at <https://optodiode.com>.

### Hydrogen alpha filters for astronomy, spectroscopy introduced by Alluxa

Alluxa Inc. in Santa Rosa, Calif., is introducing the two electro-optical hydrogen alpha (H-alpha) emission line filters for astronomy applications. These filters are tailored to monitor H-alpha spectra in astronomy, and also can be used in applications where spectral line discrimination is critical, such as spectroscopy, plasma monitoring, and fusion research. The filters have a 50 percent BW of 0.35 nanometers, a 1 percent BW of less than 0.6 nanometers, a peak transmission of approximately 80 percent and is blocked to OD6 out of band. Alluxa's cavity H-alpha filters features a narrow design with a FWHM of 0.12 nanometers and peak transmission of greater than 90 percent. For more information contact Alluxa online at [www.alluxa.com](http://www.alluxa.com). ←





# Navy asks Leonardo DRS to provide open-architecture shipboard displays

BY John Keller

WASHINGTON – U.S. Navy surface warfare experts are buying additional shipboard consoles, displays, and peripherals from Leonardo DRS in Johnstown, Pa., to promote maximum software reuse aboard Navy surface combatants.

Officials of the Naval Sea Systems Command in Washington announced an \$33.6 million order to DRS for the Consoles, Displays, and Peripherals (CDP) program.

The CDP is composed of air-cooled and water-cooled variants of the Navy's Common Display System (CDS); consoles, portions of the Aegis weapon system Aegis Modernization Upgrade equipment, and peripheral equipment.

The Navy is buying the shipboard electronics equipment as part of technical insertion (TI) 16 production equipment and spares to support the Navy's future surface ship combat systems. The order includes foreign military sales to Canada and South Korea.

The CDP program includes thin client displays and multi-mission displays. The CDS consoles are a set of open-architecture watch station three-eyed horizontal display

▲ The CDP is composed of air- and water-cooled consoles, portions of the Aegis weapon system Aegis Modernization Upgrade equipment, and peripheral equipment.

consoles that provide the human machine interface between the sailor and the ship's combat systems.

The contract involves shipboard electronics equipment that meets Technology Insertion (TI) 16, and will be for vessels like future versions of the Arleigh Burke-class destroyer; the DDG 1000 Zumwalt-class surface-attack destroyer, as well as for Aegis modernization efforts aboard the Navy's Ticonderoga-class cruisers and Burke-class destroyers.

This contract combines purchases for the U.S. Navy, and the military forces of Spain. On this contract DRS will do the work in Johnstown, Pa., and should be finished by August 2023. ◀

For more information contact DRS Laurel Technologies online at [www.leonardodrs.com/locations/naval-electronics-laurel-technologies-johnstown-pa](http://www.leonardodrs.com/locations/naval-electronics-laurel-technologies-johnstown-pa), or Naval Sea Systems Command at [www.navsea.navy.mil](http://www.navsea.navy.mil).



# Lockheed Martin to support electro-optical imaging systems aboard submarines

BY John Keller

WASHINGTON – Submarine combat systems experts at Lockheed Martin Corp. will continue a project to upgrade and support a U.S. Navy electro-optical surveillance system designed for several classes of attack and guided-missile submarines.

Officials of the Naval Sea Systems Command in Washington have announced an \$54 million order to the Lockheed Martin Rotary and Mission Systems segment in Manassas, Va., to support the AN/BVY-1 Integrated Submarine Imaging System (ISIS).

ISIS provides mission critical, all-weather, visual, and electronic search, digital image management, indication, warning, and platform architecture interface capabilities for Los Angeles-, Ohio-, and Virginia-class submarines, Navy officials say. The system has the potential for installation on current and future ballistic missile submarines.

The ISIS submarine electro-optical surveillance system rolls-up existing components and near-term capabilities into an architecture for inserting future capabilities as they become available, including items taken from the Virginia-class submarine photonics program, Navy officials say.

ISIS is a back-fit system to integrate all imaging capabilities on existing Navy submarine classes. It is part of the Navy's submarine Photonics Imaging System, a non-hull-penetrating replacement

for existing optical periscopes. The Photonics Imaging System uses a wide portion of the electromagnetic spectrum with advanced daylight cameras, infrared thermal imaging sensors, and communications intercept and electronic warfare support.

The ISIS program seeks to replace the optical light path of existing submarine periscopes with high-definition cameras and fiber optic digital imagery. The project seeks to use infrared cameras for image enhancement, provide active and passive range finding control, and install image enhancement capabilities and analysis tools for real time and recorded imagery.

The ISIS program also will provide Navy submarines with image recording, storage, and recall capabilities, as well as provide the ability to transmit imagery off the submarine to other naval and joint forces.

ISIS revolutionizes Navy submarine surveillance capabilities by integrating digital video and still images from devices on a submarine's exterior and presenting real-time imagery and analysis on existing control room tactical displays.

ISIS provides digital image enhancement for data from a modern submarine's photonics mast, which uses optical fiber to move imaging data from a raised mast aboard a submerged submarine through tiny openings in the submarine's hull to tactical displays around the interior of the vessel.

The photonics mast replaces or augments the traditional periscope aboard U.S. submarines. The photonics mast not only replaces the large opening in the submarine pressure hull necessary for the optics and hydraulics of a traditional periscope, but also can blend image data from several kinds of electro-optical sensors aboard the photonics mast, including visible-light and infrared cameras.

The ISIS system enables submarine crew members to manipulate a photonics mast with a joystick, while looking at digital video on a computer monitor, and share that video real-time with the submarine's combat team on various displays aboard the vessel. ◀



▲ Lockheed Martin is supporting the U.S. Navy AN/BVY-1 Integrated Submarine Imaging System (ISIS), which provides visual and electronic search for missile and attack submarines.

On this order Lockheed Martin will do the work in Manassas, Virginia Beach, Fairfax, and Arlington, Va.; Northampton, Mass.; and Waterford, Conn., and should be finished by September 2023. For more information contact Lockheed Martin Rotary and Mission Systems online at [www.lockheedmartin.com](http://www.lockheedmartin.com), or Naval Sea Systems Command at [www.navsea.navy.mil](http://www.navsea.navy.mil).





## SOFTWARE

### ▲ Navy asks Raytheon to upgrade data package and software in JSOW smart munitions

Precision munitions experts at Raytheon Technologies Corp. will upgrade hard-target-penetrating and data-linked medium-range precision-guided smart munitions for the governments of Taiwan, Bahrain, and Canada under terms of a \$29.4 million contract.

Officials of the U.S. Naval Air Systems Command at Patuxent River Naval Air Station, Md., are asking the Raytheon Missiles & Defense segment in Tucson, Ariz., to upgrade the technical data package and software for the AGM-154C Block III Joint Standoff Weapon (JSOW) munition for these allied nations.

The AGM-154 JSOW is medium range precision-guided glide bomb for attacking defended targets from outside the range of standard anti-aircraft defenses. Pilots typically fire JSOW from ranges of 22 to 70 nautical miles. The JSOW Block III adds a Link-16 weapon data link and moving maritime target capability to the AGM-154C.

The weapon can launch from F/A-18, F-16, F-15, F-35, and Jas Gripen jet fighter-bombers; as well as from B-1B, B-2A, and B-52H long-range jet bombers. The AGM-154C JSOW unitary variant uses an imaging infrared seeker with autonomous guidance.

The two-stage AGM-154C carries the BROACH warhead made up from a WDU-44 shaped augmenting warhead and a WDU-45 follow through bomb, and is designed to attack hardened targets like armor, concrete, and earth to enable a large following warhead to explode inside the target. The JSOW is 13 feet long and weighs about 1,000 pounds.

On this systems upgrade contract Raytheon will do the work in Tucson, Ariz.; Goleta, Calif.; McAlester, Okla.; and other U.S. locations, and should be finished by July 2025. For more information contact Raytheon Missiles & Defense online at [www.raytheonmissilesanddefense.com](http://www.raytheonmissilesanddefense.com), or Naval Air Systems Command at [www.navair.navy.mil](http://www.navair.navy.mil).

## TORPEDO DEFENSE

### ▼ Ultra Electronics to build torpedo-defense decoy to protect surface warships from torpedoes

U.S. Navy surface warfare experts needed torpedo-defense decoys to help protect surface warships from torpedo attack. They found their solution from Ultra Electronics Ocean Systems Inc. in Braintree, Mass.

Officials of the Naval Undersea Warfare Center Division Keyport in Keyport, Wash., announced a \$42.1 million contract to Ultra Electronics to build the Acoustic Device Countermeasure (ADC) MK 2 torpedo decoy for surface warships.

The ADC MK 2 is a battery-powered expendable sonar countermeasure for use by surface ships and submarines to counter torpedo threats. When deployed, it hovers vertically at a pre-selected depth using a pressure-controlled motor driving a small shrouded propeller in the tail of the decoy, and emits an acoustic signal to spoof incoming torpedoes.

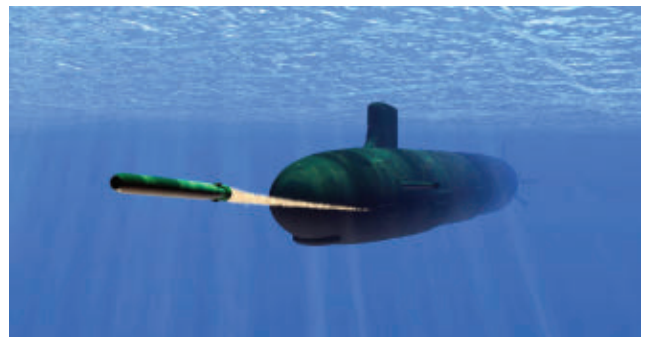
The five-year contract ADC MK 2 training devices used on surface vessels and submarines. Purchasers will include the United Kingdom and The Netherlands.

The system essentially uses sound to divert or confuse homing torpedoes to help naval forces create a multilayer defensive screen. The ADC MK 2 is part of an integrated sense-to-effect solution that helps surface ships survive torpedo attacks.

The system employs advanced acoustic processing techniques to detect and classify torpedo threats with a very low false alert rate and high probability of correct classification.

On this contract Ultra Electronics will do the work in Braintree, Mass.; Chantilly, Va.; and Wake Forest, N.C., and should be finished by July 2027.

For more information contact Ultra Electronics Ocean Systems online at [www.ultra.group/our-business-units/maritime](http://www.ultra.group/our-business-units/maritime), or the Naval Undersea Warfare Center Division Keyport at [www.navsea.navy.mil/Home/Warfare-Centers/NUWC-Keyport](http://www.navsea.navy.mil/Home/Warfare-Centers/NUWC-Keyport).







### SENSORS

#### ▲ General Dynamics to buy sensors for active-protection missile defense in Abrams tanks

Armored combat vehicle experts at General Dynamics Corp. will integrate active protection sensors to shield the Army's fleet of M1A2 Abrams main battle tanks from rocket-propelled grenades, anti-tank guided missiles, and similar threats.

Officials of the U.S. Army Contracting Command at Detroit Arsenal in Warren, Mich., has announced a \$280.1 million order to General Dynamics Land Systems in Sterling Heights, Mich., to procure kits for the Trophy expedited active protection system aboard M1A2 Abrams SEPv2 and SEPv3 tanks.

General Dynamics is working with the Leonardo DRS Land Systems segment in St. Louis to procure the Trophy active-protection system for the Abrams tank. DRS is adapting technology developed by Rafael Advanced Defense Systems Ltd. in Haifa, Israel, to help shield M1A2 Abrams main battle tanks from rocket-propelled grenades and anti-tank guided missiles.

DRS and Rafael are adapting the Rafael Trophy active protection system to the M1A2 Abrams tank. Rafael developed Trophy together with the Elta Group of Israel Aerospace Industries Ltd. in Ashdod, Israel. The Trophy system intercepts and destroys incoming missiles and rockets with a shotgun-like blast.

Trophy vetronics is designed to locate and destroy incoming enemy fire instantly using a 360-degree radar, processor, and on-board computer. It can locate, track, and destroy approaching anti-tank-guided-missiles, rocket-propelled grenades, or similar anti-armor weapons by launching a countermeasure to detonate the incoming munition away from the vehicle.

The interceptor uses small shaped charges attached to a gimbal on top of the vehicle. The small explosives fire to a point in space to intercept and destroy the approaching

round. Trophy locates and identifies incoming threats with radar that scans the tank's perimeter out to a known range. The on-board computer determines the optimal kill point for any incoming threat.

Trophy has been used in combat on Israeli Merkava tanks. In addition to locating and destroying incoming missiles and rocket-propelled grenades, the system also can locate and cue weapons to the positions enemy shooters.

The DRS-Rafael Trophy system can defeat known anti-armor shaped-charge weapons, like missiles, rockets, and tank-fired high-explosive anti-tank shells before they strike the tank.

The system enables networked threat awareness by pinpointing and reporting shooter location improves platform protection with low risk of collateral injury, and can ensure freedom of movement and maneuver, DRS officials say. On this order General Dynamics will do the work in locations to be determined with each order, and should be finished by July 2027.

For more information contact General Dynamics Land Systems online at [www.gdls.com](http://www.gdls.com), Leonardo DRS Land Systems at [www.leonardodrs.com/who-we-are/our-segments/land-systems](http://www.leonardodrs.com/who-we-are/our-segments/land-systems), Rafael Advanced Defense Systems at [www.rafael.co.il](http://www.rafael.co.il), or the Army Contracting Command-Detroit Arsenal at <https://acc.army.mil/contractingcenters/acc-dta/>.

### GUIDANCE AND CONTROL

#### ▼ Army picks Northrop Grumman for proximity fuze in artillery shells

U.S. Army artillery experts needed advanced proximity fuzes with state-of-the-art electronic technologies for 105- and 155-millimeter artillery shells. They found their solution from Northrop Grumman Corp.

Officials of the Army Contracting Command at Rock Island Arsenal, Ill., has announced a \$533.9 million contract





to the Northrop Grumman Allegany Ballistics Laboratory in Rocket Center, W.Va., for M782 multi-option fuzes for artillery.

The M782 Multi-Option Artillery Fuze (MOFA) is for high-explosive fragmentation- and burster-type 105- and 155-millimeter artillery projectiles.

The proximity fuze has four functional modes: variable time, time, point detonating, and delay. The fuze contains an electronic timing system that may be set to function from 0.5 to 199.9 seconds in increments of tenths of a second.

A proximity fuze detonates an explosive device automatically to destroy or damage targets such as planes, missiles, ships at sea, and ground forces. It provides a more sophisticated trigger mechanism than the common contact fuze or timed fuze to increase artillery lethality by 5 to 10 times, compared to these other fuzes.

The M782 fuze is remote-set automatically before firing via an inductive communication link like the TM 9-1290-210-12&P M1155 portable inductive fuze setter. The mission data transferred from the setter to the fuze is confirmed by the M1155 fuze setter.

The M782 is the latest fuze artillery design and is compatible with all current 105- and 155-millimeter bursting artillery shells. It employs state-of-the-art advanced electronic technologies, and replaces seven earlier fuzes to simplify logistics and training.

MOFA incorporates a proven legacy safe-and-arm device to maintain required safety and reliability, and can be inductively set in the proximity, point detonating, delay, or time mode. This multi-option capability reduces the number of artillery fuzes the U.S. forces must maintain in inventory, Army officials say.

On this contract, Northrop Grumman will do the work at locations to be determined with each order, and should be finished by July 2027. For more information contact the Northrop Grumman Allegany Ballistics Laboratory online at [www.northropgrumman.com](http://www.northropgrumman.com), or the Army Contracting Command-Rock Island Arsenal at [https://acc.army.mil/contractingcenters/acc\\_ri](https://acc.army.mil/contractingcenters/acc_ri).

## NETWORKING

### ► Persistent Systems to provide networking for unmanned ground vehicles

Unmanned ground vehicles (UGV) designers at QinetiQ U.S. in Waltham, Mass., needed communications and networking subsystems for the Common Robotic System-Individual (CRS-I) that QinetiQ is providing to the U.S. Army. They found their solution from Persistent Systems LLC in New York.

Persistent Systems officials have announced that their company has received additional orders from QinetiQ US to provide thousands of MPU5 mobile ad hoc networking (MANET) devices in support of the Army's CRS-I program.

CRS-I will provide infantry soldiers with a lightweight mobile UGV for reconnaissance, surveillance, and target acquisition (RSTA). In 2019 the Army chose QinetiQ to provide the company's SPUR UGV for CRS-I. Persistent Systems supplies the communications and command-and-control element of the UGV.

The QinetiQ SPUR UGV offers rapid deployment from its backpack stowed state, tactical mobility, long radio range, manipulator arm, sensors, and mission modules for foot soldiers. It can be carried on a MOLLE II assault pack with a controller, pan-tilt-zoom camera and manipulator arm.

The Persistent Systems MPU5 unmanned vehicle command-and-control system is an advanced, scalable MANET radio, with secure networking, as well as data, video, voice, and Android computer system.

"The MPU5's low-latency networking capability allows the operator of the SPUR platform to send commands to the UGV as well as receive video and other sensor data back, which can also be shared with everyone else on the network," says Nick Naioti, vice president for business development at Persistent Systems.

"To date, Persistent Systems has supplied hundreds of radios for CRS-I and we are just entering full-rate production for the program," Naioti says. For more information contact QinetiQ U.S. online at [www.qinetiq.com](http://www.qinetiq.com), or Persistent Systems at [www.persisystems.com](http://www.persisystems.com).







### SUSTAINABLE AVIATION

#### ▲ Ansys selected by NASA-backed program to help validate sustainable aviation project

Ansys in Canonsburg, Pa., has been selected to support research led by the University of Central Florida (UCF) in Orange County, Fla. The program is funded by a \$10 million NASA University Leadership Initiative, which is a five-year grant program to help sustainable aviation take off.

The project aims to develop zero-carbon jet engines using liquid ammonia (NH<sub>3</sub>) as an alternate, more sustainable fuel for aircraft. Ansys' simulation solutions will be used as a key enabler of the project to both validate the use of ammonia and achieve the outcome within the desired timeline.

By integrating Ansys' chemical kinetics and computational fluid dynamics (CFD) simulation tools, Ansys Chemkin-Pro and Ansys Fluent, researchers will simulate complex, chemical reaction systems surrounding ammonia, including the vaporization of liquid ammonia inside heat exchange tubes, heat transfer, and the combustion of ammonia and hydrogen in the air. The goal is to use ammonia as a main hydrogen carrier by inducing chemical catalysis to leverage ammonia's hydrogen components while only releasing safe emissions into the air.

"We want to create a scalable solution for cleaner aviation and with Ansys' cooperation we will get there faster," said Jay Kapat, the lead investigator of the project and an engineering professor at UCF. He is an expert in his field and leads the Center for Advanced Turbomachinery and Energy Research at UCF. "We would not be able to authenticate the use of liquid ammonia as a reliable and alternate fuel without the sophistication and capability of Ansys' fluids simulation tools."

In addition to the capabilities of ammonia, it is naturally liquid at high altitudes, easier to handle than hydrogen, and does not require additional storage. In contrast, hydrogen requires special handling at high altitudes, thermal management, and ample on-board cryogenic storage.

"Simulation is reshaping a cleaner future in many industries, and today we applaud its continued impact on aviation

with this exciting new project made possible by UCF and NASA. Simulation enables companies to save resources, energy and emissions before products are ever built; and build more energy-efficient products and processes that have far-reaching sustainability impacts," said Prith Banerjee, chief technology officer at Ansys and executive sponsor of Ansys' Academic and Sustainability Programs. "Through simulation, Ansys provides the predictive certainty to realize our customers' vision for a sustainable future and model interactions that we otherwise could not analyze, such as chemical reactions. We look forward to playing a role in developing groundbreaking sustainable aviation fuel options."

### SPACECRAFT AVIONICS

#### ▼ DDC to provide 1553 databus components for CST-100 Starliner spacecraft

Spacecraft designers at the Boeing Co. needed MIL-STD-1553 avionics databus networking components for their CST-100 Starliner space capsule. They found their solution from Data Device Corp. (DDC) in Bohemia, N.Y.

Designers at the Boeing Defense, Space & Security segment in St. Louis chose DDC MIL-STD-1553 data bus components for the CST-100, which has completed a docking maneuver with the International Space Station (ISS) as part of an uncrewed orbital test flight.

DDC's 1553 transceivers and transformers are designed into the Starliner's Crew Module-Integrated Propulsion Controller (CM-IPC) and the Service Module-Integrated Propulsion Controller (SM-IPC) of the spacecraft.

Boeing chose DDC for these systems because of DDC's reliability, performance and ruggedness of our data bus solutions, company officials say.

DDC's MIL-STD-1553 application-specific integrated circuits (ASICs) have achieved over 1 billion hours of in-service history on aerospace, defense, and space applications.





"With more than 25 years of experience as a leading supplier of radiation hardened MIL-STD-1553 data bus components, DDC is dedicated to the innovation and advancement of data bus technology for space," stated Brian Forsberg, DDC's business unit manager for data bus components.

The Boeing CST-100 Starliner consists of two partially reusable spacecraft — a crew capsule and expendable service module — to transport crew to the International Space Station (ISS) and other low-Earth-orbit destinations.

The capsule is slightly larger than the Apollo command module and SpaceX Dragon 2, and smaller than the Orion capsule. The Boeing Starliner holds a crew of as many as seven people and can dock to ISS for as long as seven months. Experts say the spacecraft can be reused as many as 10 times.

It launch aboard the Atlas V, Delta IV, Falcon 9, and Vulcan Centaur rockets. NASA chose the Boeing Starliner and SpaceX Crew Dragon rocket for the Commercial Crew Transportation Capability (CCtCap) contract.

In late 2019, the uncrewed Boeing Starliner Orbital Flight Test launched on an Atlas V N22 and reached orbit, but the flight failed to meet all of its test goals. An unmanned test launched in May 2022, and the first crewed launch is scheduled for later this year.

For more information contact DDC online at [www.ddc-web.com](http://www.ddc-web.com), or Boeing Defense, Space & Security at [www.boeing.com/space/starliner](http://www.boeing.com/space/starliner).

## POWER ELECTRONICS

### ► Navy chooses Crane Keltec to upgrade power supplies in jet aircraft

U.S. Navy airborne electronic warfare (EW) experts needed upgraded power supplies for the AN/ALQ-218 signals intelligence (SIGINT) system aboard the Boeing EA-18G Growler carrier-based aircraft. They found their solution from the Crane Aerospace & Electronics Keltec segment in Fort Walton Beach, Fla.

Officials of the Naval Surface Warfare Center Crane Division in Crane, Ind., have announced a \$9.1 million contract to Crane Keltec to upgrade ALQ-218 weapons replaceable assembly 9 power supply Navy assets.

The AN/ALQ-218 from the Northrop Grumman Mission Systems segment in Baltimore is a passive sensor system that functions as a radar warning receiver, electronic support measures, and electronic intelligence.

The system provides airborne situational awareness and signals intelligence (SIGINT) by detecting, identifying,



locating, and analyzing sources of radio frequency (RF) emissions. This contract includes purchases for the U.S. Navy and the government of Australia.

Crane Keltec specializes in reliable and lightweight power conversion for military applications, including DC-DC converters and active power factor correction units. The company provides auto-transformer rectifier units; transformer rectifier units; regulated transformer rectifier units; and AC-DC power conversion.

The AN/ALQ-218 is aboard the EA-18G electronic warfare (EW) jet and the P-8A Poseidon maritime patrol aircraft, and is being considered in the future for unmanned aerial vehicles (UAVs) and submarines.

The Navy EA-18G carrier-based electronic warfare aircraft carries multi-mode radar detection, suppression, and countermeasure equipment, such as the multiple AN/ALQ-99 radar jamming pods on its wing tips and tail, the AN/ALQ-218 EW receiver, and a communications countermeasures system installed in the plane's gun bay.

The AN/ALQ-218 can operate on RF bands 0, 1, 2, and 3, with pulsed and continuous-wave radar with optional communications support, while providing specific emitter identification. It offers enhanced fine frequency measurement to support electronic jamming.

The Boeing EA-18G Growler combat jet is a specialized version of the two-seat carrier-based F/A-18F Super Hornet jet fighter bomber that is adapted for electronic warfare — specifically jamming enemy radar and communications, as well as attacking enemy radar installations with missiles that home-in on radar signals.

On this contract Crane Keltec will do the work in Fort Walton Beach, Fla., and should be finished by July 2027. For more information contact Crane Aerospace & Electronics online at [www.craneae.com](http://www.craneae.com), or the Naval Surface Warfare Center Crane Division at [www.navsea.navy.mil/Home/Warfare-Centers/NSWC-Crane](http://www.navsea.navy.mil/Home/Warfare-Centers/NSWC-Crane). ◀



## SOFTWARE

### ► **Trusted computing design and development software introduced by Lynx**

Lynx Software Technologies in San Jose, Calif., is introducing the LynxElement Unikernel software that is to be POSIX compatible for mission-critical uses. Third-party and open-source software can put any application at risk, but threats and security impact on mission-critical software is great. Unikernels work best for applications that require speed, agility, and a small attack surface for increased security, certifiability, and trusted computing such as avionics, autonomous vehicles, and critical infrastructure. Unikernels are pre-built applications that use libraries, and can reduce software vulnerabilities to hackers and other attacks. Unikernels also are suited for mission-critical systems with heterogeneous workloads that need the coexistence of RTOS, Linux, Unikernel and bare-metal guests. Lynx has based its Unikernel product on the company's LynxOS-178 real-time operating system, to enable compatibility between the Unikernel and the stand-alone LynxOS-178 product. This enables users to transport applications between each environment and is FACE- and POSIX API-compatible. The Lynx framework provides built-in security for the Unikernel for security and safety certification in mission-critical applications. For more information contact Lynx Software Technologies online at [www.lynx.com/products/lynxelement](http://www.lynx.com/products/lynxelement).

## DESIGN AND DEVELOPMENT TOOLS

### ▼ **Design and development chassis for embedded computing introduced by Elma**

Elma Electronic Inc. in Fremont, Calif., is introducing a 12-slot 3U embedded computing design and development chassis for systems designers who need alignment to the Sensor Open Systems Architecture (SOSA) and the C5ISR/EW Modular Open Suite of Standards (CMOSS) design guidelines. The chassis aligns to the SOSA 1.0 and CMOSS open-systems standards, offers high-speed RF and optical I/O, and supports I/O- and compute-intensive

processor slots, two switch slots, and one PNT slot. The development chassis and test and measurement system for embedded computing provides a complete test environment to support application development for SOSA and CMOSS initiatives. This chassis

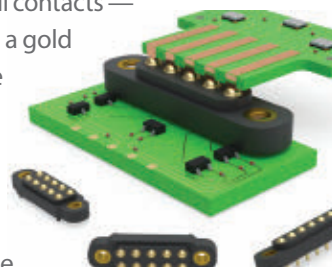


was part of an interoperability demonstration last March that involved three additional SOSA member companies at the Tri-Service Open Architecture Interoperability Demonstration (TSOA-ID). The chassis also provides two VITA 62 power slots, and is built on an Elma Type 39 84HP-wide E-Frame chassis that provides open access for testing and troubleshooting. Other options include dual high-wattage VITA 62 3U VPX pluggable power supply modules, a network timing card with radial support for IEEE 1588 precision timing and synchronization, and a 4590a 1/10/40 Gigabit Ethernet switch with copper and fiber ports from Interface Concept. Also featured are conduction-cooled slot inserts, front and rear fan trays with 12-volt DC fans and AC operation using a power cord. The platform includes a front panel on/off switch, reset switch, voltage LEDs, and test points. For more information contact Elma Electronic online at [www.elma.com](http://www.elma.com).

## CONNECTORS

### ▼ **Spring-loaded connectors that provide multi contact points offered by Mill-Max**

Mill-Max Manufacturing Corp. Inc. in Oyster Bay, N.Y., is introducing the Omniball spring-loaded connectors for applications that require several points of contact in sliding or rotational orientations. The Omniball spring-loaded contact features a rolling ball interface, that makes contact between components in axial and non-axial alignments. The connectors use Omniball contacts — spring-loaded pins in which a gold plated brass ball replaces the traditional plunger. When engaged, the ball compresses and rolls makes contact and then slides parallel while spring force





ensures consistent electrical contact. This rolling action prevents binding, premature wearing, and structural failure that traditional plunger-style spring-pin connectors can be prone to. Omniball connectors come in single- and double-row configurations, have a pin-to-pin spacing of 4 millimeters, a 6.76-millimeter above-board height, and are available in through-hole or surface-mount termination styles. There are options for threaded inserts to provide secure mounting in rugged applications and for alignment pegs on the SMT connectors. Insulator material is Nylon 4/6 for high-temperature performance, dielectric strength, and mechanical toughness. Omniball contacts feature 0.030-inch maximum stroke, gold plating on all components and a .091-inch-diameter ball interface. These spring-loaded pins have been tested to one million compression cycles and rolled over 67 miles at half stroke while still meeting specifications for contact resistance of 30 milliohms. For more information contact Mill-Max online at [www.mill-max.com](http://www.mill-max.com).



## MOTION CONTROL

### ◀ Three-axes stages for positioning applications introduced by Optimal Engineering

Optimal Engineering Systems Inc. (OES) in Van Nuys, Calif., is introducing the YPR-45-15-60 series three-axes stages for laser scanning, drilling, machining, reverse engineering, inspection, assembly, measurements, tracking, and

positioning. OES engineers developed the stages using a 60-millimeter-diameter rotary stage upper axis capable of 360 degrees of continuous operation, and two middle and lower axes goniometers with travel ranges of plus-or-minus 15 degrees and plus-or-minus 45 respectively. This series of three-axes stages feature four motor options. The -01 option is stepper motor driven, the -02 option is three phase-servo motor driven, the -03 is DC servo motor driven, and the -04

option is stepper motor driven with quadrature optical encoders for position verification. The rotary axis of the -01 and -04 versions has a maximum rotational speed of 30 degrees per second and has resolution of 0.002 degrees when 10 micro-steps per step motor driver is in use. The positional accuracy for motion control is 0.05 degrees, and repeatability is plus-or-minus 0.01 degrees. The -02 and -03 versions move at speed to 45 degrees per second. This rotary axis has a precision pattern of threaded holes for mounting tooling or fixtures. The goniometer axes of the -01 and -04 versions have a maximum speed of 14 degrees per second. The positional accuracy of each axis is 0.05 degrees, and repeatability is plus-or-minus 0.01 degrees. The -02 and -03 servo motor versions with quadrature incremental optical encoders travel to 45 degrees per second with greater resolution, accuracy, and repeatability. For more information contact OES online at [www.oesincorp.com](http://www.oesincorp.com).

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### RUGGED COMPUTERS

#### ► **SWaP-constrained rugged mission computer introduced by Curtiss-Wright**

The Curtiss-Wright Corp. Defense Solutions division in Ashburn, Va., is introducing the MPMC9337 rugged mission computer for military systems that need additional on-board processing power but must limit their size, weight, and power (SWaP) burden. The MIL-grade three-slot 3U OpenVPX mission computer comes ready to support compute-intensive general-purpose graphics processing unit (GPGPU)-driven applications like cognitive signal and image processing. It is pre-configured with a Curtiss-Wright VPX3-1220 or VPX3-1260 single board computer in the first slot and an NVIDIA GPGPU based co-processor module in the second slot. The computer board hosts a Curtiss-Wright XMC-E01 Vita 42 fiber-optic XMC module that delivers four channels of 10-gigabit Ethernet, configurable



as four 1000BASE-T Ethernet ports or four 10GBASE-SR Fiber Ethernet ports. The chassis's third slot can support a 3U OpenVPX SATA solid-state drive data storage module or an additional 3U OpenVPX PCI Express card. The MPMC-9337 also features an integrated 28-volt DC power supply. Measuring 250 cubic inches, this compact mission computer delivers reliable and predictable performance in operating temperatures as high as 71 degrees Celsius. The system uses advanced cold plate and thermal management to remove the need for fans, vehicle supplied air, liquid, or other demands from the vehicle. Designed for operation in harsh military environments, the MPMC-9337 chassis includes heaters to support cold-starts in temperatures as low as -50 C. I/O includes a dual channel CAN/MilCAN offload controller, as well as USB and video ports accessible at the front of the unit. For more information contact Curtiss-Wright Defense Solutions online at [www.curtisswrightds.com](http://www.curtisswrightds.com). ◀

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## ADVERTISERS INDEX

ADVERTISER	PAGE
Airborn Inc. ....	13
Annapolis Micro Systems Inc. ....	18
Apex Microtechnology Inc. ....	7
Elma Electronic Inc. ....	21
Fairview Microwave ....	17
General Micro Systems Inc. ....	C2
Master Bond Inc. ....	20
Mercury Systems ....	C4
New Wave Design and Verification.....	19
Pasternack Enterprises.....	3, 25
Pave Technology Co., Inc.....	11
Phoenix International.....	49
Pico Electronics Inc.....	1
RGB Spectrum.....	48
Sealevel Systems Inc.....	9
VPT .....	5

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E-mail: [MAE@omeda.com](mailto:MAE@omeda.com)

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VICE PRESIDENT/GROUP PUBLISHER **Steve Beyer**  
847-532-4044 / [sbeyer@endeavorb2b.com](mailto:sbeyer@endeavorb2b.com)

EDITOR-IN-CHIEF **John Keller**  
603 891-9117 / [jkeller@endeavorb2b.com](mailto:jkeller@endeavorb2b.com)

ASSOCIATE EDITOR **Jamie Whitney**  
603 891-9135 / [jwhitney@endeavorb2b.com](mailto:jwhitney@endeavorb2b.com)

CHIEF CONTRIBUTOR **Megan Crouse**

ART DIRECTOR **Kermit Mulkins**

PRODUCTION MANAGER **Sheila Ward**

AD SERVICES MANAGER **Shirley Gamboa**

AUDIENCE DEVELOPMENT MANAGER **Debbie Bouley**  
603 891-9372 / [dbouley@endeavorb2b.com](mailto:dbouley@endeavorb2b.com)



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## EDITORIAL OFFICES

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Military & Aerospace Electronics  
61 Spit Brook Road, Suite 501, Nashua, NH 03060  
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# Mangata Networks selects Honeywell to provide SATCOM control systems

BY Jamie Whitney

PHOENIX - Honeywell in Phoenix has announced that Mangata Networks - a telecommunications company also in Phoenix - has selected the company's space Integrated Attitude Control System (IACS) in support of its new constellations comprising 32 satellites.

Mangata's new highly elliptical orbit (HEO) and medium Earth orbit (MEO) satellite constellations provide communications and weather monitoring in areas that typically lack in quality internet connectivity.

IACS is a comprehensive control and steering solution for satellites that ensures the proper altitude and position of space vehicles, which is essential for effective signal communication and solar power generation to keep the satellites operating efficiently.

"We are excited to announce our partnership with Honeywell as it will design, develop and deliver the avionics for Mangata's constellation satellites," says Andreas Doulaveris, vice president of space systems at Mangata Networks. "Honeywell is first-in-class, and we are looking forward to continuing our relationship as together we bring Mangata Networks' vision to fruition."

The precision and reliability of Honeywell's space IACS platform enable continuous connectivity for users of Mangata's network of telecommunications satellites.

▲ Mangata Networks will use the Honeywell Integrated Attitude Control System (IACS) for a new Mangata space communications constellations that ultimately will have 32 satellites.

Together with other core elements of Mangata's network architecture, the goal is to make possible secure and high-speed connectivity for businesses and individuals in remote areas without adequate access to the internet.

"The traditional geostationary equatorial orbit (GEO) constellations already provide broadband and other connectivity solutions for consumers and commercial applications, but the existing technology has become too slow by today's standards," says Ricky Freeman, president of defense, and space at Honeywell Aerospace.

"As a result, global telecommunications companies are modernizing their networks and have started to look to HEO and MEO to provide higher data rates while lowering latency. Honeywell has extensive experience and a strong pedigree in navigation, data handling and momentum control products. Each of these is well suited to support these HEO and MEO satellite constellations, and our IACS platform will provide Mangata Networks with the precision and reliability it needs to operate its network of telecommunications satellites." ◀



# BLADE and Eve announce UAM partnership to expand sector in India

BY Jamie Whitney

NEW DELHI - FlyBlade India, a joint venture between Hunch Ventures and Blade Air Mobility, Inc. — both in New Delhi — and Eve Air Mobility in São José dos Campos, Brazil, have announced a strategic partnership that includes a non-binding order of up to 200 electric vertical take-off and landing (eVTOL) vehicles, service and support, and Eve's Urban Air Traffic Management (UATM) software.



▲ The FlyBlade India joint venture is ordering as many as 200 electric vertical take-off and landing (eVTOL) vehicles for urban air mobility applications.

The companies also plan to collaborate on a three-month pilot project connecting passengers using helicopters.

BLADE India will act as Eve's on-ground knowledge partner to create the UAM ecosystem. The data collected through BLADE India's customer experience and operations will be used to further develop Eve's eVTOL, service and support solutions, and its UATM software. BLADE India will initially underwrite 50,000 hours of flight time per year using Eve's eVTOL in the country.

"India's traffic congestion woes are only expected to get worse. This partnership allows us to leverage Eve's deep expertise in not just EVA design but also in the infrastructure required to support UAM," said Amit Dutta, managing director, BLADE India.

"We are thrilled about partnering with BLADE India and pioneering the urban air mobility market in the country, which has the potential to be one of the largest markets globally. This initial order will allow us to enter into service in India and further develop the ecosystem according to the community's needs. We look forward to offering the people of India a zero-emission UAM solution in the future that will be quiet, efficient, and accessible," said André Stein, co-CEO of Eve. ◀

## AirAsia India selects CAE's AI-powered training system

AirAsia India in Bengaluru, India needed a simulator training system. They found their solution from CAE in Montreal. AirAsia India and CAE have announced their collaboration to integrate the CAE Rise Training System into the airline's simulator training program. CAE Rise utilizes analytics to provide real-time data during training sessions while giving instructors insights that enable them to objectively assess a pilot's technical competencies and performance. AirAsia and CAE have worked together since 2014 on pilot training at CAE network training centers. Launched in 2018, the CAE Rise training system enables the translation of simulator training data into valuable insights for instructors and training managers. This new training system compares independent sources to provide increased confidence in grading data quality. In addition to monitoring SOP compliance, CAE Rise augments each instructor's capability to identify pilot proficiency

gaps and evolve training programs to the most advanced aviation safety standards including AQP, ATQP, and EBT methodologies. "This collaboration uniquely incorporates CAE's distinct features, which enable a more robust data-driven training program for our pilots," said Capt. Manish Uppal, Head of Operations, AirAsia India. "At AirAsia India, we continue to be at the forefront of integrating technology and ensuring that safety is paramount in every aspect of our training and operations."

## All Nippon Airways is launch customer for new Boeing Insight Accelerator

All Nippon Airways (ANA) in Tokyo needed technology to improve operation efficiency and avoid service disruptions. They found their solution from the Boeing Company in Arlington, Va. ANA will be the launch customer for Boeing's Insight Accelerator (IA), a new cloud-based digital solution employing artificial



# Smiths Detection launches HI-SCAN 7555 DV dual-view X-ray scanner with enhanced capabilities

BY Jamie Whitney

**LONDON** - Smiths Detection, a London-based threat detection and security screening technology company, has announced the launch of the HI-SCAN 7555 DV. A dual-view X-ray scanner, the HI-SCAN 7555 DV delivers high image quality, automatic explosives detection, and a compact footprint, to provide efficient screening in high threat applications.

Equipped with an advanced dual-view X-ray scanning system, the new model offers increased operational efficiency by eliminating the need to re-position or rescan objects. Smart display functions further support the scanner's effectiveness, by facilitating accurate and rapid discrimination between substances. Two 120 Hz 24-inch monitors expedite image evaluation and reduce motion blur, ensuring that operators can make accurate and fast decisions.



**Smiths Detection is introducing the HI-SCAN 7555 DV dual-view X-ray scanner that delivers high image quality, automatic explosives detection, and a compact footprint.**

The HI-SCAN 7555 DV offers an automated explosives detection algorithm as standard and optionally an ECAC EDS CB C1 certified algorithm in combination with optional iCMORE weapons capability, to allow for the automatic detection of weapons. The new scanner is compatible with Checkpoint. Evoplus, Smiths Detection's central screening and digital management solution, which offers real-time data, allowing actionable insights and health status monitoring. The HI-SCAN 7555 DV can also be equipped with Smiths Detection's latest automated detection algorithm, iCMORE currency, which assists with the automatic detection of large stacks or bundles of notes.

With a compact footprint, the HI-SCAN 7555 DV has been designed to be integrated into both Smiths Detection and third-party lanes, making it suitable for high-throughput environments such as airports, customs, government facilities or embassies. ←

intelligence to improve operational efficiency and avoid high impact service disruptions. While the latest generation of commercial airplanes like the 787 generate a large amount of flight data, many operators lack the infrastructure to manage and leverage the information. By using augmented analytics to discover and deploy predictive algorithms for anomaly detection, our Insight Accelerator solution enables airlines to take proactive maintenance and repair action and prevent unscheduled delays. Boeing developed the IA platform based on decades of experience supporting the global fleet and developing rigorous methods while assisting 'Airplane-on-Ground' situations.

## Phase Four unveils iodine-based thruster propellant for LEO constellations

Phase Four in El Segundo, Calif., has announced that it will expand its Maxwell turn-key plasma propulsion line and offer

satellite manufacturers a high-performance engine using an inexpensive, domestically sourced iodine-based propellant. Max-V leverages the Maxwell Block 2 engine's architecture and builds on the radio-frequency thruster's propellant agnostic capabilities. Phase Four's Maxwell Block 1 engine gained flight heritage in early 2021. Maxwell Block 2 engine deliveries began earlier this year. Maxwell's new chassis-style design enables on-ramping of improvements in the core areas of the thruster, power electronics and propellant subsystems. Max-V is anticipated to be available for order in the second half of 2023. The system is designed to operate from 200 Watts to 1.5 kilowatts, and achieve 50 mN thrust, over 1,200 s Isp and deliver over 100 kNs total impulse. Max-V's iodine-based propellant will cost under \$400 per kilogram and be incorporated in the purchase price. Max-V's form factor is similar to Phase Four's current Maxwell Block 2 engine. ←