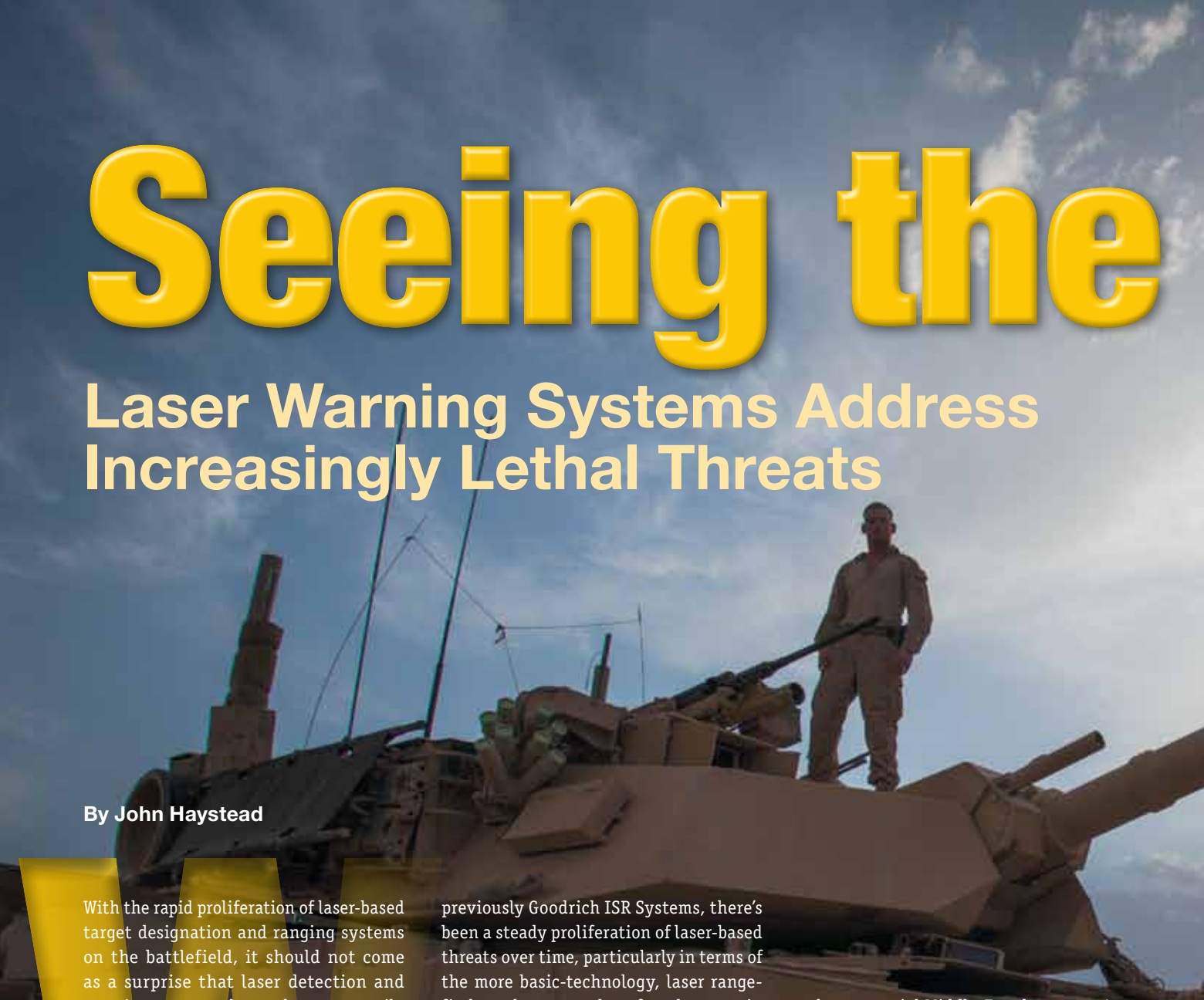
Seeing the

Laser Warning Systems Address Increasingly Lethal Threats



By John Haystead

With the rapid proliferation of laser-based target designation and ranging systems on the battlefield, it should not come as a surprise that laser detection and warning systems have also necessarily become more important and prevalent. On the battlefield, lasers are used as rangefinders, target designators, and in their most lethal application, as guidance systems for "beam-rider" missile systems. To counter them, laser warning systems have been installed on (or integrated into other threat warning systems aboard), a wide variety of airborne and ground-based platforms, naval vessels, and even individual soldiers. In some cases, in addition to alerting to a threat, laser warners may automatically trigger some form of countermeasure system such as a smoke or aerosol screen, laser countermeasure ("dazzler"), laser jammer, or basic counterfire.

As observed by Brian Gephart, Senior Program Manager, ISR Systems, UTC Aerospace Systems (Danbury, CT), previously Goodrich ISR Systems, there's been a steady proliferation of laser-based threats over time, particularly in terms of the more basic-technology, laser rangefinders where a number of products are in fact readily available commercially. "Laser rangefinders have become smaller, more portable, cheaper, and thus much easier to acquire, but there's also been increased proliferation of more sophisticated laser target designation technology beyond what was once just the more advanced militaries of the world – technology that significantly increases the probability of a target hit and kill."

Most worrisome, Gephart notes, is the fact that advanced-technology beam-rider missile threats, which are often difficult to detect early enough for their target to take evasive action, are also increasingly appearing on the stage – for example turning up in the recent engagement between Hezbollah and Israeli forces – with the likelihood that these sophisticated weapon are also being sold into other potential Middle-East hotspots. As described by Bill Kasting, Vice President and General Manager, ATK Defense Electronic Systems Division (Woodland Hills, CA), "the weapons that use beam-riding technology are not only difficult to detect but are also probably the most difficult to defeat, with the real goal being to detect the enemy on the ground that is trying to engage you before the weapon is even launched."

SENSOR TECHNOLOGY

The core technology behind laser warning systems are semiconductor photodetectors, such as PIN diode arrays or cascaded/avalanche photodiode/phototransistor arrays. Phototransistors are photodiode/amplifier combinations integrated within a single silicon chip that provide internal gain, thus making them

Light

substantially more light sensitive than PIN diodes of a comparably-sized area.

Excelitas Technologies (Vaudreuil-Dorion, Quebec), is a supplier of both off-the-shelf and customer-specific laser sensors designed into laser warning systems in use with militaries around the globe including the US. Eric Desfonds, Excelitas Senior Application Engineer for High Performance Sensors and Defense, points out that, although they also do a lot of work with avalanche photodiodes (APDs) and phototransistors, "it's often a challenge to use the technology for laser warning systems because of the large amount of light that is usually reaching a target."

"Most of our customers use PINs, which do not have built-in gain, and as such, are less sensitive to sunlight and very high energy light pulses," Desfonds says.

In general, the range of laser wavelengths of interest on the battlefield is typically between 0.4 - 1.8 µm, although other types of battlefied lasers operating outside this range are also present. ISR's Gephart explains, as you get into lasers outside of this general range, however, the cost of fielding the technology becomes a major factor. Still, he says, "We're always working with our customers to learn of any new emerging threats they may be interested in."

Excelitas' photodetection sensors are built using silicon and/or InGaAs materials to meet a variety of size, sensitivity and speed requirements. It operates its own fully-integrated production process including foundry, assembly, test and finishing facility. Its High Angular Resolution Laser Irradiance Detector (HARLID) products are used in laser warning systems onboard ground vehicles, naval vessels, fixed and rotary wing aircraft, as well as carried by individual soldiers, to detect laser rangefinders and target designators.

Manufactured using fully-automated robotic technology, the HARLID-362 module combines 9-element Silicon and InGaAs PIN detector arrays for a spectral sensitivity range of 0.5 - 1.65 µm, together with 6-bit digital encoding for precise AOA (±0.7 degree accuracy in either azimuth or elevation.) As described by Desfonds, the AOA accuracy of the HARLID is a critical parameter, noting that while a helicopter may respond to laser-illumination by releasing flares which need only be fired

in the general direction of the threat, "in order to direct a more precise countermeasure or counterfire toward a threat, you had better know its location with much greater accuracy." The response speed of the detector is also critical in order to provide timely target-type and friend-or-foe information.

Although the HARLID sensor is considered an appropriate solution for detecting individual pulses from multiple lasers simultaneously and accurately determining their location, laser warning systems specifically designed to detect beam-rider threats will use a different sensor technology which, as described by Desfonds, may in some cases be avalanche photodiodes (APDs) fabricated in either InGaAs or Silicon, depending on the specific requirements of the customer. APDs can have a detection range between 0.4 and 1.1 µm with a wide range of sensitivity and speed.

As explained by Desfonds, "The more sensitivity you have, the more sensitive you are to the baseline or environmental light as well, but, given that it's often a question of life and death whether your system detects the person that's targeting you or not, everyone usually wants us to push the sensitivity to the maximum, wherever possible, to get that last little photon of light." In the end, he observes, it will always come down to a tradeoff, and be up to the final system designer to mix and match the sensor capabilities and sensitivities of PINs and APDs to best meet the requirement. "Beyond the sensors, there is a lot of art involved in how you process these signals and how you make decisions to trigger the right responses."

Desfonds says one of the biggest challenges he sees ahead for sensor technology is cost. "These are complex systems to build, requiring great precision, such as plus or minus 0.8-degree AOA accuracy. But, at the same time, there's significant disparity in the types and value of the platforms customers are looking to protect, ranging from multi-million dollar aircraft to individual light-armored vehicles, to perhaps protection for unmanned vehicles and drones. Although we've succeeded in being able to cost-effectively manufacture these high-end devices in volume, there's still a transition point in terms of cost and budget pressures where we need to talk about lower-end equipment with less resolution in order to meet cost limitations."

ISR's Gephart agrees. "Over time, we're seeing semiconductor laser technology advancing steadily, but in addition to keeping pace with the capabilities of emerging threats, we also have to continually take advantage of new technology that can help drive down size, weight, power (SWAP) and ultimately cost." Along these lines, he says a major principle behind their detector technology development is achieving as much commonality of design as possible, with technologies that can support multiple applications, platforms and operational domains. He also points out that another cost-addressing feature of their systems is that they're compatible with the Multiple Integrated Laser Engagement System, Air-to-Ground Engagement System II (MILES-AGES II) training system, which allows them to be used in simulated tactical combat exercises and significantly reduce training overhead costs. The training system is used by the US military and other armed forces around the world.

In terms of the evolving threat, Desfonds says they are indeed seeing more and more laser systems operating in the longer wavelenth (2 and 3 µm) range which allow them to be used more stealthily on the battlefield. As a result, Excelitas has already begun working internally to develop longer wavelength capabilities through different chip technologies. "The HARLID was designed from the outset to be upgradeable, and future versions will likely offer extended range capabilities."

AIRCRAFT SYSTEMS

Rotary-wing aircraft were among the first platforms to receive the benefits of laser warning technology. And today, according to Erich Wagenbauer, Key Account Manager, Airborne Self-Protection Division of Cassidian (Ulm, Germany), a division of EADS, "laser warning systems are even more important for protection and situational awareness, especially in the asymmetric battlefield."

Cassidian makes the Advanced Laser Threat Alerting System (ALTAS)-2QB system fielded on German Army CH-53 helicopters as well as other aircraft, and perhaps most revealing regarding the size and scope of the threat, is Wagenbauer's observation that "users of the system have actually learned through its use that there are many more laser threats on today's battlefield than they thought. And the number is still growing."

The ALTAS-2QB detects laser rangefinders and target designators in the 0.5 – 1.65 µm range as well as missile beamrider threats from 0.8 - 1.1 µm. Its sensitivity is less than 15 W/m^2 for rangefinders and designators, and less than 1 mW/m^2 for beamriders, with a false alarm rate of less than one per eight hours. The system can be integrated with an onboard Defensive Aid Subsystem (DAS) to deliver pre-processed laser threat information for pilot display and deployment of countermeasures, as well as with the EADS' Airborne Missile Protection System (AMPS).

In the US, ISR Systems' AN/AVR-2B is the standard laser warning system for all US Army helicopters and is also fielded on a number of US-made helicopters in

service with other international users. In October, the company was awarded a five-year, $208.5 million contract by the Army for continued procurement of the AN/AVR-2B(V), an improved-performance version of the system which is also smaller, lighter and uses less power than previous versions.

Meanwhile, the US Navy and Marine Corps have integrated a laser warning capability into the AN/AAR-47(V)2 IR missile warning system currently in widespread use on both their rotorcraft and fixed-wing aircraft. The AN/AAR-47 is built by ATK (Woodland Hills, CA), but its laser warning sensor is provided by BAE Systems (Nashua, NH). The latest variant of the system, the AAR-47B(V)2, includes improved detection performance, clutter detection, hostile fire indication (HFI) capability, as well as laser warning. For the AAR-47B(V)2, laser threat warning includes threat-class identification and mid-to-high-resolution angle of arrival (AOA) information within milliseconds of illumination. Up to seven simultaneous threats can be processed and reported by each sensor. According to BAE, the total weight added to each AAR-47 sensor to provide the laser warning function is less than 5 ounces and requires less than 3W of additional power. Navy and Marine aircraft with the capability include the AH-1W/Z, UH-1N/Y, CH-53D/E, HH/SH/MH-60, P-3, C- 130, CH-46 and V-22.

Through the Navy's acquisition program, a number of Air Force platforms, including the C-5, C-141, C-17, MH-53J, HH-60G, C-130E/H/J, and HC-130N/P, as well as a number of foreign military aircraft, have been equipped with the AN/AAR-47A(V)2 variant of the system, which also includes a laser warning capability.

Looking ahead, the Navy's next-generation airborne IR-missile-threat warning systems also incorporate laser warning, including the new AN/AAR-59 Joint and Allied Threat Awareness System (JATAS) being developed by ATK and teammate BAE Systems. Although the approach to integrating laser warning into the AAR-59 is similar to that taken with the AAR-47 upgrade, the laser warning sensor in this case is provided by ISR Systems. As noted by ATK's Bill Kasting, "One of the biggest challenges JATAS had to deal with was providing all of the capabilities of a stand-alone system like ISR's AVR-2B within the much smaller space available within the combined solution. Today, the AN/AAR-47 and the AN/AAR-59 are still the only systems out there that integrate laser warning, missile warning, as well as HFI in this size and weight."

For the Navy's larger aircraft platforms, the Advanced Threat Warner (ATW) being developed by Northrop Grumman Land and Self Protection Systems Division (Rolling Meadows, IL) for the DoN Large Aircraft IR Countermeasures (DoN-LAIRCM) system also includes a laser warning capability together with two-color IR missile warning and HFI.

Although the US Army has historically provided laser warning to its fleet of rotorcraft and small fixed-wing aircraft through the dedicated AN/AVR2B system, it is now also looking at integrating the capability into the AN/AAR-57 Common Missile Warning System (CMWS). Built by BAE Systems, the CMWS is currently incorporating a new HFI capability as a QRC upgrade to the system, which together

with the Gen III Electronic Control Unit (ECU) also being added, will potentially also allow for the integrated laser warning capability.

ISR's Gephart says it's a continuing objective of the Army to determine what additional capabilities they can provide to the warfighter within the current footprints available on their platforms. "This encompasses both what more they can get out of their current systems, as well as what they can do through Engineering Change Proposals (ECPs) as opposed to new starts in this austere budget environment."

As an example, Gephart points to the new laser-warning system technology which ISR recently delivered to the Army. Known as the AN/AVR-2X variant, the system incorporates an additional camera/detector to provide an HFI capability – categorizing and providing AOA and geolocation information on weapon systems ranging from RPG's to small arms. Says Gephart, "This program really showed what can be accomplished by working together collaboratively from the beginning of the process. As the requirements

"the real challenge... is delivery of effective countermeasures...to beam-rider missiles"

emerged and evolved, and the Army determined what they needed, we, in turn, showed what was in the realm of the capable. Ultimately, we went from initial concept to delivery of system for testing in 16 months."

Bill Staib, BAE Systems Director of Threat Management Solutions, also sees the merit in this approach, and his company is in fact already working with ISR and its AVR-2X technology. Ultimately, Staib observes that regardless of the type of threat warning (whether laser, missile, radar, or HFI), system design requirements are moving toward multi-mode, multi-spectral solutions for situational awareness.

"It's a question customers are continually raising and it's a big part of what we're focused on – whether it makes sense to continue to field multiple, specific, dedicated systems exclusively for each threat, or rather move toward an integrated, multi-mode threat-warning system (such as JATAS) where, for example, the laser warning function is incorporated as one element within an overall threat-warning system. The big advantage is real estate on the aircraft, but it also means not cutting another hole in the platform, adding less weight, and taking advantage of existing processing power."

For his part, Cassidan's Wagenbauer notes that the real challenge for aircraft laser warning systems is not the warning function itself, but rather the "delivery of effective countermeasures against increasingly sophisticated laser-based threats, particularly modern, laser beam-rider missiles." But, he adds in counterpoint that this in turn necessarily means that "one of the biggest challenges for airborne laser warning is achieving sufficiently accurate AOA information required for such sophisticated countermeasures to be implemented successfully."

GROUND SYSTEMS

The deployment of, and design requirements for, laser warning systems intended for ground-vehicles has also evolved over the years. ISR Systems' AN/VVR-1 laser warning system has been tested and incorporated on vehicles such as M-1 Abrams tank and the M-2 Bradley Fighting Vehicle. This was improved with the subsequent AN/VVR-2 version that incorporated a single, mast-mounted sensor, and again with AN/VVR-3 which added a beam-rider detection capability.

As described by Gephart, ground-based systems pose unique challenges for laser-warning systems due to environmental clutter and laser reflection creating false-positives or inaccurate AOA information. To deal with this, ISR Systems has incorporated reflection-processing algorithms within its sensors and systems that ensure true directional information is reported. The systems also include a coherency detector which, since lasers generate coherent light, can be used as a mitigating parameter to ensure that detected light is not from some other source on the battlefield, such as an explosion.

Although Gephart admits that the initial requirement they were working toward was largely to protect rotary wing aircraft, at the same time, they were nevertheless also developing capabilities for ground vehicles, "both evolving in parallel over the years through ECPs, technology advances, and SWAP improvements." ISR Systems has sold its VVR-series systems via US Government Foreign Military Sales channels to militaries all over the world including Canada, Australia and New Zealand. Says Gephart, "We expect our customers will continue to look at laser-warning systems for their ground vehicles, particularly in the context of the increased value these sensors provide when you begin to add things like active protection systems, but also as stand-alone capabilities that can provide the necessary level of advanced early warning times for crews to be able to maneuver, return fire, or take other defensive actions."

In that regard, Gephart adds that although their work with the US Army on the AV/AVR-2X was initially aimed at rotorcraft, "we also have an eye toward ground combat vehicles in future as well."

Elbit Systems (Haifa, Israel) also builds a range of laser warning systems for armored vehicles. In use with a number of militaries around the world including NATO nations, the systems provide 360-degree threat coverage via four sensor packages. Specific to low-power, beam-rider threat detection, the company cites a spectral response range between 0.9 - 1.1 µm with a detection sensitivity of 0.3 to 1 µW/cm^2 and an AOA accuracy of 5 µW/cm^2, detection time of 100 msec and threat classification within 300 msec. The systems provide both audible and visual warning, and can operate independently or be integrated with a variety of countermeasure system types.

In the case of the US Army, much of its laser-warning technology deployment has been tied to budget realities and program starts and stops – for example, to the Future Combat System (FCS) program that was cancelled in 2009, and now to

the Ground Combat Vehicle (GCV) program intended to replace a portion of the Bradley fighting vehicle fleet, and that is now also facing possible cancellation.

NAVAL SYSTEMS

Although not receiving the level of attention of airborne or ground platforms, laser-directed threats to naval surface vessels are also proliferating and can be found in both littoral and blue-water combat environments. ISR System's Gephart says that, while not a principle focus, they have done some work for surface naval applications in the past including for the Joint High Speed Vessel (JHSV) in use with the Military Sealift Command to transport troops and equipment, as well as a laser warning system for the ultimately-cancelled Marine Corps Expeditionary Fighting Vehicle. (EFV)

Saab Electronic Defence Systems (Cape Town, South Africa) has developed a laser warning system specific for the naval domain. In use with both the German and UAE Navy's, the Naval Laser-Warning System (NLWS) provides laser detection and identification across the 0.5 – 1.7 µm wavelength range with an azimuth AOA accuracy typically better than 7.5 degrees RMS at the higher end of the wavelength scale.

The system consists of a controller unit, junction box, and a number of sensors distributed across the vessel's superstructure. The number of sensors required to achieve full platform coverage depends on the size of the platform, but depending on the installation, spatial coverage can be up to 360 degrees in azimuth and 70 degrees in elevation.

The NLWS can operate as either a standalone system with its own display and control, or be integrated with another onboard combat system or ESM system. It can operate in a fully-automated mode and also be integrated with a countermeasures system. A threat-library management system (TLMS) option can prepare mission files for threat identification and analyze recorded data

GROWING DEMAND

As is true of much of the electronic warfare field, the community of expertise developing and fielding laser warning system technology is very small. But, it is also a community of expertise in great and growing demand. As summed up by Paul Brierley, General Manager, Excelitas Photon Detection Division, "Laser detection is a sophisticated and relatively unique technology with a very limited number of players involved. It's already not a trivial problem to solve, but it will only get harder as more and more lasers are deployed, and more and more people are using them on the battlefield."

To deal with the challenges and keep pace with the threat in times of very limited budgets, companies are necessarily maximizing their capabilities by sharing resources and expertise. Says ISR Systems' Gephart, "the business framework these days is not so much everyone competing against each other, but really more of a cooperation where we are all working together as teams going forward to meet the customers' tough problems, and all providing our own unique value-added."

Photos courtesy US Department of Defense.