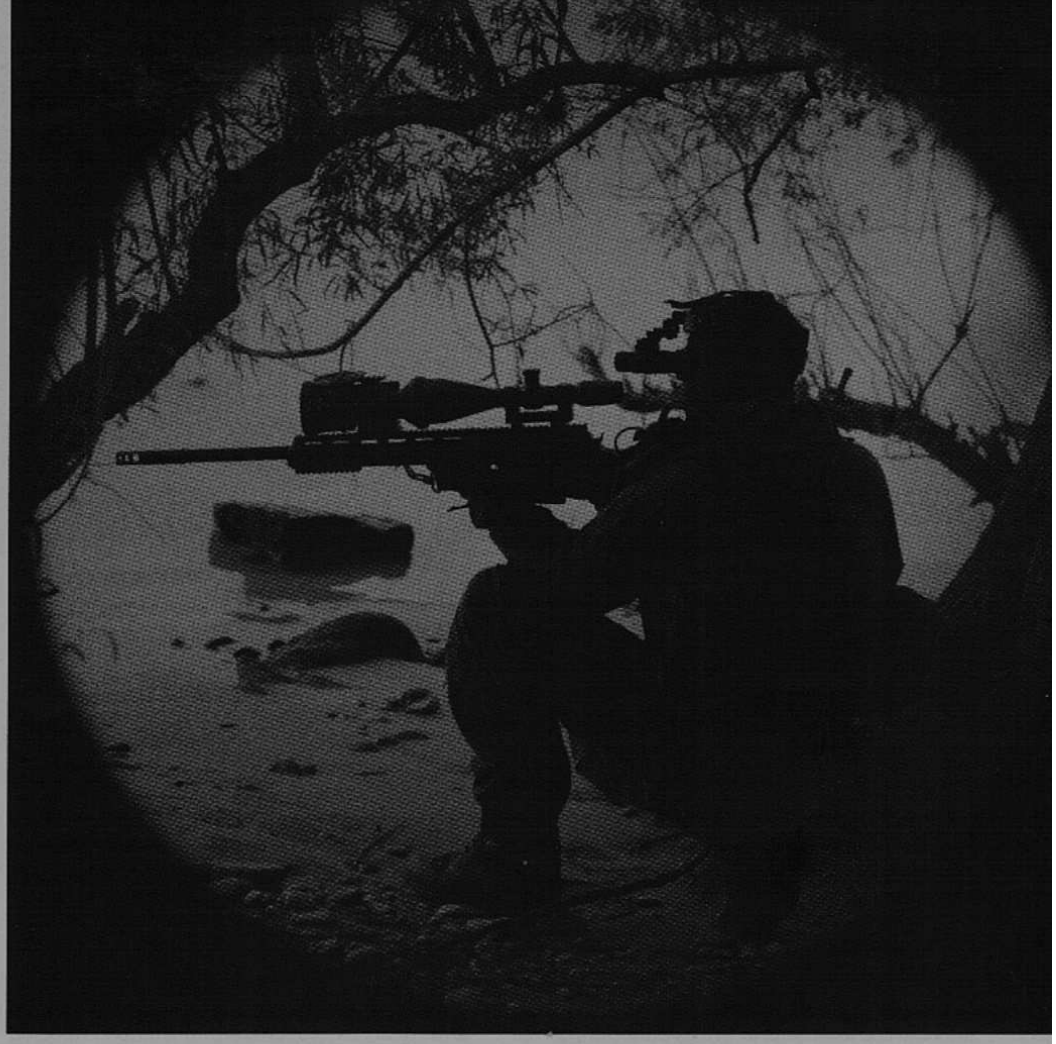
Ted Hooton

The Future of Night Vision Technology

The night has been the friend of soldiers providing some shelter initially from enemy fire power and air power. But during the past half century, developments in electro-optical (EO; often called optronic) technology have rendered this shelter useless and created the background for the 24-hour battlefield on land, which will be the focus of this article.



Traditionally, land forces execute their missions during daylight hours while using nighttimes for other activities, such as redeployments of forces, logistics, and SAR and reconnaissance activities. With high demands from Armed Forces over the last two decades, companies such as Photonis Technologies started the long process of improving I2 tubes performance. I2 tubes performance improvements have taken three parallel routes: reduce size & weight, improve resolution and signal-to-noise ratio (both parameters combined into what is now recognized as the FOM – Figure-of-Merit), and minimise and overcome excessive light - the major enemy of I2 tubes. There are two methods of operating night vision systems: "passive" or "active." Passive systems amplify the existing environmental ambient lighting, while active systems rely on an IR light source to provide sufficient illumination. Military applications generally require passive operation, as an active system's IR illumination device can be easily spotted and tracked by others equipped with night vision devices, placing the user at a distinct disadvantage. This is mission critical to those in Iraq and other similar theatres of operation. (Photo: Photonis)

In the first Generation (Gen I) equipment incoming light was collimated by fibre optic plates before striking a multi-alkali photocathode tube, which released electrons that themselves struck a phosphor screen. The screen emitted green light into a second fibre optic plate and later into a third to provide an overall gain of 10,000. Gen II equipment, which succeeded them used a micro-channel disc or "plate" made up of several million microscopic hollow glass channels, each about 0.0125 mm in diameter and coated with a special semiconductor that liberates electrons. When an electron enters a channel it creates, under the influence of applied voltage, it "bounces" down the tube like a broom in a dirty hall way and just as a brush creates clouds of dirt so the electron stirs up hundreds of electrons that are collimated by the channel. This increased both the gain in light amplification and the resolution.

Most modern image intensifiers are Gen III devices, which use a gallium arsenide photocathode with an ion barrier coating to the microchannel plate. This extends the wavelength sensitivity into the near infrared (IR), i.e. above 0.7 microns (μm) allowing the device to exploit not only moonlight but also starlight to boost the effective available light by approximately 30%, bringing the total gain to some 30,000. They are also more reliable than their predecessors having an average life of some 10,000 hours compared with a maximum of 4,000 hours.

Night Blindness

The image intensifier suffers from drawbacks, in particular "blooming" or "halo" effects. These occur when a bright light source overloads the intensifier tube rather like suddenly turning up the volume in a personal music player. It was more serious in earlier devices, but it can still create short periods of night "blindness." Despite this drawback the image intensifier remains popular because it is reliable and requires very little power because it receives energy from small (AA) commercial-pattern batteries and one soldier can carry some 14 without problems.

Major producers of the 18mm tubes included ITT, L-3 Electronics, Photonis Night Vision (which has developed a 16mm tube), and Qioptiq, whose latest product is MERLIN. Photonis' most recent product is the XR-5 (eXtended Range) with integrated Auto-Gated power supply, facilitating operation under dynamic lighting conditions while there is a significant reduction in power consumption from 35-45 milliamps in most Gen III tubes to 18-30 milliamps.

Personal Night Vision Systems

Initially image intensifiers were used simply for surveillance and observation and hand-held products, such as the Aselsan M975 (licence-built versions of the Northrop Grumman units) with Gen II Plus and M976 with Gen III, Delft Sensor Systems Multiple Use Night Observation System (MUNOS) with Gen II, Gen II Super and Gen III tubes and Simrad's KDN 250 with Gen II or Gen III and are typical. Over the past decade there has been a change to personal Night Vision (NV) systems in the form of goggles (Night Vision Goggles - NVG), which can be helmet or head-harness mounted for hands free operation. The US AN/PVS-7, produced by both ITT Night Vision and L-3 Communications together with the O' Gara Group's low-profile (for Special Forces) AN/PVS-21 are typical examples, and most can be removed and held in the hand. The goggles not only provide the infantry the ability to operate at night but also extend it to vehicle drivers and the pilots of both fixed- and rotary wing aircraft.

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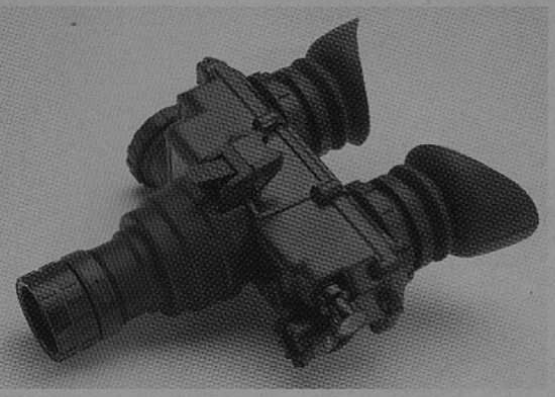


ITT's AN/PVS-7D NVG enables military ground forces to conduct critical missions during the darkest of night. (Photo: ITT)

The size of the market may be gauged from the US Army's inventory which includes 150,000 PVS-7 NVGs, 55,000 AN/PVS-4 weapon sights, 36,000 AN/PVS-14 Monocular NV Device (MNVD) and 10,000 AN/TVS-5s for crew-served weapons. Since 2005 ITT has produced 400,000 AN/PVS-14 monocular devices and 3,000 PVS-7 as well as 100,000 spare tubes while L-3 EO Systems (formerly Northrop Grumman EO Systems) acts as second source for these products.

In an attempt to provide substantial increases in target detection range and resolution there were attempts to remove the ion barrier film and "gate" the system power supply to create the so-called Gen IV sensor. But these had high failure rates and it was then discovered that similar improvements in performance could be achieved by providing a thinner ion barrier and auto-gating the power supply in Gen III tubes. But the difficulty of exporting these sensors has meant that a more "commercial" unit is being produced in the form of ITT's PINNACLE and L-3's ULTIMA, which can replace existing tubes.

Image Intensifier versus Thermal Imager

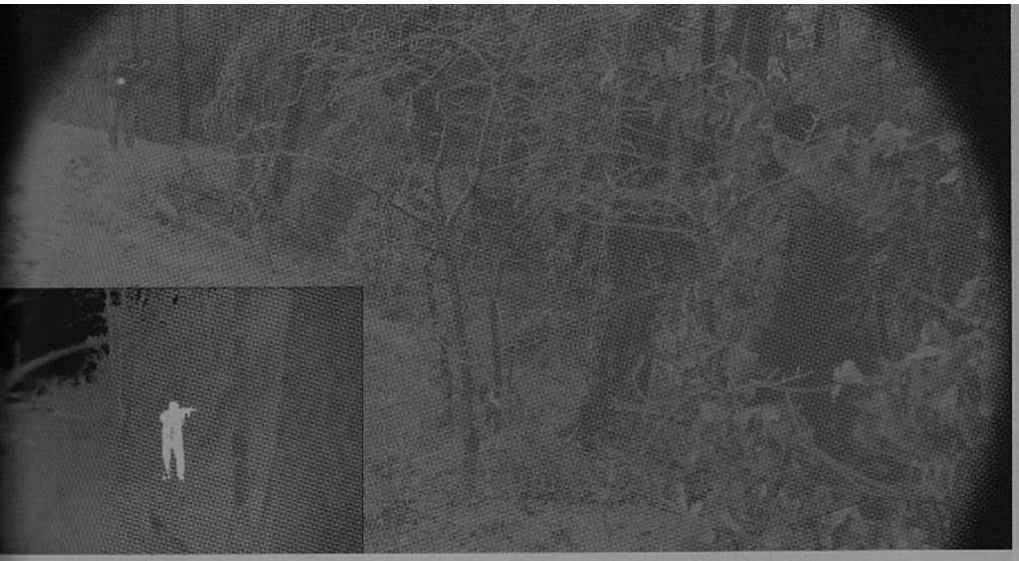
Although binocular image intensifier seem the most popular, there remains a range of monocular products both for compact personal observation and as a weapon sight because it can offer such detail in the dark and permit identification. The Qioptiq KITE family, a Gen II and Gen III system, is available for a variety of weapons from rifles to machineguns (Maxi-KITE) and some 60,000 have been produced for 56 countries. KITE illustrates another feature of image intensifier systems in that the sensor can be used in a wide range of roles. The OIP LUNOS family, with Gen II or Gen III tubes, can be used for night driving and for long range observation in the LUNOS 1 and -6 versions, the latter on tripod-mounted or even mast-mounted observation systems.

If the image intensifier operates in the visual and near IR spectrums, ultimately needing some ambient light, the other stalwart of battlefield EO, the thermal imager, operates in the medium and far IR wavelengths and is independent of external light levels.

All objects emit radiation as a function of their temperature and the higher the temperature then the greater the radiation but neither is visible to the naked eye. The thermal imager detects this radiation and processes the images independent of visible light levels through semi-conductor detectors, which are either cooled or uncooled. They operate in medium-wave, 3-5 m, sometimes called N-band and in long-wave, 8-12 m, sometimes called L-band the former having a better performance in cold and wet conditions while the latter is better in dry and dusty environments.

The DEWAR cryogenically cooled detectors were the first onto the modern battlefield and usually operate in the 60-100 Kilojoule range. The most common materials used in detectors are mercury cadmium telluride (3-5 m, 8-12 m) (MCT) and indium antimonide (3-5 m) (InSb) with cooling typically achieved through pressurised gas, such as nitrogen, or through rotary Stirling engine cryocoolers. The cooled detector sensors have traditionally had superior performance to the uncooled ones in terms of image quality and can use long focal length lenses. But they are bulky and consume a great deal of power and once switched on require time to cool down before they can operate.

Uncooled thermal cameras use either a sensor operating at ambient temperature or one



Night Vision vs. Thermal Imaging.

stabilised at a temperature close to ambient using small temperature control elements based upon changes of resistance, voltage or current when heated by IR radiation. These changes are then measured and compared to the values at the operating temperature of the sensor. While uncooled sensors can be stabilised to an operating temperature to reduce image noise, they do not need to be cooled to low temperatures and do not require cryogenic cooling systems. This makes IR cameras smaller and cheaper. But their performance has tended to be poorer than cooled systems with lower resolution and image quality although this has steadily improved over recent years.

From the late 1970s thermal imagers have become an essential tool of all Armies and have many advantages over image intensifiers, especially as surveillance and sighting devices. They can detect objects not only at night but also in the day, in rain, haze, dust or smoke, while conventional means of camouflage, such as foliage and netting is useless against them. However, means of concealment have been developed including smoke systems which operate in both visual and infrared wave bands (Russian tanks initially used to burn fuel oil) while several manufacturers are developing camouflage netting which is designed to reduce or even cancel IR signatures. It is worth noting that thermal imagers can also detect where men and machines have been for heat traces remain detectable for some time after man or machine has moved.

The Need for Cooling Systems

The need for cooling systems meant that the initial applications of thermal imager systems was intended for AFV fire control systems and long range observation. The vehicle systems provide both day and night operation, and can accept data from a laser rangefinder with a typical system being the Carl Zeiss Optronik's WBG-X thermal sight with OPHELIOS camera for the LEOPARD MBT. Russia has begun licence production of the Thales Optronique CATHERINE for its new T 90 MBTs and from 2012 these systems will use Russian-made optics. The CATHERINE family uses Quantum Well IR Photodetector (QWIP) technology, initially operating in the 8-12 m wave band, also used by the French Army's VCI; later versions can also operate in the 3-5 m band.

A typical long range observation system is the Raytheon/Kollsman AN/TAS 6 Night Observation Device, Long Range (NODLR), which consists of a cooled thermal imager based upon the partners' Modular Common Thermal Night Sights (MCTNS) system. This is a tripod-mounted system, which forms the AN/UAS-11 in association with a hand-held laser rangefinder and a goniometer, which is a very accurate elevation and azimuth scaled tracking head. Raytheon, like many manufacturers such as Opgal and SDC, uses detectors of vanadium oxide (VoX) which is less

Vectronix' Miniature Thermal Acquisition Clip-On System TACS-M is a micro-sized thermal imager that clips on to already fielded night vision devices. Shown: TACS-M I² and outline mode view (Photo: Vectronix)

susceptable to solar damage but France's Ulsis reportedly prefers Amorphous Silicon (a-Si) for improved efficiency.

CONTROP's cooled thermal imaging cameras incorporate third generation FPA sensors, having 320x256 or 640x512 pixels and are highly sensitive in a 3-5µm spectral range; a proprietary highly powerful continuous optical zoom lens with power ranges from x12 to x36 and focal length of up to 1400mm; high quality automatic focus for every chosen field of view; image enhancement algorithms for dynamic battlefield applications; and light weight and small size suitable for difficult weight and size limitations.

Development of Uncooled Thermal Imager Technology

The price of uncooled thermal imager detectors has dropped 10 times in recent years allowing smaller and more power-efficient units to be available even to individual soldiers. The very long range, up to 10km, is increasingly important in asymetric warfare but the disadvantage is that they usually operate in 8-12 m range. An idea of where these systems are going may be gained from Vectronix, who have developed the Thermal Acquisition Clip-on System-Miniature (TACS-M), a micro-sized thermal imager that clips on to existing NV devices, such as goggles, as well as helmet or weapon mounted devices.

Sagem's JIM LR is a 3-5µm sensor (JIM MR covers 8-12µm) providing day and NV and with a laser pointer, Global Positioning System capability and sales of JIM LR now exceed 4,500 units. (Photo: Mönch / DPM)

The MCTNS is also used in weapon sights, such as the AN/TAS-4 for the TOW anti-armour missile and the AN/PAS-13B (V)2 and PAS-23B(V3). But the development of uncooled thermal imager technology has meant this has become a growth market for the application of these sensors which can be used not only on crew-served weapons but also with individual weapons. Typical applications are the Elbit Systems ELOP A-TIM and the OIP Sensors ILTIS. The former uses ELOP's lightweight long-wave Thermal Imaging Module (TIM) and is available as an add-on night sight upgrade for the Soviet-era 9M111 FAGOT (AT-4 SPIGOT) and 9M113 KONKURS (AT-5 SPANDREL) anti-armour missile launchers while the latter is a Long-Wave sensor for medium range and heavy weapons.

BAE Systems, which has delivered more than 91,000 thermal weapon sights worth more than $1 billion since 2004, uses the company's MicroIR uncooled IR sensor technology to support operations of the US Army and its allies in Iraq and Afghanistan. One of its latest sales being to Rheinmetall Canada Inc. for the 40mm grenade launcher's fire control system as part of the Canadian Army's Close Area Suppression Weapon.

CONTROP's thermal imaging cameras are NV cameras, which provide excellent image quality for day and night use. These cameras are suitable for a wide range of air, land and sea night vision applications. The company develops and manufactures thermal imaging IR cameras, including the optics, electronics, mechanics and software, enabling modification or changing of the camera to meet any customer requirements or any new technologies. CONTROP's wide-range of uncooled thermal imaging cameras incorporate, high sensitivity uncooled micro bolometer FPA detector, sensitive in 8-12 µm spectral range, a proprietary highly powerful continuous optical zoom lens with the power of up to x4, and light-weight and miniature size cameras.

At IDET 2011, ETRONIKA presented several optical devices including its new KTL-30 thermal camera designed for observation in day, night, fog and smoke conditions. Based on uncooled 640x480 resolution detector and wide-angle lens gives possibility to locate heat emitting objects. The body housing is made of magnesium alloy, which imparts strength while maintaining moderate weight. According to the company, KTL-30 is an optimal solution if high image quality, small dimensions and light-weight are required.

FLIR Systems is dedicated to EO/IR imaging systems, and can be found in the full spectrum of operations: handheld, weapon sights, land and vehicle combat sensors and sights, as well as airborne and maritime surveillance and targeting systems.

From one of the largest uncooled IR manufacturing facilities in the world come the RECON M pocket night scopes, and FLIRVisionTM, a clip-on thermal imager (COTI), delivering a blended thermal and NV capability for the individual soldier. FLIR's Soldier Vision products provide a combination of performance and affordability. The FLIRVision M32-C is a clip-on thermal imager that is compatible with standard monocular NV devices and NVGs. It is equipped with a longwave thermal

imaging sensor and a patented internal image injector. The FLIRVision M32-C's enhanced 34° field of view, small and lightweight size, and simple operation make it a powerful and portable tool for soldier missions.

ITL's line of tactical night vision products range from battle-proven image-intensified monoculars to hand-held pocket scopes and mini-weapon sights for covert night observation and intelligence gathering. At the forefront of EO, ITL is an acknowledged industry leader, partnering with its customers in order to assure that all of its EO solutions match the latest operational scenarios. Its EO systems enable day/image intensified night vision/thermal imaging, target observation and acquisition, utilising sophisticated software applications, video processing and design and implementing diode-pumped solid-state laser technology based on Er:Glass. The company' offers cooled 3-5um wavelength thermal imaging systems and uncooled 8-12um systems with high target resolution, improved transmittance, and superior performance under adverse environmental conditions.

In the field of NV, Qioptiq is one of the world's principal designers and manufacturers of IR and image intensified NV equipment, including NV weapon sights and surveillance equipment using visible image intensifying and uncooled thermal imaging technology. To date, over 50,000 sights have been supplied to over 50 countries for a wide range of defence, police, coastguard and SAR applications.

Qioptiq's portfolio of NV products includes a complete range of equipment for the dismounted soldier – all designed to satisfy the most stringent requirements of international defence procurement authorities and all fully qualified for use in the most extreme environmental conditions.

Uncooled thermal imagers are also being used extensively for observation and surveillance. At last year's Eurosatory exhibition, new products displayed included ELOP's MICRO-CORAL, a derivative of the 3-5 m CORAL range, which uses a 384×288 pixel Epsilon detector while Thermoteknix Systems revealed the TiCAM 750 hand-held thermal imager, using the 384×288 pixel variant of MicroCAM detector, which is available in 3-5 m (TiCAM 750MR) and 8-12 m (TiCAM 750 LR) versions.

Sagem, for example, have recently received an order for 1,175 JIM LR 2 new-generation long-range multifunction IR binoculars, intended for the French Armed Forces. The contract also includes 500 remote-control tactical terminals, offering enhanced ergonomics and compact design, with a new A4 size tablet. The deployment of these JIM LR 2 systems will be able to call on the Level 1 and 2 support network already in service for the JIM LR system. Sagem will also provide training for users and maintenance staff.

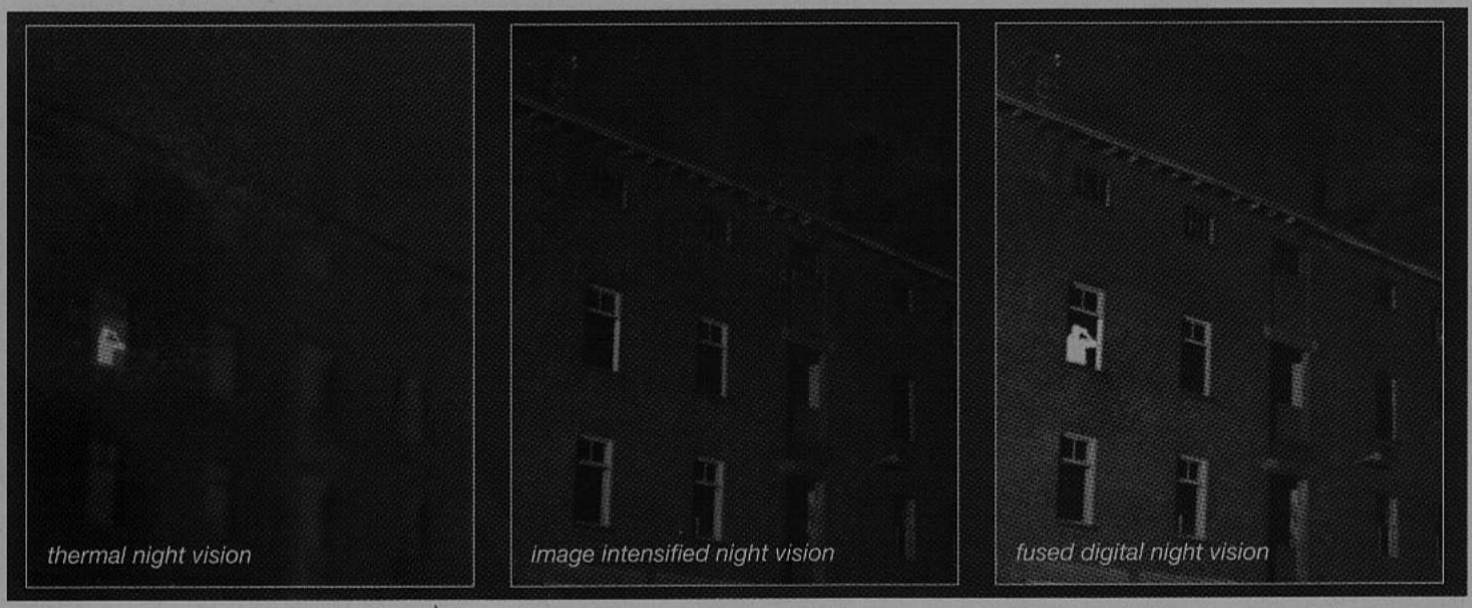
While the thermal imager has many advantages in its ability to detect targets it inevitably suffers from disadvantages. It may detect targets concealed within buildings unlike image intensifier, whose images are detailed enough to permit the identification of individuals, but the one reason they are preferred by law enforcement agencies in surveillance operations is, it produces images that are general outlines.

This is especially a problem in asymmetric warfare as one US Army STRYKER brigade commander discovered in Mosul, Iraq, for when his troops detected a group of armed men with the vehicle's thermal imager they were unable to determine whether or not they were friendly or hostile troops without dismounting and using image intensifiers at closer range, thereby exposing themselves to hostile fire. However, thermal imager manufacturers are working to higher resolution and this may overcome the problem in the longer term.

Developments in the Field of Thermal Imager Technology

US and British companies are reported to be seeking to put mercury-cadmium-telluride on silicon for long-wave infrared detection with low defect density. The challenge is to achieve good operability in the low wavelengths as scientists work to overcome lattice mismatches between the two different layers.

SCD is developing under a $1.75 million DARPA XBn IR detector technology contract. This features a new type of semiconductor



(Graphic: Photonis)

hetero-structure detector, in which no depletion layer exists in any narrow band-gap region. Instead, the depletion layer is confined to a wider band-gap barrier material. This will allow operating temperatures to be achieved in the region of 150K without degrading the detector's performance.

Meanwhile, Irvine Sensors Corporation is developing a personal miniature thermal vision system (PMTV) incorporating a Raytheon focal plane array, which may also have applications in a variety of platforms ranging from an infantry man's helmet to ground vehicles. It can be configured as a weapon sight, a pocket scope or a camera.

Given the strengths and weaknesses of each EO system it is no surprise that industry is seeking means of fusing the two technologies. But achieving a solution is no easy task because combining the two currently has a tendency to produce rather heavy equipment, too heavy and bulky for field deployment, while power consumption is often high. The provision of power supply becomes a key one for the combat soldier now has to carry considerable numbers of batteries not only for electro-optical systems but also for radios – and no one wants the trooper overburdened.

The focus is now to cut weight and to improve power supply for the combined unit, although questions are raised as to the need for such a combined unit when Armed Forces can use them separately; the thermal imager to

detect the target and the image intensifier to identify it. This is also important because situational awareness is becoming ever more important not only for the infantryman but also for armoured vehicle crews, especially those in urban environments.

AIM INFRAROT-MODULE GmbH develops, manufactures and sells premium IR detectors and thermal sights, as well as Stirling cooling engines required for the operation of detectors at cryogenic temperatures. The high-tech company combines all necessary core competencies, such as electronic engineering, microelectronics, semiconductor technology including crystal growth, optics and precision engineering under one roof.

Since its foundation AIM has produced more than 30,000 detectors and Stirling coolers for FLIR systems and more than 45,000 IR detectors for seeker head applications. The product portfolio includes: Cooled IR detectors based on HgCdTe (MCT) and superlattice layers as Integrated Detector Cooler Assemblies (IDCA) including control electronics. Dewar-, integration and cooling technologies modified for thermal imaging applications in land-, sea and air carriers and missiles; thermal devices on the basis of uncooled IR detectors; thermal sights for UAS on the basis of cooled and uncooled IR detectors; thermal targeting sights for small arms with long range; and linear/Rotary Stirling Coolers with integrated regulation electronics.

In the field of sensor fusion Northrop Grumman EO (now L-3 EO) appeared to have reached the Holy Grail first with the Fuzed Multi-spectral Weapon Sight (FMWS) in 2004, but this does not appear to be marketed currently by L-3. ITT has produced its Enhanced NV Goggle (ENVG) or AN/PSQ-20, originally developed for the Future Force Warrior Programme from 2004 to replace the PVS-7 and PVS-14. The digitally-fused sensors were deployed from the spring of 2008, but they reportedly cost $10,000 each and weigh 0.91kg, making them more expensive and heavier than the sensors they aim to replace.

Clearly the two rivals (as well as BAE Systems) need to refine the technology to produce a lighter and more cost-effective sensor although industry pessimists have expressed the view that this might not be achieved until the next decade. ITT has won a second production contract, worth $260 million, for the ENVG and will supply some 6,500 units bringing the US Army inventory to 8,900. This will be for the SPIRAL ENVG, which incorporates the 18mm image intensifier tube, uses ENVG subassemblies and is powered by three AA batteries to reduce the logistics burden.

Europe is also examining the technology and at Eurosatory last year, DEP Imaging, a subsidiary of Photonis, revealed the GRIFFIN. The company claims the 99g, 7cm unit is the smallest and lightest fully digital fusion module in the world and consumes less than 2.5W making it suitable for hand-held, head or helmet mounted devices. It is based upon its purpose-built Photonis 16 mm diameter image intensifier tube and a Ulis uncooled 8-12 m imager to provide 30 frames-per-second fusion high-definition image in real-time. The unit has been sold to three customers including Israel and Poland while France's Direction Générale de l'Armement (DGA), with Bertin Technologies and Thales Angenieux, is also known to be working on this technology to produce NVGs.

The Soldier of the Future

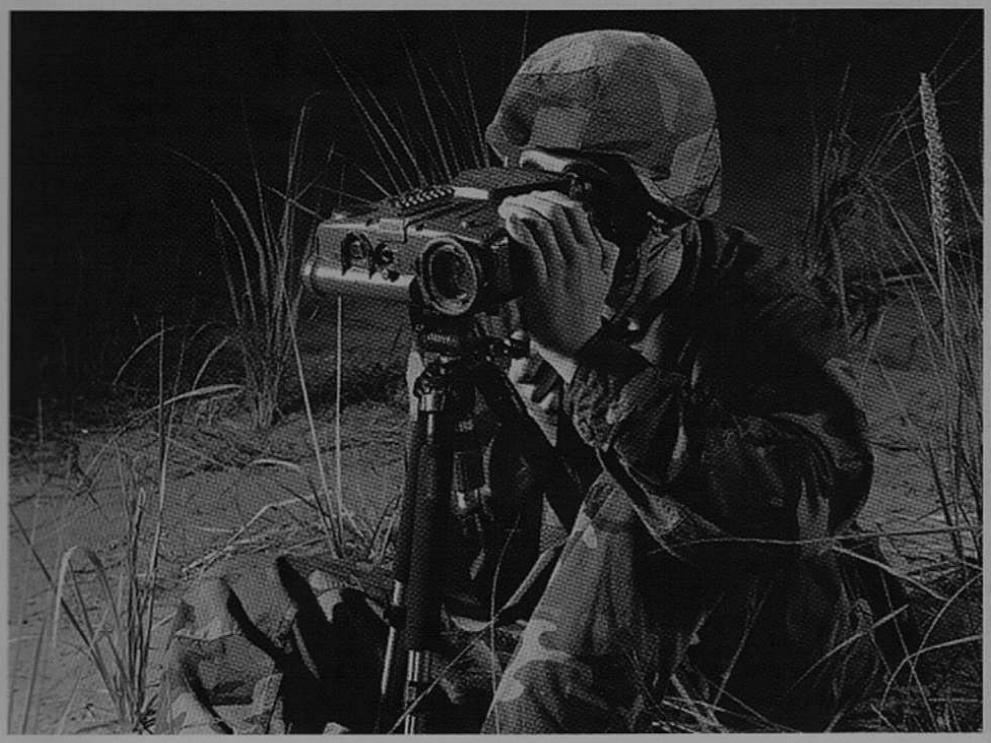
The drive for a fused sensor system may also be driven by the development of soldier systems. These are high-technology programmes designed to give the infantry trooper an integrated set of equipment and even uniforms linked to an array of battlefield communication resources. It envisages enhanced versions of existing equipment together with new technologies to form a network centric response to battlefield challenges. More than 20 programmes are under way including the US Army's Land Warrior, France's FELIN, Germany's Infanterist der Zukunft (IdZ), India's F-INSAS, Italy's SOLDATO FUTURO and the UK's FIST.

The soldier of the future will require the existing range of EO sensors and will be able to use existing sensors in a new way; individual weapon sights, for example, may be used for reconnaissance with images displayed in command posts. FELIN, for example, has a compact image intensifier to provide multi-source video display, SWORD thermal-imager weapon sights and an intensifier for small arms, a specialised thermal sight with laser range finder for snipers and JIM MR for squad leaders. Sighting systems can transmit still or animated images to the information system. JIM LR can be linked to a RVM 08P terminal to allow remotely controlled observation and to Instro Precision Remote Observation Support System (ROSS) remotely controlled mount.

Selex Galileo has developed its Night Mobility Sub-System (NIMOS) with SOLDATO FUTURO in mind. NIMOS is a modular lightweight Helmet Mounted Display including Gen II/III tube integrated with low light level digital television and can receive and display thermal imager or TV video images from the ASPIS rifle sight through a wireless data link for 'shooting-around-the-corner' capability. The company will also supply other sensors such as LINX multifunctional, hand-held target locator which includes an uncooled thermal imager. Clearly the soldier of the future will continue to be a physically strong person to cope with the added burden of equipment and lightweight sensors with low power consumption are key factors.

Conclusion

There is also an intriguing reason why fused sensors may become an even more vital element of the future battlefield. It has been known for some time that various countries have been working on technology to make combat vehicles invisible on the battlefield. The concept, rather like the "invisibility suit" used by the Predator in the movie, is not pure science fiction and in January it was revealed that BAE Systems are working on a system based upon electronic ink to camouflage vehicles, with sophisticated electronic sensors attached to the vehicle hull to project images of the surrounding environment onto the outside, enabling it to blend into the landscape. These images would change along with the surrounding terrain to ensure the vehicle remains disguised and, perhaps optimistically, it has been suggested they might be deployed by the middle of the decade.



The CORAL-CR hand-held (3-5 µm FPA) Thermal Imaging Camera offers continuous optical zoom (based on a 640 zoom FLIR) and the addition of an integral digital compass, GPS receiver and a laser rangefinder. CORAL-CR's light weight, ruggedised construction and excellent picture quality are well suited for security and perimeter defence target acquisition missions. CORAL-CR can also function as a night sight for medium range weapon systems or night binocular for light patrol boats and MBT/AFV commanders.