Advanced ISR for land warfare

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Intelligence Surveillance Reconnaissance (ISR) capabilities have displayed extraordinary growth in technology since the end of the Cold War. All of the basic technologies used in ISR equipment and supporting networks have exponentially followed a growth path in performance at the top end while declining costs have enabled the penetration of technologies, once reserved for strategic use, down to squad or platform level. This is an unprecedented development in the evolution of warfare.

ISR capabilities involve the use of sensors to collect intelligence, surveil areas of interest, and reconnoitre space prior to and during operations. During the 'analogue era' prior to the end of the Cold War digital processing and storage was bulky, expensive and limited in performance and capacity. Today specialised processing chips costing only dollars apiece are mass produced to do this task.

Two decades ago when the Soviet Union collapsed most ISR systems used for direct land force support or joint roles like battlefield interdiction, were analogue technology, with a small number of key systems in US service digital. High quality optical and infrared imaging cameras were widely used, as were some very good imaging Synthetic Aperture Radars (SAR). Nearly all of these devices captured their imagery on film, which had to be processed and dried, then 'enlarged' on photographic paper for scrutiny.

In combat, time matters and the realities of analogue imaging technology meant that the operational cycle revolved around the time it took to capture imagery, process film, then analyse the imagery to produce intelligence. In the 1991 Desert Storm campaign, the whole targeting cycle took about 24 hours, considered an exceptional achievement for the period.

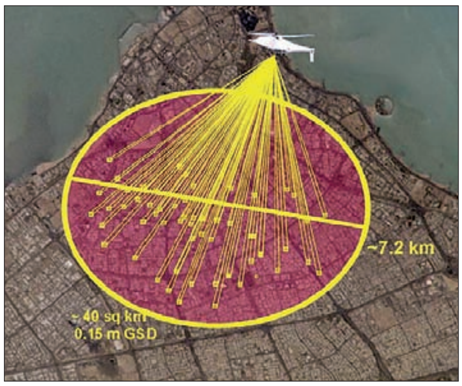
This turnaround time problem was similar for electronic and signals intelligence gathering, where data was collected and recorded on magnetic tape spools, then processed into a form that could be used by planning staffs and their electronic combat analysts.

What digital technology brought to battlefield ISR is not only new sensors and improvements in existing sensor technologies, but also it has fundamentally changed the timescales in ISR processes. Hours have compressed to minutes and in some instances, mere seconds.

Advocates of Network Centric Warfare (NCW) have touted the improvements in decision cycle times and thus operational tempo as decisive, but whether the transition has been simple or cheaper, improved the quality of the ISR collected, improved decision quality or improved operational tempos, remains open to question.

In many instances, quality of ISR has not improved, and often declined. Often, the time pressures of higher op-tempo and degraded ISR quality coincidentally result in degraded decision quality; in turn resulting in collateral damage or friendly fire outcomes.

The ARGUS-IS sensor pod images up to 1.8 Gigapixels, employing an array of 368 CCD imaging chips, each with 5 Megapixels of resolution.



Advancing Imaging ISR in Land Warfare

Broadly, imaging ISR systems encompass optical, infrared and radar systems that can produce imagery. In these technologies there has been a pervasive shift to digital capture and recording of imagery. While this has improved the timeliness of ISR product delivery and reduced recurring operational costs by removing a costly wet film process, it has not generally resulted in improvements in imagery quality, usually increases the cost of the equipment, and adds in the cost of the networks and the datalinks needed to move the imagery around quickly.

Digitisation has been a double edged sword in imaging ISR: the advances in timeliness that have often proven decisive in combat against insurgent forces have incurred major costs in supporting systems and lifecycle maintenance along with upgrade costs across the whole chain of systems, from sensor to shooter.

Radar technology for battlefield applications has also made important advances over the past decade, also driven by evolutionary growth in basic technology.

High resolution SAR (Synthetic Aperture Radar) ground mapping radar is playing an increasingly important role in land warfare. While this technology first emerged in the early 1960s to provide strategic reconnaissance aircraft with the ability to penetrate cloud cover, by the late 1960s it found its way into the US Army's ISR suite, carried by the venerable OV-1D Mohawk.

Three technologies have transformed battlefield imaging radars from a scarce and niche capability to an almost pervasive one, carried by fixed wing aircraft of all sizes, manned and unmanned, and rotary wing aircraft.

At the processing end of the system, wet-film cartridge technology has been replaced by digital solid state processing and solid state or hard disk storage modules. At the radio-frequency sensor end of the system, ultra high stability oscillators and solid state radio-frequency MMIC technologies have improved performance and reliability, without increases in costs. Active array or AESA antenna technology operating in the centimetre X-band and developed for fighter air intercept radars has produced basic radars with the potential for high resolution.

As a result, all weather cloud penetrating radar ISR imaging is now available on almost all fighter aircraft types and other aircraft retrofitted with such radars.

The state of the art in this technology can produce patch maps of hundreds of metres a side with resolution down to centimetres. More than often, if fitted with sufficient data storage and processing power, such radars can produce high resolution strip maps along the direction of flight.

The technology is now available across the full spectrum of platforms. At the 'high end' large ISR systems (E-8 JSTARS, RQ-4B Global Hawk, U-2 and Sentinel R.1/ASARS) can map continuously areas or swaths up to the radar horizon of ~240 nautical miles. At the 'low end' RPVs like the RQ/MQ-1 Predator/Reaper can produce high resolution maps from tens of miles away.

While conventional imaging SARs have captured most attention in the media eye, arguably no less important developments have occurred in other areas.

GMTI (Ground Moving Target Indicator) radar emerged in the 1960s, achieving a high public profile during Desert Storm when a pair of E-8 JSTARS prototypes tracked hundreds of Iraqi ground vehicles from 200 nautical mile distances, penetrating cloud and sandstorms, largely compromising all attempts at manoeuvre operations by the Iraqi ground forces.

Like SAR, this technology has proliferated into X-band fighter radars, and since then into many other surveillance radars, including many UAV radars.

The most important recent development in this area is the capability to track single personnel and groups of personnel from a distance. This is a challenging technical problem, since human targets produce very small Doppler shifts, compared to moving vehicles or aircraft, and have very much smaller radar signatures.

The first radar known to have this capability is the DARPA sponsored Northrop-Grumman Vehicle and Dismount Exploitation Radar (VADER), which was developed to detect and track 'dismounted' insurgent teams planting IEDs, or otherwise occupied. The radar is compact enough to be carried on a larger UAV wing pylon. At this time technical detail is limited, but the radar is likely to be limited in range and area coverage.

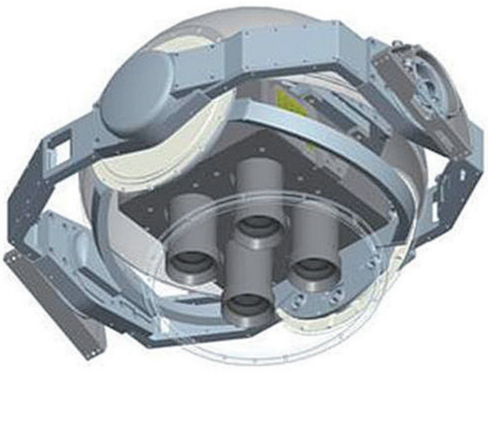
There have been important advances in framing and video cameras, replacing wet film media with CCD and CMOS imaging chips. In a large part military providers have been beneficiaries of the truly phenomenal advances in consumer still image and video camera technologies over the past decade. Often, the high resolution imaging chip installed in a military camera system is the same type used in commercial professional photographic equipment.

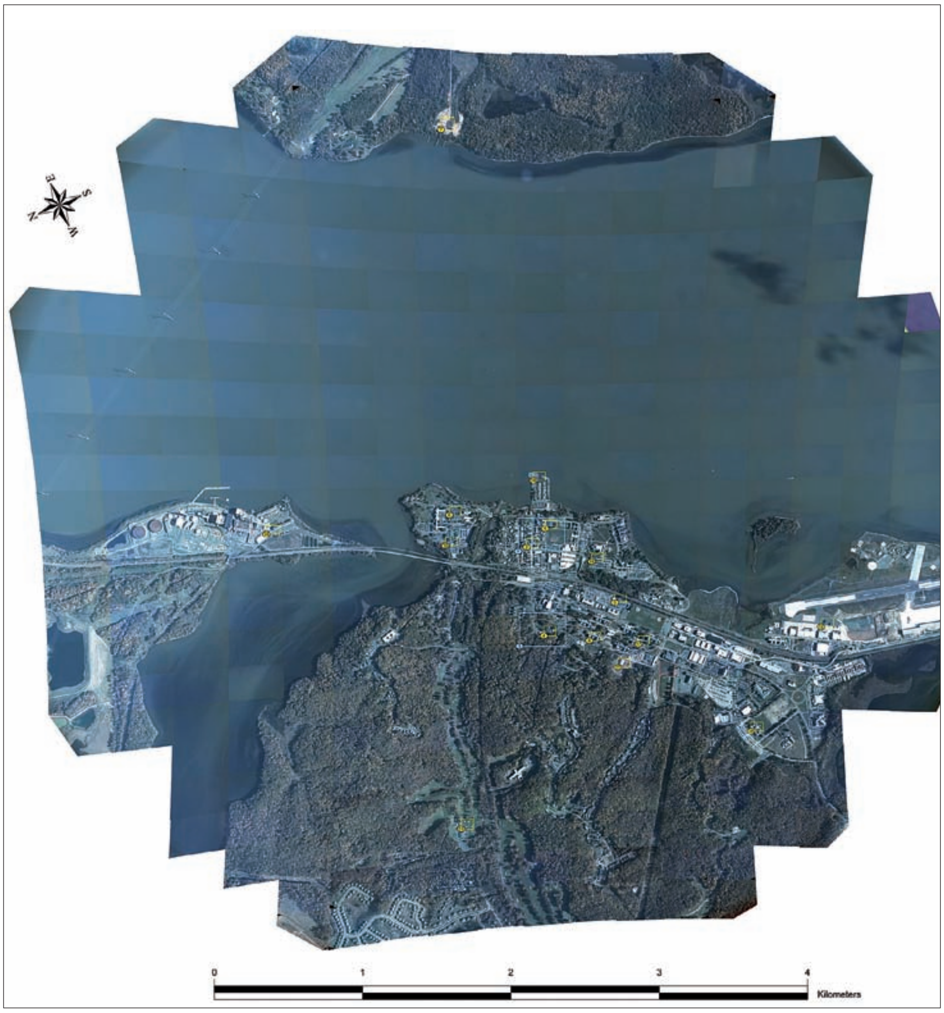
While consumer level cameras are currently using imaging chips with 8 to 14 Megapixels of resolution, professional still cameras are now being produced with 60+ Megapixel class chips. Such resolution is becoming comparable with wet-film technology used in military film cameras such as the KS-87 series, a mainstay of Cold War ISR.

One benefit of CCD/CMOS imaging systems is that the capture area is smaller, which permits more compact lens systems and newer imaging cameras to be carried on a wider range of platforms, or smaller platforms like UAVs or RPVs. Another less obvious advantage is that CCD/CMOS imagers can typically operate over a much wider range of light conditions (ie dynamic range) compared with photographic film.

Advances in microchannel imaging intensifying tube technology, popularly known as NVG (Night Vision Goggle) technology have resulted in more sensitive Gen IV devices now widely used, both in manportable and helmet-mounted applications. Earlier generations of this technology were used extensively for ISR during the Vietnam War, but are uncommon today in ISR systems, mostly replaced by thermal imagers.

While visible band digital imaging has advanced strongly, infrared imaging has seen only modest gains over the past decade. This reflects in part smaller research and development investments, as defence budgets have been swallowed by operational costs in current insurgent campaigns, but also the technical challenges of fabricating chips using materials which qualify as 'exotic' compared with commodity Silicon.





"ARGUS-IS sensor pod".

Right: "ARGUS_IS Mosaic Image of Quantico, Virginia".

The MQ-9 Reaper is expected to carry the Gorgon Stare pod.

The latest technology to emerge in this area will have an enormous long term impact. These are QWIP (Quantum Well Imaging Photodetector) chips, fabricated from Gallium Arsenide rather than traditional materials. This has profound implications, as thermal imagers built using QWIPs can simultaneously image different infrared colours, no differently than a consumer digital camera simultaneously images red, green and blue on a single chip. Moreover, since GaAs is less difficult to fabricate, even early developmental QWIPs matched or exceeded the number of pixels on mature imaging chips built from legacy materials. Advancing basic technology in visible band and thermal imaging chips will impact land warfare strongly over the next decade, since these advances permit smaller and lighter imaging cameras, still or video, in many instances with improved optical performance. Refrigeration capability for thermal imagers will continue to drive the weight and bulk of these imagers.

Smaller UAVs and RPVs designed to support land forces at smaller unit levels will have improved imaging capabilities, but with the caveat that stabilised optical telescopes will continue to be expensive and drive the weight of payloads. This technology is likely to become pivotal to affordable UGVs.

Daylight and thermal imaging systems on helicopters and AFVs will become cheaper, lighter and have improved optical performance, as technologies like CMOS daylight imagers and QWIP thermal imagers replace legacy and current thermal imaging modules in legacy and new build equipment.

A good example of the power of this technology is the new Gorgon Stare pod developed for the US Air Force, for carriage by COIN UAVs in Afghanistan. The pod carries no less than 12 imaging sensors, to permit continuous surveillance of the 4 kilometre footprint – a vast capability gain compared to the single imaging telescope system on most UAVs.

Gorgon Stare is modest compared to the recently disclosed DARPA sponsored BAe Systems ARGUS-IS (Autonomous Real-Time Ground Ubiquitous Surveillance Imaging System) pod. This 5-metre long pod design employs no less than 368 visible band CCD imaging sensors, each with 5 Megapixel resolution, grouped into four camera systems to provide an aggregate ability to simultaneously image up to 1.8 Gigapixels. The CCD imaging chips are of a type used in mobile phone cameras, with a frame update rate of 12 – 15 frames per sec, which is about half the frame rate required for cinema or television broadcast quality. The ARGUS-IS internal data processing system with 28 parallel processors is claimed to be able to handle 400 Gigabits/sec of data. US industry sources also claim that a thermal imaging derivative is in development. The prototype pod has been carried on a YEH-60B Blackhawk helicopter, but is intended for fixed and rotary wing UAV employment. The demonstrator employs a 274 Mebgabit/s TCDL downlink to transmit imagery to a ground station – this is well below the data rate of the sensor package.

In conclusion, Moore's Law driven evolutionary growth is beginning to produce important dividends in battlefield ISR capabilities. The principal challenge now faced by system integrators is the 'bandwidth bottleneck', as even specialised high data rate downlinks like CDL and TCDL – the best currently available – cannot match the raw data gathering capabilities of many of these new generation ISR sensors.