Battlefield ISR - needs and goals

Dr Carlo Kopp

Remotely Piloted Vehicles such as this MQ-9 Reaper have proven to be highly valuable ISR platforms in COIN operations, but are unusable against nation state opponents armed with modern battlefield SAMs and fighters.

DRAMATIC evolutionary growth in Battlefield Intelligence, Surveillance and Reconnaissance (ISR) over the past decade is largely the result of protracted Counter-Insurgency (COIN) campaigns providing the impetus and funding for growth in this capability. In a Moore's Law driven technology environment, this evolution is far from over, and whether there is any 'end-state' in the evolutionary growth path for ISR remains an open question.

As the Vietnam conflict and the more recent 'War on Terror' demonstrate, COIN campaigns stimulate growth in ISR, as such conflicts tend to be ultimately ISR driven. The enemy has a propensity for concealment, lacking the resources to field large mechanised forces that are easy to locate and track.

The 'War on Terror' coincides with a period during which military forces of developed nations convert from analogue era technology to digital era technology, encompassing sensors and networks for the collection and distribution of ISR products. Given advancements in the basic technology available for constructing sensors and supporting networks, the growth of the past decade has been a byproduct of the confluence of ISR-centric COIN effort and available basic technology.

Until the 1960s the primary ISR tool was the visible light wet film camera. The Vietnam conflict brought the first thermal imaging sensors using analogue electronics and the first Synthetic Aperture Radars, using wet film rolls as a capture and storage medium. Photographic film has now been displaced by optical imaging and radar imaging systems. Visible band and infrared imagers will continue to evolve, as will radar, to better resolutions, better band coverage, and increasing ability to autonomously identify targets. Analogous growth has also occurred in passive radio-frequency sensors for signals and electronic intelligence.

At the most fundamental level, physics and mathematics dictate what can be achieved using basic technology, and basic technology at any time puts hard limits on what can be built and operationally deployed. Whatever need or want an operator might have in ISR capability will be ultimately bounded by these hard limits. No amount of wishful thinking or marketing presentations can change this immutable reality.

ISR and dispelling the 'Fog of War'

The ultimate goal of all ISR has always been to dispel what Prussian strategist Carl von Clausewitz eloquently labelled nearly two centuries ago as the 'fog of war'. Contemporary publications on ISR and NCW are replete with this term.

'Fog of war' amounts to the uncertainty a commander must confront on the battlefield, in terms of the enemy's deployment and intent, the deployment of his own forces, and sometimes the intent of his own subordinates.

The idea driving much of the investment in ISR, other than that driven by pragmatic short term needs such as the detection of Improved Explosive Devices (IED), is that more ISR means less 'fog', and a lot more ISR means no 'fog' at all. One could be forgiven for imagining that the 'fog of war' is indeed an artefact of the distant past, when reading commentaries on the subject, especially by vendors of military equipment or advocates of Network Centric Warfare / Network Enabled Operations.

Is the goal of removing the 'fog of war' feasible, or even possible? Contemporary advocates of NCW/NEO will often say "yes." Science says "no."

Science or advocacy driven opinion?

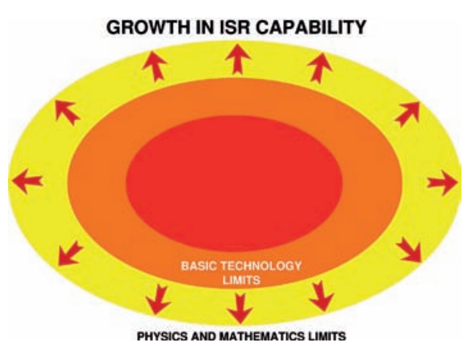
The scientific perspective is that the uncertainty arises primarily from the absence of knowledge, or from knowledge that is not clearly correct, by intent or otherwise. A commander making a decision based on absent or incorrect understanding will make bad choices, and often these bad choices will lead to defeat, especially if the enemy makes good choices and fewer bad choices.

Returning to the science, the construct used most commonly for explaining the dynamic of battlefield operations is Boyd's well known Observation-Orientation-Decision-Action or 'OODA' loop. A commander observes, studies his observations, orients, makes a decision, and then acts. This cycle, or loop, is repeated continuously.

Boyd observed that commanders who cycled through their OODA loops faster than their opponents nearly always won. The player with the slower OODA loop was in a perpetual state of confusion, being unable to understand what was happening in the battlespace, making as a result late decisions and mostly wrong decisions.

Much of the argument raised for ISR and NCW is that both contribute to accelerating the OODA loop, as enemy deployment and movements can be accurately observed with little delay and directives issued very quickly, thus directly accelerating the Observation and Action phases of the OODA loop.

Why then would Clausewitz's 'fog of war' persist in a world of advanced ISR and NCW/NEO?



The technological shift to digital systems has impacted all tiers of ISR capability, across all domains – aerial, maritime or land warfare – and where land warfare involves nation state armies using manoeuvre forces, or COIN campaigns.

If the opponent is a cave dwelling insurgent armed with AKMs, or a nation state equipped with decades old Soviet-era foreign aid export equipment, then a player with advanced and pervasive ISR and NCW capabilities will indeed be capable of cycling through OODA loops many times faster than a pre-information age opponent.

However, when two opponents are both equipped with modern ISR and NCW then the 'game' changes drastically. To understand why this is so, an examination of what engineers term "Nyquist's sampling theorem" is necessary. It is a simple statement with vast implications, which is also at the root of the design of all digital equipment built to handle analogue inputs.

Nyquist says that to accurately reproduce any observation of a time-varying subject, the 'snapshots' must be at a rate twice as fast as any change in the observed subject. This is why TV, cinema and thermal imagers run at 24 or more frames per second and why accurate surveillance of a hostile harbour may require hourly visits by reconnaissance platforms. If observations are made at a rate slower than Nyquist's limit, information will be lost. This is an immutable mathematical reality.

Returning to the example of two opponents cycling through their OODA loops at a similar or identical tempo, what we observe is that Nyquist's limit can never be satisfied. Both players are sampling each other's activities at about one half of the mathematically safe rate to capture a complete picture of reality. This is in the words of one observer "the mathematical proof of Clausewitz."

The relationship between Boyd's OODA loop and Nyquist sampling rates is not well known. In fact, only one published academic research paper connects the two ideas, and then only peripherally. Prima facie, one could argue that a player, given good enough ISR, could continuously surveil their opponent. Good ISR enables this, but alone cannot overcome inadequacies in the human components of the loop.

If staying ahead of the opponent and having a clear picture of their activities and intent requires an OODA loop tempo at least twice as fast, it becomes abundantly clear that if both players have similar ISR and networking capabilities, the prevailing player will only achieve this result by thinking and acting much faster than the opponent. If this cannot be achieved, the 'fog of war' will persist no matter how good the technological ISR and networking might be.

This begs the inevitable question of whether there is any point in seeking to dispel the 'fog of war' completely.

The answer is that in any competitive arms race, players who do not match or exceed opposing capabilities inevitably lose. If the opponent's ISR and networking capabilities is matched then a force will prevail by having smarter and better trained commanders who can make the difference, along with equal or better weapons and warfighter numbers.

In the era predating modern ISR when all players were limited to 'eyeball' ISR, the human OODA loop element was dominant. Successful commanders intuitively understood the OODA loop game, and risk managed their decisions and actions to account for uncertainties they knew about in the ISR product they worked with. Napoleon's famous saying about "never disturbing an enemy while they are making a mistake" speaks for itself.

There is no question therefore that more and better ISR and supporting networking is a good idea and should be actively pursued but dispelling the 'fog of war' requires much more than a technological solution, as significant concurrent investments must be made in educating and intensively training command personnel in how to make good decisions quickly, how to assess uncertainty in battle, and manage the operational risks that arise from uncertainty. While the latter can be facilitated by technology, success is far more a result of properly selecting personnel for command postings, and subjecting them to intensive education and training in proper decision technique, and sharpening this training with real operational combat experience.

Assessing trends versus goals in ISR

Western ISR capabilities are the strongest they have ever been, in terms of the capability to collect data, especially imagery, and electronically transmit that imagery. Given the impacts of exponential growth on optical imaging sensors and monolithic chips used to build computers, radars and networking hardware, clearly ongoing growth in the 'bandwidth' of sensor technology used to collect raw ISR product is assured.

The coming generation of QWIP technology thermal imaging chips, CMOS technology visible band imaging chips, imaging Synthetic Aperture Radars, and Ground Moving Target Indicator radars will be able to collect many more Megabytes or Gigabytes per second than the technology currently deployed. Passive radio-frequency sensors used for SIGINT, COMINT and ELINT will also improve further, although less dramatically as these are more heavily dependent upon supporting antenna and receiver technology, which is not growing exponentially.

This is an important trend, with potentially valuable impacts, as improving sensors will permit more reliable detection of threats or targets, more reliable identification and, in many instances, 'fingerprinting' or identifying specific platforms by hull number, tail-code or serial. This has been the case in ASW sonar tactics for decades, and more recently in ELINT, identifying specific radar emitters.

The extent to which improving sensor technology output can be exploited to an advantage remains an open question.

Several critical problem areas remain to be addressed in long term planning. First and foremost is the growing 'bandwidth bottleneck' between ISR sensors and users of ISR product, as spectral congestion of radio-frequency networks and basic radio propagation physics limitations preclude growth in network bandwidth in any fashion approaching the kind of exponential growth observed in technologies used to build ISR sensors.

The solution for the propagation physics problem for platforms equipped with AESA radars, such as aircraft or warships, is the use of the radar as a datalink to transmit Gigabits/sec data bursts between radar pulses. This has been tested experimentally five years ago, and the theory is more than a decade old (Lynch, David, Jr and Kopp, Carlo, Multifunctional Radar Systems for Fighter Aircraft, in Radar Handbook, Third Edition, Ed. Merrill I Skolnik, McGraw Hill, Columbus OH USA). This is understandably not viable for land vehicles, small UAVs and most other battlefield ISR platforms, so a good 'ubiquitous' solution to this problem is yet to be found.

The problem of radio frequency band congestion experienced by commercial services will also not improve, although a partial solution exists in using frequency agile network terminals that can switch between bands to use spectrum not congested at some time and place. This does not work all of the time but can provide transmission windows where conventional fixed band network terminals are unusable.

Another emerging problem is lower resistance to jamming, in contested battlespaces. This has not been an issue in COIN campaigns since opponents lack the means of defending jammers, and often lack the technological literacy to even understand such. However, nation state opponents are typically

This E-8 JSTARS provides unprecedented capability to collect battlefield ISR product using its large Synthetic Aperture / Moving Target Indicator radar system. It has poor survivability against 160 – 240 nautical mile range "Counter ISR" Surface to Air Missiles.

more sophisticated, with both Russia and China openly exporting a range of capable COMJAM and radar jamming equipments from HF through to the Ku-band. Sadly, the ability to penetrate sophisticated jamming is not an agenda item in the current Western defence debate, arguably a byproduct of zealous and uncritical NCW advocacy over the last two decades.

The combat survivability of ISR platforms is another problem almost completely ignored in the Western defence debate since 2001. Gnats, Predators, Reapers and similar UAVs are effective, viable and survivable ISR assets in a battlespace where the most sophisticated anti-air threat is a MANPADS or a twin barrel pintle mounted ZU-23 bolted down on a 4WD or utility.

However, where the opponent is operating modern SAMs, SPAAGs and SPAAGMs, such UAVs have virtually zero survivability. An SA-15 Gauntlet, SA-17 Grizzly, SA-19 Grison, SA-22 Greyhound, LD-2000 SPAAGM, or Sino-Crotale would score a kill every time. Fitting defensive radar and optical countermeasures is problematic, as the weight is comparable to the ISR payload and effectiveness unspectacular against sophisticated threat radars.

The platform survivability problem extends to larger vehicles, such as the E-8 JSTARS, Sentinel R.1 and analogues, as high mobility SAMs with ranges of out to 240 nautical miles are now in the global market.

Political and ideological fixation on COIN operations across the West was produced unprecedented complacency in the area of ISR platform survivability, just as it has produced such complacency in providing for network jam resistance.

Advanced point defence SAM systems such as the Tor M2E / SA-15 Gauntlet (right) and Pantsir S1 / SA-22 Greyhound (below) present a genuine survival risk for nearly all contemporary battlefield ISR platforms, be they RPVs or helicopters.

The solution is the replacement of non-survivable UAVs with highly stealthy UAVs, and the use of stealth fighters as ISR platforms, accepting than many would need to be dedicated to such use with weapon bays filled with ISR sensors. While the technology is available, a pervasive lack of interest has seen this whole area effectively ignored, or dismissed with arguments that extant fighter-bomber radars or thermal imagers are sufficient. The tenfold to thousandfold differences in area coverage are conveniently ignored.

ISR visionaries such as former US Air Force Lieutenant General David Deptula have articulated these issues over and over again, to no avail.

The long term needs and goals for battlefield ISR are clear, yet often poorly understood, and seldom properly addressed in planning.

While the West's competitors are still catching up in the battlefield ISR game, the pervasive complacency seen in Western planning will eventually see this reversed, if these inadequacies are not addressed, and soon.