QINETIQ

Hide and Seek:

In the Air

Warfare has always been about signatures: finding your enemy's, and controlling yours. Whether that be a visual signature, heat signature, radar signature, or another kind – if you can't find the enemy, you can't defeat them. And if you can't hide, you may, in turn, be seen and defeated.

This age-old game of 'hide and seek' remains fundamentally the same, but the onset of the Information Age has altered its dynamics – multiplying the number of challenges and opportunities around detection. New technologies, open source intelligence, and advanced sensors provide more defence and security information than ever before.

Detailed information is pieced together from networks of sensors stationed in multiple locations and operating on different parts of the EM spectrum – resulting in improved situational awareness. Better processing hardware coupled with improved AI algorithms can fuse raw data and analyse it to ultimately create actionable intelligence.

On the other side of the equation – materials science drives the development of systems that are almost entirely resistant to radar and infrared detection, and even ones that can even disguise themselves, chameleon-like, against their visual backdrop. Advances in passive sensing allow craft to detect enemies with greater accuracy, all without giving their positions away.

On the macro scale there is growing global instability, more sophisticated adversaries and an increasingly noisy electromagnetic backdrop. Hide and seek now happens on more fronts and in more ways than ever before - playing out in underhanded grey zone conflict, and the ever-evolving race between sensors and stealth technology.

In the air domain, aerial ISR (Intelligence, surveillance and reconnaissance) could be thought to date back to the French Revolutionary Wars, and the use of observation balloons. A high vantage point paired with optical magnification provided a rudimentary (yet useful) ISR advantage in preparing accurate battlefield maps, and surveilling the (relatively slow moving) frontlines of the day.

Things have, obviously, come quite a long way since then.

Passive radar: from Klein Heidelberg to Starlink

Developed just a few years before World War 2, radar proved itself to be a war-winning technology. Britain's Chain Home system is famous as world's first early warning radar network, and the first operational military radar. What is less known is how the Germans, in secret, used Chain Home as a means to track British aircraft.

The German 'Klein Heidelberg' sent no signals of its own – instead, it used a series of six receiver stations along the western coast of continental Europe to secretly surveil the British radar system. These stations received both the primary signal from the Chain Home transmitter and the weaker reflected secondary signal from the British craft, plotting the time delay between both signals to predict where the British aircraft were.

Klein Heidelberg is an example of passive radar, and wasn't discovered by the allies until well after the D-Day invasion. The concept is still very relevant today. For example, by picking up the reflected emissions off the adversary, passive radar could use GNSS satellite emissions to triangulate the position of an adversary.

This technology will inevitably be aided by the addition of new cubesat constellations, such as SpaceX's Starlink. Such constellations will offer power densities orders of magnitude more powerful than GNSS – creating a larger network of powerful signals for passive radar to exploit. Terrestrial 5G transmitters (which are increasing in number) could also be used for much the same reason.

A similar technology of interest is quantum radar – which presents the possibility of being able to detect stealth aircraft. Proponents of the technology claim that quantum radars may also be stealthy in operation, with very low transmission powers that are impossible to detect – though this alleged benefit has not yet been demonstrated at useful ranges.

These photons are difficult to generate, and any theoretical 'quantum benefit' has only been shown at very low power and at extremely short distances (metres to tens of metres). The premise of quantum radar involves the use of two entangled photons – the 'signal photon', which is beamed towards objects of interest, whilst the 'idler photon' is stored on the device.

If a stealth craft interferes with the signal photon, this is detected back at the sensor on the entangled partner. Many believe that quantum radar will never be capable of long-range uses, such as detecting stealth aircraft. But being able to detect stealth aircraft is an increasing priority.

A new stealth era?

Since the first flight of the US F-117 Nighthawk in 1981, stealth aircraft have provided a significant advantage to Western forces on the air front. But such technology is no longer limited solely to the West.

Russia's Su-57 Felon, the country's first stealth fighter, entered service in late 2020. China has its own equivalent in the Chengdu J-20, which bears a noticeable resemblance to the US's F22 (unsurprising, since the J-20 may well be based on stolen US designs). Beijing's Xian H-20 has not yet entered service, but will be the country's first stealth bomber. In 2019, Iran debuted 'Mobin' – which it claims is the world's first jet-powered stealth unmanned aerial vehicle (UAV), and which can reach altitudes of 45,000 ft at 900 kph.

America, of course, continues to drive the technology forward. For example, Northrop Grumman (who have ample experience with stealth craft), are developing the B-21 Raider as the successor to the venerable B2 Spirit (which first flew in 1989).

The Raider is expected to enter service around 2026-27. Describing the capability as "more affordable, maintainable and sustainable", Northrop Grumman also claims that Raider will address many of the challenges presented by previous stealth platforms:

> "stealth aircraft have always had challenges related to maintainability due to the need for specialised personnel, equipment, materials, and facilities. That's not the case with the B-21."

Drones: a cheaper way to do aerial ISR?

Stealth in the air took a different turn with the recent proliferation of commercial off the shelf (COTS) drones. For example, inexpensive uncrewed aerial vehicles can be fitted with rudimentary sensors and used for intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) against much more expensive targets. In the air, domain traditional radar techniques often struggle to detect these smaller class 1 UAVs, due to their low radar cross-section and low Doppler signatures – making discrimination from clutter sources (like birds) difficult.

But even stealthier drones are on the horizon. As reported in QinetiQ TechWatch 5, material scientists from the University of South Australia working with the Australian Department of Defence have developed a range of lightweight panels that can change colour on demand, allowing drones to match their appearance to the background colours of the sky.

The lightweight panels are made from polymers known as 'electrochromic' materials, which are able to change colour when activated by an electric field. The exact colours can be tuned to specific voltages and, in the case of these specific panels, they operate in the range from -1.5 to +1.5 volts, allowing operation with just one AA battery.

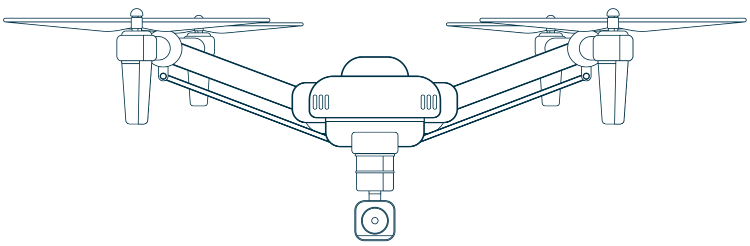
Besides their chameleon-like characteristics, the scientists report that the panels are inexpensive, lightweight and durable, and can be either rigid or flexible, making them ideal for use on drones of all sizes and specifications.

Surveillance in the stratosphere

Uncrewed aerial vehicles operating at higher altitudes provide another opportunity for sensing, and with the potential for increased coverage due to their stratospheric paths. These are known as 'high altitude pseudo satellites' (HAPS) – which could combine operating costs of an unmanned aerial system (UAS), with the sensor capabilities of a small satellite.

Perhaps the best known example is Airbus' Zephyr, which relies on solar energy, with secondary batteries charged in daylight to power overnight flight. Boeing claims that Zephyr's flight time is carbon neutral.

HAPS will be some of the first adopters for software-defined multifunction systems, like Software Defined Multifunction LIDAR (SDML). In 2018, QinetiQ began developing a SDML system for Zephyr. Because such systems can combine multiple capabilities (eg. various types of sensor, electronic warfare and optical communications) into a single form factor – they offer enormous potential for space and weight constrained platforms, like HAPS. Being software-defined allows remote updates to the sensor platform, allowing it to evolve as its mission changes. This is particularly important, as HAPS may be required to remain on station for many months at a time, unable to receive a physical refit.



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