Solution:

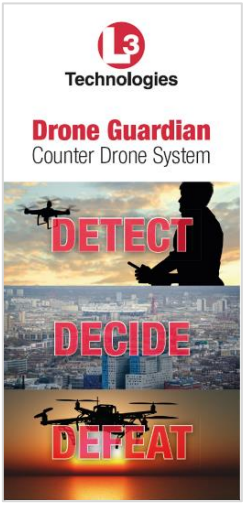
L3's DRONE GUARDIAN

Technology behind the solution

L3's vision when designing Drone Guardian was to give Security and Safety Managers a cost-effective solution to deter, detect and defeat the threat of non-compliant drones.

In summary, L3's Drone Guardian product is:

- **Mature** - with assured and proven software at its heart
- **Integrated** - providing situational awareness to all locations
- **Proven** - employing carefully selected components, exploiting military-grade technologies
- **Cost effective** - offering a choice of components, with capability and price points to match the unique needs of each location
- **Reliable & Supported** - It's from L3



1.1. Introduction to Drone Guardian

The detection, tracking and defeat of small drone threats is a complex problem for which no single technology solution has, as yet, been shown to provide reliable performance across the full range of required operational environments. Systems based solely on individual components such as radar, acoustic, Electro Optical/Infra-Red (EO/IR) or RF (Radio Frequency) detection have all been deployed with varying degrees of success in different operational situations. Equally, systems mounted on a single mast have all been seen to have limitations when faced with real-world environmental and topographic constraints. Finally, systems which rely on cooperative data from drones are dependent on the support of the drone manufacturer and assume that the drone pilot will not take one of many simple measures to mask their drone's presence.

DETECT, TRACK and IDENTIFY - The L3 Drone Guardian system creates a counter-drone 'distributed sensor system' using modern correlation and fusion techniques to enable multiple sensors, of different types and capabilities, to operate together to consistently detect, track and identify (DTI) the threat.

EFFECT - The track produced from the DTI process can then be used to reliably cue or direct various "effector" technologies to defeat the threat, including hard effects such as RF jamming, physical capture (eg: nets) or kinetic (eg: gun systems).

This integrated approach provides an effects-based defence against drones, calibrated to the likely threat, which adheres to a typical Observe, Orientate, Decide, Act (OODA) process cycle, as shown in Figure 1 below.

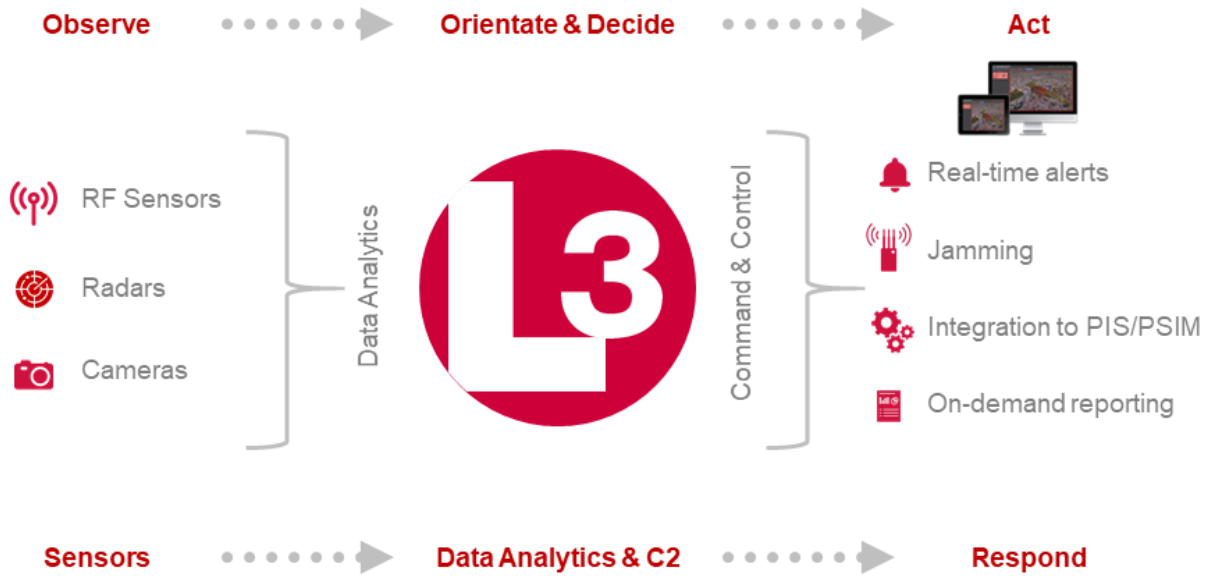


Figure 1: L3 Drone Guardian Effects Based Defence OODA Cycle

Figure 1 above shows the L3 Command and Control (C2) and Data Analytics component at the heart of the Drone Guardian system, acting as a platform for the effective integration of other components. The L3 Drone Guardian system is 'component independent' and scalable, meaning a solution can comprise of any combination of quantity and capability of sensors, all connected to a unified command software. This attribute of Drone Guardian ensures future-proofing; allowing for new and improved sensor and effector technologies to be integrated easily. The system can deliver the following benefits:

Item	Benefit
C2	Integrated Command and Control platform at the heart of the system, capable of multi-mission operations.
Any Sensor	Integration of multiple sensor types to ensure earliest possible detection.
High accuracy	High probability of detection and identification, due to the inherent capability of multi-sensor fusion.
Many targets	Multiple target detection, identification and tracking to support complex decision-making.
Counter measures	Integrated management of effector systems, with the ability to cue/slew and/or digitally task multiple active defence systems.
Future proof	A flexible component architecture to accommodate future threat and technology changes.

Table 2: Summary of system benefits

1.2. System Architecture

The L3 Drone Guardian system has been designed to enable the incorporation of different sensor types/models and integration with third-party effector defeat systems. The selection and configuration of these can be tailored to the requirements of each customer application.

The system can be installed within a fixed location or protected area, in temporary locations or in a portable deployment using a number of vehicles to house the various components.

1.3. Core Components

- **Drone Guardian C2 Server:** Provides the core C2 integration of data derived from the various sensors, and command of a connected effector system. Fusion and correlation of the sensor data is based on L3's advanced tracking technology, developed over the past 25+ years in air defence and other military domains (as described in Section 5 of this document).

- **Drone Guardian Workstation:** Provides state-of-the-art operator interaction with the alerts, image and video feeds provided by the various sensors and composite tracks produced by the Drone Guardian C2 system. An operator Human Machine Interface (HMI) provides visual tracking of detected and identified drones against customer-specified background mapping or imagery and enables operator command of a connected effector system. Warning areas and areas of potential false alarm can be configured by the operator. This workstation HMI can be hosted on existing Airport security IT infrastructure through a standard web browser or it can be provided as a standalone installation.

1.4. Sensor Components

- **Drone Tracking Radar:** Provides active radar detection and tracking of multiple autonomous drones. A number of suppliers have tailored existing low power radars to the task of drone detection. Radar provides a longer range for early warning (typically 3km) over the full 360 degrees and provides geo-location of detected targets. L3 will choose an appropriate radar sensor, dependent on the threat, environment and other customer specification.

- **RF Detection Nodes:** Provide passive detection of RF (Radio Frequency) emissions from a drone, in particular the command and video channels. These are typically monitored in the 2.4 GHz and 5.8 GHz bands, although the nodes are capable of monitoring any frequencies between 10 MHz and 6 GHz.

  A distributed array of nodes enables accurate geo-location by the Drone Guardian C2 system using Time Difference of Arrival (TDOA) processing. L3 will choose appropriate RF sensors, dependent on the threat, environment and other customer specification.

- **Drone Tracking Cameras:** Provide optical detection of drones using powerful camera and lens combinations, and state-of-the-art visual detection and analysis. Moving

objects of interest are tracked and then viewed in higher resolution to enable drone discrimination. These images also enable the operator to confirm identification of a hostile drone, whilst the tracks generated contribute to the fused picture in the Drone Guardian C2 system. Thermal cameras can optionally be added to improve day/night operation. L3 will choose appropriate cameras, dependent on the threat, environment and other customer specification.

- **Acoustic Detector (Optional):** Provides early warning of an approaching drone based on its audio signature. L3 will choose appropriate acoustic sensors, dependent on the threat, environment and other customer specification.

- **Co-operative Drone Component (Optional):** Provides the ability to launch and fly a drone either to intercept a hostile drone or to provide visual intelligence on its ground operator or mission. Telemetry is fed back to the Drone Guardian C2 system to add to the overall situational awareness. Video from a friendly drone is provided to the operator.

- **ADS-B or other Receiver (Optional):** Provides live transponder returns from aircraft or other friendly drones in the vicinity to the Drone Guardian C2 system. This is particularly useful in a busy air environment; e.g. around an airport.

1.5. Defeat & Effector Components

The detected drone tracks which are output from the L3 Drone Guardian C2 system can be used to manually or digitally task a range of active defeat systems, appropriate to the environment. In particular:

- **Mobile or Static RF Jammers:** Block the communication channels between the operator and drone, usually in the 2.4 GHz and 5.8 GHz bands. Blocking the video channel disrupts operator control and video surveillance. Blocking the control channel will cause the drone to either land immediately or return to base, depending on drone type and configuration. It is also possible to jam the GPS receiver on the drone, preventing its autonomous operation.

  Jammers can operate omni-directionally to effect the disruption and defeat of multiple drones at shorter range, or they be steered directionally and with controlled frequency banding to maximise the effect on a specific drone at a longer range. L3 will choose appropriate jammers, dependent on the threat, environment and other customer specification.

- **Drone Capture Nets:** Usually projected using air-powered cannon to capture the drone and bring it to the ground using parachutes. The cannon can be controlled by the C2 system but, more usually, by a ground operator.

1.6. Network Architecture

The L3 Drone Guardian system has been designed to operate over a standard IP-based network with options for firewalls and encryption between the core C2 elements and connected sensor or effector systems.

Figure 2 below shows a representative network architecture for a full suite of sensor and effector components.

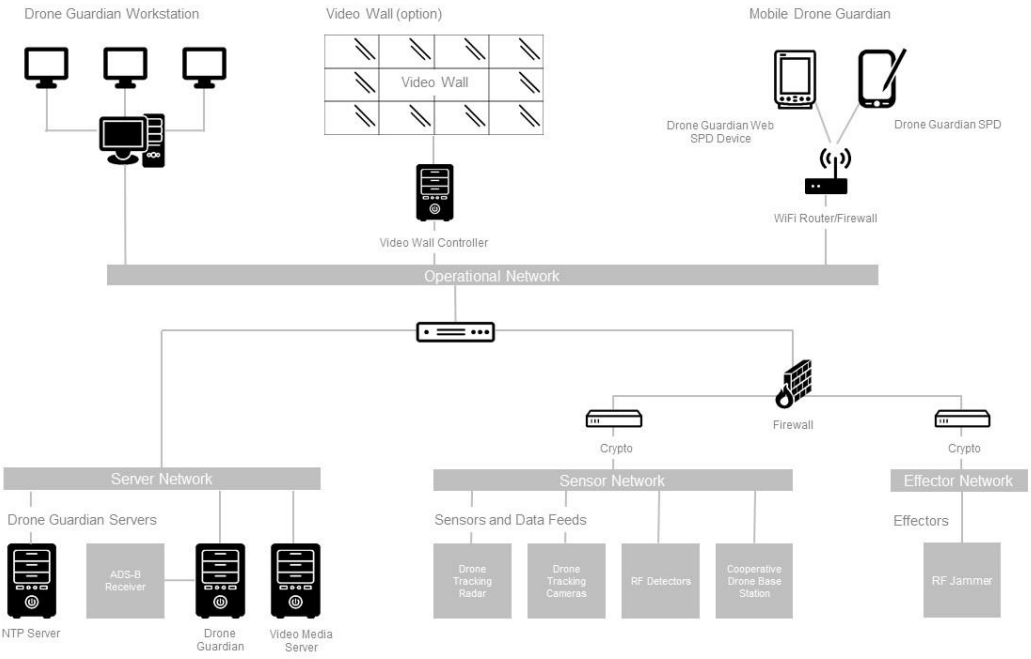


Figure 2: L3 Drone Guardian Network Architecture

Conversion to/from third party sensor and effector system APIs is performed in the Drone Guardian C2 Server. Alternatively, an 'open' API for connection to Drone Guardian can be provided. This allows the system to be evolved over time and reduces the dependencies on single sensor and/or supplier technologies.

Options are available for connection to a video wall system and to a Drone Guardian Web Situation Picture Display (SPD) app running on standard mobile devices. The latter capability allows ready integration with first responders or other agencies who will simply be provided with log-in information to allow them to follow the counter-drone events through their own device.

1.7. Performance

The L3 Drone Guardian system has been demonstrated and instrumented in live trials in the UK using drones flown in realistic threat trajectories against a defended base. The sensor types deployed were an X-band continuous wave radar, an optical camera system and a network of RF detector sensors. The drones flown included commercial DJI Phantom and DJI Inspire systems that are used for aerial photography or to carry small items.

Two demonstration scenarios were devised to place challenging demands on the system: an intelligence gathering drone mission and a contraband delivery drone. These were performed multiple times to gather meaningful statistics on the sensor and system performance. The results from the two scenarios are shown in Figure 3 below.

In both cases the combined Drone Guardian C2 system detected and tracked 100% of the drone incursions at ranges of more than 500m from the protected area and with maximum speeds exceeding 55 km/hr.

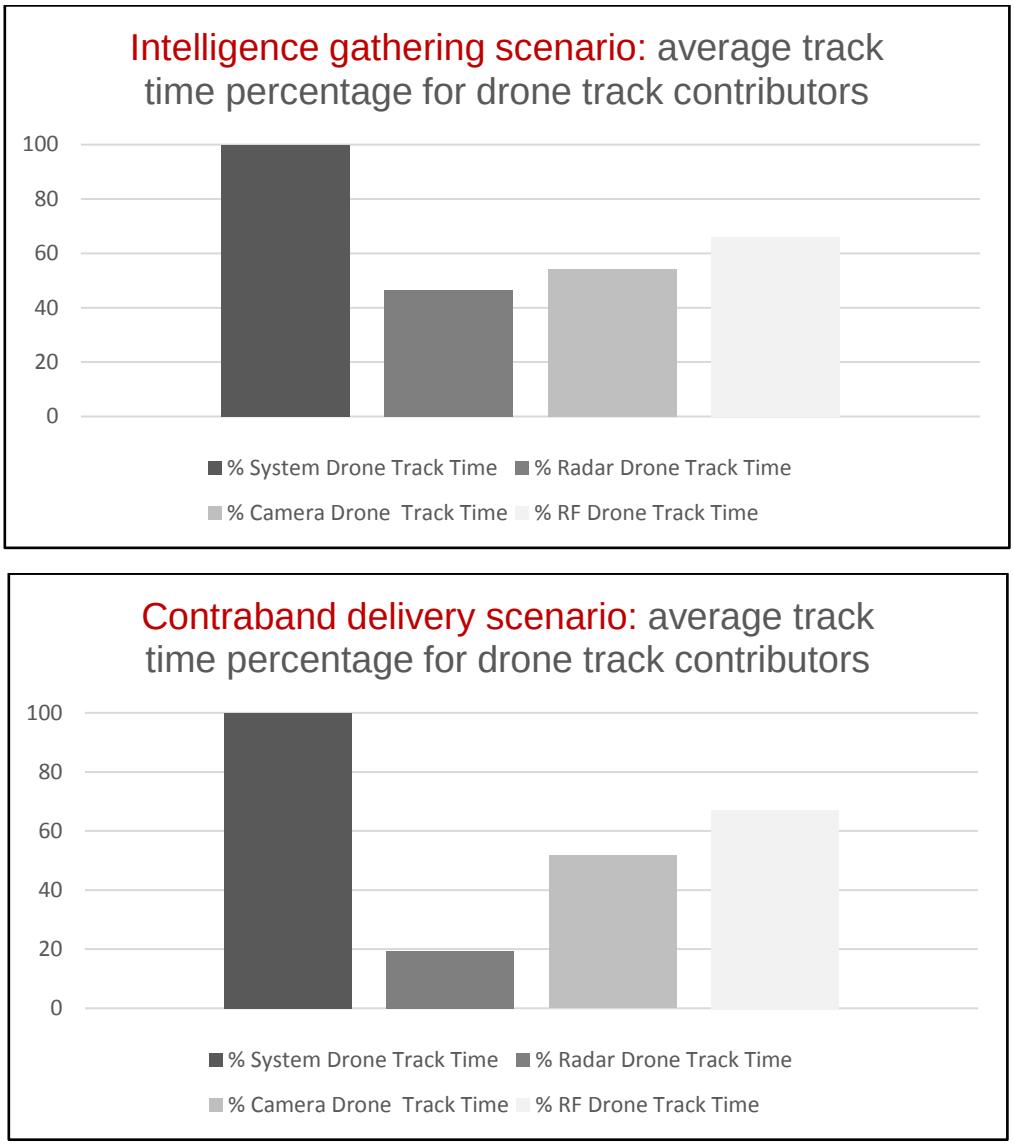


Figure 3: Average Percentage Contributions of Sensors

1.8. Product History

At the core of the L3 Drone Guardian system is a military-grade sensor data fusion engine which has been developed by L3 Technologies over more than 25 years using both company R&D funding and UK/US government funding. Although originally conceived for ballistic missile tracking, the software engine has been extended to handle difficult airborne targets of various types as well as ground and surface targets. The engine has an open architecture message interface and provides the control functionality required for use by C2 systems.

As a result, the sensor data fusion engine has been trialled and deployed in a wide range of domains, many of which contribute to the counter-drone application of Drone Guardian, as shown in Figure 4 and listed below. Of equal importance, the underlying engineering expertise of L3 Technologies, developed in military systems over many years, has been brought to bear on a commercial product and will be available to support design, development, deployment and through life support of the Drone Guardian solution.

- **Ballistic and Theatre Missile Defence (BMD/TMD):** Used to track ballistic missiles, optimise Early Warning Radars, and extend the capabilities of air defence radars and C2 networks.
- **Air Defence:** Used to improve Combat ID, enhance radar/Elector Optical sensor integration and in UK Ground-Based Air Defence applications.
- **Space Situational Awareness:** Used to optimise long-range radars to detect small objects and debris in orbit.
- **Counter Rocket Artillery & Mortar (C-RAM):** Used for base area protection and threat assessment in operational theatre for UK MoD.
- **Intelligence Surveillance Target Acquisition Reconnaissance (ISTAR):** Used in the fusion of Electronic Warfare data and RF detections into a combined air picture.

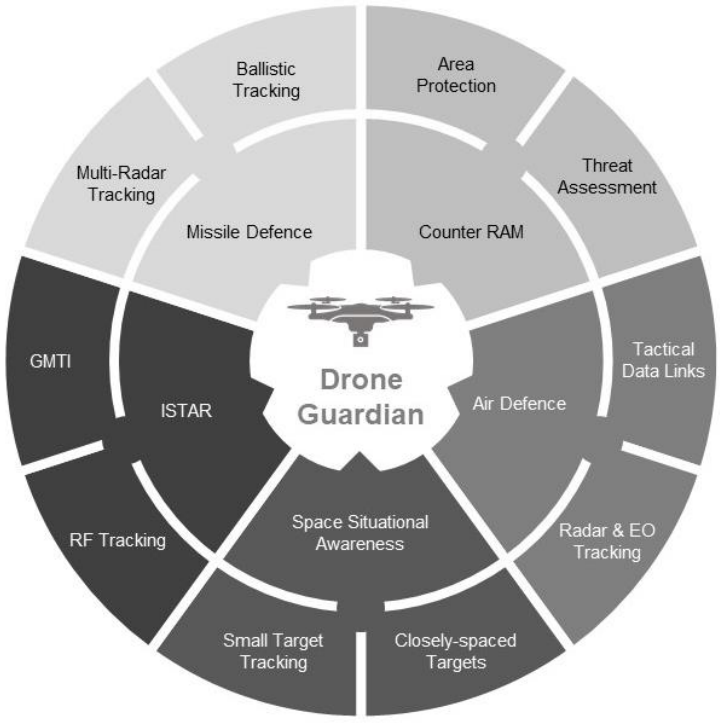


Figure 4: Sensor Fusion Experience Employed in the Counter-Drone Solution

1.9. Summary

The L3 Drone Guardian system is based on the strong pedigree of sensor fusion and correlation technology developed by L3 Technologies. As such, Drone Guardian differs from other C-UAS systems in its focus on the provision of a flexible C2 platform with a truly open architecture.

The system has been designed to use multiple sensor and effector technologies to deliver a robust and effective solution to the growing drone threat.

The system provides a cost-effective solution tailored to meet specific operational needs and is readily integrated with existing airport security and operations infrastructure.

L3's Drone Guardian system uses proven military-grade capability, backed by experienced engineering support, to provide a reliable solution to the most challenging drone threats.

More information can be provided by contacting L3 at cuas.asa@l3t.com.