

Building an effective multi-sensor drone detection solution

Why using RF, radar, and cameras in concert is your best bet against drone intrusions



The case for “sensor fusion” in a drone detection system

In a [recent white paper](#), ZBeta thought leaders discuss the proliferation of unmanned aerial vehicles (UAVs), better known as drones, and their potential as a new threat vector in many physical security scenarios ranging from smuggling and aviation interference to espionage and terrorist acts. In our conclusions, we emphasize that drone security awareness entails looking and thinking beyond our industry’s traditional, terrestrial measures for threat prevention, investigation, and response.

When forming a strategy to deal with this threat, companies have multiple drone detection technologies to consider, including radar, passive radio frequency (RF), electro-optical/infrared (EO/IR) pan-tilt-zoom (PTV) cameras, and acoustic. While it’s possible to build a solution using only one of these, the best solutions combine multiple sensor types to produce a clearer, more informative picture of the detected drone. This “sensor fusion” approach incorporates the strengths of each system element and uses them in orchestration to produce superior results.

Drone detection: Choosing sensors

Determining your sensor modalities is crucial in counter-drone planning because different sensors provide diverse and complementary data essential for accurate drone detection, identification, and tracking.

Let's briefly examine the sensor types individually, including their key strengths and limitations.

- + **Radar sensors** are sophisticated active sensors that emit radio waves, which travel through the air and reflect off objects in their paths. By analyzing the returned signals, radars can determine the presence, position, and movement of objects. This technology is essential in counter-drone programs where detecting and tracking small, low-flying drones are paramount.

Be aware that active radar systems that monitor ground or airspace are subject to Federal Communications Commission (FCC) license requirements.

- + **Passive RF sensors** are indispensable tools for detecting and tracking drones. Unlike active radar systems, passive RF sensors do not emit signals. Instead, they monitor the RF emissions from drones and their ground control stations (GCS). By analyzing these RF signals, passive RF sensors can identify and locate drones based on their unique radio signatures.

This reduces the risk of alerting drone operators to counter-drone activities while minimizing interference with other electronic systems. Passive RF sensors are especially effective in environments where covert drone detection is crucial.

- + **Electro-optical (EO)/Infrared (IR) sensors**, commonly known as pan-tilt-zoom (PTV) cameras, use advanced camera technologies to capture visual (EO) and thermal (IR) data, providing a comprehensive picture of your environment.

EO sensors are highly effective in daylight conditions, capturing high-resolution images that can be analyzed to identify drones based on their visual signatures. IR sensors, on the other hand, detect heat emissions from drones, making them invaluable for nighttime operations or scenarios where visual detection is challenging.

- + **Acoustic sensors** are an innovative technology for detecting drones based on their sound signatures. These systems utilize arrays of sensitive microphones to capture the unique acoustic emissions generated by drone motors and propellers. Each drone model produces distinct sound patterns and frequencies, both of which can be analyzed to identify and locate the source.

Acoustic detection is particularly useful in environments where visual or RF-based methods may be less effective, such as in dense urban areas or heavily forested regions.



What is a multi-sensor drone detection system?

The ideal drone detection system has three sensor components: RF, radar, and EO/IR (PTZ cameras). Each system has unique capabilities that complement the others while offsetting their limitations. Our [white paper](#) discusses the relative advantages of these sensor types.

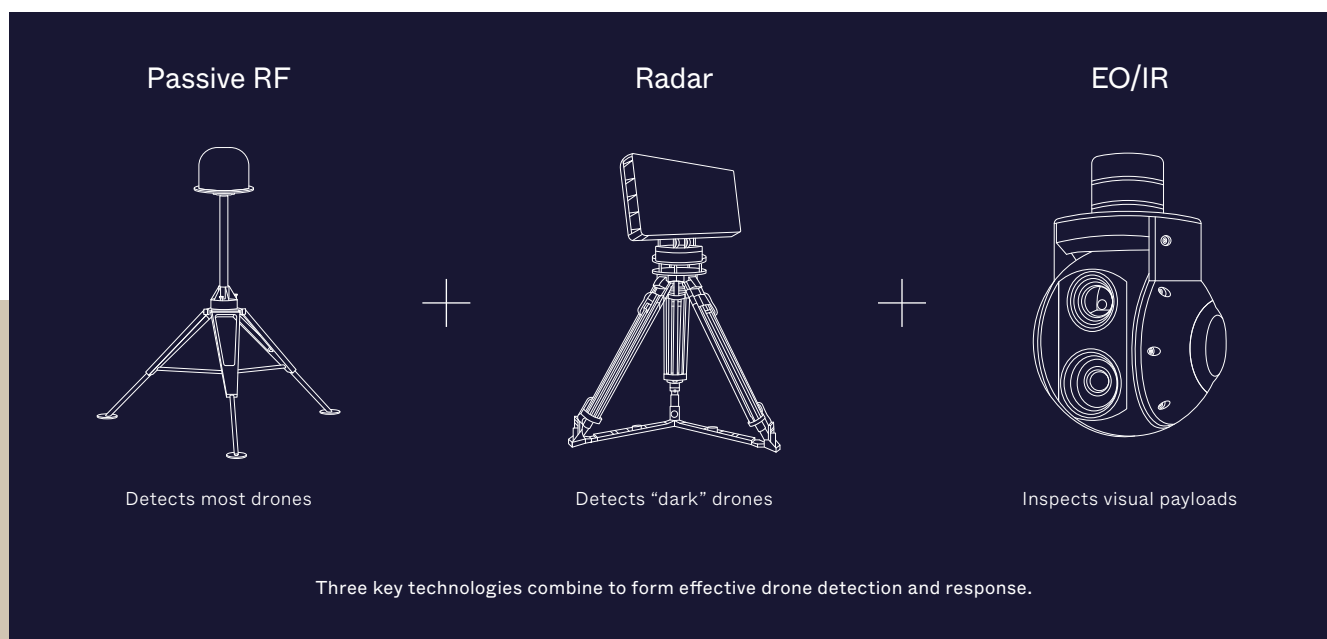
Passive RF is one of the most common methods for detecting drone activity because it is cost-effective and reasonably reliable for identifying the presence of drones and other RF-emitting devices. RF detection can capture technical details such as the drone's make, model, and communication signals, and in some cases, its Remote ID—a unique identifier required by the FAA in the U.S. These details provide valuable data for assessing a detected drone's activity and comparing it against historical records.

However, used on its own, RF drone detection creates visibility gaps in cases where a drone is “flying dark” by not emitting an RF signal. Dark drones generally evade RF signal emission by being programmed to travel to a specific GPS waypoint. In many cases, this work-around can be suspiciously elusive and serve nefarious purposes for dangerous payload delivery or other malicious activity.

To spot dark drones, you need a secondary method like radar. Radar sensors don't care whether a drone is emitting a signal; they just know the drone is present. So, when a dark drone flies into the security perimeter you've identified for monitoring, radar will likely pick it up. And yet on its own, radar without RF also presents many challenges. Unlike RF, radar lacks the capability to capture technical drone details. Radar also has frequent blind spots at low altitudes, difficulty differentiating targets, and susceptibility to environmental interference. Be aware that implementing radar sensors is much more expensive than RF, and sometimes requires pre-authorization for use.

The use of these two sensor types together will adequately identify drones, including dark drones, in most cases.

What happens next is crucial. As soon as your solution detects a drone, you want to visualize the drone as quickly as possible using cameras to start assessing its payload and taking action as needed. By closing the gaps of an RF-only or radar-only system and using PTZ cameras to complete the picture, a multi-sensor solution significantly decreases your risk of missing an imminent threat.





Increased speed and accuracy under a single pane of glass

Multi-sensor solutions succeed by fusing the capabilities of two or more sensor types within a single drone detection solution and delivering their combined output to a central dashboard for assessment and response. This response typically takes the form of security personnel pursuing manual action, but you might also design your system to execute programmatic tasks based on thresholds you have set for drone-related system events, including specific alerts and their corresponding responsive actions. Alerts in a multi-sensor solution are more reliable and actionable than alerts in a single-sensor system, because of the granular data provided by multiple sensors.

By this centralized method, a multi-sensor solution can automate the tracking of a detected drone in helpful ways. The system can track a drone's movements on cameras pointed directly at it, rather than relying on drone response operators to follow the drone using a joystick as it flies around. Meanwhile, the system can capture comprehensive information about the drone and check it against historical data you've collected to see whether it's a known device to you, and if so, how its current movements compare to its behavior in the past.

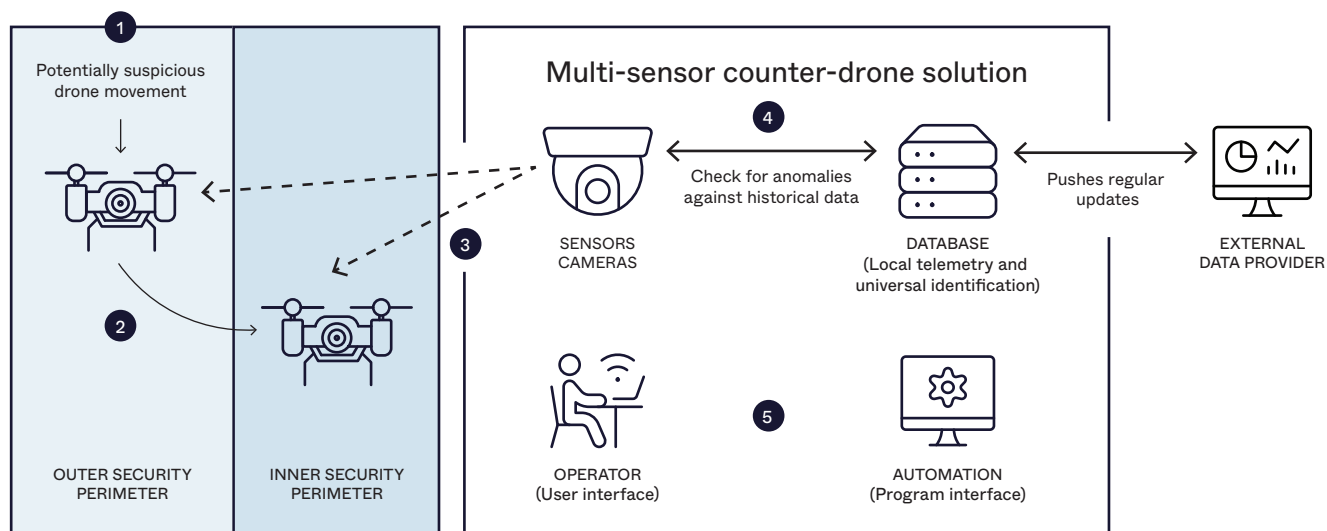
Data management

Much of a counter-drone program's success relies on the ready availability of key data. While you can store drone identification data in a local database, a common enhancement is to contract with software solution providers who deliver this storage service. The main advantage of outsourcing this data management role is that the external provider will continuously update your system with new information about drone types and capabilities, similar to the over-the-air updates you might receive on the navigation system in your car. Using this kind of service means your drone detection solution can always identify new drone models that have arrived on the market, as well as any new signal types existing drones are able to emit—all essential data for drone threat-related investigations.

As for telemetry, a superior drone detection solution will also store historical data pertaining to drone activity at your facility. This means that in addition to identifying new drone types and capabilities using service-provided data, you can look up a drone by its serial number (which you detect via RF sensor) and look up what flights it's flown previously—for example, did this same drone recently fly around another customer site you monitor?— and take action based on actual intelligence, not guesswork. Local telemetry data is also useful for white-listing drones you know to be harmless based on previous identification and the telemetry patterns you've observed.

Coordinated detection and response

This drawing describes the end-to-end workflow of drone detection using a multi-sensor system:



High-level overview of a multi-sensor drone detection system.

To put the advantages of this design in perspective, think about the alternative to having a centralized dashboard: data arriving piecemeal in various locations at different times. Without a clear and composite visual of the drone with all of its information in one place, drone response operators spend valuable time piecing together data and trying to locate the drone on cameras as it continues to move. In this lost time might lie the vulnerability to grievous error. The best drone detection system is one where workflow moves from detection to remediation with speed, intelligence, and intention.

Designing the right drone detection solution for your needs

In a previous article, we offered advice on how to assess your company's unique risk from the threat of drone activities. If you find you are vulnerable and need drone detection capabilities, it's likely that a multi-sensor design will be your best option, based on the advantages we've discussed. To summarize, a multi-sensor drone detection system can:

- + Put your drone detection approach into perspective, triangulating data across sensor outputs to help visualize drones as they enter your field of observation.
- + Enable better real-time coordination of your response to a potential drone threat where drone response operators manage incidents as they occur rather than reactively or after a delay.
- + Produce granular data that better informs intervention planning or standard operating procedures, along with triggering more meaningful programmatic alerts or other system events.
- + Allow the gathering and storage of historical data about drones in your vicinity so that your drone detection program becomes more useful and powerful the longer you use it.



Read our white paper [Physical security in the drone dimension: Assessing and addressing new threats from the air](#) to learn more about how the recent surge of drone activity affects physical security strategies at companies like yours.

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