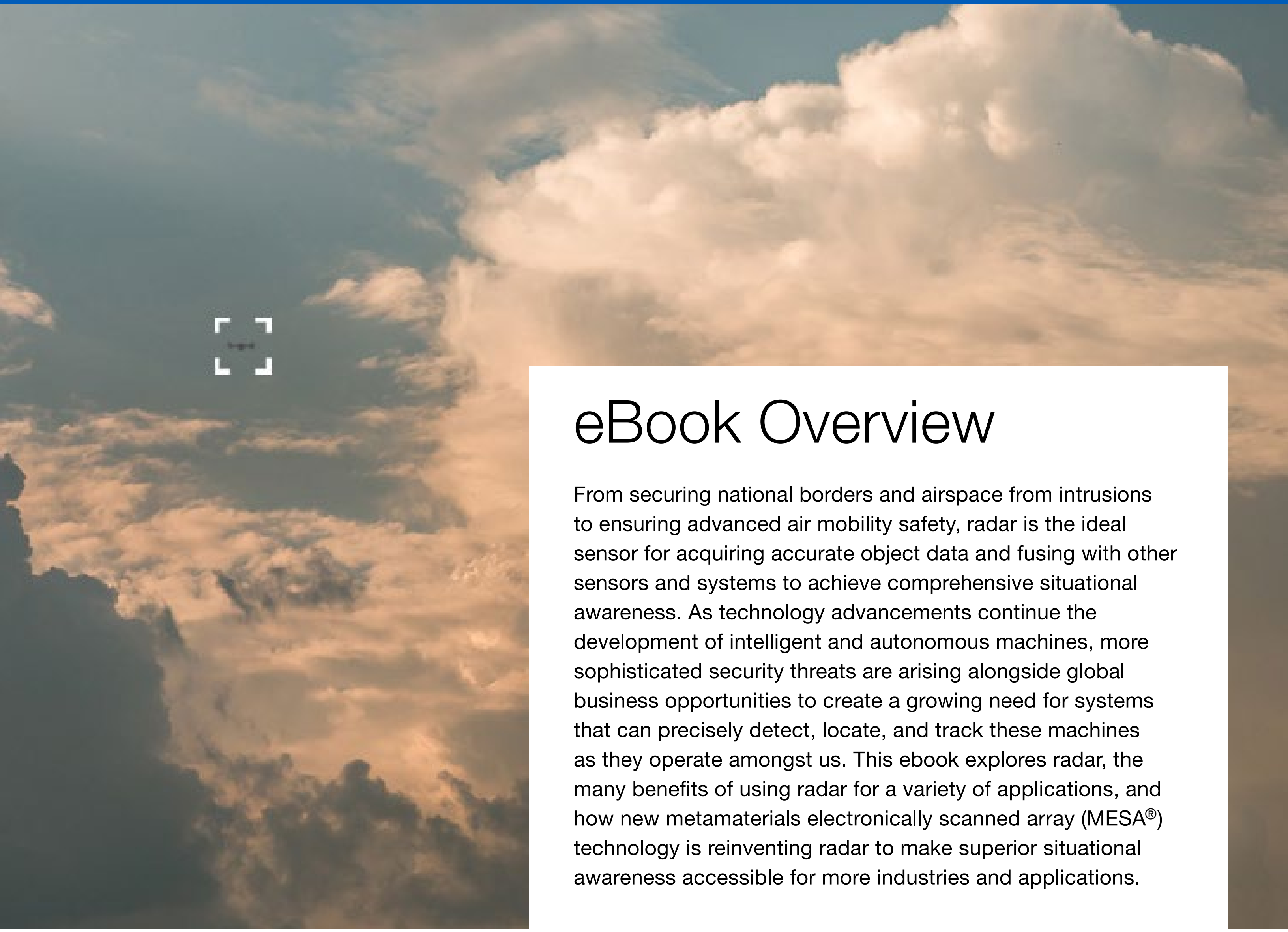
Smarter Security Through Radar



eBook Overview

From securing national borders and airspace from intrusions to ensuring advanced air mobility safety, radar is the ideal sensor for acquiring accurate object data and fusing with other sensors and systems to achieve comprehensive situational awareness. As technology advancements continue the development of intelligent and autonomous machines, more sophisticated security threats are arising alongside global business opportunities to create a growing need for systems that can precisely detect, locate, and track these machines as they operate amongst us. This ebook explores radar, the many benefits of using radar for a variety of applications, and how new metamaterials electronically scanned array (MESA®) technology is reinventing radar to make superior situational awareness accessible for more industries and applications.

Preface

Why radar? Perhaps an odd question, given that asking “what is radar” might be the better starting place. However, “why radar” is the more pertinent question as many security organizations grapple with the impact of autonomous machines as tools and as threats and are seeking to understand which sensors provide the clarifying situational awareness required to support smooth and safe operations.

No matter the play, radar is the cornerstone sensor in the perimeter intrusion detection stack, boosting situational awareness and elevating the performance of other sensors. For security applications, low size, weight and power (SWaP) is preferred. However, not all compact radars are equal. The richness of your awareness begins with high-performance, dependable radar capturing and sharing high-fidelity target data with other systems and sensors.

This eBook examines common detection sensors - cameras, RF, acoustic, radar – to reveal the advantages of specific sensors and how security teams can leverage a layered sensor stack for optimal awareness and informed decision making. You’ll also discover how the right radar can be used to create superior multi-domain surveillance and security systems.

Table of Contents

CHAPTER 1

What is Radar?

Radar is an incredibly powerful tool for performing object detection and location for a variety of applications. Radar, which is an acronym for radio detection and ranging, uses electromagnetic waves (EW) within the radio frequency (RF) spectrum to detect, locate, track, and identify objects of interest on the ground or in the air over long ranges. At the most basic level, the EW signal is transmitted into the environment and the radar “listens” for a return signal, or echo. A return signal is generated when an object is in the path of the original signal, causing a reflected signal that bounces back to the receiver. It is often assumed that the object commonly referred to as a target, must be metal to reflect a radar signal, but it can be constructed of almost any type of material sufficiently different than the air that the radio wave is propagating through (plastic, rubber, glass, metal, wood, etc.). The time between the transmission of the original signal and reception of the return signal, which is known as time of flight, provides a significant amount of information about the detected object, including its location, distance, velocity, and characteristically unique features of motion which can be used to classify a target.

Since radar uses EWs that are pulsed and received rather than light waves or imaging technology, radar systems can accurately detect objects even under adverse weather and lighting conditions. Other common object detection and location technologies such as optical, infrared, and LiDAR-based sensing devices are significantly degraded. And even though radar is commonly confused with RF detection sensors because both devices detect EW signals, the way these two devices operate is quite different. Instead of sending out its own RF signals, RF sensors actively “listen” for RF signals emitted from other devices. Therefore, if an object is not emitting an RF signal, an RF sensor cannot detect that object (more on this in Part 3).

Types of Radar in Use Today

The basic concepts behind radar originated from electromagnetic radiation experiments performed by Heinrich Hertz in the late 1880s. While an early form of radar based on these concepts had limited use and functionality in the early 1900s, they were able to help sailors avoid ship collisions in inclement weather. In the 1930s, militaries became primary drivers of radar development with a focus on precision object detection.

Fast-forward to today, and there is now a wide variety of sophisticated radar technology available for numerous detection applications.

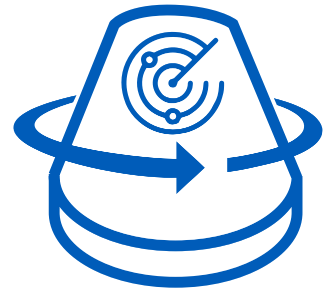
Describing radar without the use case can be challenging, so the focus here is on radar for surveillance and security applications. In this context, and to make this complex discussion of radar much simpler, we’ll divide the types of radar into **electronically scanning** and **mechanically scanning**. If it’s not a phased array, it’s likely not being used for security purposes (well, at least not yet).

Radar can also be further divided based on the way signals are transmitted and received – active versus passive. While active radar technologies will be the primary focus of this series, it is worth noting how passive radar works. Unlike an active radar, a passive radar does not have a dedicated transmitter that sends signals out for object detection. Instead, a passive radar is programmed to detect signals sent from third-party emitters - already working in the environment such as analog TV signals, FM radio signals, or digital audio and video signals. The receiver in a passive radar system can work in a variety of ways, but one way is to measure the time difference between the arrival of a signal directly from the transmitter and a signal arriving after it was sent by that transmitter and then reflected off an object. Passive radar has many excellent use cases but generally lacks the precision required when drones are the intruders.

Types of Phased-Array Radar

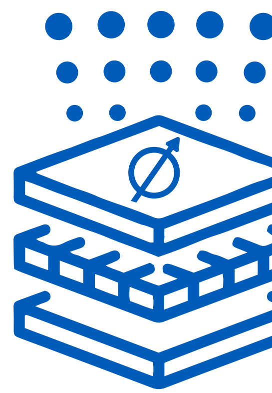
As mentioned, an active radar works by sending out EW signals and listening for a return signal that is generated when the original signal makes contact with an object. But not all active radars are created equal. There are a variety of methods for sending and receiving signals that can impact the size, weight, power, and cost (SWaP-C) as well as the performance of the radar system. Let's compare four common types of active radar.

Rotating Radar



One of the key differences between radars is how efficiently the radar transmits and receives signals. A rotating radar uses mechanical components to rotate a fixed radar beam in a complete circle (360 degrees). This severely limits the region of observation due to design compromises that must be made regarding the beam shape. In the security market, this typically results in a product that is capable of only tracking slow moving air objects in a limited elevation (vertical) segment or is focused on slow moving ground objects. As an example, consider a rotating marine radar which only tracks objects on the water surface. The rotational speed also limits how often it is possible to get an update on an object's position and therefore limits the number of possible targets and the positional accuracy that can be maintained. The fastest rotating radar rotates at 2 Hz, or 2 times per second. While rotating radars can produce very good data about movement in the airspace, the 2 Hz speed can often be too slow for maintaining optical lock or for targeting an intruder, which can slow or stop processes within an observe, orient, decide, act (OODA) loop.

Active Electronically Scanned Arrays

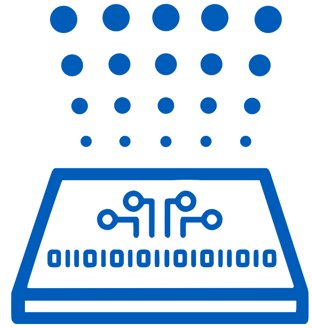


An active electronically scanned array (AESA) uses high power to generate strong signals that are highly directional and can be steered in the airspace almost instantly without physically moving the antenna. This is historically accomplished by using an expensive array of transmit/receive phase control modules evenly positioned across the array surface at standard half-wavelength separation. The number of modules in the horizontal (azimuth) and vertical (elevation) direction across the array determines the beamwidth of the antenna. Each antenna element in the array is electronically controlled to configure the module to transmit and receive energy at a specific phase. When all the "N" signals are added in phase the direction of the beam is controlled as if the array physically moved. These modules with integrated phase shifters, transmitter, and duplexing receiver are called T/R Modules. By using more T/R modules, the beam narrows and improves angular accuracy. The entire assembly of "N" phase-controlled T/R Modules is referred to as a Phased Array antenna. Since the beam can be electronically steered almost instantly to any position in the field of view, many objects (targets) can be simultaneously detected and tracked.

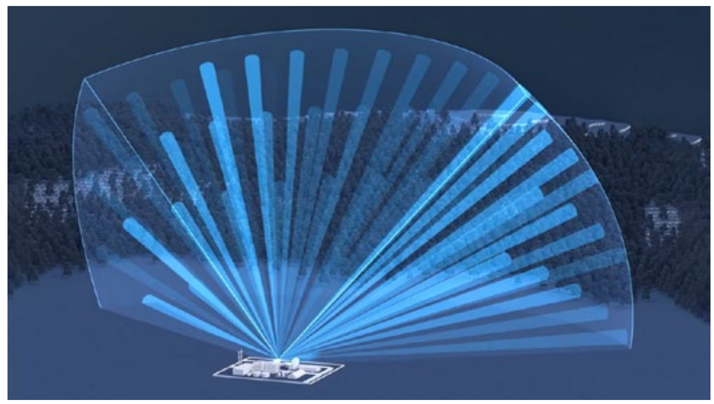
However, using more T/R modules means higher acquisition and operational costs and generally larger arrays, so there is a big cost-performance trade off required when using an AESA. As a result, AESA style radars with high T/R module count (often numbering more than 300 to 1000) are mainly used for large detection arrays in high-performance military applications such as fighter jets, while low T/R AESAs have emerged as a lower-cost commercial option, but still have high SWaP and are costly to maintain given the construction complexity.

Metamaterials ESA

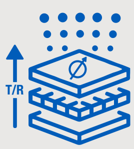
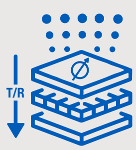
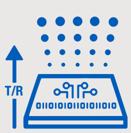
The recent development of the metamaterial ESA (MESA®) marks the first significant change in radar technology in decades. Using standard materials in a unique design, a MESA radar offers the performance benefits of an AESA without the complex mechanical limitations of traditional designs. Using commercial PCB fabrication and standard surface mount assembly techniques it is now possible to significantly reduces upfront equipment costs, maintenance costs, and overall system SWaP requirements. A phased array radar without hundreds of T/R Module phase shifters enables a range of features and functionality very similar to those advanced military designs but with the primary benefit of producing narrow beams under electronic control while only utilizing a single transmit receive module for the entire array. The metamaterial design process is scalable technically and in manufacturing to meet a wide variety of needs.



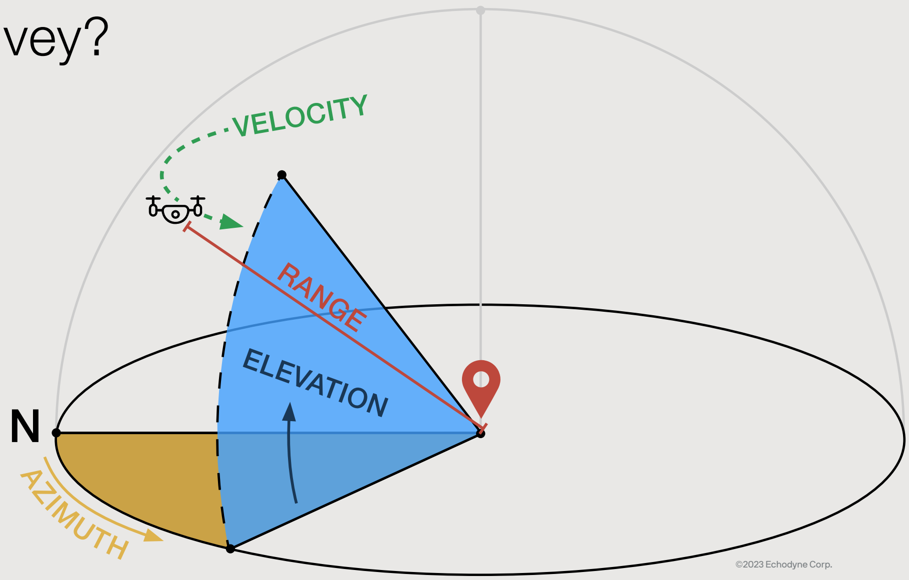
It is also important to distinguish MESA radar from some of the other commercial off-the-shelf (COTS) radar options emerging today. Most active COTS radar options are two dimensional, so the radar beam only covers a narrow elevation of <20 degrees. And in the few examples of COTS radar with high elevation coverage, they tend to lack range and precision. Many of these radars are designed for surveillance of perimeters where fence lines, obstructions, and gates with guards would dissuade intruders. MESA is a rare, fundamental breakthrough in antenna design that creates a three-dimensional radar with a very large field of view (120° x 80°, 130° x 90°). Perhaps more importantly though, MESA radar is a COTS option designed for surveillance of both the airspace and the ground. Additionally, other three-dimensional radars, like the AESAs mentioned above, may not be capable of adapting to detecting small objects, such as drones, yet even if these could, the system would still have the SWaP-C burden.



The table below shows a side-by-side comparison of the SWaP-C and performance of these four types of active radar when used for airspace situational awareness for a counter-uncrewed aircraft system (C-UAS) application.

RADAR TYPE	SIZE	WEIGHT	POWER	COST	PERFORMANCE
ESA High T/R 	★☆☆☆☆	★☆☆☆☆	★☆☆☆☆	★☆☆☆☆	★★★★★
ESA Low T/R 	★★★☆☆	★★★☆☆	★★★☆☆	★★★☆☆	★★★★★
MESA 	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Rotating 	★★★★★	★★★★★	★★★★★	★★★★★	★☆☆☆☆

What Information Does Radar Convey?



Radar is only as good as the data it conveys to the user. If the radar receives incomplete, unclear, non-actionable data, the available system data is just a dot on a map that conveys nothing but anxiety. To understand what a radar can, and should, convey, it is important to understand the following four data dimensions of radar:

- **Azimuth** – The horizontal angle of the radar beam with respect to north.
- **Elevation** – The angle of the beam with respect to the ground.
- **Range** – Distance between the radar and the target.
- **Velocity** – The speed of the target in a given direction - This fourth data dimension can be approximated by position change in time by most radars. However, precision instantaneous velocity is only possible to calculate if the system includes Doppler radar, which measures the shift in phase between a transmitted signal and the received signal.

Since an object in the path of the radio signal will cause a reflection, and that signal will bounce back to the radar's receiver, it is the return signal that contains a wealth of data about the target including the following:

- The object's size – It is important to note that the radar cross section (RCS) of the object, which is how detectable an object is, is greatly impacted by both the physical size of the target and the material reflectivity it is constructed as related to the radio wavelength.
- How far away the object is located, or the range.
- Where the object is located – The location is based on azimuth and elevation data.
- Which direction the target it is going, or orientation.
- How fast the target is traveling, or velocity.
- The objects physical motion as it interacts with the radar modulation provides characteristic signatures that can be used to classify (or identify) the object type.

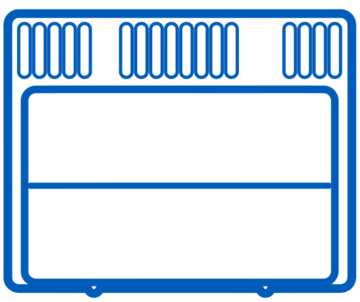
Additionally, a radar is generally programmed to search its entire field of view at a regular interval, such as every second. If an object is detected, it forms a track that then gets regularly measured with multiple beams over the course of a few seconds. This will generate different reflections on the return signals, which will help determine both velocity and direction of the object. Using this information, the object's movement toward or away from the radar, can also be determined. Echodyne radars provide TOCA (Time of Closest Approach) and DOCA (Distance of Closest Approach) in track packets to user systems which is highly valuable for prioritizing target threats. In other words, the radar reports which targets will come closest to your position and which target threats will arrive the soonest.

CHAPTER 2

Why Use Radar for Situational Awareness?

Situational awareness of movement by people, vehicles, vessels, and drones is an essential requirement for ensuring the safety of communities and gatherings as well as the success of military and national security missions. Today, there are a number of sensors and tools available for achieving situational awareness of a wide range of airborne, terrestrial, and maritime objects. This includes external data sources such as cameras, acoustic sensors, RF systems, and radar as well as tools like the UAS Traffic Management (UTM) and other pertinent data sources. So how does one know which tools are best for the application's situational awareness needs?

The short answer is that comprehensive coverage is achieved through a layered solution of sensors, software, and data to create a complete and accurate picture of the operating area. The command and control software layer, or C2, is where both sensor performance and use case differences are magnified and compounded. Sluggish data updates or poor positional accuracy may seem small, but manageable challenges are magnified when the result is optical sensors that can neither locate nor follow a drone intrusion. There are significant performance and application distinctions between the different sensor types that must be considered during planning, deployment, and operational phases.



Radar provides four key data dimensions of an object:

+ Azimuth

+ Elevation

+ Range

+ Velocity

Radar: The Baseline for Superior Situational Awareness

As discussed in Part 1, radar provides four key data dimensions of an object – azimuth, elevation, range, and velocity. This radar data serves as an essential baseline for all other tools used in the surveillance system. This precision data is necessary for other sensors to perform well. The easiest example is found in every security process: to get "eyes on object" to determine identity, risk, and further actions. Optical sensors used to identify drones and follow their flight path are cued by radar data to lock on a target, requiring data rates that match drone speed and positional accuracy to track flight path. Drone agility and speed also require highly accurate radar data flows for optical or laser-based fire control solutions.

Radar itself has many benefits including the following:

- Works reliably in all weather and lighting conditions.
- Detects all movement in the air, on the ground, or in the water at long range.
- Maintains individual privacy as EWs are used for detection, not RF signals or cameras.
- Provides velocity information when Doppler radar technology is incorporated, which is key information for quickly determining if an object is moving towards or away from the base station and how much time is available to respond, intercept, or deconflict.
- Micro-Doppler is also an essential capability for both detecting hovering drones and detailed classification of any drone type.
- Produces highly actionable data and the most comprehensive data baseline - other sensors and overall system performance all rely on radar.

To build on this last point, let's dive into details of the other sensors commonly used in conjunction with radar.

Acoustic sensors
Detect and track drones by their acoustic signature. These sensors are ideal for sensitive facilities in remote locations, but acoustic sensors will face challenges when used in locations with high background noise and are inherently range limited.

Electro-Optical/InfraRed (EO/IR)
Also known simply as optical sensors, these sensors are essential as every security process requires "eyes on object" to determine response actions. Many facilities use dozens to hundreds of optical sensors that are primarily cameras fixed to stare at the ground plane. For a counter-drone system, a pan-tilt-zoom (PTZ) optical sensor is required.

RF sensors
These sensors can be powerful tools in the counter-drone system but must be used carefully as there are potential individual privacy and legal implications. We will explore RF sensors in detail in the next chapter.

UTM data feeds
As drones take to the air for commercial purposes, their flight plans will be filed and distributed through a network of data services. This concept is called UAS Traffic Management (UTM). Having this set of known traffic available helps distinguish rogue drones from commercially scheduled flight.

A comparison of the most common detection, tracking, and locating technologies used today.

SENSOR	DETECTION AREA	RANGE	LIMITATIONS	VELOCITY DATA AVAILABLE
FIXED CAMERA	Ground only	Short range; long range is very expensive	Will not work in bad weather or poor lighting conditions and cannot detect objects in the air	No
PAN TILT ZOOM	Ground and Air	Short range; long range is very expensive	Will not work in bad weather or poor lighting conditions	No
ACOUSTIC	Air only	Short range, <500m	Requires a quiet environment	No
RF	Air only	Long range	Will not detect objects that do not emit RF signals or RF signals not included in the sensor's RF library	No
RADAR	Ground and Air	Long range	Requires FCC certification and approval to operate	Yes, with Doppler Radar

Evolving Radar to Support Additional Applications that Require Situational Awareness

Historically, high-performance radar was used solely for object detection for military and national security applications. Because national security threats have conventionally focused on high-flying missiles, bombers, and fighter jets with relatively straight trajectories or on force protection systems, such as active protection systems, these conventional radar systems have been a great fit. High-performance radar systems are rarely used for applications beyond national security though because these systems have:

- High SWaP
- High acquisition costs
- High operational/lifecycle costs

Phased arrays commonly used in military and national security applications for example are generally large and the T/R Phase Control modules are mechanical and densely packed in the array generating enormous heat requiring complex cooling systems, resulting in increasing operational and maintenance costs. These complexity and density aspects to AESA radar are realized in large maintenance windows and high lifecycle costs.

To provide a radar-like solution at the opposite end of the cost spectrum, rotating radars emerged. This relatively small and inexpensive radar technology does not use beamforming, making these systems very inefficient. While rotating radars can generally provide sufficient situational awareness when it comes to knowing if an object such as a small plane is in the area, these radars usually cannot offer details on exactly where an object is located, making them insufficient to use for security purposes. Additionally, most rotating radars provide two-dimensional coverage so these systems can only see the ground, typically at <500m. While some rotating radars can provide three-dimensional surveillance of air and ground space, the coverage is typically insufficient, and these devices cannot detect small threats such as drones.

With rapid growth in drone usage, demand for a radar solution with comprehensive object detection in new security and safety applications is emerging. Until recently, the SWaP-C of ESA radar systems and performance limitations of rotating radars were big barriers to entry for applications that require enhanced situational awareness – radar was either too big and expensive or too small and ineffective. After many years of research and significant innovation, a breakthrough low SWaP-C radar system employing a novel antenna architecture, MESA®, is finally removing these barriers. MESA radars are more appropriately tailored for new threats, like drones, and create symmetry in technology and cost between the threat and the threat detection system.

CHAPTER 3

The Current and Future Role of RF Sensors

RF detection tools are sometimes confused with radar, to the point where one might be similar with or replace the other. These systems are actually quite different! The ability to accurately distinguish between the two is becoming imperative as the need for drone detection is increasingly urgent and many organizations are considering using RF sensors for their counter-drone technology.

The general rule remains: one tool is never sufficient - layered systems are the answer.

Let's start with the differences between these two systems by looking at the method these devices use for object detection. RF sensors are passive tools that identify objects such as a drone by detecting the signal in the radio spectrum used for remote control of the drone. The RF sensor provides details about the drone itself, the signals used to communicate, and details about the operator.

Radar instead actively transmits signals in the radio spectrum. Any object located in the path of the radar signal will generate a reflected signal back to the radar. The received radar signal is rich with information about the size, shape, location, range, velocity, and orientation of the object.

While radar can offer significant information about the object, it has no means to detect or interrupt any communication to and from the drone. Since RF sensors detect the RF communication signals from the drone operator to the drone itself, it is possible to track the location of the drone operator, which can then be reported to authorities if necessary.

The Evolving Role of RF Sensors in Drone Detection Solutions

The primary reason RF sensors are currently a productive means for drone detection is a consequence of how the drone industry started and grew. One company, DJI from China, has been the dominant supplier of drones for many years, at one point having a near monopoly of the drone market. Each DJI drone sold required the customer to accept DJI's end-user license agreement (EULA), which has fine print that provides explicit permission for DJI, and users of DJI's AeroScope drone detection platform, to monitor communications between the operator and the drone. The method for DJI drones to be so easily identifiable can be changed by firmware updates or creative individual manipulation, and either are possible at any time.

One of the key reasons DJI was able to use this EULA is because they designed drone communications to use an unlicensed portion of the RF spectrum. While RF spectrum is a public good governed by national governments, the unlicensed portion is open for non-exclusive usage. For drones to grow in popularity, choosing unlicensed spectrum for remote operation removed usage charges or monthly costs, as with mobile devices. Just as any person can find and use an app to detect Wi-Fi networks and learn the fundamental technical specifics of networks in range, any company can build and operate a sensor solution to detect, identify, and interrogate drone signals operating in unlicensed portions of the available RF spectrum. A user can always find public Wi-Fi services, but VPN services are recommended because unlicensed spectrum can be hacked. A drone is basically a flying computer. Hacking a drone to make it less visible to RF tools or to manipulate the drone to use different Mobile device service is indeed the right comparative. Mobile devices are one user cost, like a drone is a cost, while a usage or recurring charge is required to use the network. The device can still access free Wi-Fi networks, but mobile networks require payment because the RF spectrum allocated for use is licensed to mobile network operators. The mobile network operator pays for and receives a license to use that portion of the RF spectrum from the national regulatory authority and then creates a service environment for customers through mobile phone plans. This user agreement with the service provider includes a degree of privacy that secures user communication from external intercept or interrogation without law enforcement investigations, legal proceedings, and court actions. And in nearly all statutory areas, only law enforcement agencies can use RF tools to interrogate encrypted wireless digital activity in paid-for services operating in licensed spectrum.

The mobile operator industry is working diligently to enable use of licensed spectrum for airborne objects, with the industry group [3GP issuing Release 17 in the summer of 2022.] This technical architecture paves the way for mobile operators to design, build, and operate communication services for drone operators. Communication services will be a critical safety component for commercial drone operators, so redundant infrastructure, professional operations, and guarantees of privacy and service quality will create significant airspace density that traditional RF tools will not be able to detect. Additionally, drone operators will be able to consider low-Earth-orbit (LEO) satellites for very low latency communications, which are also outside the scope of RF sensors.

Even with today's current use of unlicensed spectrum and a EULA that allows for some drone communication to be interrogated, the legality of obtaining (viewing) personally identifiable information (PII) about the drone operator or details about the drone, or the communications between the drone and operator remains unclear. And, in all cases, electronically or kinetically interfering with drone flight remains illegal in all cases.

There was a day when DJI's AeroScope would solve every drone problem, but that was never going to last long. RF tools will continue to play a significant role in any layered system for many years. In situations where radar data clearly identifies a drone in the wrong place and RF tools detect no object, this creates a heightened level of alert and importance of maintaining optical lock while the security processes unfold. For high-risk facilities and sensitive locations, a system of multiple layered sensors with radar as the baseline is always the best approach.
Many drones will be communicative, and defense and some national security agencies will likely retain high-performance RF capabilities in the tool shed. And, just like radar and optical and some acoustic, each sensor will be used as needed for the mission and risk profile.

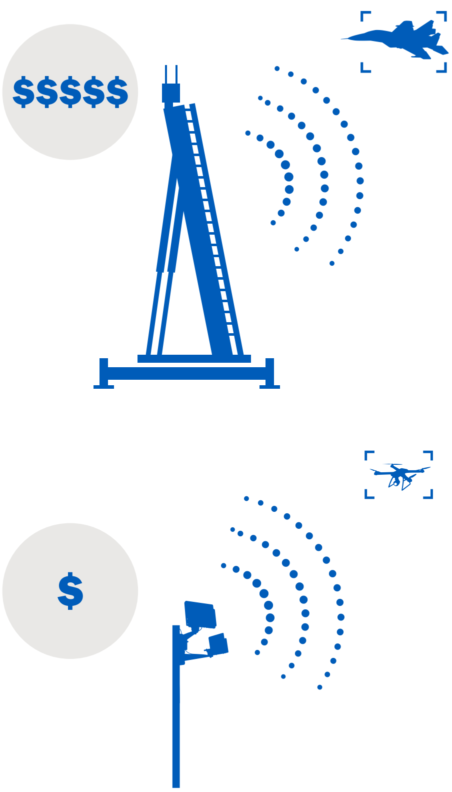
> Radar, at least high-performing radar, will detect, track, and classify any object that moves in the airspace, communications signature or not, and it will accurately cue optical sensors that maintain visual lock on suspect objects.

CHAPTER 4

Balancing Innovation and Cost Symmetry Against Newer Threats

Since the dawn of radar, defense and national security leaders have had two choices: high-performance, high-cost ESA radar or low-performance, low-cost rotating radar. The performance gap between the choices is substantial, with rotating radars generally being a poor fit for defense and national security applications. Given the existential drivers, the only true choice for these applications has been ESA radar. Because of the extensive capital investment required, high operational costs, and long development times, ESA radar advances are driven by defense requirements rather than market forces. Even today, after decades of development and effort, ESA radars are defense-restricted products with a lead time measured in years and decades.

As long as the national security need was defined by detecting and tracking missiles and large aircraft from a small handful of adversarial nations, there was little incentive to change this development dynamic. With each party confronting similar costs for offensive and defensive postures, these conflicts achieved an equilibrium of risk and reward. With the rise of non-state actors employing guerrilla tactics through access to inexpensive yet lethal tools, change is rippling through these traditional security frameworks. Rather than well-known points of origin for traditional adversaries, todays' non-state actors can appear at any location at any time. Instead of high-altitude flights with relatively straight trajectories, today's threats fly low, fast, and often without any detectable RF transmissions. Threat-detection symmetry is lost, leaving nation states unprepared for drone threats.



COTS ESA - Low Cost, Attritable, High Performance

If a non-state actor can launch a drone attack that costs less than $0.02M, the answer for detecting this type of threat cannot be a multi-million-dollar system bristling with $1+M interceptors designed for yesterday's adversary. If the adversary employs low-cost, disposable, effective weapons, then the security framework must become both more effective, attritable, and financially competitive. This shift in symmetry has prompted many defense and national security system operators to seek COTS products to regain the balance between threat and threat detection.

While there are defense and national security applications that benefit from private industry development, the idea of using COTS products in defense and national security applications is largely novel. Hunting, for example, remains a popular pastime that supports development of weapons, scopes, ammunition, and clothing. For many applications though, the opportunity for dual use is limited both by market needs and defense export restrictions, especially International Traffic in Arms Regulations (ITAR). Still, the idea of COTS in defense remains an attractive option.

For sensors that detect, track, classify, identify, and target intruders, the challenge is even greater. Outside of defense and national security, there is little dual use for traditional ESA radars or the RF tools essential to combating drone threats. It was not until recently that a true breakthrough in radar technology occurred with the development of a low-cost COTS product with ESA performance.

Let's examine how to evaluate using new COTS radars for contemporary defense and national security threats.

Evaluating Radar for Contemporary Threats

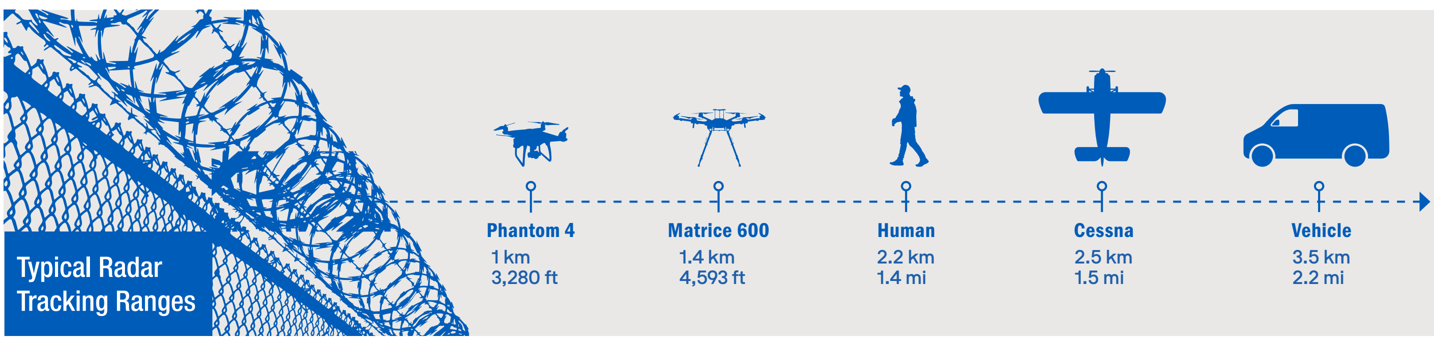
As the number of airborne objects continues to increase, the potential threats caused by drones are expanding beyond what national security organizations are responsible for monitoring. As covered in Part 1, traditional ESA radar systems are not practical options for monitoring these newer threats - it's not feasible to bring a high-cell-count ESA to a national or a mass gathering, for example. The selected threat detection system needs to track all objects of interest while also understanding where blue forces are located, or which are legitimate commercial aircraft, or who is flying near the National Mall. Selecting the sensors appropriate to so many needs is a paper unto itself. Here, we focus on evaluating radar within threat detection and response systems.

Detection Range

Every conversation seems to begin with a question of detection range, so let's start there. While many might claim range is the most important consideration, it must now strive for symmetry with the drone threat, creating a price-performance filter to range. With the size and maneuverability threats posed by drones, and especially in the context of identification and targeting, the level of precision data delivered by the radar creates another evaluation filter. Lastly, there is replacement of the radar, or its attritability - how replaceable is it and at what operational cost?

As a general rule of thumb, range is a result of power times aperture. The bigger the aperture and the more power available, the longer the range. But range is relative to the type of threat likely for a particular risk. Defense applications may consider all drone types a threat but only some small fraction will require the capabilities to detect and track Group 3 or larger drones. The idea of range, then, requires a specific drone or type of drone as the baseline. Identifying a type of drone, say a DJI Phantom 4, and requiring a certain range, say 3 kilometers, starts to sketch the evaluation criteria.

There is also the idea of range for which particular function and at what confidence interval. Some radar manufacturers will cite a detection range that is all too often well beyond actual capabilities, but that's a story for a different day. In evaluation, the relevant aspect of a cited detection range is how often will that range be achieved; this is the confidence interval. If a radar's description refers to ranges, always ask about the confidence interval. Anything less than 50 percent is a coin flip and generally means that only some fraction of that range will be achieved on a consistent basis. A range curve for drone types relative to your risk profile with the confidence interval stated should be available.



Function

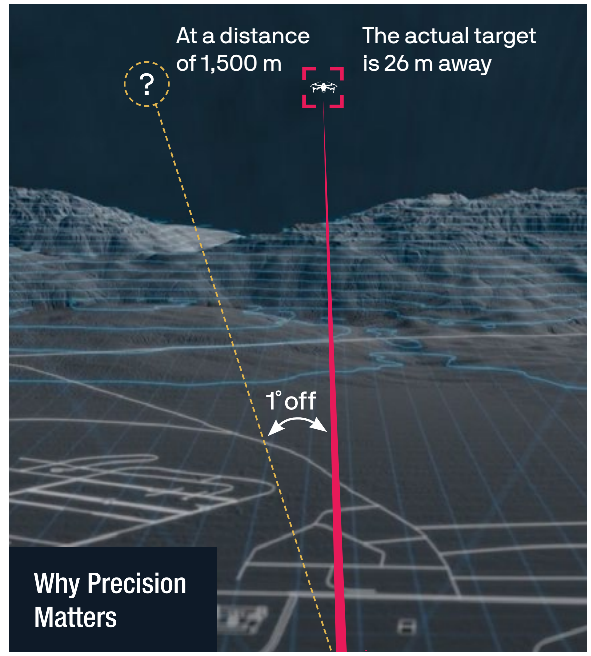
Function references resources used by the radar to acquire data pertinent to a threat detection system and actionable for system operators. Many radars will refer to "detection ranges" of certain distances. Detections are the least valuable data element produced by the radar. Only when signal processing and software intelligence determines the object should be TRACKED - classifying the object as a drone, devoting more radar resources to the intruder, providing faster position updates for slew-to-cue optical, and, where applicable, cueing kinetic mitigation systems - does the threat detection system benefit from radar in the solution. The evaluation should focus not on radar detections but radar tracks and the value of that data to other sensors and to the system.

Drones also challenge radar performance by their minuscule size and maneuverability, especially relative to traditional adversaries, risks, and threat vectors. The response to this is highly precise data delivered at high speed from the primary sensor layer, radar. Accuracy and data speed are key metrics for performance evaluation. Without high degrees of accuracy, optical sensors cannot be trained to the intruder for "eyes on object". Without high data rates, optical sensors cannot smoothly follow the intruder's flight path. In radar terms, precision is the radar's angular accuracy. Think of this as the tightness of the box around the intruding drone - the tighter the box, the more accurate the optical track, and the faster data, the more fluid the optical performance.

Accuracy

Perhaps one of the biggest new filters to consider when evaluating COTS radar solutions is accuracy on target. While generally not discussed when considering ESAs, accuracy on target is critical as data without accuracy is just anxiety, causing worry over the possibility of something being present without enough data to know if the object is actually a threat. To guarantee accuracy on target, the radar system must first be able to appropriately classify the object, suppressing false positives and negatives.

Then, the radar must be capable of maintaining a lock on the object so that other sensors and systems can use the radar data to train their focus on the object as well. This will then let the system trigger highly efficient targeting, using the least amount of munitions possible to defeat the intruder if required. The radar data serves as the fundamental baseline data that makes everything else in this chain work. With this type of high-fidelity data generated by a COTS radar solution, performance will greatly increase while costs remain low.



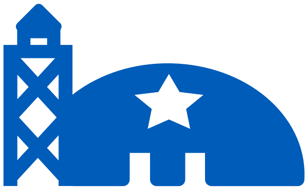
Flexibility / Malleability

It is also important to evaluate which features can be tweaked in newer software-defined radar systems, leading to even greater accuracy. With software-defined radar systems, users can adjust waveform, beam schedules, and other configurations of the system to adapt to operator, location, and mission requirements. With a range mask for example, a user can program the radar to only communicate data for objects detected within a certain range, such as < 3 km for a certain volume of airspace. The radar will continue to detect objects at greater distance but will not clutter the user interface, allowing operators to focus on the pertinent data.

Capital / Cost

It's also important to consider both upfront capital and lifecycle costs. This involves looking at both maintenance and operational costs, including if downtime is required to maintain the system and how this would be handled in mission-critical scenarios. A unique cost-related characteristic of COTS equipment is that COTS equipment is attritable, meaning if it is destroyed for any reason, it can typically be replaced quickly and easily without significant monetary or time investments.

Let's now look at how to apply this evaluation criteria to three key areas that need radar to monitor these fast-evolving new threats – defense, government, and critical infrastructure.



Radar Considerations for New Threats to Defense Applications
Today's rapidly evolving drone threats are now requiring C-UAS technology be incorporated across a variety of defense applications such as base security, portable ISR, and remote weapons stations (RWS). While range is still a driver in monitoring for drone threats, data fidelity makes a huge difference in performance and outcomes. Therefore, radar that provides superior situational awareness of all movement – people, vehicles, vessels, and drones – is a crucial component for a layered threat detection system for defense applications. This is because the C2 software needs to receive highly accurate data from all aspects of the system to present mission operators information pertinent to the decision and action process steps. Plus, maintaining optical lock on fast, agile intruders is necessary for all processes, making accuracy on target a key consideration for new or supplemental radar solutions.

Additionally, as the number of new threats that are not multi-million-dollar jets and missiles continues to increase, the way defense organizations evaluate threat detection costs also needs to shift. For detecting newer drone threats, the large, multi-million-dollar ESAs defense organizations are accustomed to are not a great fit. Instead, to create capital symmetry between threat technology and threat detection systems for defense applications, it is much more practical to consider a high-performance, low-cost, attritable COTS radar.

Radar Considerations for Government and High-Risk Civilian Applications
Drones are also a growing problem for federal and state agencies managing public safety. While many of these agencies are used to using ground surveillance equipment, radar can offer a tactical advantage by providing public safety teams with fast, high-fidelity airspace situational awareness data. Instead of requiring long-range radar systems, these applications need radar systems that provide high accuracy even when buildings and other structures in these environments create chaotic and confusing landscapes. Instead, newer short-range radar systems thrive at providing high-accuracy data in these more crowded environments. Additionally, capital symmetry, as mentioned in the prior section, is also important to how these organizations evaluate costs.

Radar Considerations for New Critical Infrastructure Protection Requirements
For critical infrastructure sites such as airports, ports, electric generation and transmission plants, water and wastewater treatment facilities, chemical, oil and gas, and nuclear sites, range becomes a much softer requirement while accuracy is pivotal as the drone problem scales. Many of these facilities have traditionally relied on ground security systems as air threats were historically not considered a threat; yet this is quickly changing. Since these organizations already have effective ground monitoring tools in place, when bringing in new tools such as radar, integration with the information provided by the existing ground monitoring systems is critical. Additionally, for these systems to work well together, precision radar must be the data-driver for a variety of functions such as accurate and timely control, slewing optics, sounding alarms, reducing false alarm rates, and making better decisions.

CHAPTER 5

Enhancing Layered Threat Detection Solutions for Defense Applications with Radar

The United States Department of Defense (DoD) has a mission to provide military forces with the equipment needed to deter war and ensure our nation's security. Achieving this mission has become progressively more complex as adversaries increasingly use non-conventional tools, like drones. Continuous innovations in robotics and autonomous technology constantly raise threat levels, extending the threat perimeter from surface to sky, while also reducing the costs of deploying destructive and life-threatening missions. Yet, the large, fixed radar systems most defense organizations are invested in were developed for tracking traditional large, high-energy-producing targets such as airplanes, missiles, and large vehicles, not newer adversaries such as fast, low-flying drones.

As the threat landscape our nation faces evolves, defense agencies are identifying drones as a serious risk to forces and the homeland. Since traditional multi-million-dollar electronically ESAs are not designed for tracking these new low-level fast-moving adversaries, the DoD now needs a variety of tools to provide comprehensive threat detection and situational awareness.

Even if ESA radars were suited for drone detection, these expensive systems would not be a practical option for tracking these low-cost threats. In addition to the expense of acquiring ESA radar, ESAs are also costly to maintain and often require downtime for maintenance. While this downtime may be acceptable when monitoring for sporadic threats such as large aircrafts or missiles, given the large number of drones operating today, downtime like this may put warfighters at risk, which is not acceptable.

To establish better financial symmetry between threat and detection and aim for uninterrupted coverage, defense organizations initially looked to incorporate RF sensors into their solutions. While these technologies could track some of these newer threats, these solutions had large gaps in coverage and performance, such as the inability of RF sensors to track dark drones, or drones that do not emit RF signals. It was not until recently that a true breakthrough in radar technology that could meet the needs of defense organizations occurred with the development of a low-cost COTS product with ESA performance – MESA radar.

Driving a Layered Threat Detection Solution with New MESA Radar Technology

For comprehensive coverage and optimal situational awareness, a layered system consisting of multiple sensors with MESA radar as the baseline is the best approach for a variety of defense applications. Let's look at how this type of system is optimized to track and mitigate some of the newest threats the defense industry is facing.

Counter-UAS

Group 3 and larger drones represent increased lethality with enhanced electronic warfare and intelligence, surveillance, and reconnaissance (ISR) capabilities. With speeds approaching 150 mph and hundreds of miles of range, relatively inexpensive drones as loitering munitions represent a significant threat to force protection and battlespace dominance. When it comes to mitigating these threats, protecting the warfighter is the overall goal. Therefore, military personnel need technology for C-UAS detection that will allow for the highest level of protection.

MESA radar is the only system capable of tracking the low, fast, and irregular flight patterns these threats take, including dark drones that do not emit RF signals. Additionally, since Echodyne MESA radar solutions operate in the Ku band and include micro-Doppler, these systems can provide comprehensive coverage of micro-movements that systems without micro-Doppler and those that operate in the S band cannot. This includes detecting small (Group 1 or Group 2) hovering drones and performing prop detection, which is the detection of the tiny sound waves small drone propellers create in the air.

Base and Force Protection
Resilient base security in permanent or temporary locations is essential for achieving mission objectives and providing force protection. Multi-mission radars that detect and track all movement on the ground and in the air across a large field of view are essential components for developing a 3D perimeter surveillance architecture. Forces are not always located at a base though, making it necessary to have a small, light-weight radar solution to protect forces when they are outside the base.

Portability is needed for those in the tactical field to achieve situational awareness to the best of their ability. Applications of this that can be done using MESA radar include the following:

- **Counter Rocket Artillery and Mortar (CRAM)** – Radar is placed on moving vehicles to detect where a rocket or artillery round originated from to let forces know if something else is coming and if they need to move or brace for impact.
- **Active Protection Systems (APS**) – Radar is mounted on a vehicle and has sense-and-detect capability as well as soft kill and hard kill effectors to mitigate threats.

Portable ISR
Group 1 or 2 drones can be an enormous threat when it comes to collecting intelligence or watching the enemy to create a mitigation plan or battle strategy. High-performance radar that is also easily portable is a critical asset in tracking these threats so that forces can develop an effective mitigation strategy.

Using High-Fidelity Radar Data to Trigger Calculated Threat Responses

Data fidelity makes all the difference to mission success. In the field, there is no time for data to be recompiled or examined by experts. More accurate data rapidly ingested creates better systems and safer outcomes. One key to ensuring data accuracy is using software-defined filters to ensure acquired data is accurate enough to be immediately actionable. The data must be as clear as if a user had their own eyes on the target so they can make rapid data-driven decisions in as close to real-time as possible.

For example, with highly accurate data, layered systems can queue and slew to threats based on the radar data and classification of the detected target. The data must also continue to accurately feed to the system so the radar can remain queued to the target to create a more visible and accurate mitigation response. This may include a kinetic response, which requires the utmost information accuracy to properly target the threat, or a non-kinetic response, which may include jamming a drone, taking over a drone, or capturing a drone.

The Advantages of Making Radar Accessible to All Military Members for the Long Term

Legacy radar systems require users to undergo extensive training for effective operation. MESA radar technology is much simpler and more user friendly, making it much easier for more people to be fully capable of using these systems. MESA radar technology can quickly empower the warfighter to be an expert in ground to air reconnaissance, surveillance, and air domain awareness. Plus, Echodyne's software-defined MESA radar can very quickly integrate with all government-provided C2 systems, reducing the time it takes for a MESA radar to be fully functional and providing data within an organization's already established system.

Not only is usability simplified with MESA radar, the SWaP of the radar versus an ESA radar is significantly decreased, opening the possibilities for using radar in many applications and areas where it could not be used before. Since MESA radars are a low-cost COTS product, these systems are attritable. This means redundancy can inexpensively be added to systems in the field. If a panel is destroyed or broken, maintenance can replace the panel and still have the system running, unlike an ESA where the entire system needs to be taken down for a repair, causing a gap in protection.

Finally, since Echodyne's MESA radar technology operates in the Ku band, there are less latency issues than radars operating in the overcrowded S band, resulting in faster and more accurate data. By planning ahead and designing radar operations in the Ku band, these systems are inherently prepared for long-term operability.

CHAPTER 6

Improving Situational Awareness for Government Security Applications with Radar

For decades, government security devices used for border patrol, public safety, and asset security have relied mainly on fixed position cameras, video surveillance, and RF sensors. This combination of monitoring tools typically provides decent ground coverage, but very little air coverage for most scenarios. As threats continue to multiply in dangerous and creative ways, especially as drones have become inexpensive to acquire, easy to operate, and simple to hack, gaps in coverage for these new aerial threats exist when using fixed position cameras, video surveillance, and RF sensors.

Even if a ground sensor, such as an RF sensor, does have some ability to provide aerial monitoring, drones can be made nearly invisible to these sensors. Plus, these agencies are also facing demands to multiply ground surveillance range without raising individual privacy concerns. These two needs can only be met by adding radar to these layered threat detection solutions.

While the SWaP-C of traditional radar systems prohibited government organizations from enhancing situational awareness with radar, a recent breakthrough in radar technology has changed this. New MESA radar – a low-cost COTS product with ESA performance – is finally bringing the benefits of radar technology to applications outside traditional military and defense use cases. Let's look at how several common government security applications can experience the benefits of incorporating MESA radar into their solution stack.

Incorporating Radar into Border Security Solutions

Border security is a critical part of ensuring our nation's safety. At 5,525 miles, the United States shares the longest international border in the world with Canada. The US also shares the busiest border in the world with Mexico (1,951 miles). Protecting the 7,476 miles of border shared with our northern and southern neighbors is a big task as there are a number of pedestrian and airborne threats to monitor for.

In recent years, threats have become more sophisticated and the number of ultralight manned and unmanned aircrafts crossing borders has increased dramatically. For example, small, manned aircrafts are performing partial drops of weapons and narcotics at facilities across borders and drones are surveilling borders to find gaps in border patrol activity to determine where people can potentially cross undetected.

Instead of solely using optical and RF sensors for ground surveillance and some air surveillance, the Department of Homeland Security (DHS) now needs comprehensive tools that provide three-dimensional monitoring of all air and ground threats. By adding MESA radars to the stack of solutions, the DHS is greatly increasing situational awareness and border security intelligence. MESA radars are now providing the data foundation necessary for the DHS and border security to perform advanced classification and take next steps such as slewing long-range optical sensors for better object identification or taking additional mitigation steps such as jamming of a drone. Plus, MESA radars are proven to operate reliably without interruption for their lifetime, a crucial factor since these systems must be deployed in remote areas.

Enhancing Public Safety and Asset Security with Radar

Drones are also a growing problem for federal and state agencies charged with public safety for VIP events and sensitive assets. These organizations must have a defensive strategy in place to protect these assets and personnel from drones sent to cause harm as well as drones seeking intel on sensitive assets. This is challenging to do with tools such as RF sensors without potentially impacting individual privacy rights or interfering with existing wireless signals, especially as drone operations move from unlicensed to licensed portions of the RF spectrum.

Incorporating radar into the solutions stack provides a tactical advantage for keeping communities safe without causing any privacy concerns. The radar system enhances defense against all types of threats by both supplementing existing ground security systems and providing comprehensive air domain awareness. Public safety teams now have fast, high-fidelity airspace situational awareness data without causing any privacy concerns. These systems are also more comprehensive as radar can track dark drones, which RF sensors cannot do.

Since MESA radar is offered in a small form factor, there is a lot less weight for the end user to incorporate, and the system is easy to configure and move. This offers a strategic advantage as users do not have to lug around massive amounts of gear and these systems can easily be moved between locations as needs change.

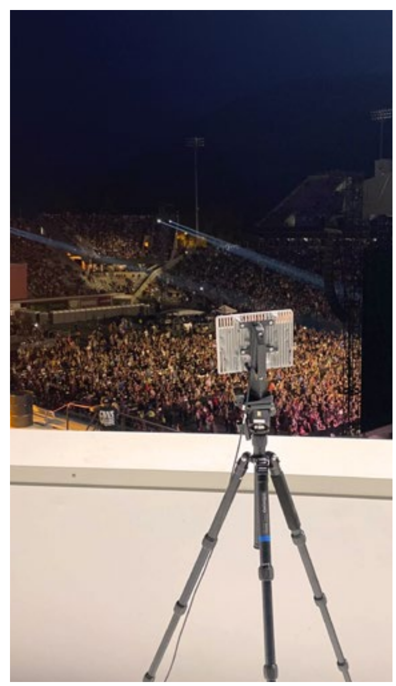
Improving the Safety of Drone as First Responder Programs

Beyond monitoring for nefarious drones, radar is also a critical component for public safety agencies such as law enforcement or fire departments who are planning or operating Drone as First Responder (DFR) programs. DFR programs are meant to have drones serve as an "eye in the sky" that provides additional information about a situation such as an accident, crime scene, or fire. This can be especially useful in scenarios that are especially dangerous for human first responders such as those involving hazardous materials, unpredictable weather, or locations that are difficult to access.

As part of this program, these agencies must ensure the airspace where the drone will fly is clear, especially if the drone will launch from an area where low-flying aircraft, such as helicopters launching from a hospital's Flight for Life helipad, may be common. For these beyond visual line of sight (BVLOS) applications, MESA radar can serve as an excellent solution for monitoring the air space and providing easy-to-understand data that will greatly enhance the safety of these operations.

Creating Counter-Drone Solutions for Government Applications by Adding Radar to the Solution Stack

Whether securing fixed assets or a temporary perimeter for a VIP event, COTS MESA radar solutions bring the gold-standard in radar performance to government agencies seeking comprehensive 3D ground and air situational awareness. Therefore, a counter-drone solution stack used by any government agency should now include radar, a camera/optical sensor, an RF sensor, and possibly other types of sensors depending on the specific requirements of the situation.



In addition to serving as the baseline for providing object data, radar will also enhance each of the other sensors in the solution. The radar and RF solution can work together to hear or see the object so that the radar can lock on the target and then slew and queue the camera to then identify the object – is it a bird or an actual threat like a drone? Then, depending on how the object is classified, the information can be escalated to the appropriate person for mitigation, or the system can trigger a further action.

Already in use across nearly all U.S. federal agencies, MESA radars provide on-the-move capabilities to extend field operations, creating an information advantage for government agencies charged with protecting public safety and a variety of assets.

CHAPTER 7

Enriching Critical Infrastructure Security with Radar

It's no secret that our nation's critical infrastructure, including facilities such as airports and ports, electric generation and transmission plants, water and wastewater treatment facilities, correctional institutions, and chemical, oil and gas, and nuclear sites, face a variety of adversarial threats. Historically, these facilities only needed to be concerned with tracking potential terrestrial adversaries. However, as drones are becoming more accessible and more common, threats to these facilities have taken to the skies.

Drones are interrupting airport operations, with the Federal Aviation Administration (FAA) now receiving more than 100 reports per month of uncrewed aircraft system (UAS) sightings. The DHS and FBI are also seeing more incidents of drones attempting to damage electric generation and water/wastewater treatment facilities or posing cybersecurity threats to corporations or large data centers. While traditional critical infrastructure security systems consisting of devices such as cameras and thermal sensors, and maybe an RF sensor or human guard, have provided adequate critical infrastructure security in the past, these systems are not sufficient for detecting new aerial threats.

Facilities now need critical infrastructure security solutions that provide enhanced perimeter security coverage both of the air and at greater distances on the ground. This requires a layered solution that includes enhanced COTS three-dimensional radar for simultaneous ground and air surveillance, or focused detection in the highest-risk threat vector. High-performance radar provides the most accurate threat detection data , boosting performance of other sensors in the security stack.

Why Critical Infrastructure Security Systems Need Radar

Whether curious, clueless, or nefarious, a person, vehicle, or drone can create disruption at critical infrastructure sites by causing harm to people, assets, and operations. And for some sites, a localized disruption can have far-reaching consequences – imagine the impact to households, traffic flow, health centers, and businesses if an energy transmission site servicing a major metropolitan area goes down due to a threat disturbance.

For critical infrastructure facilities with security solutions deployed at the perimeter, threat visibility may only extend a few feet beyond the fence line and only provides two-dimensional ground-based threat detection. The effectiveness of a short-distance perimeter solution further diminishes at night and in bad weather. Even if an extended or night visibility camera is a part of the system, the optical devices will likely struggle to lock on target and maintain visibility when viewing conditions are not optimal.

Some facilities are enhancing perimeter security by adding aerial monitoring capabilities to their critical infrastructure security systems using RF sensors – and this is a good step. However, RF sensors present several gaps and issues including:

1. The inability to detect dark drones, also known as 'silent drones,' as these devices do not emit RF signals.
2. The need for multiple RF sensors to achieve threat position accuracy by way of signal triangulation.
3. Possible elevated false-positive rates in urban environments prompted by daily-use devices also emitting RF signals.
4. Potential concerns over RF "listening" as it pertains to individual privacy rights.

While RF sensors can lend value as a complementary detector, a comprehensive layered solution for critical infrastructure requires technology that detects everything that moves on the ground or in the air, even in the absence of an RF control signal. With this in mind, radar is the most effective detection technology available for critical infrastructure security. Radar provides precise location and tracking data that can be used independently and in concert with other sensors to improve security outcomes.

The Benefits of Adding Radar to Critical Infrastructure Security Solutions

For high-risk critical infrastructure sites, the most effective solution for accurate threat detection begins with radar plus PTZ cameras integrated with the security team's preferred/recommended C2 and/or video management system (VMS) software. This combination of technology delivers highly accurate all-weather, 24/7 detection of air and ground targets, visual confirmation of detected targets, and synced recording of an object's location data and observed behavior.

The combination of radar detection confirmed by PTZ reduces noise and false positives and fills a gap that would otherwise require a dedicated team member to sort false positives from true targets. In addition to providing comprehensive situational awareness, the recorded track data and video can be used to forensically dissect an incident or for prosecuting criminal activity. And for sites with higher risk and budgets to support parsing detection technology by type of threat or approach, adding RF detection, below or above ground audio sensors, or other technology may be appropriate.

Radar is Now an Accessible and Valuable Solution for Critical Infrastructure Protection

Despite the proven value of radar for defense and national security applications, using traditional phased-array radar systems for critical infrastructure security has never been a practical option. Not only is the cost and size of these systems prohibitive, but phased-array radars are designed for much longer-range detection needs and experience challenges with identifying newer drone threats.

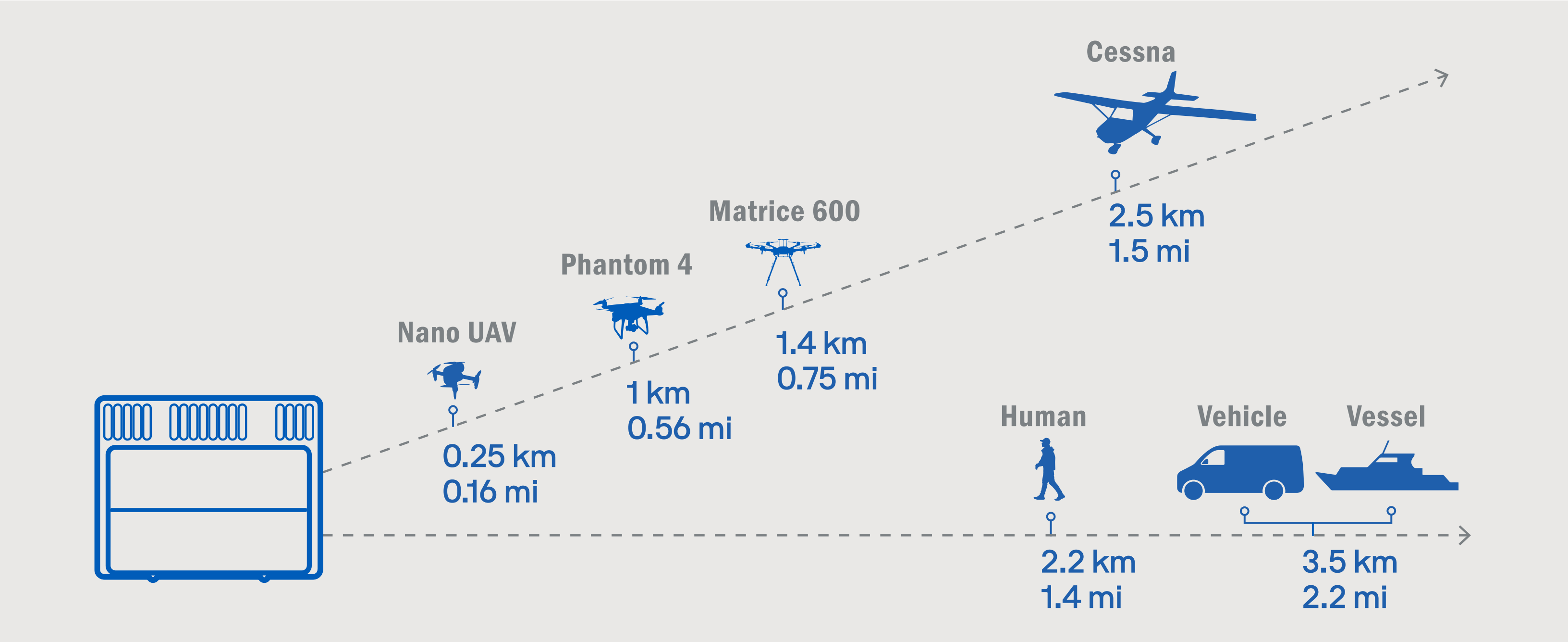
But radar technology has rapidly advanced in the last few years. While there are now several small form factor radar options available that meet basic use case requirements and budget constraints of critical infrastructure sites, most of these options underperform when it comes to providing dependable, comprehensive airspace situational awareness.

However, a new and innovative design approach called metamaterials has created a breakthrough in radar technology by reducing size, weight, power, and cost (SWaP-C) while retaining accuracy and relative detection distance. The MESA radar is the size of an iPad, weighs less than 5 lbs. and packs a power-punch, delivering detection capability symmetrical with drone technology advancements, critical infrastructure use cases, and security budgets.

Why MESA Radar is the Optimal Option for Critical Infrastructure Protection

For critical infrastructure sites seeking to expand their threat detection capabilities, choosing a radar that augments current security solutions and expands situational awareness as threats evolve is paramount. MESA radar is unique and addresses these points by providing three-dimensional coverage, detecting everything moving on the ground and in the air, and integrating with existing C2, VMS, and sensors.

MESA radar optimizes existing solutions and creates new options for maturing security solutions. For example, a site that has historically placed static cameras at 20-foot intervals along a fence line for defensive coverage can move to a radar + PTZ camera solution for broader coverage with fewer devices. This ability to use technology as a productivity multiplier is particularly important for critical infrastructure security teams that are stretched thin and challenged to do more with less staff and budget.



Dual Domain Detection
While other radars may detect one type of threat better than the other, MESA radar delivers equal efficiency, accuracy, and value in both ground and air domains, and at the same time for multiple types of threats (drone, human, vehicle, or boat). It also has a detection range that is much greater than other radars in its weight class and outcompetes sensors such as cameras by maintaining target lock and operating dependably regardless of weather or lighting conditions.

Micro-Doppler
Most effective radar systems, including Echodyne's MESA radar, utilize micro-Doppler to capture a fourth data dimension – velocity. This provides users with the speed of a target in a given direction in addition to a target's azimuth, elevation, and range. Processing the micro-Doppler frequency shift is important because it helps radar software distinguish drones from birds, for example. Micro-Doppler also makes it possible to detect hovering drones near or far from a facility and as the drone approaches. This is critical for sites that, in addition to risk of physical breach, have a moderate-to-high-risk of sensitive data being compromised or stolen using a hovering drone carrying a surveillance or data theft device.

Data Fidelity
Echodyne's MESA radar produces extremely accurate data which is why it has become a preferred ultra-low SWaP radar for defense and national security missions. The fidelity of the radar data is also ideal when using that data to slew other devices, and when seeking to get more from existing lower-functioning sensors. For example, if a critical infrastructure team wants to use existing or lower-cost camera equipment, MESA radar paired with the right video analytics platform will boost operational effectiveness by aiding in dual verification without the need to upgrade existing camera systems. This is a value for security teams who are closing security gaps and assessing risk while developing plans for future-state security system enhancements.

Open-Source Software
Echodyne MESA radars are an open platform that utilize application program interfaces (APIs) to request different datasets, which makes it simple to integrate with other sensors and call different data types. Radar data can then be streamed into the fusion layer. There, data from multiple sensors is integrated before being sent to your C2 or VMS software to realize the output of the data, such as slewing a camera. The rapid data exchange rate possible with this radar system eliminates the slew lag common in many conventional, small form-factor radar units. The result: cameras slewed using MESA radar data are more likely to retain target lock, seamlessly, throughout an incident.

As discussed throughout this eBook, radar is a critical sensor for modern security teams seeking to protect, defend, and optimize their efforts in a changing threat landscape. Radar generates precise geolocated data to accurately and reliably detect, classify, and track multiple threats simultaneously. MESA radar builds on this with the ability to detect all ground and air threats accurately and simultaneously from the same panel. Plus, radar is designed to enhance all other sensors within the layered solution. With the exacting position and track data radar provides, security teams responsible for defense, government, and critical infrastructure applications can thoughtfully observe the behavior of potential threats and calculate a suitable and timely response.

About Echodyne

Echodyne, the radar platform company, is a U.S. designer and manufacturer of advanced radar solutions for defense, government, and commercial market applications. The company's proprietary metamaterials electronically scanned array (MESA®) architecture is a rare breakthrough in advanced radar engineering, leveraging an innovative physics-design approach, Echodyne's MESA radars use standard materials and manufacturing processes to shatter unit cost barriers for high performance radar. The result is a solid-state, low-SWaP, exportable, commercial radar with advanced software capabilities that delivers superior performance, unparalleled data integrity, and exceptional situational awareness.

For more information, please visit: Echodyne.com.

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