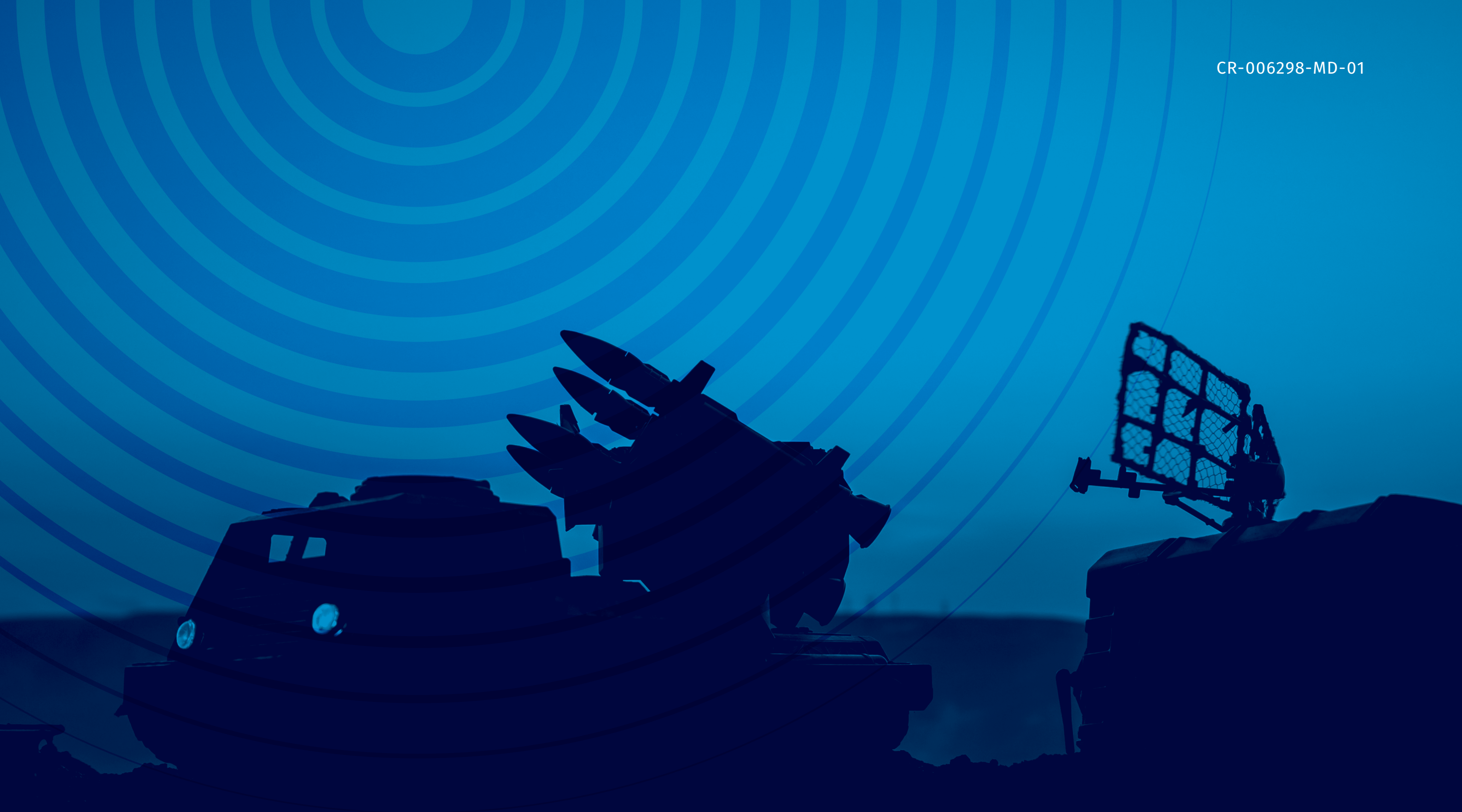

CR-006298-MD-01

PASSIVE RF DETECTION FOR

INTEGRATED AIR DEFENCE SYSTEMS (IADS)

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CRFS

EXTRAORDINARY
RF TECHNOLOGY

EXECUTIVE SUMMARY

Passive Radio Frequency (RF) systems significantly strengthen Integrated Air Defense Systems (IADS) by providing silent early warning and precise geolocation of airborne threats. These systems enable operations under EMCON and can seamlessly integrate into layered defense architectures located in active war zones, Forward Operating Bases, and fixed national infrastructure. A flexible sensor network can create an invisible air defense structure, delivering persistent, scalable, and cost-effective air surveillance.

In an Electromagnetic Operating Environment (EMOE) characterized by the enemy denying and degrading spectrum, passive RF provides the resilience that modern IADS require.

INTRODUCTION

"He who controls the air controls everything" remains a central tenet of modern military doctrine. The focus may have shifted from control as the only objective, but air power's decisive impact on a conflict remains steadfast. Yet, while air superiority remains vital, today's conflicts demand more than aerial dominance—they require understanding and control of a contested and congested electromagnetic spectrum.

To deny the enemy from gaining air superiority, Integrated Air Defense Systems (IADS) play a pivotal role in building robust Air Defense Identification Zones (ADIZ), protecting critical infrastructure and military assets, and conducting Defensive Counter-Air (DCA) operations. In these systems, spectrum awareness is paramount.

Therefore, a strong IADS is multi-layered and multi-sensor, capable of detecting all signals of interest, helping operators to identify platforms. By integrating passive RF sensing into its architecture, an IADS extends its Electronic Support Measures (ESM) capability—enabling wide-area electromagnetic surveillance beyond the reach of search or tracking radar.

Most importantly, passive RF sensors give operators time and decision space. They can act as an additional early warning threat detection system that augments radar and other sensors, validates threats, operates passively without emitting RF, allows teams to operate under EMCON, and, ultimately, increases the chances of survivability.

CRFS' RFeye technology is interoperable, scalable, modular, and automated. It reinforces the invisible backbone of air defense, helping ensure that airspace is never left uncontested because "the power of an air force is terrific if there is nothing to oppose it."

"A STRONG IADS IS MULTI-LAYERED AND MULTI-SENSOR, CAPABLE OF DETECTING ALL SOIs"

HOW RF TECHNOLOGY HELPS OVERCOME CONTEMPORARY IADS CHALLENGES

1. Successful operation in a contested and congested EMOE

Few Western forces have faced an Electromagnetic Operational Environment (EMOE) as contested and congested as Ukraine's, and IADS were not originally designed to operate in these environments. Adversaries are actively hunting air defense systems with ARH (active radar homing missiles) and jamming comms and radar. Enemy SIGINT operators intercept emissions for targeting and intelligence purposes. Meanwhile, spectrum fratricide further risks friendly C2 and radar. Downtime is not an option—air defense systems must remain active and agile in these conditions.

Passive RF technology equips operators with a real-time understanding of their own electromagnetic signatures, enabling active spectrum deconfliction and discreet operations while operating under EMCON. With wideband frequency capability, the technology can hunt threats transmitting on unconventional frequencies or using hard-to-detect waveforms that evade library-based systems. This capability delivers early detection and enables rapid EW reprogramming, ensuring persistent situational awareness in contested and congested EMOE.

2. Multi-layered threat scenarios

Modern air defense must contend with a saturated threat environment comprising more than just missiles and tactical aircraft. Low-cost FPV drones have demonstrated that small, agile UAS can destroy large IADS capital assets (e.g., radars) with minimal investment. Alongside these, loitering munitions, drone swarms, and targets with a low-RCS (radar cross section) all operate at varying altitudes and speeds, all of which have electromagnetic signatures. IADS must defend against these high-volume saturation, low-cost threats that take advantage of the cost disparities compared to expensive interceptors. Without integrated, layered sensors (including passive RF technology) capable of detecting, geolocating, and tipping and cueing other sensors, modern IADS will not optimally achieve extensive coverage and cost-effective battle management.

NATO policy states that the air surveillance capability must consist of "a combination of a wide range of active and passive, static and deployable, military and civilian networked sensors employed to cover all ranges and altitudes."

3. Exploiting gaps in enemy EMCON

Even the most exquisite, advanced stealth platforms must emit RF signals via data links during networked operations. These emissions create exploitable windows for passive RF sensors to detect, geolocate, and monitor stealth assets. Doing so negates stealth protection and enhances IADS targeting accuracy.

By capitalizing on these unavoidable RF signatures, RF technology converts stealth platforms' communication dependencies into vulnerabilities.

A MULTI-RANGE PASSIVE RF AIR DEFENSE NETWORK

Multi-range detection for individual bases

Passive, modular, scalable, interoperable RF technology offers multi-range capability for IADS.

Long-range air defense systems—beyond 50 km (31 miles)

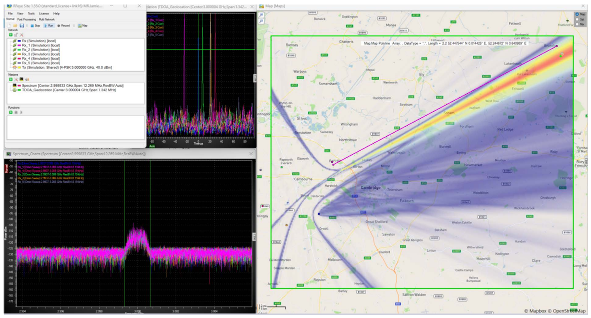
The deployment in the image below shows a real RFeye Node network using five RFeye Nodes distributed across the UK. The image shows RFeye Site (CRFS' real-time spectrum monitoring and geolocation software) detecting ADS-B, an aircraft surveillance technology. The different colors highlight signals emitted by individual aircraft.

This detector-based solution is designed to automatically detect and geolocate specific signals (ADS-B in this case) each time they are received by the sensor network. CRFS' RFeye software supports detector-based 3D TDoA, triggering signal detection and geolocation workflows the moment a matched signal is identified.

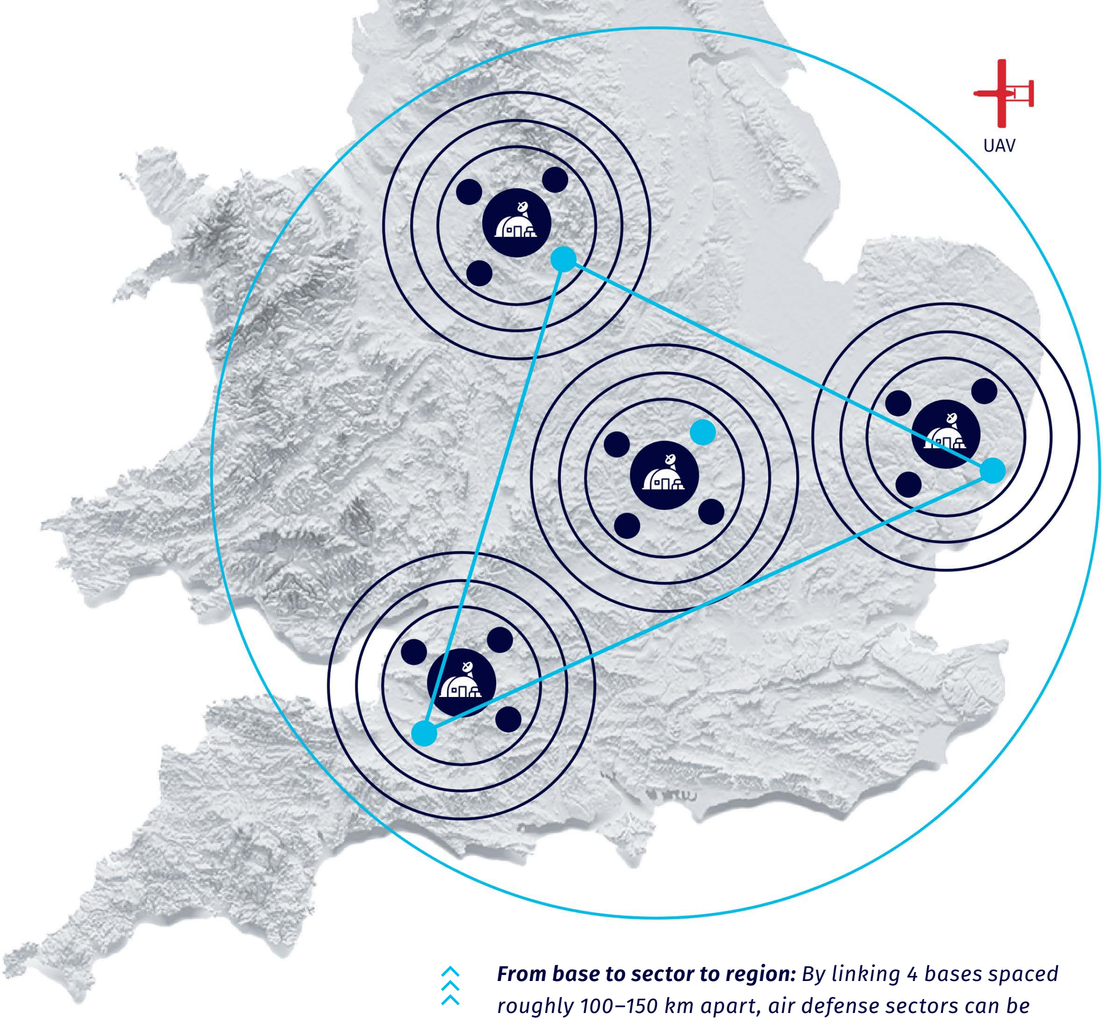
Detectors can be configured for any signal type, including frequency-hopping and hard-to-detect signals, providing automated signal intercept capability.

Medium-range GBAD—up to 50 km (31 miles)

The deployment in the image below shows a simulated RFeye Node network using six RFeye Nodes distributed across Cambridgeshire. The image shows RFeye Site (CRFS' real-time spectrum monitoring and geolocation software) detecting a signal at 3GHz with a power level of 40dBm, thought to be emitted from an ISR drone.



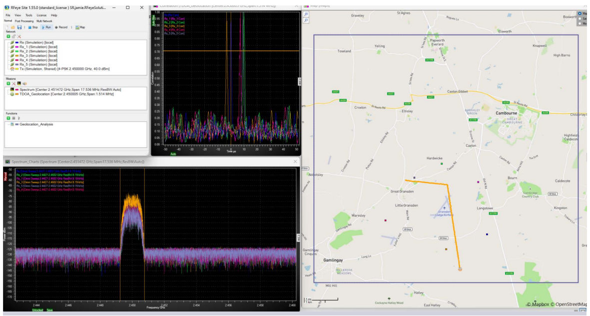
The software uses 3D TDoA to detect the signal at an altitude of approximately 2km and a distance of approximately 50km (26 miles) from the closest RFeye Node.



__From base to sector to region:__ By linking 4 bases spaced roughly 100–150 km apart, air defense sectors can be joined to provide a very long range regional integrated air defense system. Please note the map is not to scale.

Short-range SHORAD—up to 10 km (6 miles)

The deployment in the image below shows a simulated RFeye Node network using six RFeye Nodes distributed across Cambridgeshire. The image shows RFeye Site (CRFS' real-time spectrum monitoring and geolocation software) detecting a signal at 2.45GHz with a power level of 20dBm, thought to be emitted from a commercial DJI drone.



The software uses 3D TDoA to detect the signal approaching the sensor network and then tracks it as it flies. The signal is approximately at an altitude of 100 meters.

Extending range

Fixed RFeye Nodes and RFeye Arrays can be complemented with additional rapidly deployable sensors on manned or unmanned systems to increase the range of an air defense system—from short-range counter-unmanned aerial systems (c-UAS) to long-range ground-based air defense systems (GBAD). Flexibly deploying more sensors as required will help achieve optimal baseline configurations for the specific mission or threat.

From base to sector to region

By linking 4 bases spaced roughly 100–150 km apart, air defense sectors can be joined (shown above). This takes advantage of the sensors' multi-mission, multi-user functionality by linking assets from different air defense systems located in diverse sectors to provide a very long range regional integrated air defense system.

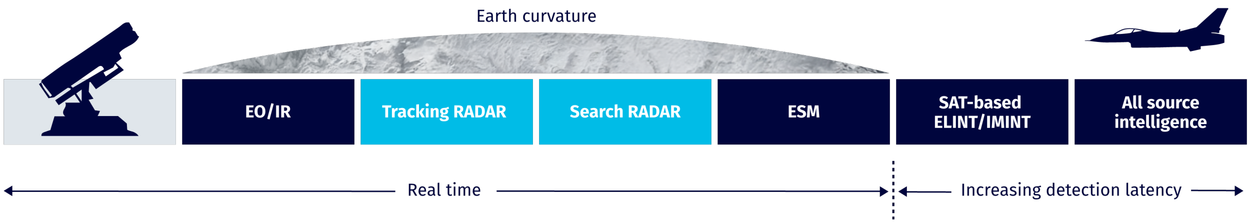
EARLY WARNING FOR AIR SURVEILLANCE

Passive RF sensing has a critical role to play in the air surveillance function of Integrated Air Defense Systems. Unlike passive radar, which depends on reflections of third-party transmissions, passive RF systems detect emissions directly.

By detecting emissions at extended range, often further than radar's maximum detection range, Electronic Support Measures (ESM) give operators more time to carry out the functions of air surveillance: detect, initiate, identify, correlate, and maintain.

The enhanced intelligence picture can positively influence the battle management function—allowing operators to choose the correct weapon for the threat.

In a situation in which time is the enemy, RF signals intelligence gives IADS operators early warning. RF sensors can be used for tipping and cueing other sensors, allowing C2 to stay under EMCON with radar turned off until the target enters the radar detection range for swift acquisition and giving more time to decide upon the correct use of kinetic or non-kinetic fires.

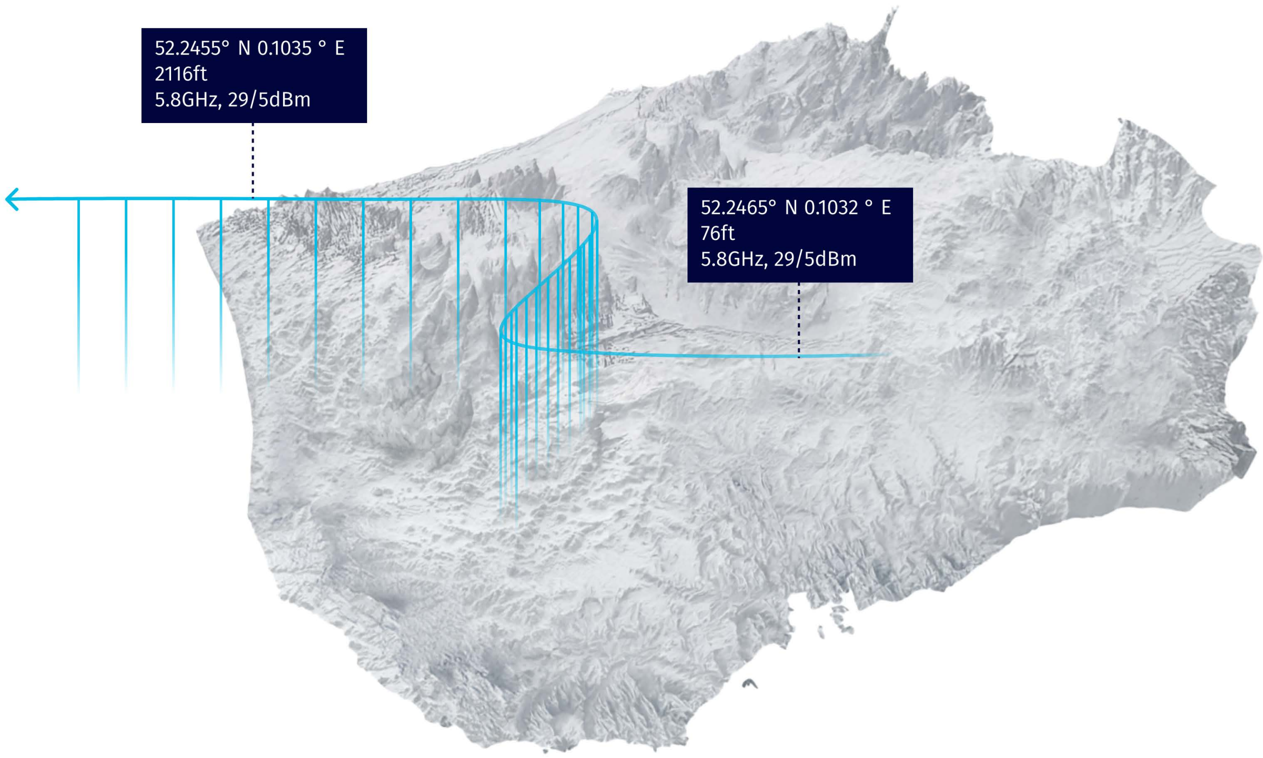


DETECT any signal within the collection cone

- Detect any signal within the collection cone
- Operate in a wide frequency range (9kHz to 40GHz)
- Sense signals, when emitted within the radio horizon
- Detect all signal types with highly sensitive sensor technology
- Establish a threat vector to enhance radar targeting precision
- Detect signals emitted by ground-based launching activities in addition to airborne targets for an enhanced intelligence picture
- Discover difficult-to-detect signals with Signal Discovery
- Conduct passive surveillance while operating under EMCON
- No library-based detection methods used—detect the signal, not the target
- EW reprogramming—rapidly create custom detectors for previously unknown signals

INITIATE precise geolocations of signals of interest

- Use multiple geolocation techniques depending on how far away the signal is
- Angle of Arrival provides a line of bearing to a far-away signal
- Precise 3D TDoA provides highly accurate geolocation of closer signals in real-time
- View geolocations move in real-time to understand trajectory, speed, and altitude of the target



IDENTIFY the signal to understand if it is friend, foe, or unknown

- Detector-based signal identification (IFF, ADS-B, Link 16)
- Identify targeted RF interference
- Discount false positives
- Identify spoofing
- Advanced SIGINT tools to analyze a signal's modulation, bandwidth, frequency, and pulse characteristics
- Build custom signal detectors for any signal of interest
- Automate signal detections

CHARACTERISTIC	BLUE FORCE (PROBABLE)	RED FORCE (PROBABLE)
Frequency use	Assigned mil frequencies or encrypted channels	ISM bands, unusual or rapidly shifting frequencies
Emission patterns	Consistent, aligned with doctrine or routes	Erratic, bursty, evasive
Comms protocol	Link 16, MIL-STD waveforms	Proprietary C2, commercial drone links (e.g. DJI)
Encryption	Strong, NATO-standard encryption	Weak or absent encryption
Tactics	Flying in coordinated formations	Swarming, unpredictable movement

CORRELATE data from multiple sensors (multi-sensor data fusion)

- Detect any signal within the collection cone
- Operate in a wide frequency range (9kHz to 40GHz)
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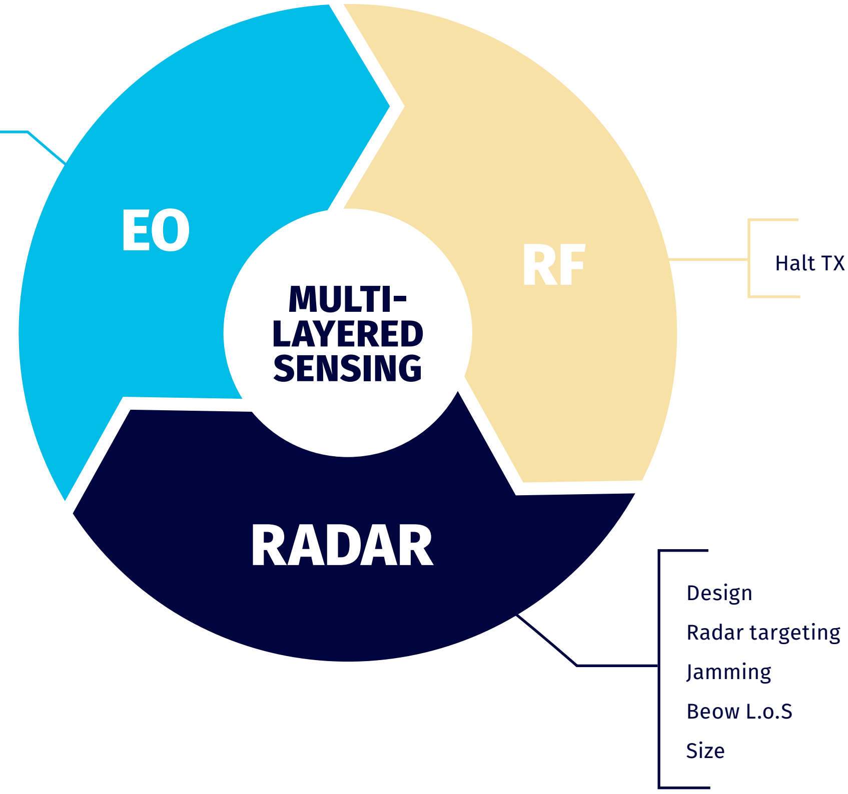

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Multi-layered sensing to defeat Electronic Countermeasures

RF sensing: Passive, high POI, scans wide frequencies, autonomous capability.

Radar: Active sensing, always visible, multiple well-known countermeasures.

Electro-Optical: Must be facing the threat. Passive sensing.

MAINTAIN visibility of the signal in real-time

- Persistent tracking of signals across time and space using heat patterns and map functions
- Continue geolocating frequency hopping and signals built to avoid detection by automating geolocation workflows with custom-built detectors

RFEYE TECHNOLOGY: AGILITY & MOBILITY

RFeye technology provides persistent, wideband, passive ESM capabilities. Optimized for SWaP and operational in the toughest environments, RFeye Nodes can be located on fixed infrastructure or deployed on unmanned systems (UxS) to extend range and for operations in remote locations.

RFeye technology allows teams to conduct missions while operating under EMCON and can provide accurate geolocations in GNSS-denied environments. An open architecture enables interoperability with all C2 systems, and advanced SIGINT features allow real-time situational awareness and EW reprogramming.

GNSS-denied environments

- Resilience to jamming
- Holdover module to provide timing in
- Accurate geolocations in GNSS-denied environments

Battle-proven

- TRL-9 technology
- Operational in contested environments across the globe

Flexible deployment

- Low SWaP
- Deployable in extreme weather conditions
- Ideal for UxS, mobile teams, remote operations, agile C2

Complement to radar

- Passive and persistent
- Less manning and maintenance required
- Can be used when radar is being maintained
- More cost effective than radar
- Detect anti-radiation missiles (ARM)

Interoperable

- Open APIs support integration into larger C2 software
- Easily integrated into multi-layered architectures
- Scalable, modular, automated RF technology

Agile

- Allows blue forces to operate under EMCON
- Early warning for signals of interest – detects emissions radar might miss
- LPI/LPD threats detected
- Tipping and cueing other sensors

CONCLUSION

Understanding and exploiting the spectrum is a necessary foundation for defending airspace in contested and congested spectrum environments. Passive RF sensors and Electronic Support Measures (ESM) deliver this capability by providing automated early-warning detection, passive geolocation, and real-time situational awareness while maintaining EMCON.

Passive RF technology integrates seamlessly into IADS to help construct multi-layered and networked air defense architectures. The technology is scalable, modular, cost-effective, and straightforward to maintain.

The threat landscape will likely evolve in future conflicts, with smaller radar cross-section platforms, degraded spectrum environments, and adaptive, low-detectability waveforms. In this scenario, passive RF's ability to operate in GNSS-denied environments, high probability of intercept, and quick EW reprogramming, will be critical for IADS resilience.

REAL-WORLD DEPLOYMENT STORY

Detection and 3D geolocation of aerial targets over wide areas

EXTRAORDINARY
RF TECHNOLOGY

CRFS creates deployable technology to detect, identify and geolocate signals in complex RF environments. With a leading position in the US, Europe and a global reach, our systems are used worldwide by regulatory, military, system integrators, government security agencies and corporates. They require actionable spectrum intelligence across the widest possible frequency range, in both congested and contested environments. They rely on our highly sensitive RF sensors, accurate transmitter geolocation, signal captures, classification and real-time RF intelligence to fulfil EMSO and electronic warfare support missions.

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