

Introduction

Echodyne is a U.S. designer and manufacturer of advanced radar solutions for defense and national security applications (TRL-9). 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 ESA radar. The result is a solid-state, low-SWaP, exportable, commercial radar with advanced software capabilities that delivers superior precision, unparalleled data integrity, and exceptional situational awareness. With leading positions in counter-UAS, force protection, base security, and portable ISR, Defense Agencies and Suppliers rely on Echodyne radar for extraordinary accuracy and consistent, reliable operation.

A more-detailed public description of the company's proprietary MESA architecture can be found in the modern McGraw Hill antenna engineering textbook (Antenna Engineering Handbook, 5th Edition, Chapter 32).

Products

Echodyne manufactures multiple software-defined radar products. A description of Echodyne radars can be found on the company's website. All radar products come with software to assist with configuration, integration, and operation.

EchoShield is a medium-range, software-defined, pulse-Doppler, cognitive 4D metamaterials ESA (MESA) radar operating in the Ku-band (15.7-16.6 GHz). With the equivalent of more than 500 Tx/Rx modules, EchoShield intelligently searches a large, customizable Field of View (FoV) and tracks ~1,000 objects of interest with industry-leading angular accuracy (0.5° az x 0.5° Douglas). High-fidelity data is delivered in a proprietary format over an industry-standard TCP/IP Gigabit Ethernet connection with multiple data-rich output options available via API. EchoShield utilizes cognitive radar concepts to combine different waveforms, beam schedules, and other resources into "Mission Sets" that tailor radar performance to need. A steady cadence of software updates offers new capabilities and add/extend Mission Sets. Highly precise object metadata enriches fusion and decision-making, while quick setup and on-the-move (OTM) capabilities bring value to multiple mission types. The radar is used for domain awareness of air and ground-based threats.

In today's operational environments, UAS threats are increasing in size, speed, and capability. Advanced UAS threats fly with no communications to detect or positioning to jam. The high velocity of change in platforms and capabilities poses increasing lethality to warfighters and missions. Detecting, tracking, and classifying UAS targets reliably and with high accuracy is pivotal to reaction time that saves lives and helps ensure mission success. A tactical solution utilizing advanced radar capabilities supports mission objectives and enhances situational awareness.

Echodyne's EchoShield is a next-generation, software-defined, medium-range, pulse-Doppler, cognitive 4D radar operating in the Ku-band for radiolocation applications. The radar can be used for detection, targeting and classification of air and ground-based threats. EchoShield shatters the

barriers to increased Tx/Rx cell density and generates the industry's most accurate spatial data for sensor fusion, command & control (C2) interfaces, and other intelligent systems and platforms. Waveforms tailored for high-accuracy target classification deliver a decluttered data stream rich with metadata about all tracked objects, regardless of UAS speed.

EchoShield

MID-RANGE, SOFTWARE-DEFINED, COGNITIVE, PULSE-DOPPLER RADAR

- **Field of View:** 130° Az x 90° El
- **Track Accuracy:** <0.5° Az x <0.5° El
- **Frequency (Ku):** 15.7 - 16.6 GHz (Security)
- Advanced pulse-Doppler cognitive radar
- Ultra-precise ESA beamforming + dynamic waveform synthesis
- μ Doppler object screening for long-range classification
- Adaptive control software directs resources when & where most effective
- Open architecture with full-featured SDK for data-rich C2 integrations
- Onboard (DTED, street maps) and offboard (customer-defined) knowledge repositories for threat prioritization



The value of radar is not scored by range alone but by level of actionable data at range. With class-leading SWaP and a large, customizable, and intelligent Field of View (FoV), EchoShield is designed for rapid customization to user, location, and mission requirements. Delivering an industry-leading <0.5° of angular tracking accuracy in both azimuth and elevation, EchoShield's data fidelity reliably delivers more precise data to cue optical sensors, enhance targeting systems (e.g., on RWS), and train effector platforms. The radar simultaneously tracks up to 1000 targets with classification at full tracking range.

Target Classification is a key reason for EchoShield's performance advantage against primary competitors. EchoShield's next-generation, highly accurate classification is enabled through cognitive radar functionality. Cognitive functionality expands radar capabilities by

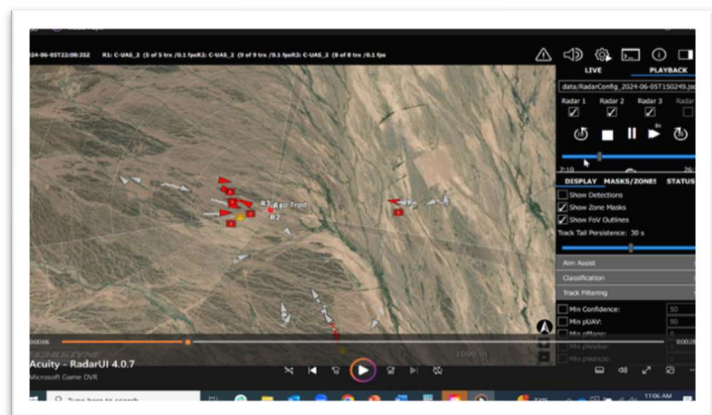


Figure 1 The scenario below is a screen shot of our classification capabilities against drone swarms (groups 2-3) at the recent JCO Swarm demonstration at YPG May/June of 2024.

optimizing radar resource allocation based on external data sources and other pertinent data sets. For Classification, EchoShield references resources specifically designed for deep, detailed target classification while continuing to search and track other objects. EchoShield also employs this functionality through its multiple Mission Sets, with tailored waveforms, beam schedules, and other resources that deliver outsized radar performance against specific targets and objectives. Combined with industry-standard integration for ease of integration, EchoShield delivers actionable data to systems and enhances warfighter safety.

Reducing the cognitive load placed on warfighters by technology remains a key focus for Echodyne. The company focuses development in two key areas: ease of use and data fidelity.

Ease of Use. At the physical level, EchoShield is the lowest SWaP, highest performance radar available. At <40 lbs. per panel, 2 warfighters can build a temporary 4-panel installation on a tripod in <1 hour. At the logical level, if the mission requirement utilizes FAADC2, or another named messaging structure for control of warfighter gear, EchoShield offers well-defined, dependable application programming interfaces (APIs) for radar control and rich data access. At the warfighter level, should the mission requirement call for direct warfighter interaction with the radar, EchoShield has an intuitive user interface software package, RadarUI, for radar control and scene management. EchoShield's advanced target classification significantly reduces scene clutter and focuses warfighter on primary targets.

Data fidelity. EchoShield's proprietary MESA architecture utilizes advanced compact arrays to emit small form factor, tight beams that delivers data only from that small area of airspace, with benefits in faster and more accurate signal processing. The screen capture demonstrates EchoShield's ability to establish and maintain track even through dense bird formations. Separating birds and clutter from actual threats is a benefit of data fidelity that enhances timely decision making to neutralize the threat.

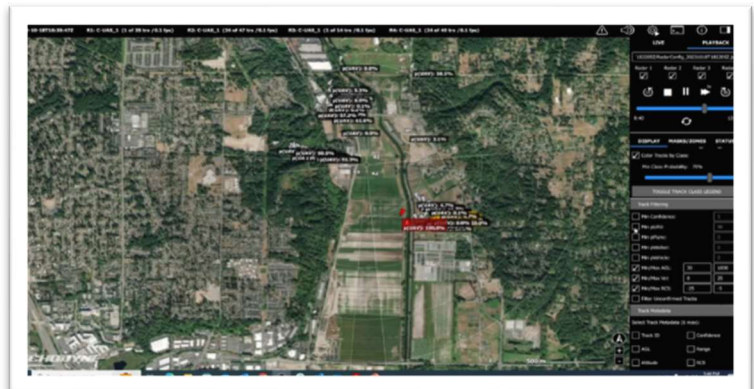


Figure 2 Demonstrates drone classification in flock of birds.

EchoGuard is designed for ground-based situational awareness of both air and ground domains, with capabilities in both radionavigation and radiolocation spectrum allocations. EchoGuard provides unprecedented performance for price and outperforms other ground-based radars in its class at a fraction of the cost. EchoGuard radars can be networked together to provide distributed airspace awareness, with advanced features like single Track ID enabled through off-radar software.

Our off-radar software suite expands the functionality of our advanced radars. RadarNet simplifies the internetworking of multiple radars to cover large volumes of space that is presented to the user as a single radar instance. RadarUI enables quick reviews of just the radar performance, with the ability to configure the radar to user, site, and mission requirements all from one interface.



Additional hardware tools, like RadarHub that simplifies the management of deployed radars, and software tools are in development.

All radars use industry-standard Ethernet for layer 2 and TCP/IP for layer 3 integrations, with a proprietary data format that is detailed in the product manuals. Both processed and unprocessed data can be sourced from the radars, with each data type sourced through the radar API. The rich radar data can be ingested via one or more APIs and include Detections (1 MB/s), Measurements (1 MB/s), Tracks (27 kB/s) or raw data (40 MB/s), allowing higher level systems to access the right data for the right reason.

EchoGuard

SHORT-RANGE, SOFTWARE-DEFINED, MICRO-DOPPLER FMCW RADAR

- **Field of View:** 120° Az x 80° El
- **Track Accuracy:** <1° Az x <1.5° El
- **Frequency (K):** 24.45-24.65 GHz (US+)
24.05-24-25 GHz (Intl)
- FOV Scan ~1Hz w/ 10Hz Track update rates
- Lowest SWaP of any ESA radar
- Sequential lobing super resolution = class-leading track accuracy
- Robust search while track for high track reliability
- Open architecture with multiple rich data outputs for easy systems integration



Target Type	Range
Nano UAS	250 m
Small 4-Rotor	1 km
Large Multirotor	1.4 km
Human	2.2 km
Small Fixed Wing	2.5 km
Small Vehicle/Vessel	3.5 km
Instrumented Range	6 km

It can track nearly two dozen targets, both ground and air, at long range while simultaneously scanning the full FOV to look for new intruders. The MESA architecture and its resultant rapid true beam scanning enable this true Search While Track (SWT) capability, providing vastly superior situational awareness. EchoGuard can track multiple targets at long range and in all-weather while simultaneously scanning the full FOV to look for new intruders.

Additionally, the azimuth accuracy of EchoGuard is a little less than one degree; the elevation accuracy is ~1.5 degrees, and the range accuracy is ~1-2m. This market-leading accuracy is primarily due to the small, discrete (2-deg in azimuth by 6-deg in elevation) beam, which is scanned around the FOV and then repeatedly interrogates a track at different positions in a technique called “sequential lobing.”

Not only can the EchoGuard track up to 20 targets simultaneously, but it is also sensitive enough to detect and track stationary hovering drones at ranges of ~250m for a Phantom 4 and ~500m for a DJI M600 due to the Doppler smearing of drone rotors and can track this movement despite its low RCS. This Doppler signature is also key to Echodyne’s native, in-radar classifier. Within ~400-500m of the radar, the EchoGuard will both deliver a probability of whether that target is a drone. This information (probability of UAV, or “p_uav”) is available in the track packet.