

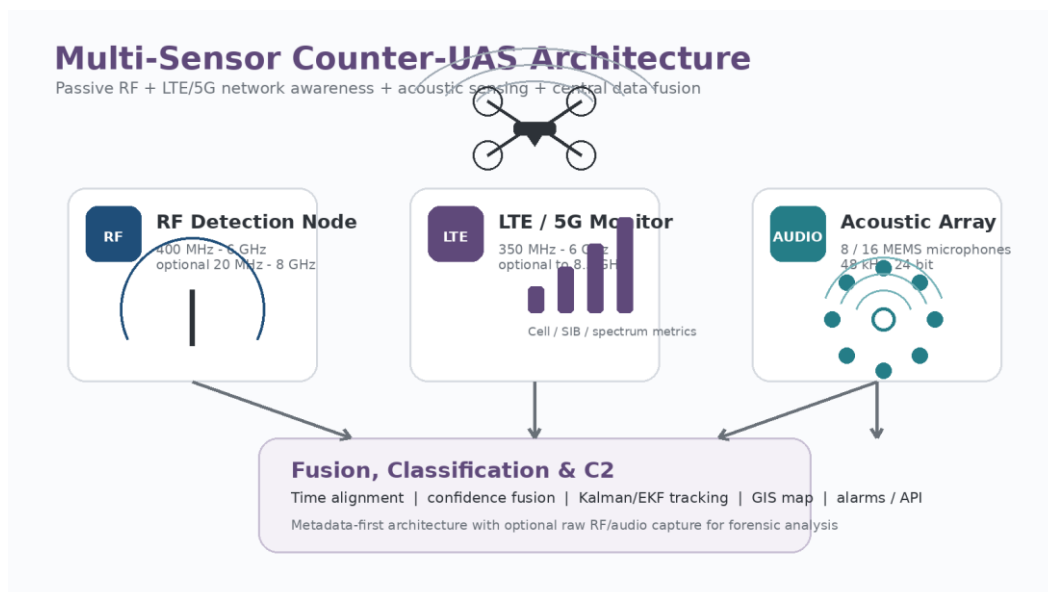
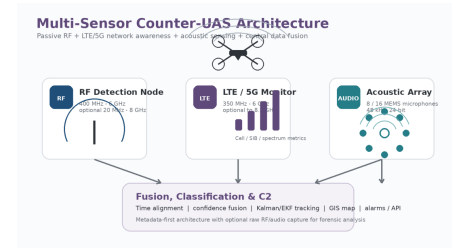
Multi-Sensor Counter-UAS Detection & Situational Awareness System

Passive RF Detection + LTE/5G Monitoring + Acoustic Arrays

Model No: MS-CUAS-360

Main Features

- Modular passive Counter-UAS detection architecture combining wideband RF sensing, LTE/5G network monitoring and acoustic drone-signature analysis.
- 360° RF situational awareness from 400 MHz to 6 GHz in the base configuration, with optional 20 MHz to 8 GHz extended receiver coverage.
- LTE/5G network scanning from 350 MHz to 6 GHz with LTE FDD/TDD and 5G NR SA/NSA measurements, broadcast-system-information decoding and spectrum analytics.
- 8- or 16-element low-noise MEMS microphone array with 48 kHz, 24-bit capture for rotor-harmonic detection and direction-of-arrival estimation.
- Edge classification and central fusion using time alignment, confidence/evidence fusion, track association and Kalman/EKF-based tracking.
- Redundant Ethernet/fiber and LTE/5G backhaul, GNSS/PTP timing, secure web GIS, alarm engine and open API interfaces.
- Urban and rural deployment profiles for critical infrastructure, airports, borders, prisons, government facilities and temporary event protection.
- Detection-only architecture. No RF jamming or other mitigation transmitter is included in this reference specification.



Important: values identified as "design target" or "reference target" are engineering objectives derived from public industry benchmarks and literature. Final contractual performance must be confirmed by selected hardware, FAT/SAT procedures and site acceptance trials.

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System Overview & Sensor Node Architecture

The MS-CUAS-360 is a distributed passive detection system intended to identify, classify and track small UAS activity without relying on a single sensing modality. RF sensing provides long-range early warning for radio-controlled drones; LTE/5G monitoring adds awareness of cellular spectrum and network activity; acoustic sensing provides a complementary path for RF-silent or pre-programmed aircraft. The fusion layer correlates these measurements into a common track picture.

Functional Architecture

Subsystem	Reference Architecture
RF Detection Node	Wideband antenna / DF array -> preselector and LNA -> multi-channel SDR/receiver -> spectrum features / protocol classifier -> AoA or line-of-bearing -> secure IP event output.
LTE / 5G Monitoring Node	Wideband cellular antenna -> autonomous network scanner -> LTE/NR measurements -> MIB/SIB and layer-3 broadcast decoding -> cell/spectrum metrics -> optional authorized operator-side metadata interface.
Acoustic Sensor Node	8/16 matched MEMS microphones -> synchronized digital audio capture -> wind/noise pre-processing -> STFT/Log-Mel features -> rotor-signature classifier -> GCC-PHAT/SRP-PHAT direction estimation.
Fusion & C2	GNSS/PTP time alignment -> spatial/temporal association -> confidence fusion -> Kalman/EKF tracking -> classification / geolocation -> GIS display, alarms and API integration.

Detection Principles

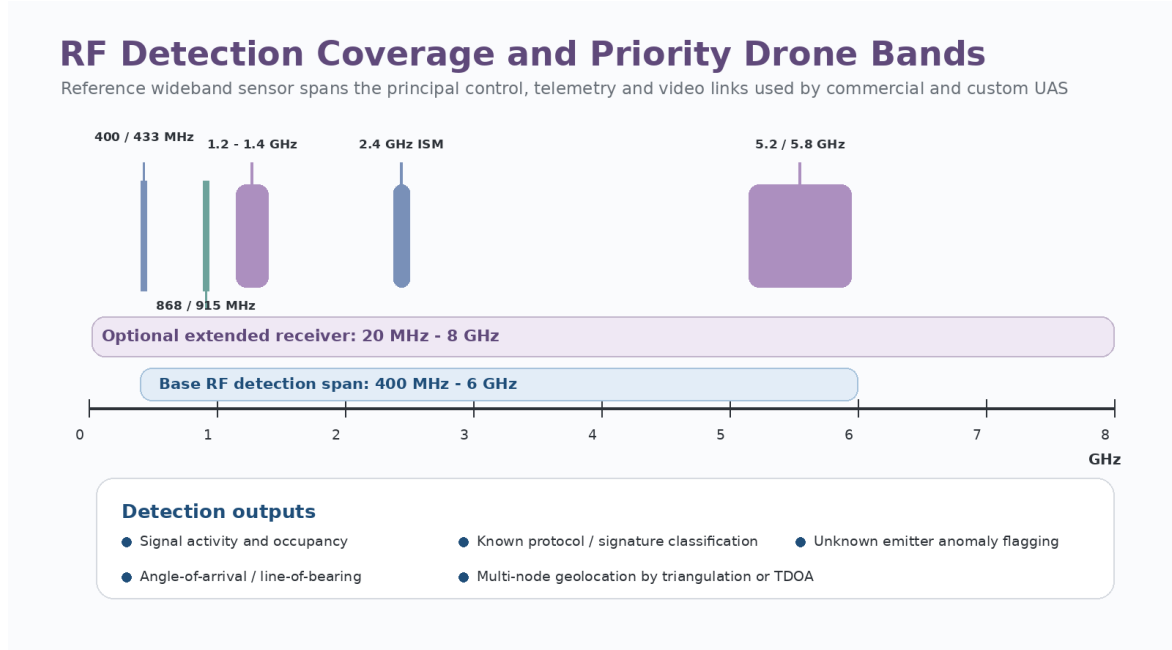
- RF modality is the primary early-warning sensor for common commercial and FPV-type radio links. It is passive and can provide direction finding when a calibrated antenna array is used.
- LTE/5G monitoring is used to characterize the cellular RF environment and local network configuration. A passive scanner alone cannot reliably attribute a specific subscriber device to a drone.
- Authorized operator-side integration may add network telemetry useful for detecting airborne-UE behavior patterns. The reference architecture explicitly excludes IMSI-catcher functions and subscriber-content interception.
- Acoustic sensing detects the tonal and broadband energy generated by motors, propellers and aerodynamic turbulence. It is short-range relative to RF but remains useful when a drone emits little or no detectable control-link RF.
- Multi-sensor confirmation is used to improve confidence, suppress nuisance alarms and maintain tracks when one modality is degraded by clutter, multipath, terrain or ambient noise.

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Wideband RF Detection Sensor Node

The RF node is designed for continuous passive monitoring of radio-control, telemetry and video signals associated with commercial, industrial and custom UAS. Public C-UAS products demonstrate 400 MHz to 6 GHz class coverage, optional extension toward 8 GHz and direction-finding accuracy in the low-single-digit degree range. [R1][R2][R3]



Parameter	Specification
Frequency range - base	400 MHz to 6 GHz continuous monitoring target
Frequency range - option	20 MHz to 8 GHz extended wideband receiver target
Priority UAS bands	400/433 MHz, 868/915 MHz, 1.2-1.4 GHz, 2.4 GHz, 5.2/5.8 GHz; configurable
Receiver architecture	Multi-channel SDR / monitoring receiver with RF preselection, attenuation
Instantaneous bandwidth	40 to 100 MHz class, receiver dependent
Antenna / coverage	360° omnidirectional detection; optional 4/8/16-sector or interferometric DF
Direction finding	AoA / line-of-bearing, typical calibrated target $\leq 3^\circ$ in favorable LoS geometry
Geolocation	Multi-node AoA triangulation; optional TDOA with synchronized receivers
Signal processing	Energy/occupancy analysis, protocol features, known-signature matching and unknown-emitter anomaly detection
Typical RF range target	Urban 1-3 km; rural/open LoS 2-5 km for common commercial UAS with active control/video links
Environmental / interfaces	IP65 class; -20°C to +55°C target; GNSS, PTP/NTP, 1GbE, optional PoE++ and cellular backup

RF range depends on transmitter power, protocol, site elevation, spectrum occupancy and line-of-sight. The 2-5 km class reflects public RF-C-UAS benchmarks and is not a guaranteed envelope. [R1][R2]



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LTE / 5G Network Monitoring Sensor

The LTE/5G monitoring node complements generic RF detection by continuously measuring the cellular radio environment. Current autonomous network scanners support simultaneous LTE/5G NR measurements across 350 MHz to 6 GHz, including SIB/layer-3 decoding, while newer wideband scanners extend above 6 GHz for full FR1 coverage. [R4][R5]

Supported Measurements

- LTE FDD/TDD, LTE-M, NB-IoT and 5G NR SA/NSA measurement support, depending on scanner software license and regional configuration.
- RF metrics: RSSI, RSRP, RSRQ, SINR, channel power, spectrum occupancy and interference indicators.
- Cell/network metadata: PLMN, band, EARFCN / NR-ARFCN, PCI, Cell ID / NCI where broadcast, TAC, SSB/beam information and decoded MIB/SIB system information.
- Cell-change and spectrum-anomaly events can be fused with RF and acoustic detections to increase confidence and explain environmental changes.
- Optional authorized mobile-operator interface may ingest network-side metadata or alarms for airborne-UE analytics. This is outside the capability of a stand-alone passive scanner and is subject to operator authorization, privacy law and local regulation.

Reference Cellular Frequency Coverage

Parameter	Specification
Scanner RF span - base	350 MHz to 6 GHz
Optional wideband extension	10 MHz to 8.5 GHz class for complete 5G NR FR1 coverage through 7.125
Low bands	600 / 700 / 800 / 900 MHz families - e.g., LTE B12/B13/B20/B28 and NR n5/n8/n20/n28 where regionally deployed
Mid bands	1.7/1.8 GHz, 1.9/2.1 GHz, 2.3 GHz, 2.5/2.6 GHz - LTE B1/B3/B7/B38/B40/B41 and related NR bands
5G FR1 C-band	n77 / n78 approximately 3.3-4.2 GHz; n79 approximately 4.4-5.0 GHz
Upper FR1 / shared spectrum	n46 / 5 GHz family where applicable; optional receiver extension for 6-7.125 GHz allocations
FR2 option	External downconverter/scanner module, typically 24-53 GHz class, only when mmWave monitoring is required
Network decode	LTE and 5G NR broadcast system information to Release 17 class, scanner dependent [R4]
Typical update rate	1-20 Hz aggregate engineering target depending on number of configured carriers and technologies
Timing / interfaces	GNSS, PTP/NTP, 1GbE, API output; optional 5G/LTE backhaul modem
Cellular-monitoring limitation: passive scanning provides RF and broadcast network awareness. It does not by itself prove that a particular LTE/5G device is a drone. Per-device attribution requires authorized operator-side telemetry or another independent sensor correlation.	

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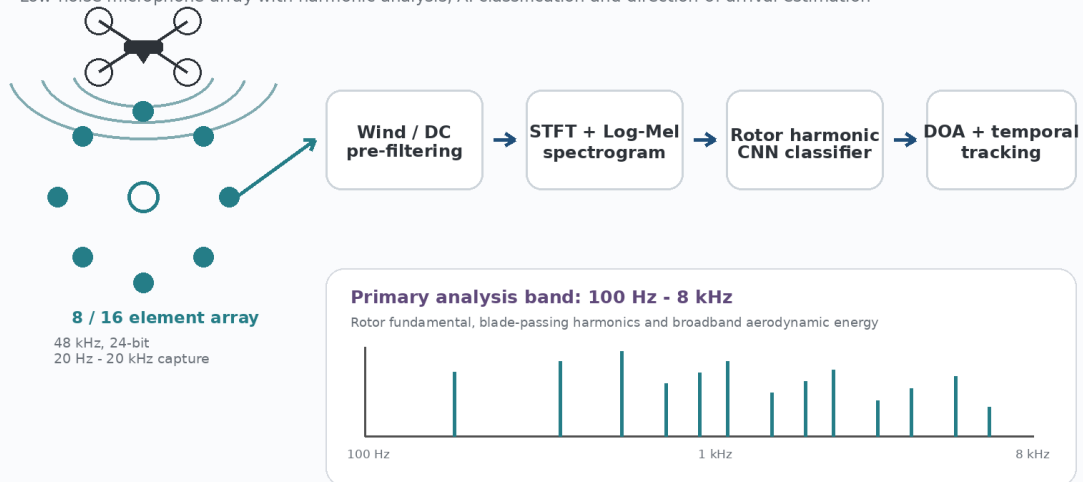


Acoustic Sensor Array & Rotor Signature Processing

The acoustic node is a passive close-to-medium-range sensor that exploits the characteristic tonal structure of multirotor motors/propellers and the broader aerodynamic noise spectrum. Research and deployed acoustic C-UAS systems show that useful drone energy extends from low hundreds of hertz through several kilohertz, with 48 kHz sampling commonly used for robust feature extraction. [R6][R7][R8]

Acoustic Rotor Signature Extraction

Low-noise microphone array with harmonic analysis, AI classification and direction-of-arrival estimation



Parameter	Specification
Array configuration	8 microphones standard; 16 recommended; optional 32/64-element site array
Microphone technology	Matched low-noise MEMS, digital PDM or low-noise differential analog front end
Microphone benchmark	69-70 dB(A) SNR class, ≥ 124 dB SPL AOP; low-frequency cutoff $\leq 30-75$ Hz [R7]
Capture bandwidth	20 Hz to 20 kHz nominal audio capture
Primary analysis band	100 Hz to 8 kHz for rotor harmonic and blade-passing signatures; higher-frequency features retained when useful
Sampling / resolution	48 kHz, 24-bit synchronized multichannel capture
Array geometry	Circular / hemispherical 250-500 mm aperture, phase calibrated, with outdoor wind protection
Feature extraction	Wind/high-pass filtering -> STFT -> Log-Mel spectrogram -> harmonic and spectral-envelope features
Classification	CNN / compact transformer: drone, non-drone, unknown; site-trained nuisance models
Direction finding	GCC-PHAT / SRP-PHAT / beamforming; reference DOA target $\leq 5^\circ$ at adequate SNR
Reference range targets	Small multirotor: urban 100-250 m, rural/open 200-500 m; louder/fixed-wing UAS: up to ~ 1 km favorable [R6]

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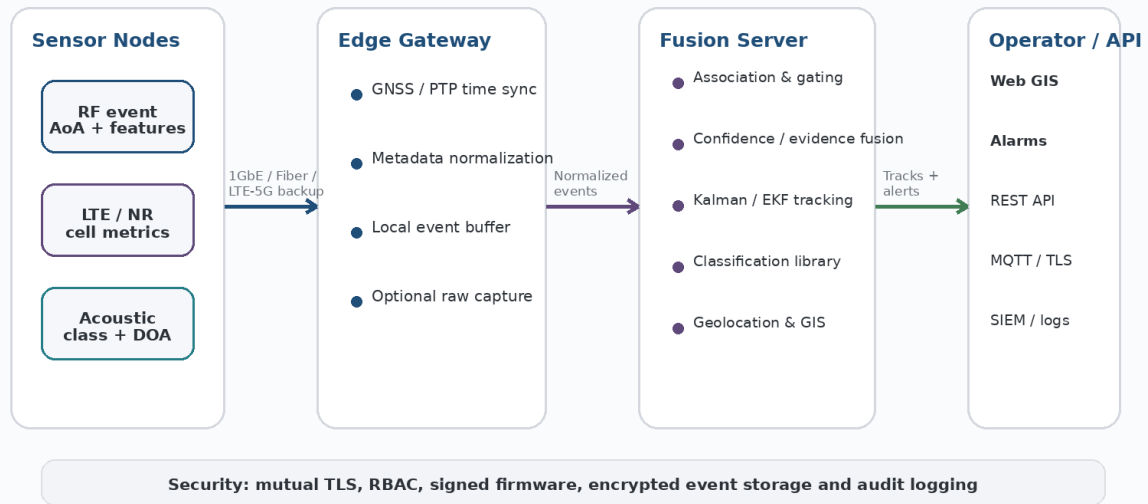


Data Fusion, Classification & Multi-Target Tracking

The fusion engine converts heterogeneous sensor events into a single georeferenced track picture. The architecture uses metadata-level fusion for routine operation and stores raw RF/audio snapshots locally for forensic review or algorithm improvement. Kalman-family tracking and evidence-based fusion are well established approaches for asynchronous multi-sensor UAV tracking. [R9][R10]

Data Fusion, Backhaul and C2 Flow

Edge analytics minimize bandwidth; central fusion combines time, bearing, spectral and acoustic evidence into a single track picture



Fusion Pipeline

Stage	Function
1. Time alignment	GNSS / PTP timestamps are normalized to a common time base; asynchronous measurements are interpolated within configurable time
2. Event normalization	Each sensor reports position/bearing, band/frequency, class probabilities, SNR/quality, timestamp and sensor-health indicators.
3. Association & gating	Candidate measurements are associated by time, angle, estimated position, motion compatibility and sensor-specific quality.
4. Confidence fusion	Weighted Bayesian scoring or Dempster-Shafer evidence combination merges partially independent class/confidence estimates while preserving
5. Tracking	Kalman / Extended Kalman filtering is the default constant-velocity tracker; UKF or GM-PHD multi-target tracking is optional for dense or maneuvering
6. Track management	Tentative -> confirmed -> coast -> dropped track logic prevents single-sensor spikes from creating persistent operational alarms.
7. Threat / policy engine	User-defined zones, time-of-day rules, whitelist/authorized UAS data and confidence thresholds generate alerts without automatic mitigation action.

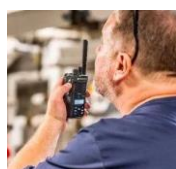
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Network Backhaul, Edge Computing & Cybersecurity

The reference system is designed as a distributed IP sensor network. Routine traffic consists primarily of metadata and compressed event features, while high-rate raw RF I/Q or multichannel audio is retained at the edge and transferred only on demand.

Parameter	Specification
Primary backhaul	1GbE copper or fiber Ethernet; PoE++ IEEE 802.3bt where sensor power budget permits
Redundant backhaul	Integrated or external LTE/5G router; optional microwave / private LTE backhaul for remote sites
High-rate option	2.5/10GbE for sustained raw sensor transfer or multi-receiver research configurations
Metadata bandwidth	Typically <1 Mbps average per node; burst rate depends on event frequency and logging policy
Raw acoustic data	Approx. 9.2 Mbps for 8 channels or 18.4 Mbps for 16 channels at 48 kHz / 24-bit before framing/compression
Raw RF I/Q	Can exceed 1 Gbps for tens of MHz of complex bandwidth; therefore normally captured locally and retrieved on demand
Time synchronization	GNSS disciplined clock plus IEEE 1588 PTP; NTP fallback for non-DF services
Protocols	REST/JSON, MQTT over TLS, WebSocket event feed, SNMPv3, syslog/SIEM; optional Cursor-on-Target gateway
Encryption	TLS 1.3 in transit; AES-256 class encryption at rest
Identity / access	Mutual X.509 certificates, RBAC, MFA at C2, signed firmware and secure-boot target
Resilience	Store-and-forward event queue, heartbeat / sensor health, watchdog restart, redundant C2 server option
Deployment	On-premises preferred for sensitive sites; private cloud or hybrid deployment optional



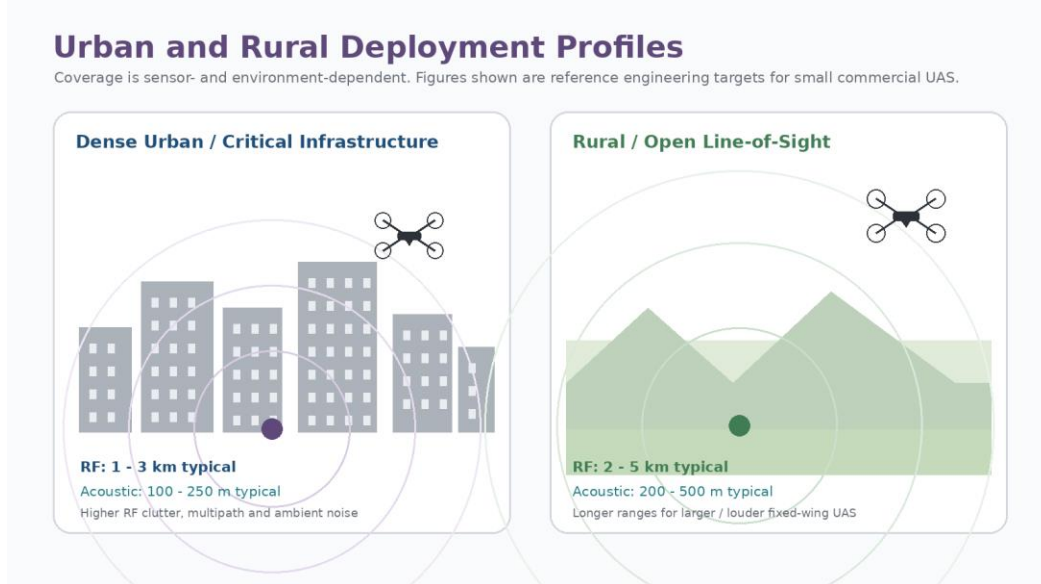
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Recommended Edge Compute Profile

- RF node: FPGA/DSP capable receiver plus x86 or ARM edge CPU; optional CUDA-class GPU/NPU for wideband AI classification.
- Acoustic node: low-power ARM/x86 processor with DSP acceleration; local 30-120 minute rolling audio buffer configurable by policy.
- Fusion server: 8-core or higher CPU, 32-64 GB RAM, NVMe event storage and optional GPU for model inference / retraining; redundant server pair for critical sites.
- All software components should support remote signed updates, rollback and configuration audit history.

Recommended data-minimization principle: retain only the sensor data required for UAS detection, engineering analysis and incident evidence. Cellular content interception and unrelated communications collection are outside the reference design.

Urban & Rural Operational Performance



The following values are reference engineering targets for system sizing. They are not guaranteed detection envelopes. Final performance depends on target type, RF emissions, acoustic signature, terrain, antenna/sensor height, weather, RF congestion and site-specific nuisance sources.

Metric	Urban	Rural / Open	Engineering Notes
RF detection - small commercial UAS	1-3 km typical	2-5 km typical	Active control/video link; 360° antenna. Stronger/louder or
Acoustic - small multirotor	100-250 m typical	200-500 m typical	Strongly affected by traffic, machinery, wind and microphone
Acoustic - larger fixed-wing / loud UAS	200-500 m class	Up to ~1 km favorable	Consistent with public acoustic-vector-sensor benchmarks for

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LTE/5G environment monitoring	Local monitored cell footprint	Local monitored cell footprint	Not a conventional range metric. Per-device attribution requires
RF direction finding	3-6° practical target in clutter	$\leq 3^\circ$ target in calibrated LoS	Geometry, array calibration and multipath dominate error.
Acoustic DOA	5-10° practical target	$\leq 5^\circ$ target at adequate SNR	Array aperture and wind/noise control dominate error.
Initial alert latency	1-3 s target	1-3 s target	Depends on confirmation policy and classification window.
Fusion track update	1-5 Hz typical	1-10 Hz typical	Higher update rates available when sensor events are frequent.
Qualified fusion detection target	$\geq 95\%$ with ≥ 2 independent modalities	$\geq 95\%$ with ≥ 2 independent modalities	Qualification target only; must be defined against a controlled
Nuisance alarm target	≤ 1 alarm/hour after site tuning	≤ 1 alarm/hour after site tuning	Reference commissioning target, not a universal guaranteed FAR.

Consolidated Technical Specification - Reference Configuration

System-Level Specifications

Parameter	Specification
System type	Passive multi-sensor Counter-UAS detection and situational-awareness
Sensor modalities	Wideband RF detection / DF, LTE/5G network monitoring, acoustic array
Coverage	360° RF and acoustic coverage with site-dependent elevation coverage
Processing	Distributed edge analytics with centralized track fusion and web GIS
Node scale	1 to 64 sensor nodes per fusion-server reference target; software-scalable
Concurrent tracks	≥ 100 track software target, configuration dependent
Time base	GNSS + PTP; NTP fallback
Event interfaces	REST/JSON, MQTT/TLS, WebSocket, SNMPv3, syslog; optional third-party C2 gateway
Cybersecurity	mTLS, RBAC, signed updates, encrypted storage, audit logs
Deployment	Fixed site, temporary tripod, rooftop, mast, vehicle-supported sensor kit
Mitigation	Not included in base system; external authorized effectors may be integrated through a separate C2 interface

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Outdoor Sensor Node Environmental / Power Targets

Parameter	Specification
Ingress protection	IP65 minimum reference target; IP66 option where selected hardware permits
Operating temperature	-20°C to +55°C standard target; -30°C to +60°C extended option
Storage temperature	-40°C to +70°C target, selected hardware dependent
Power input	48 VDC PoE++ or 24/48 VDC; 100-240 VAC via external PSU option
Typical power - RF node	25-60 W depending receiver / antenna electronics
Typical power - LTE node	20-60 W depending network scanner and compute
Typical power - acoustic node	10-25 W depending microphone count and edge compute
Mounting	Pole / mast / rooftop / tripod with surge protection and grounding
GNSS antenna	External active GNSS antenna or integrated sky-view module
Maintenance	Remote health monitoring, field-replaceable PSU/network

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Typical Applications & Public Technology Benchmarks

Typical Applications

Critical Infrastructure Power plants, oil & gas, telecom sites, data centers and industrial campuses.	Airports & Airfields Perimeter monitoring, approach-area awareness and temporary high-risk events.	Borders & Remote Sites Distributed sensor grids with fiber, private LTE or cellular backhaul.
Prisons / Government Unauthorized drone delivery and surveillance detection around restricted facilities.	VIP / Public Events Rapidly deployable sensor nodes for temporary protected zones.	Defense / Public Safety Passive local airspace awareness and C2 integration, subject to customer authorization and local regulation.

Representative Public Market References - Engineering Benchmark Only



Dedrone RF-360

Passive networked RF sensor. Public data sheet states 2 km normal and up to 5 km ideal detection for specific drones; AoA localization; IP65; LTE/Ethernet connectivity. [R1]



R&S TSMA6B

Autonomous mobile-network scanner covering 350 MHz to 6 GHz with LTE/5G NR and broadcast SIB/L3 decoding through Release-17 class capabilities. [R4]



Microflown SKYSENTRY

Passive acoustic-vector-sensor C-UAS concept. Public tests cite up to 250 m for a small 2 kg quadcopter and up to 1 km for a small fixed-wing aircraft. [R6]

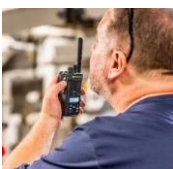
The reference products above are not represented as EMTS components or committed suppliers. They are shown only to document the public technical benchmark used while defining this reference architecture.

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Engineering References

- [R1] Dedrone RF-360 Data Sheet V2.0 and RF-360 product page - passive RF detection, AoA localization, 2 km normal / up to 5 km ideal range, IP65, LTE/Ethernet.
- [R2] Rohde & Schwarz ARDRONIS Locate Compact - 400 MHz to 6 GHz monitoring and >5 km class threat detection in public product description.
- [R3] Aaronia AARTOS DDS X9 public technical material - 400 MHz to 6 GHz base RF coverage, optional extension toward 8 GHz, 1° to 3° class tracking accuracy and IP65 class hardware.
- [R4] Rohde & Schwarz R&S TSMA6B product brochure - 350 MHz to 6 GHz autonomous mobile network scanning, LTE/5G NR and SIB/layer-3 decoding.
- [R5] ETSI / 3GPP TS 38.101-1 - 5G NR FR1 frequency range defined through 7.125 GHz in current releases.
- [R6] Microflown AVISA SKYSENTRY - passive acoustic C-UAS sensor post; public initial test ranges up to 250 m for small quadcopter and 1 km for small fixed-wing aircraft.
- [R7] Infineon IM69D130 and TDK/InvenSense high-SNR MEMS microphone data sheets - 69-70 dB(A) SNR class, 124-130 dB SPL AOP class and wide audio response suitable for microphone arrays.
- [R8] Sensors / acoustic-UAS literature - 48 kHz capture, STFT and Log-Mel features for rotor harmonic extraction; drone harmonic energy commonly extends through several kHz.
- [R9] Multi-sensor UAV tracking literature - Kalman filtering for asynchronous heterogeneous sensor measurements and improved track continuity.
- [R10] MUTES acoustic/optical fusion research - microphone-array cueing and Kalman-based multi-sensor trajectory fusion.



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