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Harrier-Awac: A Collaborative Swarm Architecture for Distributed Airborne Early Warning and Autonomous Kamikaze Intercept Cueing

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Abstract
This paper presents HARRIER-AWAC, a distributed airborne early warning and control (AEW&C) architecture built on a swarm of collaborating unmanned aerial vehicles (UAVs) rather than a single large radar-carrying aircraft. Each swarm node carries a lightweight FMCW (Frequency-Modulated Continuous Wave) radar on a rotating rotodome, and nodes are actively held equidistant from one another, forming a regular geometric pattern with predictable, overlapping detection envelopes. This equidistant geometry gives the swarm a built-in multi-static triangulation capability that a single AWACS aircraft cannot achieve economically. When any node detects an inbound object, the detection is fused across the mesh, classified, and — if declared a threat — cued to the nearest available kamikaze (loitering munition) drone for intercept. An AI-driven self-healing capability continuously monitors each node's link quality, sensor health, and formation error, and autonomously reconfigures the ring, reroutes mesh traffic, and reassigns roles before a degrading node can disrupt coverage. This paper describes the aerodynamic platform, radar/rotodome payload, formation-keeping control logic, detection-to-engagement data chain, self-healing architecture, and the concept of operations (CONOPS) for a scaled demonstrator, and includes system diagrams and representative design-parameter tables.

Index Terms—AWACS, UAV swarm, FMCW radar, rotodome, loitering munition, kamikaze drone, distributed sensing, threat cueing, formation flight.

1. INTRODUCTION

A. Background

Conventional Airborne Early Warning and Control (AWACS) systems rely on a single large, expensive aircraft carrying a powerful rotating radar dome. This design gives excellent coverage but carries three structural weaknesses: the platform is a single point of failure, it is extremely costly to build and operate, and it constitutes a single high-value target. A swarm-based approach instead distributes the detect-classify-cue-engage mission across many small, individually inexpensive and expendable aircraft. The loss of one node degrades the overall picture only marginally; there is no single point of failure and no irreplaceable asset.

B. Motivation

The HARRIER-AWAC concept extends the HARRIER fixed-wing UAV platform (cranked-arrow planform, MH-45 airfoil family) by substituting a compact FMCW radar and rotodome subsystem for its baseline payload, and distributing that same subsystem across several airframes flown in a fixed geometric pattern. The central contribution of this work is that the arrangement of the swarm — holding nodes equidistant from one another — is itself the sensing innovation: it converts N independent radar returns into a single wide-area, cross-referenced detection picture, and provides a ready-made geometric basis for handing a detected threat off to the nearest interceptor.

C. Scope

This paper covers the aerodynamic and structural platform used per node, the radar/rotodome payload, the control logic of equidistant formation-keeping, the detection and track-fusion pipeline, the communication architecture used to cue a kamikaze drone, the full operational sequence from launch to intercept, and a discussion of limitations and scale-up path.

2. SYSTEM OVERVIEW

HARRIER-AWAC comprises three cooperating UAV classes operating as a single system: (i) Sentinel nodes, based on the HARRIER airframe, which form the persistent equidistant radar-watch ring; (ii) an optional Relay/Command-and-Control (C2) node, which aggregates tracks and extends mesh range to the ground station; and (iii) kamikaze (loitering-munition) drones, which perform terminal intercept once cued. Sentinel nodes form the outer detection ring, the Relay/C2 node fuses tracks from that ring, and kamikaze drones loiter at a forward staging point awaiting a cueing vector.

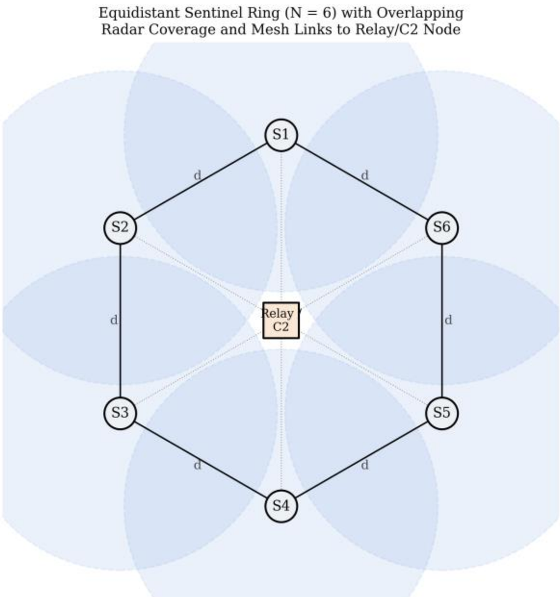

Fig. 1. Equidistant Sentinel ring (N = 6) with overlapping radar coverage envelopes and mesh links to the center Relay/C2 node. The label "d" marks the equal inter-node spacing enforced by the formation controller.

TABLE I SWARM FORMATION GEOMETRY — SYMBOLS AND DESIGN RELATIONS

Symbol	Definition / Design Relation
N	Number of Sentinel nodes forming the ring
R	Ring radius — distance from ring center to each node
d	Inter-node spacing, $d = 2R \cdot \sin(\pi/N)$
cov_r	Per-node radar detection radius
Coverage condition	$cov\_r \geq d/2$ required for gap-free ring coverage

3. SENTINEL AIRFRAME DESIGN

Each Sentinel node uses the HARRIER aerodynamic design: a cranked-arrow wing planform, chosen for a favorable balance between low-speed loiter efficiency and stability margin under the added yaw/pitch inertia of a nose- or dorsal-mounted rotodome, and an MH-45 airfoil family section, selected for benign stall behavior and a wide low-drag bucket suited to the loiter-dominant flight regime of a watch-station node. The airframe uses composite construction (wet-layup / vacuum-bagged shell) consistent with a target maximum take-off weight (MTOW) of approximately 10 kg for the scaled demonstrator. The radar rotodome is integrated dorsally or in a ventral pod and driven through a slip-ring assembly, allowing continuous rotation without wire wind-up. Platform sizing reuses BEMT-based propulsion, Helmbold-corrected lift-curve-slope ($CL\alpha$), wind-load, and planform-sizing calculators previously developed for the HARRIER 10 kg demonstrator.

TABLE II HARRIER SENTINEL AIRFRAME — DESIGN SUMMARY

Parameter	Design Value / Approach
Wing planform	Cranked-arrow
Airfoil family	MH-45
Target MTOW	≈ 10 kg (demonstrator scale)
Primary structure	Composite — wet-layup / vacuum-bagged shell
Radar integration	Dorsal or ventral rotodome pod, slip-ring driven
Dominant flight regime	Loiter / station-keeping, not dash
Sizing basis	BEMT propulsion, Helmbold $CL\alpha$, wind-load, planform calculators

4. SENSING PAYLOAD: FMCW RADAR AND ROTODOME

A. Rationale for FMCW

FMCW radar is selected over pulsed radar for three reasons: (1) it provides simultaneous range and Doppler (closing-speed) information from a single continuous waveform, enabling separation of a fast inbound threat from clutter; (2) FMCW radar-on-chip modules are small, low-power, and low-cost, fitting the mass and power budget of a sub-10 kg airframe in a way that pulsed AWACS-class radar cannot at

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this scale; and (3) continuous-wave operation integrates more readily with a slip-ring/rotodome mechanization than high-peak-power pulsed systems.

B. Onboard Processing Chain

Each node executes the following chain once per rotodome revolution: rotodome rotation (motor and slip ring) feeds the FMCW radar chip, which produces raw beat-frequency samples; an onboard single-board computer performs range/Doppler FFT processing and CFAR detection to extract plots; the flight controller fuses each plot with the node's own GPS/IMU state, converting a relative range/bearing detection into an absolute earth-frame position; the geo-referenced plot is then transmitted over the RF telemetry datalink to the rest of the swarm and/or the ground station. This GPS/IMU fusion step is essential — without it, a raw plot cannot be meaningfully combined with plots from other nodes.

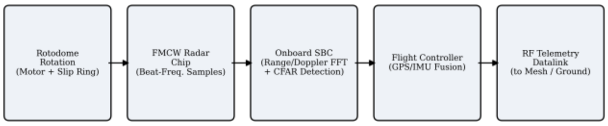

Fig. 2. Per-node onboard radar processing chain, executed once every rotodome revolution, from raw RF rotation to a geo-referenced plot on the mesh datalink.

TABLE III FMCW RADAR SUBSYSTEM — REPRESENTATIVE DESIGN PARAMETERS

Parameter	Representative Value / Design Target
Waveform	Frequency-Modulated Continuous Wave (FMCW)
Radar form factor	Chip-scale FMCW module (radar-on-chip)
Scan mechanism	Continuous 360° rotodome rotation via slip ring
Native measurements	Range, bearing, Doppler closing speed
Onboard processing	Range/Doppler FFT + CFAR detection (SBC)
Position referencing	Plots fused with node GPS/IMU before transmission
Output to mesh	Geo-referenced plot (earth-frame position, velocity)

5. EQUIDISTANT SWARM FORMATION

A. Concept and Rationale

The defining feature of HARRIER-AWAC is that Sentinel nodes are actively flown and held at equal distance from one another, forming a regular geometric pattern (e.g., a regular polygon ring, or a ring with a center node) over the area of interest. This equidistant constraint is chosen for three reasons. First, uniform coverage: unequal spacing creates weak zones with little or no radar-footprint overlap, whereas equal spacing guarantees a known, predictable minimum overlap between every adjacent pair of nodes, so no approach direction goes unseen. Second, built-in multi-static geometry: because every node is a known distance from its neighbors, a target detected by two or more nodes can be geometrically resolved — via range-difference and bearing-crossing — into a substantially more accurate absolute position than any single node's radar alone could provide. Third, simplified handoff geometry: because the swarm geometry is regular and known, identifying which kamikaze drone is closest to a predicted intercept point becomes a straightforward geometric query rather than a complex optimization.

B. Maintaining Equidistance

Each Sentinel node runs a local formation-control loop. Each node knows its own GPS position and receives neighbor positions over the mesh datalink. A distributed control law (a virtual spring-damper model is one convenient implementation) computes a correction velocity so that measured inter-node distance converges to the commanded spacing. The full ring pattern can be commanded to translate, expand, contract, or rotate as a single formation — for example, to re-center over a moving high-value asset or to widen the ring for deeper standoff range. Loss of a node triggers automatic re-spacing of the remaining nodes around the smaller ring, so coverage degrades gracefully rather than leaving a fixed, permanent gap.

6. DETECTION, TRACK FUSION, AND THREAT CLASSIFICATION

The end-to-end pipeline proceeds as follows: (1) local detection — each node extracts candidate plots (range, bearing, Doppler) every rotodome revolution; (2) mesh sharing — each node broadcasts geo-referenced plots to formation neighbors and/or the Relay/C2 node; (3) track fusion — plots seen by multiple nodes are associated into a single fused track, using the known equidistant geometry to resolve position more precisely than any single node's bearing/range estimate; (4) classification — closing speed, track heading stability, radar-cross-section proxy, and altitude profile are used to score a track as clutter, friendly, or inbound threat; and (5) threat declaration — a track crossing the classification threshold is pushed onto the cueing channel described in Section VII.

7. CUEING AND ENGAGEMENT HANDOFF

A. Interceptor Selection

Given a fused threat track, the system computes a predicted intercept point (PIP) by projecting the target's velocity vector forward, then computes the time-to-intercept from each available kamikaze drone's current position to that PIP. The drone with the shortest time-to-intercept — not necessarily the geometrically nearest one, since wind, remaining energy, and current loiter geometry all affect true intercept time — is selected and cued.

B. Cueing Message and Two-Phase Guidance

The cueing message contains the threat's last fused position and velocity vector, the predicted intercept point and time, and a terminal-handoff instruction. Guidance proceeds in two phases: during mid-course, the kamikaze drone is guided by track updates relayed from the Sentinel swarm, requiring no long-range sensor of its own; upon entering a terminal basket around the PIP, the drone transitions to its own short-range terminal seeker for final aim-point refinement and closure. This two-phase handoff keeps the kamikaze drones small, cheap, and expendable, since the continuous, expensive sensing task is performed entirely by the reusable Sentinel swarm.

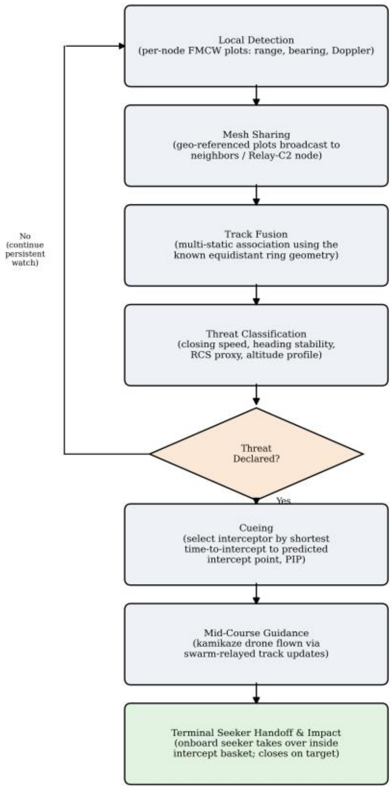

Fig. 3. Detection-to-engagement data flow, from per-node local detection through mesh fusion and classification to interceptor cueing, mid-course guidance, and terminal seeker handoff.

8. AI-DRIVEN SELF-HEALING SWARM ARCHITECTURE

Beyond re-spacing after an outright node loss (Section V-B), each Sentinel node runs a lightweight AI health-monitoring process that watches for gradual or partial degradation — a weakening mesh link, a drifting or noisy radar plot, growing formation-keeping error — rather than waiting for a node to disappear entirely. When the monitor flags an anomaly, the swarm's onboard AI diagnoses which of the node's roles are affected (pure sensing, mesh relay, Relay/C2 duties, or several at once) and triggers an autonomous reconfiguration: the ring re-spaces around the affected node, mesh traffic is rerouted around a degrading link, and if the anomaly affects a node acting as Relay/C2, that role is handed to a healthier neighbor before the fusion picture is disrupted. The swarm then verifies that coverage and mesh reachability have actually been restored before returning to normal watch. This closes the loop between simple loss-triggered re-spacing and a more general self-healing capability: the swarm is designed to notice it is degrading and repair itself continuously, not only after a hard failure.

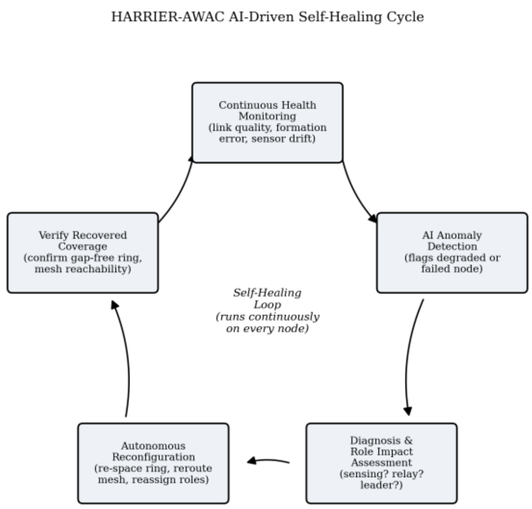

Fig. 4. AI-driven self-healing cycle: continuous health monitoring feeds an AI anomaly detector, which diagnoses role impact, triggers autonomous reconfiguration (re-spacing, mesh rerouting, role handoff), and verifies recovered coverage before the loop repeats.

9. CONCEPT OF OPERATIONS (CONOPS)

TABLE IV CONOPS PHASE SUMMARY

Phase	Action
1	Deployment — Sentinel nodes launch and climb to formation station; controller assembles the commanded equidistant pattern.
2	Persistent watch — rotodomes scan continuously; formation-keeping corrects for wind drift; mesh exchanges plots.
3	Kamikaze staging — interceptor drones loiter or stand ready-launch within reach of the protected area.
4	Detection & classification — an inbound object is detected, fused, and classified as a threat.
5	Cueing — the best-placed kamikaze drone is selected and cued with the fused track and PIP.
6	Mid-course guidance — the kamikaze drone flies to the intercept basket using swarm-relayed cues.
7	Terminal engagement — the drone transitions to its own seeker and closes for impact.
8	Reformation — the Sentinel ring automatically re-spaces to restore full coverage.

10. ADVANTAGES OVER A SINGLE-PLATFORM AWACS

- No single point of failure — losing one Sentinel node degrades coverage gracefully.
- AI-driven self-healing — the swarm detects its own degradation and reconfigures before a failing node disrupts coverage, rather than only reacting after a node is lost outright.
- Distributed triangulation "for free" via known equidistant geometry.

- Low cost per node relative to a single large phased-array AWACS radar and host aircraft.
- Built-in engagement pathway from the same real-time geo-referenced tracking used for early warning.
- Scalable coverage — the ring can be widened, narrowed, or resized without redesigning the system.

11. LIMITATIONS AND OPEN ENGINEERING QUESTIONS

Several aspects require further engineering validation before operational use: mesh-network robustness under electronic countermeasures; the detection-range ceiling inherent to chip-scale, low-transmit-power FMCW radar, which must conservatively bound the chosen ring spacing; formation-keeping accuracy under wind and gust loading, since it directly affects triangulation accuracy; false-positive/false-negative rates in threat classification against birds, weather clutter, and friendly traffic; and the re-validation required at each step of scaling from a sub-10 kg demonstrator to an operational-size composite airframe. The AI self-healing monitor itself needs validation against its own false-positive and false-negative rates — an anomaly wrongly flagged can trigger unnecessary reconfiguration, while a missed one delays recovery — and its behavior under the same electronic countermeasures that threaten the mesh network needs dedicated testing. Any live kinetic testing of kamikaze drones additionally requires appropriate range clearance, licensing, and safety protocol; this paper describes the sensing-and-cueing architecture only, not weapon effects.

12. CONCLUSION AND FUTURE WORK

HARRIER-AWAC reframes airborne early warning as a distributed sensing problem rather than a single-platform engineering problem. Combining the HARRIER airframe with a miniaturized FMCW radar/rotodome payload, deliberately holding swarm nodes equidistant, and layering an AI-driven self-healing capability on top, produces uniform, gap-free coverage that both resists and actively recovers from node degradation, at a fraction of the cost of a conventional AWACS aircraft. The same real-time, geo-referenced track that provides early warning is reused directly as the cueing signal that vectors an expendable kamikaze drone onto an intercept, cleanly separating the expensive, reusable sensing function from the cheap, expendable engagement function. Recommended future work includes: flight-testing a 2–3 node Sentinel ring to validate formation-keeping and multi-static fusion accuracy against a known ground-truth target; characterizing the FMCW chip's real detection range and Doppler resolution against a representative small-UAV target; developing and bench-testing the mesh cueing protocol and measuring end-to-end detection-to-cue latency; testing the mid-course-to-terminal handoff logic on a non-kinetic surrogate interceptor; validating the self-healing monitor's anomaly-detection accuracy under induced link and sensor degradation; and documenting the equidistant-formation triangulation-and-cueing method as the core novel claim for patent filing.

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