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A DOCTRINE INFORMED APPROACH TO THE EXPANDING UAS THREAT SPECTRUM

Mammadov E.S.
National Defense University; Baku, Azerbaijan

This article develops and substantiates a multi layered Counter Unmanned Aerial Systems framework that integrates detection, identification, neutralization, and passive defense within a coherent operational concept. The point of departure is the accelerated diffusion of small and relatively inexpensive UAS that merge reconnaissance and strike roles, operate at low altitude with a small radar cross section, and can be fielded at scale by state and non-state actors. Recent conflicts have shown that such systems exploit gaps in traditional air defense architectures, especially where sensors are optimized for higher altitude and larger signatures. The result is a persistent operational and economic asymmetry in which expensive surface to air missiles are employed against low-cost drones. A sustainable response requires layered protection, cost aware engagement choices, and organizational measures that reduce exposure.

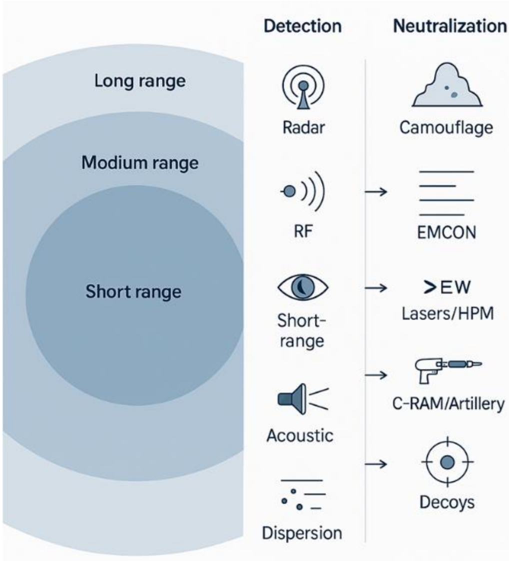

Fig. 1. Multi layered CUAS defense model

The methodology combines normative and empirical evidence. First, a structured review of NATO and U.S. Department of Defense classifications establishes performance envelopes by class, range, and payload. Second, open-source case studies from the 2020 Second Nagorno Karabakh war and the war in Ukraine provide field observations on employment patterns, countermeasures, and adaptation cycles. Third, a comparative synthesis evaluates detection technologies, neutralization options, and passive defenses against technical, tactical, and cost criteria. This mixed approach permits not only technical scoring but also assessment of feasibility under rules of engagement and airspace safety constraints.

Findings indicate that no single C UAS solution is adequate across environments. However, a layered model is consistently rational when scaled to mission and terrain. At the detection tier, sensor fusion that combines radar, radio frequency monitoring, electro optical and infrared sensing, and acoustic detectors improve probability of detection while reducing false alarms. Low probability of intercept waveforms and small physical signatures complicate single modality detection, yet cross cueing among sensors restores coverage and supports timely classification. The study recommends data fusion pipelines that employ AI assisted tracking and classification, with attention to adversarial spoofing and clutter in urban environments.

Neutralization must be selected with respect to both technical effects and engagement cost. Electronic warfare is effective where drones depend on control links or satellite navigation yet loses impact against fully autonomous platforms. Lasers offer precision, short dwell time, and low marginal cost per shot, although power supply, beam control in adverse weather, and platform integration remain constraints. C RAM and artillery provide volume fire against short range threats but require careful deconfliction with friendly air traffic and counter battery risks. Surface to air missiles remain necessary against large Class III systems, although fire discipline and tiered decision authority are required to avoid unsustainable expenditure. For Class I platforms, electronic warfare and lasers dominate. For Class II, radar plus EO IR fused detection with C RAM provides a workable balance. For Class III, only SAM class interceptors deliver reliable defeat, subject to availability and cost.

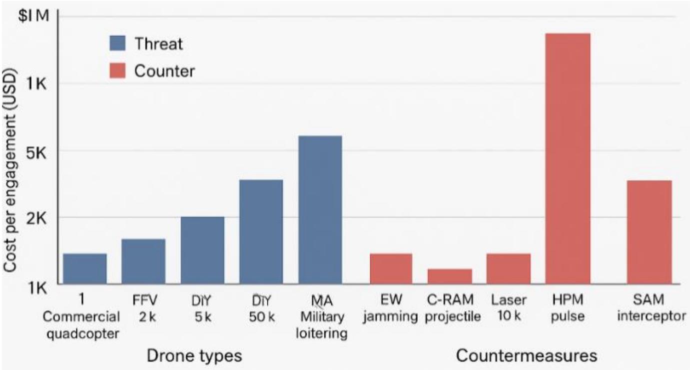

Fig. 2. Economic asymmetry: cost of drones versus countermeasures

Passive defenses are essential complements that do not depend on attrition of the threat. Camouflage and multispectral signature management reduce detection and tracking. Electromagnetic emission control limits exposure to RF geolocation. Force dispersion reduces the damage of successful strikes. Decoys and dummies saturate the attacker's sensor and decision loops and draw fire away from critical assets. These measures are low cost, repeatable, and resilient against adaptation by the attacker, which makes them core elements of any persistent defense.

Operationalization of the layered model requires integration with spectrum management, airspace control, and safety cases that protect civil aviation and critical radio services. The article proposes cascading rules for engagement that match threat class, range, and collateral risk with proportional effectors. It also recommends post event forensics for continuous improvement, including telemetry capture, debris analysis, and electromagnetic environment logging. Training should link tactical practice with technical capabilities, with emphasis on cross unit coordination among air defense, electronic warfare, engineers, and intelligence sections. Limitations include multipath and clutter that degrade sensing in built up areas, rapid evolution of adversary tactics such as frequency hopping, mesh networking, and autonomy, and heterogeneous national legal frameworks that shape permissible countermeasures. Future work should prioritize standardized cost effectiveness metrics, mobile integration of directed energy weapons, robust AI models for sensor fusion that are resilient to spoofing, and mission informed placement of sensors and effectors that reflect terrain, weather, and traffic patterns. In conclusion, multi layered C UAS is not a single system but a doctrine informed architecture that combines complementary technologies with disciplined tactics and cost aware decision rules. When supported by clear authority, safety interlocks, and iterative learning, it provides an adaptable and sustainable defense against the expanding spectrum of UAS threats.

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