Ethiopian International Journal of Multidisciplinary Research

pISSN:2349-5707 Volume:13,Issue 3, March -2026 eISSN:2349-5715

ECONOMIC SUSTAINABILITY OF AIR DEFENSE SYSTEMS IN COUNTERING ASYMMETRIC THREATS: A MULTILAYERED APPROACH

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Abstract

This article is devoted to the transformation of air defense systems in the context of the widespread proliferation of unmanned aerial vehicles (UAVs) and high-precision weapons in modern military conflicts. The study analyzes the resilience of traditional defense systems against asymmetric threats and scientifically substantiates the prospects for implementing integrated multilayered (echeloned) systems, as well as the use of laser weaponry, artificial intelligence, and high-power microwave weapons to neutralize these threats.

Keywords

Air Defense (AD), asymmetric threats, integrated system, microwave weapon, UAV, echeloned defense, artificial intelligence.

Armed conflicts throughout human history have always consisted of a constant competition between the "sword and the shield." However, by the third decade of the 21st century, the concept of air defense (AD) entered an era of radical transformation. While previously the primary task of AD was to combat the enemy's expensive and scarce strategic aviation or ballistic missiles, today the number of tasks—more precisely, the type and number of aerial targets—is increasing.

The emergence of asymmetric threats[1] on the modern battlefield—particularly the mass use of small-sized kamikaze drones and cruise missiles—poses new and extremely complex conditions for classical echeloned AD systems. Now, a defense system must not only shoot down high-speed targets but also withstand a "swarm" of hundreds of cheap and low-altitude vehicles.

The traditional principles of echeloning air defense are partially losing their effectiveness in the conditions of asymmetric warfare. Problems such as "system saturation" and economic inefficiency are emerging within these systems. Therefore, revising the AD strategy and enriching it with new technological solutions and integrated management methods remains one of the most important tasks of modern military science.

The concept of asymmetric warfare forces the defending side to strike not at its strongest points, but at its weakest and most expensive points. For echeloned AD systems, we can identify three main asymmetric risks today: information saturation and "exhausting" the system, economic depression, and the use of low-altitude "blind spots" and terrain.

1. **System Information Saturation and "Exhaustion":** Modern radar and control systems have a limited number of targets they can track and fire upon simultaneously. *Tactics of use:* The enemy launches dozens of cheap drones, decoys, and missiles at the same time. As a result, the AD system enters a state of "information saturation." It cannot react to all targets simultaneously or distinguish the most dangerous targets from cheap mock-ups. This leads to |a gap in the defense.

[1] **Asymmetric threat** — the use of non-traditional tactics and tools against an opponent with technological superiority in a struggle between parties with unequal power (Joint Publication 3-0, "Joint Operations" — U.S. Department of Defense).

pISSN:2349-5707 Volume:13,Issue 3, March -2026 eISSN:2349-5715

2. **Economic Depression:** This is not a war on the battlefield, but a war between budgets. The main problem is that a single cheap kamikaze drone (e.g., $20,000–$30,000) forces the AD system to use a missile costing millions of dollars. Consequently, the attacker weakens the defender's missile reserves economically rather than on the battlefield. Missile stocks are limited and take months to produce, while drones can be manufactured by the hundreds daily [1].

3. **Low-altitude "Blind Spots" and Use of Terrain:** Asymmetric threats often skillfully exploit the laws of physics and the Earth's structure. Cruise missiles and small drones move close to the ground (at altitudes of 10–50 meters). The curvature of the Earth and the terrain (mountains, buildings, forests) block radar waves. As a result, the defense system detects the target very late—only seconds before it hits the object. This leaves no time for reaction.

Asymmetric threats are forcing AD to shift from a "war of quality" to a "war of quantity and speed." Now, in overcoming these threats and problems, "precision striking" alone is not enough; providing a "cheap and rapid response" is becoming vital.

To find a solution to the crisis caused by asymmetric threats, the echeloned AD system must undergo a conceptual transformation. In this regard, the main focus should be on the **economic stability**, **reaction speed**, and **intelligence level** of the system.

The primary solution to overcoming economic asymmetry is to apply non-kinetic impact[2] to air attack assets and minimize the cost per shot by using laser technologies, microwave weapons, and artificial intelligence to destroy them. This can certainly be achieved by creating an integrated single information space and mobile, multifunctional small echelons.

Directed Energy Weapons: As of 2025, the USA, UK, Israel, Australia, and China are using laser weapons for air defense. This indicates a serious shift in military strategy and an increase in combat effectiveness. Target destruction with a laser beam is based on the focusing of thermal energy. The cost of a single laser pulse is measured only by the electricity consumed (approximately $1–$10). This provides a fundamental solution to the "cheap drone – expensive missile" problem [2].

Microwave Weapons: These destroy the semiconductors and microcircuits of drones by emitting a wide-directional electromagnetic pulse. They provide the ability to destroy a "swarm of drones" attacking across a wide front simultaneously. This is one of the most effective scientific solutions against "drone swarms."

Artificial Intelligence (AI) and Cognitive Radars: AD assets placed in individual combat orders or classical control systems cannot ensure the repelling of attacks from the large number of air attack assets present today. The problem of overload cannot be solved by the human factor alone. Using AI for automated decision-making can be considered a primary tool for solving the problem. AI algorithms analyze thousands of targets in thousandths of a second. They determine whether a target is a real threat or a deceptive mock-up based on its trajectory, speed, and radar signature [3].

Cognitive Radars: Radar systems adapt to the environment and interference, changing their own frequency. This allows for minimizing the impact of the enemy's Electronic Warfare (EW) assets.

Integrated Single Information Space: Modern AD must transition to the "network-centric" principle. The integration of all information fields, radars across all echelons, optical sensors, and even portable devices held by ordinary soldiers are linked to a single database. If one radar does not see a target, another will and automatically transmit the data. In this *distributed defense* system, the destruction of a single command center does not disable the entire AD, as each block has the ability to make independent decisions [4].

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[2] **Non-kinetic impact** — losing the function of a target using directed energy (laser, microwave) or information technology, rather than mechanical destruction (IHS Jane's Weapons & Technology: "Non-kinetic counter-UAS strategies").

pISSN:2349-5707 Volume:13,Issue 3, March -2026 eISSN:2349-5715

Implementation of Mobile and Multifunctional Small Echelons: Stationary AD objects become primary targets for air attack assets in modern warfare. Therefore, for close-range protection, it is necessary to increase the number of highly mobile, rapid-fire anti-aircraft artillery systems. It is advisable to use weapons with "smart shells" wherever possible. In this case, shells explode when near the target, creating a "cloud of fragmentation" and guaranteeing the destruction of the drone.

Echeloned AD is a multi-stage defense chain that allows for the detection, tracking, and destruction of enemy air attack assets at various distances and altitudes (from the ground surface to the stratosphere). The main goal of this system is to leave no "open areas" for the enemy and ensure the stability of the defense [5].

An echeloned air defense system is a complex of anti-aircraft missile and radio-technical troops with different technical characteristics, managed based on a single algorithm. Its conceptual basis relies on the "defense in depth" strategy, implying a consistent reduction of the enemy's attack potential at each stage [6].

Based on research results, the modern structure of echeloned AD is proposed as follows: **Long-range echelon** (Strategic protection); **Medium-range echelon** (Operational-tactical protection); **Short-range and object echelon** (Point protection); **New "Micro-AD" and EW layer** (Response to asymmetry) table 1.

table 1: Comparative Analysis of Modern AD Echelons

Echelon Layer	Typical Targets	Primary Weapon Systems	Cost per Engagement
Strategic (Long-Range)	Ballistic Missiles, Strategic Bombers	Patriot PAC-3, S-400, THAAD	High ($Millions)
Operational (Medium-Range)	Cruise Missiles, Fighter Jets	NASAMS, IRIS-T, Buk-M3	Medium ($Hundreds of Thousands)
Tactical (Short-Range)	Guided Bombs, Large UAVs	Pantsir-S1, Tor-M2, Crotale	Moderate ($Tens of Thousands)
Micro-AD (New Layer)	Kamikaze Drones, Swarms	**Laser, Microwave, AA Guns**	**Low ($1 - $1,000)**

- **Long-range echelon:** This layer is the outermost boundary of defense. Its task is to destroy the enemy's strategic aviation, ballistic missiles, and long-range strike assets before they approach the object (at distances of 150–400 km). Today, this echelon includes S-300, 400, 500, Patriot PAC-3, and FD-2000 systems. The main problem is that these systems are very expensive, and using them against small drones is considered an economic and strategic error.
- **Medium-range echelon:** This layer activates if a target passes the first barrier. Its task is to destroy cruise missiles, fighter-bombers, and large drones at distances from 30 km to 100 km. Assets belonging to this echelon include S-350 Vityaz, NASAMS, IRIS-T, Buk-M3, and KS-1. This echelon bears the main burden of protecting cities and critical infrastructure from mass missile attacks.
- **Short-range and object echelon:** Serves as the "last line" around the directly protected object (e.g., a factory, headquarters, or power plant). The primary task is to destroy low-altitude missiles, guided bombs, and drones at distances from 1 km to 20 km. This layer includes AD assets such as "Pantsir-S1," "Tor-M2," Crotale NG, FM-90, OSA-AK, Strela-10, as well as Man-Portable Air Defense Systems (MANPADS) and anti-aircraft artillery units.
- **New "Micro-AD" and EW layer:** This is a partially prospective layer primarily countering asymmetric threats. Modern warfare necessitates the creation of a new, fourth

pISSN:2349-5707 Volume:13,Issue 3, March -2026 eISSN:2349-5715

echelon. This layer relies not on classic missiles, but on cheap and effective assets, namely anti-aircraft artillery and EW tools, lasers, and microwave weapons.

Anti-aircraft artillery: Includes rapid-fire machine guns and complexes with programmable ammunition (against drone swarms). Currently, Pantsir-S1/SM, "Derivatsiya-PVO" 2S38, M-SHORAD, C-RAM, Skyranger-35, ZU-23-2, and others are used.

EW assets: Systems that "blind" the communication and GPS channels of enemy drones. Examples include Krasukha-4, Murmansk-BN, Leer-3, and others.

Laser weapons: Innovative tools that disable targets via heat or electromagnetic beams within seconds. Examples include "Iron Beam" (Israel), "DragonFire" (UK), and "Apollo" (Australia).

Microwave devices: Unlike lasers, these use electromagnetic radiation to disable electronics, capable of destroying a "drone swarm" attacking across a wide front. Examples: Epirus Leonidas (USA), "Alabuga" (Russia). [7]

This study shows that in the era of asymmetric threats, an echeloned AD system must be not just a set of technical tools, but a flexible and intelligent management strategy. Based on the analysis, the following conclusions are proposed:

Transition to Economic Proportionality: The greatest success for a future AD system is using a defense asset that is cheaper than the attacking asset. Therefore, the rapid integration of laser and microwave weapons into short and medium-range echelons is the only way to ensure the economic stability of defense.

Artificial Intelligence and "Human-out-of-the-loop" Decisions: The speed and scale of asymmetric attacks are exceeding the limits of human reaction. Implementing AI as the "brain" of the AD system to automatically sort targets and assign firing decisions (under strict supervision) increases defense reliability.

"Network-Centric" Principle and Vertical Integration: The AD system must become a single, centralized, and highly mobile information field. All links, from the smallest anti-drone device to the largest strategic missile systems, must exchange data in real-time. This prevents system "paralysis" during periods of overload.

Synthesis of AD and EW: Air defense and electronic warfare should no longer be separate systems but a single complementary system. EW should act as the "softener" of the attack, while anti-aircraft missiles and artillery serve as the "finishing" link.

In forming their defense strategies, states should not rely solely on expensive "brand" systems but prioritize creating cheap, mobile, and numerous small echelons. Ultimately, victory in asymmetric warfare lies not just in possessing the most powerful weapon, but in being able to manage the most flexible and cost-effective system.

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