

STRATEGIC IMPLICATIONS DETERMINED BY THE MASSIVE USE OF LOW-COST DRONES

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DOI: 10.19062/1842-9238.2026.24.1.1

Abstract: *This paper analyzes the structural cost asymmetry and strategic implications of the massive use of low-cost drones (e.g. Shahed-136, Geran-2) in the context of the Drone War, using the Ukraine conflict as a case study. We demonstrate that the use of high-performance interception systems (approximately millions of dollars) against low-cost drones (thousands of dollars) creates a cost asymmetry. Being unsustainable in the long run, this can be analyzed as a key economic vulnerability.*

Thus, a rapid review of integrated military doctrines is required for the new layered defense architecture, introducing "Layer 0" and the transition to non-kinetic countermeasure solutions (EW, DEW) and smart artillery.

The research method used is Multiple Cause Comparative Analysis (MCCA), supported by Cost-Effectiveness Modeling (CEM), which allows us to demonstrate that cost asymmetry is not an isolated event but a structural feature of modern warfare.

Keywords: *Cost asymmetry, defense doctrines, C-UAS, electronic warfare, War in Ukraine, Deterrence*

1. INTRODUCTION

The current strategic context on NATO's Eastern Flank is marked by physical intrusions of drones and fragments of Shahed-136/Geran-2 attack drones [1], especially on the territory of Romania and Poland [2]. Repeated discoveries of attack drone fragments, even if they do not represent a problem of airspace violation (in accordance with international law) [3], can represent a major challenge to the architecture of the collective defense system. These incidents are not simple accidents, but stress tests for collective defense procedures, which can undermine NATO's deterrence mechanisms.

Integrated Air and Missile Defence Doctrine (NATO IAMD) is based on air superiority and on defence against missiles and aircraft from air strike groups [4]. New types of sub-conventional threats, cheap, easy to mass produce and extremely difficult to detect for opportune neutralisation, establish a new strategic context that defines the sequences of massive use of drones as methods of intimidation, giving them a new role, namely that of *saturation weapons*.

Conventional systems such as Patriot or NASAMS (National Advanced Missile Surface- to-Air Systems) were designed for high-speed and high-value targets [5], not for low-RCS, low-Altitude and low-cost drones. Thus, a cost asymmetry appears as a systemic vulnerability where the defender exhausts his financial resources and ammunition stocks in the face of saturation weapons.

This paper focuses on the argument that addressing the cost asymmetry issue goes beyond the purely economic dimension, constituting a strategic imperative for doctrinal adjustments across all military architectures. While this approach does not entirely eliminate the dilemmas generated by conducting military operations in the context of the *Drone Warfare* model [6], it does contribute significantly to maintaining the shared credibility of deterrence on NATO's Eastern Flank.

2. COMPARATIVE COST ANALYSIS (HARD-KILL vs. SOFT KILL)

The analyzed empirical data on the estimated prices for the analyzed systems are presented in Tables 1 and 2. We note that the prices shown are estimates based on publicly reported production costs or export contracts and may vary depending on the specific configuration [7] [8] [9].

Table 1 - Table with the price and suppliers of attack drones frequently used in Russian attacks

Drone model	Origin / Manufacturer	Estimated unit price (USD)	Use
Shahed-136/ Geran-2	HASA (Iran) and locally assembled	20,000-50,000	Strategic strikes on Ukrainian critical infrastructure
Mohajer-6	Qods Aviation Industry (Iran)	3-5 million.	MALE (ISR/Attack) – especially in the Black Sea area
Lancet-3	ZALA Aero Group (Russia)	Approx. 35,000	Tactical use for precision strikes on high-value targets (artillery, armored vehicles, etc.)
Orion/ Inochodets	Kronstadt (Russia)	20-25 million.	MALE (ISR/Attack) – strategic drone capable of carrying guided munitions
Forpost-R	Ural Civil Aviation Plant (Russia)	5 million.	Reconnaissance, fire adjustment and secondary attacks
Kub -BLA	ZALA Aero Group (Russia)	15,000-25,000	Tactical use, at short distances, intended to destroy ground targets

Table 2 - Table of prices and suppliers of interception vectors from Allied forces

System	Interceptor (Missile)	Estimated unit price (USD)	Main supplier	Use
NASAMS	AIM-120 AMRAAM	1 -1.2 million.	Raytheon Tech. (USA)	Medium-range air defense
Patriot PAC-3	PAC-3 MSE	4-5 million.	Lockheed Martin (USA)	Defense against ballistic and cruise missiles. Can be used against drones as a final course of action
SAMP/T system	Aster 30	2-3 million.	MBDA (France, Italy)	Mobile, medium-long range air defense
Skyguard / Oerlikon	Skyranger	5,000-10,000	Rheinmetall (Germany)	Intelligent Projectile (AHEAD), as a low-cost kinetic solution against drones and artillery projectiles

As can be seen, the price of the Shahed-136 (row 1/Table 1) contrasts with that of the interceptor vectors. Due to the cost asymmetry, the market is rapidly moving towards the development of low-cost C-UAS solutions, including electronic warfare (EW) systems and directed energy weapons (DEW), as well as defensive strategies to counter any saturation attack executed by drones.

To highlight the magnitude of that imbalance, we compared the price of the Shahed-136/Geran-2 drone to that of interceptors, in an efficiency indicator: **Interception Cost Asymmetry Ratio**.

Table 3 - Cost Asymmetry Analysis

Threat (Drone)	Interceptor (Missile/System)	Drone cost (USD)	Interceptor cost (USD)	Asymmetry ratio
Shahed-136	Patriot PAC-3 MSE	30,000	4,000,000	1:133
Shahed-136	AIM-120 AMRAAM (NASAMS)	30,000	1,200,000	1:40
Shahed-136	Skyranger (AHEAD)	30,000	10,000	3:1 (<i>Advantage</i>)
Shahed-136	EW/DEW/Laser system	30,000	Approx. 100 (marginal price)	300:1 (Optimum)

Analyzing the evolution of the Ukraine conflict, it can be deduced that the war based on technological superiority is slowly but surely transforming into a problem of financial resource management. Faced with this new sub-conventional threat, based on the exploitation of the weaknesses of systems designed for high-performance threats, a dual strategic response becomes imperative. The effective integration of solution aimed at urgently addressing cost asymmetry, the adoption of non-kinetic "soft-kill" countermeasures (such as EW, DEW weapons, lasers systems etc.), and a fundamental shift in the offensive operations conduct will require a rapid transformation of air defense doctrines. Such adaptation is essential to enable defense architecture to deliver decentralized, layered and threat-adaptive responses with the evolving operational environment.

3. RESEARCH METHODOLOGY

The most appropriate method to substantiate this strategy is Comparative Qualitative Analysis (CQA), supported by Cost-Effectiveness Analysis (CEA). CQA is a qualitative-empirical method that allows the examination of two or more relevant situations to identify common variables, recurring causes and systemic trends [10].

Based on this method, we demonstrate that cost asymmetry is not an isolated incident, but a structural feature of modern warfare.

To justify the need for doctrinal changes towards low-cost asynchronous threats and the universal support of the type of aerial threat through UAS, we performed a comparative study of three types of conflicts and the particularities of the use of drones/UAS depending on the technological development specific to the respective historical stage (table 4).

Table 4

The problem studied	Focus of the analysis	Strategic conclusion
The war in Ukraine	Usage Rate of Shahed/Geran Drone vs. Interception Success Rate and Cost (Patriot, NASAMS)	Justifies the asymmetry by demonstrating stock depletion and unsustainable operational cost levels.
Nagorno-Karabakh conflict/2020	Bayraktar drones' impact on conventional armored platforms	It justifies doctrinal transformations and demonstrates the vulnerability of conventional forces to UAS threats, at the operational level.
Use of V-1 rockets in World War II	Britain's defensive response to Nazi V-1 missile attacks (early forms of low-cost and low-RCS threats)	It justifies the generation of alternative solutions and the need for the rapid development of ad-hoc and cheap technologies (cannons, EW) instead of much more expensive fighter jets.

Cost-Effectiveness Modeling [11] is a quantitative method that can be used in defense policy analysis to compare the costs of different alternatives (e.g. air defense systems) in relation to achieving the same objective (e.g. neutralizing the drone threat). Based on it, we mathematically justify the need to cost asymmetry resolves.

Thus, we establish the model variables and the quantification of key variables:

- C_{UAS} – the unit cost of a drone;
- C_{Int} – Unit cost of the interception system;
- C_{EW} – the marginal operational cost of a jamming attack (practically "0" once the system is purchased);
- P_{Kill} – Probability of neutralization/success of each method;
- R_{Ops} – The operation/maintenance rate of each system.

The *Crossover Point* is determined by the number of drones neutralized after which the total cost of an expensive system (kinetic system: NASAMS + number of missiles) exceeds that of a cheaper C-UAS system (non-kinetic: Mobile jamming system + its maintenance).

$$\text{Cost}_{\text{Total}} (\text{Kinetic}) = N \times C_{\text{Int}} + C_{\text{Systems}} (\text{Kinetic}) \quad (1)$$

$$\text{Cost}_{\text{Total}} (\text{Non-Kinetic}) = N \times C_{\text{EW}} + C_{\text{Systems}} (\text{Non-Kinetic}) \quad (2)$$

where "N" represents the number of commitments.

It is observed that for a high volume of engagements (characteristic of drone attacks), solutions with large C_{Int} quickly become exponentially unsustainable compared to C_{EW} solutions. This approach provides a robust justification, combining empirical evidence from real conflicts with a rigorous economics of defense solutions.

Variables:

- C_{UAS} – unit cost of the drone Shahed – approx. 30,000 (USD);
- C_{Int} – Unit cost of the AIM-120 / NASAMS interceptor missile – approx. 1,200,000 (USD);
- C_{EW} – marginal operational cost of a jamming system per engagement – approx. 100 (USD);
- $\text{Cost}_{\text{System}} (\text{Kinetic})$ – Initial cost of a NASAMS artillery battery – approx. 150,000,000 (USD);
- $\text{Cost}_{\text{System}} (\text{Non-Kinetic})$ - Initial cost of a high-performance EW system – approx. 20,000,000 (USD)

The total cost of using a system is determined from the initial acquisition cost and the marginal cost per engagement ("N" of engagements). Thus:

$$\text{Cost}_{\text{Total}} (\text{Kinetic}) = N \times 1,200,000 + 150,000,000 \quad (3)$$

$$\text{Cost}_{\text{Total}} (\text{Non-Kinetic}) = N \times 100 + 20,000,000 \quad (4)$$

The mathematical model compares a kinetic (NASAMS) with a non-kinetic (EW) systems.

The *Crossover Point* is the number of commitments (N) at which the total cost of the two equations becomes equal:

$$N \times 1200000 + 150000000 = N \times 100 + 20000000 \quad (5)$$

Solving the equation, we obtain:

$$\begin{aligned} N \times 1199900 &= 130000000 \\ N &= 108.34. \end{aligned} \quad (6)$$

We use **109 engagements** (drones used) as the *Crossover Point* value.

Therefore:

- **Under 109 engagements:** The kinetic system is cost-effective due to immediate accuracy, with the higher initial cost of the EW system not yet recouped through missile savings;

- **Over 109 engagements:** The EW system is cost-effective, becoming critical for economic survival as the marginal cost of the missile (approx. \$1.2 million) increases linearly towards unsustainability.

4. ANALYSIS AND DISCUSSION: IMPLEMENTATION OF “LAYER 0”

This cost-effectiveness analysis fully justifies the model of attack drone countermeasure scenarios in operations conducted during the Ukraine war in which the threshold of 109 drones is quickly exceeded.

The main operational-strategic consequences are:

1. **Economic exhaustion:** Continuing these operational procedures to combat attack drones leads to a rapid and unsustainable depletion of defense budgets, forcing NATO forces to spend precious resources to neutralize a technologically marginal potential threat;

2. **Stock depletion:** Intensive use of expensive interception vectors with a long production cycle leads to stock depletion, leaving NATO's Eastern operational flank vulnerable to high-value threats (aircraft, cruise missiles etc.);

3. **Decreased credibility of deterrence:** The failure to develop an effective and cost-efficient response to the low-cost threats signals to a potential enemy the existence of exploitable vulnerabilities that may be leveraged in a possible attack.

Following the ongoing analysis, we consider the following immediate solutions to correct the gap caused by this asymmetry are shifting interest towards non-kinetic and low-cost kinetic investments:

- **Advanced electronic warfare solutions:** We consider them to be the fastest alternative to counter attack drones. Investments in jamming systems capable of neutralizing GNSS (Global Navigation Satellite System) components and C2 (Command and Control) of drones offers a high success rate for the ratio of marginal cost vs. number of interceptions;

- **Directed energy weapons and lasers:** The development and integration of systems based on microwaves, very high frequencies, as well as high-power lasers, which are already present in numerous applications and systems, can offer solutions with a cost of approximately "zero" per shot, once the system is purchased;

- **Modern anti-aircraft artillery systems:** The use of modern anti-aircraft artillery systems, with reprogrammable projectiles and high firing rates, can saturate the airspace with strikes much cheaper than a missile, representing the complementary solution for targets that are not affected by EW.

The continued exclusive use of expensive kinetic methods (most of the current doctrinal frameworks applicable to all categories of armed forces) has become an unsustainable strategy in the long term and amounts to a planned financial self-exhaustion by the adversary.

We appreciate that the quantitative results obtained through CEM provide a mathematical and logical basis to support the operational effectiveness depending on the number of engagements of an anti-drone air defense system, for the following approaches:

1. **Economic:** Since C_{Int} (Kinetic) is unsustainable, funds must be allocated for the development of C_{Int} (Non-Kinetic) solutions, which are much cheaper, thus solving the issue of cost asymmetry;

2. **Doctrinal:** Because EW-based C-UAS systems are often decentralized and mobile, operating at low altitude, their large-scale implementation requires doctrinal changes from a centralized architecture to a distributed, multi-layered and integrated C-UAS architecture.

The current NATO IAMD doctrine (updated on 13 February 2025) must be implemented quickly to cover detection and combat gaps at altitudes below 300 m.

The Qualitative Stratification principle, currently adopted, is outdated, unable to cope with low-RCS technologies and the extremely large dispersion of drones. Attack drones can operate at low altitudes (below 300 m) and low speeds (below 200 km/h) and are often unidentified by radars designed with filters to ignore signals from birds, from relief forms in the vicinity of the combat position and other asynchronous jamming signals. This creates detection gaps in the lower layers of defense, being designed to ensure good protection of high-value points (HQ, air bases, missile division positions, other territorial objectives of strategic importance). In the event of a dispersed attack with drones, this can no longer be applied, as drones pose a challenge to current centralized, fixed and semi-mobile air defense systems.

We believe that new doctrinal measures must focus on air density management and multi-domain, multi-layered defense of C-UAS systems, namely:

1. **Development of "Layer 0":** Creating a level of defense below that provided by IAMD. This will consist of multimodal sensors (optical, thermal, acoustic), mobile EW systems, other small radar systems etc., to compensate for the limitations of conventional radars.

2. **Integration of civil-military warning architectures (All-Domain Awareness):** The recognition that drones cross civil airspace determines the involvement of non-military warning structures, as civil telecommunications operators, air traffic control and even ad-hoc civil-military visual observers (gendarmes, police officers, other agents from the ensuring public order system and even individuals present occasionally in the drones' area of action) having a very important role in providing timely information for creating the Common Operating Picture (COP), in real time;

3. **Decentralized decision-making:** C-UAS systems must be able to engage targets in the shortest possible time, which is impossible under centralized coordination management. These systems must be capable of autonomous or semi-autonomous decision-making to reduce reaction time in the face of drone swarms.

4. CONCLUSIONS: SUSTAINABILITY OF DETERRENCE

This paper justifies the need for a fundamental change in the air defense doctrine of Romania and other NATO armies, with an emphasis on the integration of EW systems and other low marginal cost countermeasures, not as a tactical option but as a strategic necessity imposed by the economic logic of modern warfare.

Cost asymmetry is a form of financial self-depletion planned by the adversary. From an economic and operational point of view, it can lead to a number of vulnerabilities for national and the Alliance security.

We conclude that to maintain the credibility of deterrence on the NATO Eastern Flank, the Ministry of National Defense and NATO must prioritize:

- Massive investments in Electronic Warfare (EW) and Directed Energy Weapons (DEW);
- Adopting a distributed and mobile architecture, capable of protecting not only high-value points but also extended geographical spaces against hybrid threats;
- Updating the legal framework to enable an agile response to sub-conventional threats.

These transformations will ensure not only the protection of national airspace, but also the financial sustainability of deterrence, in the medium and long term.

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