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From commodities to weapons: a political-economic critique of the "cost inversion" of FPV drones from the perspective of Marx's theory of machinery

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Abstract. The systematic deployment of First-Person-View (FPV) drones in the Russia–Ukraine conflict has revealed a pronounced phenomenon of "cost inversion": FPV drones costing only a few hundred dollars each can repeatedly destroy high-value weapons platforms worth millions or even hundreds of millions of dollars. Tactical drones now account for 60% to 70% of total equipment losses. Taking Marx's theory of machinery as its analytical framework, this paper examines the theoretical implications of this phenomenon through the lens of the antagonistic relationship between "fixed capital" and "living labor". Although the concept of "cost asymmetry" in existing security studies describes the phenomenon, it fails to uncover the underlying logic of production relations. Drawing on the systematic deployment of FPV drones in the Russia–Ukraine conflict as an empirical case, this paper conducts an empirical analysis of their cost structures and exchange ratios based on publicly available data. It introduces the concept of "disembedding from the logic of fixed capital" and argues that FPV drones systematically dismantle high-value weapons platforms through three interconnected mechanisms: consumableization, commodity-based supply chains, and low operational barriers. These mechanisms enable FPV drones to escape the constraints imposed by the recovery of value invested in military fixed capital. This analysis extends Marx's theory of machinery from the sphere of production to the analysis of military technology, providing a new analytical framework for critique within the field of the political economy of war.

Keywords: Marx's theory of machinery, fixed capital, FPV drones, cost inversion, political economy of war

1. Introduction: a military phenomenon requiring a political-economic explanation

1.1. Statement of the problem: the starting point of operation Spiderweb

On June 1, 2025, the Security Service of Ukraine launched a special operation codenamed "Spiderweb". A total of 117 FPV suicide drones were concealed in wooden compartments built into modified trucks and transported through civilian logistics networks to locations near five military airfields, including Olenya Air Base in Murmansk Oblast and Belaya Air Base in Irkutsk Oblast. After being assembled within approximately

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200 kilometers of their targets, the drones were remotely controlled via satellite communications and launched coordinated attacks. According to estimates based on publicly available information, each FPV drone used in the operation cost only $300–$600, putting the total cost of the 117 drones at just $60,000–$150,000. By contrast, one of the targeted aircraft, a Tu-95MS strategic bomber, was worth more than $100 million [1]. The cost ratio between the attacking and targeted sides in a single strike was therefore extraordinarily disproportionate.

Operation Spiderweb provides a useful starting point for this paper not because of its tactical innovation—concealing drones within civilian logistics networks to facilitate infiltration was not an entirely new method—but because of the theoretical tensions embedded in its economic structure. The fundamental question is why a weapon system converted from civilian commodities can inflict systematic and devastating damage on an adversary's high-value equipment at a cost as low as one-thousandth or even one-ten-thousandth of its value. Answering this question requires an examination of the economic characteristics of weapons systems and the underlying contradictions inherent in their modes of production.

1.2. The systemic and widespread nature of the phenomenon

Operation Spiderweb was not an isolated incident. An assessment report published by the Royal United Services Institute (RUSI) in 2025 indicated that tactical drones accounted for 60% to 70% of total Russian equipment losses, a figure corroborated by multiple independent assessments[1]. In terms of the exchange ratio between individual weapons systems, FPV drones costing $400–$1,000 have repeatedly destroyed M1 Abrams main battle tanks valued at $8 million–$10 million [2]. Even under the extremely conservative assumption that ten drones are required to destroy one tank, the cost ratio remains as high as 1:1,000. In an interview in March 2026, Brovdi, commander of Ukraine's Unmanned Systems Forces, reported that the force had achieved a loss ratio of 400:1, with an average cost per kill of approximately $878. These figures suggest that "cost inversion" has evolved from an occasional tactical occurrence into a reproducible military-economic model[2]. From the broader perspective of unmanned systems deployment, this trend has also prompted researchers to reassess the logic of victory and the structure of military power in modern warfare [3].

Table 1. Comparison of cost asymmetries between typical weapons systems in the Russia–Ukraine conflict

Weapons system	Unit cost (USD)	Typical target	Unit cost of target (USD)	Cost ratio
FPV drone	300–600	Tu-95MS strategic bomber	More than $100 million	Approximately 1:170,000 to 1:330,000
FPV drone	400–1,000	M1 Abrams tank	$8 million–$10 million	Approximately 1:8,000 to 1:25,000
FPV drone (system-wide average)	878 (average cost per kill)	Combined personnel and equipment targets	—	Loss ratio of 400:1

Note: Data sources are provided in references [1] and [2] cited in the text[3,4].

[1] Watling, J., & Reynolds, N. (2025). Tactical developments during the third year of the Russo-Ukrainian War (pp. 1–24). Royal United Services Institute.

[2] Elephant News. (2026, July 10). A thousand-mile strike on Moscow: Are Ukraine's drone tactics becoming increasingly aggressive? An examination of the economics behind them. Retrieved October 15, 2026, from https://www.hntv.tv

[3] See Note 1.

[4] See Note 2.

Table 1 does not merely present isolated data points. Rather, it reveals an internally consistent economic structure: the cost efficiency achieved by low-cost weapons systems in destroying high-value targets has exceeded the explanatory scope of the traditional concept of "asymmetric warfare" in military economics.

1.3. Limitations of existing explanations and the theoretical approach of this paper

Security studies and policy analysis have introduced the concept of "cost asymmetry" to characterize the phenomenon described above. The central argument is that FPV drones overturn traditional calculations of relative military power through their exceptionally low unit costs. However, the explanatory power of this descriptive concept has clear limitations. The use of low-cost means to counter high-value targets is not new in the history of guerrilla warfare. From landmines to improvised explosive devices, the strategy of using inexpensive means to deplete an adversary's costly resources has persisted throughout the history of modern conflict. What requires explanation is not asymmetry itself, but why asymmetry under current technological conditions has reached an unprecedented magnitude, and whether this change in scale indicates a structural transformation in the underlying logic of military production.

This paper argues for a return to Marx's theory of machinery as developed in *Capital* and his manuscripts. Marx examined three central dimensions of machinery: machinery as a representation of the productive forces and a "collection of instruments of labor"; machinery as a form of fixed capital and a "means of producing surplus value"; and machinery as an accomplice of capital and "the most powerful weapon for repressing the working class" [4]. In Marx's analysis, capitalist production dominated by machinery systems leads to the progressive expansion of fixed capital as an objective condition of living labor. Relative to living labor, fixed capital becomes increasingly independent and confronts living labor as an alien power [5]. The distinctive value of this framework lies in its understanding of machinery not in terms of technological efficiency, but in terms of capital relations, thereby revealing the inherent contradiction of machinery as fixed capital: its high value necessitates a long service life and stable operating conditions, yet these very requirements contain the possibility of its destruction by low-cost means [6].

1.4. Core argument and structure of the paper

The central argument of this paper unfolds at three levels. At the empirical level, it systematically presents the characteristics of the "cost inversion" phenomenon associated with FPV drones and the supporting empirical evidence. At the theoretical level, it uses the antagonistic relationship between "fixed capital" and "living labor" in Marx's theory of machinery as its analytical framework to demonstrate that the theoretical significance of "cost inversion" lies in the logical crisis confronting high-value weapons platforms as forms of military fixed capital. At the level of theoretical extension, it introduces the concept of "disembedding from the logic of fixed capital" and analyzes how FPV drones systematically dismantle high-value weapons platforms by becoming disembedded from this logic.

This chapter takes Operation Spiderweb as its starting point, elevating the "cost inversion" of FPV drones from an isolated case to a systemic military-economic phenomenon. It identifies the descriptive limitations of the concept of "cost asymmetry" in security studies and proposes Marx's theory of machinery as the analytical framework. The next chapter develops this theoretical framework in a systematic manner.

2. Constructing the analytical framework: core propositions of Marx's theory of machinery and the introduction of the concept of "disembedding from the logic of fixed capital"

Chapter 1 established the "cost inversion" of FPV drones as a systemic military-economic phenomenon and pointed out that the descriptive concept of "cost asymmetry" in security studies fails to investigate the production relations underlying this phenomenon. This chapter aims to construct a theoretical framework capable of addressing this question through three successive theoretical tasks: clarifying the core propositions of Marx's theory of machinery; demonstrating the rationale and limitations of extending this framework from the capitalist production process to the process of military consumption; and introducing the central analytical concept of this paper, namely, "disembedding from the logic of fixed capital".

2.1. Core propositions of Marx's theory of machinery: machinery as fixed capital and the domination of living labor by "dead labor"

2.1.1. Theoretical implications of machinery as fixed capital

In the chapter "*Machinery and Large-Scale Industry*" in Volume I of *Capital*, Marx examines machinery within the overall structure of capital relations and elaborates on three of its central dimensions: machinery as a representation of the productive forces and a "collection of instruments of labor"; machinery as a form of fixed capital and a "means of producing surplus value"; and machinery as an accomplice of capital and "the most powerful weapon for repressing the working class" [4, 6]. Among these dimensions, the determination of machinery as fixed capital provides the theoretical foundation for understanding the other two.

In Marx's analysis, the productive power of machinery systems derives primarily from the transformation of instruments of labor through science and technology operating independently of individual workers, rather than from the extension of workers' individual skills. As "organs of the human brain created by the human hand", machinery systems embody "the power of knowledge objectified". In the *Grundrisse: Foundations of the Critique of Political Economy, 1857–1858*, Marx further identifies the automatic machinery system as the "most adequate form" of fixed capital. Rooted in scientific and technological progress, such systems can reduce necessary labor to the greatest possible extent and increase relative surplus value [5]. The widespread application of machinery systems in production enables capital to establish a distinctive mode of production suited to its own nature, one in which machinery replaces labor as a principal measure of social productive power [4]. This means that, under the capitalist mode of production, fixed capital is not merely a material asset but also a reified form of social relations: it embeds the relations of capital's domination over labor within the autonomous operating logic of machinery systems. As one scholarly account summarizes, machinery systems constitute the reification of the social relations governing labor and of the power of capital, serving as the consummate vehicle of fixed capital and the highest realization of the logic of capital [7].

2.1.2. The domination of "dead labor" over "living labor"

The theoretical implications of machinery as fixed capital are further developed in Marx's analysis of the relationship between "dead labor" and "living labor". In the "*Fragment on Machines*" in the *Grundrisse: Foundations of the Critique of Political Economy, 1857–1858*, Marx explicitly states: "Objectified labor confronts living labor in the labor process itself as a power that dominates it ... as the instruments of labor are transformed into a machinery system, living labor is transformed into a mere living appendage of this machinery system" [5]. This argument contains two distinct propositions. First, as the crystallization of objectified labor, machinery systems are transformed into a form of power that dominates living labor under

capitalist relations. Second, workers are reduced from the subjects of the labor process to the "living appendages" of machinery systems [8].

The expansion of social production under the dominance of machinery systems leads to the progressive expansion of fixed capital as an objective condition of living labor. Relative to living labor, fixed capital becomes increasingly independent and confronts living labor as an alien form of power [5]. In machine-based production, capital's power to control workers is transformed into the autonomous operating logic of machinery systems. This transformation not only legitimizes the power of capital through the standardized metrics of science and technology and their far-reaching civilizational effects, but also reinforces the structure of capital's power through the stability and continuity of machinery systems [7]. From the perspective of the labor process, machinery systems tend to deskill living labor. This does not mean that skills are eliminated; rather, they are objectified in operational procedures and automated equipment [8]. The theoretical significance of this process of "deskilling" lies in its revelation of a central characteristic of the logic of fixed capital: the more the use value of machinery depends on its own technical performance, the more marginal the position of living labor becomes in value creation.

2.1.3. The internal contradiction of the logic of fixed capital: the risk of low-cost attrition of high-value assets

Marx's theory of machinery contains a proposition that has not yet been fully developed but has considerable analytical potential: the internal contradiction of the logic of fixed capital. At the heart of this contradiction is the fact that the high value of fixed capital requires a sufficiently long service life and sufficiently stable operating conditions to enable its value to be recovered gradually over the course of sustained production. Yet this very requirement creates the possibility that fixed capital may be undermined by low-cost means.

From the perspective of value realization, the recovery of the value of fixed capital depends on the rate at which its value is gradually consumed and transferred during the production process. If fixed capital suffers unexpected damage or is retired prematurely in actual use, the portion of its value that has not yet been transferred cannot be recovered, thereby interrupting the process of capital accumulation. In his analysis of the circulation of fixed capital, Marx observes that the value of fixed capital is "gradually transferred to the product through use". This transfer process presupposes that the material form of fixed capital remains intact over an extended period [6]. Once this precondition is disrupted—whether by technological obsolescence or physical destruction—the very existence of fixed capital as capital faces a fundamental crisis. From the perspective of use value, the high value of fixed capital requires it to possess sufficient survivability in adversarial environments. When the cost of means of attack falls to a level at which attackers no longer need to prioritize precision in individual strikes and can instead rely on numerical superiority to achieve saturation attacks, the logic governing the survival of fixed capital undergoes a fundamental change. The defending side must incur extremely high unit costs to maintain the operational effectiveness of its platforms, whereas the attacking side can expend very little to deplete the adversary's defensive resources. The deeper implication of this economic logic is that the high value of fixed capital, rather than constituting an advantage, becomes a liability: it turns high-value assets into attractive targets for cost-effective attacks by low-cost weapons.

2.2. Theoretical translation from capitalist production to military production: rationale and boundaries

2.2.1. The "fixed capital" characteristics of weapons systems

The extension of Marx's analytical framework of machinery as fixed capital to the military sphere is justified by the structural homology between weapons systems and productive fixed capital. Modern weapons

platforms, including main battle tanks, air defense systems, and fighter aircraft, share highly similar economic characteristics with machinery systems in factories in terms of their modes of production.

First, they require substantial investment in research and development and have long production cycles. Take the M1 Abrams main battle tank as an example. The U.S. Army invested more than $400 million in the development and testing of the M1A2 SEPv4 between fiscal years 2018 and 2024 alone [2]. A complete Patriot air defense system costs more than $1 billion, including approximately $400 million for the launch system and $690 million for the missiles[5]. This pattern of substantial R&D investment is fundamentally similar to the investment required to develop large-scale machinery and equipment in factories: both embody objectified knowledge, and their value must be recovered gradually through long-term use. Second, they require long service lives and incur high maintenance costs. The operating and maintenance costs of heavy armored vehicle fleets account for approximately 70.81% of their total life-cycle costs, increasing exponentially as the equipment ages [2]. This means that the value of a tank is reflected not only in its purchase price but also in the sustained investment required to maintain the entire support system associated with it as "fixed capital", including supply chains, maintenance facilities, and personnel training systems. This characteristic is entirely consistent with Marx's analysis of machinery as fixed capital: the high value of machinery derives not only from its manufacture but also from the comprehensive supporting infrastructure required to keep it operational [6]. Third, they require specialized operation. The effectiveness of high-value weapons platforms depends on trained operators. This resembles the role of workers as "living appendages" in machine-based production: operators must acquire highly specialized skills, yet these skills remain subordinate to the technical logic of the weapons systems they operate [8].

Table 2. Structural homology between productive fixed capital and military fixed capital

Economic characteristic	Productive fixed capital (machinery systems)	Military fixed capital (weapons platforms)
Value composition	High R&D investment and long production cycles	High R&D investment and long production cycles
Value recovery	Gradually transferred through long-term production processes	Gradually "consumed" over long service lives
Maintenance requirements	Continuous maintenance to preserve operational efficiency	Continuous maintenance to preserve combat effectiveness
Relationship with personnel	Workers serve as "living appendages"	Operators serve as technical adjuncts to the platforms
Form of existence	Assets intended for long-term use	Platforms intended for long-term service

The correspondences presented in Table 2 indicate that weapons systems exhibit structural homology with productive fixed capital in terms of their underlying economic logic. This homology provides the basis for the theoretical translation undertaken in this paper.

2.2.2. Boundaries and limitations of theoretical translation

However, the rationale for theoretical translation does not imply unconditional applicability. Clearly defining the boundaries of this translation is essential to maintaining the academic rigor of the analytical framework. The translation undertaken in this paper requires explicit limitations along two dimensions.

[5] See Note 2.

The first concerns differences in the objects of analysis. In *Capital*, Marx examines the relationship between machinery and living labor in the capitalist production process, in which machinery, as fixed capital, participates in the valorization process, while living labor, as the source of value creation, is subordinated to the machinery system [6]. The object of analysis in this paper, by contrast, is the confrontation between weapons systems in the process of military consumption, specifically the attritional strikes carried out by low-cost FPV drones against high-value weapons platforms. This difference means that the present study does not analyze the process of value creation but instead focuses on the logic of value consumption. In this sense, the concept of "fixed capital" employed here is applied in terms of its value form and conditions of survival, rather than its role in value creation. This qualification is necessary to avoid mechanically applying Marx's analysis of surplus-value production to the sphere of military consumption.

The second concerns differences in theoretical function. Marx's theory of machinery is a critical analysis of the capitalist mode of production, with the aim of revealing the internal contradictions of capitalist relations [6]. The purpose of employing this theoretical framework in the present study is not to reproduce Marx's critique of capitalism, but to apply his analytical tools to explain a new empirical phenomenon that he could not have anticipated. Marx did not foresee drone warfare, nor should he be expected to have accounted for the "cost inversion" of FPV drones. Nevertheless, his analysis of machinery as fixed capital and of the internal contradictions of fixed capital provides a logically coherent starting point for understanding this phenomenon [5, 6]. The theoretical validity of this translation lies in the effectiveness of the analytical tools employed, rather than in any assumption that the conclusions are predetermined.

2.3. Introducing the concept of "disembedding from the logic of fixed capital"

Building on the preceding theoretical analysis, this paper proposes "disembedding from the logic of fixed capital" as its central analytical concept. The term refers to a process in which certain weapons systems break away from the form of high-value, long-cycle fixed capital and are transformed into a low-value, expendable form of circulating capital.

This "disembedding" does not constitute a rejection of Marx's theory; rather, it extends the boundaries of the theory in light of new empirical conditions. Marx's theoretical framework takes machinery as the "typical form" of fixed capital as its object of analysis, with the core assumption that fixed capital necessarily operates along a trajectory characterized by high value, long service life, and maintenance requirements [6]. The distinctive feature of FPV drones is that they are designed from the outset to reject this trajectory. Rather than being designed as assets for long-term use, they are intended as single-use expendable items, making them more akin to ammunition than to weapons platforms [2]. This "self-expendable design" allows them to shed the burdens associated with fixed capital: they do not require a maintenance infrastructure, highly trained specialist operators, or complex logistical support. Their value is consumed in a single use rather than transferred gradually over an extended period of operation.

The analytical function of this concept lies in its provision of a unified explanatory framework that integrates the commodity characteristics of FPV drones (civilian supply chains and consumer electronics cost curves), their technical characteristics (single-use design and low operational barriers), and their economic characteristics (cost inversion) within a single theoretical logic. When a weapons system is designed to become "disembedded" from the logic of fixed capital, it simultaneously relinquishes both the burdens and the advantages of fixed capital. It no longer possesses the technical performance or survivability of a high-value platform, but it also escapes the high cost pressures and constraints on flexibility that such platforms inevitably face. The "cost inversion" associated with FPV drones is the direct economic consequence of this choice to become disembedded.

This chapter has established the analytical framework for the paper as a whole. At the theoretical level, it has systematically examined three core propositions of Marx's theory of machinery: machinery as fixed capital, the domination of "living labor" by "dead labor", and the internal contradictions of fixed capital. At the level of theoretical translation, it has demonstrated the structural homology between weapons systems as military fixed capital and productive fixed capital, while clarifying the boundaries of this translation in terms of both the object of analysis and theoretical function. At the conceptual level, it has introduced "disembedding from the logic of fixed capital" as the central analytical concept and defined its relationship to Marx's original theoretical framework and its analytical function. The next chapter shifts from theoretical construction to empirical analysis, examining the specific pathways through which FPV drones are transformed "from commodities to weapons".

3. "From commodities to weapons": the commodity logic and weaponization pathways of FPV drones

Chapter 2 developed the analytical concept of "disembedding from the logic of fixed capital" at the theoretical level, established the structural homology between weapons systems as military fixed capital and productive fixed capital, and identified the distinctive feature of FPV drones as their rejection, from the outset of their design, of the trajectory dictated by the logic of fixed capital. This chapter shifts from theoretical construction to empirical investigation. Following the analytical sequence of "commodity characteristics—weaponization pathways—wartime production capacity expansion", it examines the specific process through which FPV drones are transformed "from commodities to weapons" and reveals how this transformation poses a substantive challenge to the logic of military fixed capital.

3.1. The commodity characteristics of FPV drones as consumer electronics products

3.1.1. Civilian technological foundations and consumer electronics supply chains

Before becoming weapons, FPV drones are first and foremost consumer electronics products. Their technological prototypes are racing-grade quadcopters, a category of consumer products that matured within the model aircraft enthusiast community during the 2010s. Equipped with onboard cameras that transmit video signals in real time to the operator's VR goggles, these drones provide an immersive first-person flying experience. The defining feature of this technological approach is that all its key components are sourced from consumer electronics supply chains [2].

In terms of their material composition, the core components of a combat FPV drone include a flight controller microcontroller (unit cost: $2–$10), an image sensor ($20–$80), a radio-frequency communication module ($5–$20), a power management chip ($3–$15), and an optional NAND storage module ($5–$20) [2]. The chip families used in these components, such as STMicroelectronics' STM32 series of microcontrollers and Sony's consumer-grade image sensors, belong to the same product lines as chips used in industrial robots, automotive electronics, and Heating, Ventilation, and Air Conditioning (HVAC) controllers [2]. As one analysis observes, an FPV drone is essentially a "flying stack of semiconductors". None of the components listed in its bill of materials was developed specifically for military applications; instead, they are standardized products that have been validated through mass production in the global consumer electronics market [2].

The theoretical significance of this characteristic is that the technological foundations of FPV drones naturally subject them to the cost-reduction curves and production-capacity expansion logic of the consumer electronics industry. The development of military-specific weapons systems follows a linear trajectory of "demand-driven development—specialized design and development—small-batch production". By contrast,

the technological evolution of FPV drones is embedded in the cycle of "mass production—cost reduction—performance iteration" that characterizes the consumer electronics industry[6].

3.1.2. Cost reduction curves

Changes in the cost of FPV drones directly reflect the economies of scale associated with the consumer electronics industry. Based on publicly available data from multiple sources, the total system cost of combat FPV drones followed a steady downward trend between 2022 and 2025 [2].

Table 3. Changes in the cost structure of combat FPV drones (2022–2025)

Year	Basic platform cost (USD)	Total system cost (USD)	Principal cost drivers
2022	200–300	400–600	Small-batch assembly in manual workshops; fragmented component procurement
2023	150–250	300–500	Greater component standardization; initial supply chain integration
2024	120–200	250–450	Large-scale production; substantial reductions in the cost of flight controllers and video transmission modules
2025	100–150	200–400	Mature consumer electronics supply chains; increased automation in assembly

Note: Data sources are provided in reference [2] cited in the text.

Table 3 shows that the cost of the basic platform, excluding the warhead and military-grade reinforcement, declined from approximately $200–$300 in 2022 to the $100–$150 range in 2025. The total system cost, including the warhead, electronic hardening, and control systems, fell from $400–$600 to $200–$400 over the same period [2]. The shape of this cost curve closely resembles the typical cost-reduction curves of consumer electronics products, such as smartphones and aerial photography drones.

3.2. Low-cost weaponization pathways

3.2.1. Technical characteristics of modification methods

A defining feature of the transformation of FPV drones from commodities into weapons is the low technical barrier to weaponization. The modification process does not involve altering the underlying technical architecture of the platform itself; it is limited to adding a warhead and a simple aiming device. Warheads are typically adapted from off-the-shelf RPG-7 rocket-propelled grenade warheads or shaped-charge warheads produced through 3D printing, at a unit cost of approximately $50–$200. Aiming devices are implemented through simple modifications to civilian video transmission systems [1]. In terms of deployment, airborne delivery and dispersal technologies further lower the barriers to deploying FPV drones, enabling their mass deployment over greater distances and under more complex battlefield conditions [9].

This means that the "weaponization premium" of FPV drones—that is, the additional cost required to transform a civilian platform into a functional weapons system—typically does not exceed $200–$300 [1]. A civilian FPV drone with a market price of $500–$800 can be modified through software adjustments and the

[6] Xue, Zichen. (2026, October 12). How can military equipment worldwide transition to low-cost models? Retrieved October 15, 2026, from https://www.aisixiang.com

addition of a warhead, with its total cost remaining below $3,000. Yet its battlefield effectiveness is comparable to that of the Javelin anti-tank missile, which costs $150,000 per unit. In terms of cost efficiency[7], FPV drones are 100 to 350 times more cost-effective than Javelin missiles[8].

3.2.2. The logic of transformation from commodities to weapons

The theoretical significance of the modification process described above lies in its revelation of a transformation logic fundamentally different from that of military-specific weapons systems. Traditional weapons development follows the trajectory of "military requirements → specialized design → independent production", with military requirements determining the technological pathways and cost structures of weapons. By contrast, the weaponization of FPV drones follows the trajectory of "civilian technology → commercial product → simple modification → weapons system", with their core components sourced from consumer electronics supply chains and their development governed by the cost-reduction curves of consumer electronics [2].

The essence of this transformation is not a technological breakthrough but an "incursion" of commodity logic into the domain of military production[9]. The destructive capabilities of FPV drones do not derive from specialized military R&D, but from the continuous advances made by the consumer electronics industry in flight control algorithms, image transmission, battery energy density, and other technologies [2]. The extremely low marginal cost of weaponization means that almost anyone with basic practical skills can convert a civilian FPV drone into a weapons system. The barriers to weapons production are thus shifted away from specialized military-industrial complexes toward dispersed small workshops and individual operators[10].

3.3. Production capacity expansion under wartime production regimes

3.3.1. Ukraine's FPV drone production system

Ukraine's FPV drone production system is a representative case of the logic of commodified production under wartime conditions. In 2025, Ukraine produced approximately three million FPV drones over the course of the year, equivalent to one drone rolling off the production line every ten seconds. Ukraine's defense industry has an annual production capacity exceeding eight million drones, with more than 160 companies involved in production, some of which can manufacture over 100,000 units per month. The supply of FPV drones to Ukraine's Unmanned Systems Forces reached approximately 200,000 units per month in 2025. Production capacity increased approximately one thousandfold, from several thousand units in 2022 to three million in 2025 [1].

The organizational characteristics of this production expansion include a high degree of decentralization and market orientation. Production is undertaken by hundreds of small enterprises and even individual workshops rather than being concentrated in a small number of large defense manufacturers. This model of "distributed production" is possible precisely because the technical and capital barriers to FPV drone production are extremely low: the core components can be purchased on the open market, and assembly requires no specialized production facilities[11].

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7 See Note 2.

8 See Note 2.

9 See Note 6.

10 See Note 6.

11 See Note 6.

3.3.2. Russia's FPV drone production system

Russia has also substantially expanded its production capacity. In June 2026, First Deputy Prime Minister Denis Manturov stated that Russian companies could produce more than 15,000 FPV drones per day, whereas in 2023, this volume represented their monthly output. This indicates an approximately thirtyfold increase in production capacity over three years. According to publicly available intelligence assessments, Russia planned to produce 7.3 million FPV drones and 7.8 million drone warhead units in 2026 [10].

Russia has adopted an organizational model that differs from Ukraine's. The introduction of standardized munitions interfaces, fiber-optic control technology, and assembly lines for mass production has brought its production system closer to the conventional model of large-scale defense manufacturing [10]. Nevertheless, the two countries share the same underlying economic logic: production capacity expansion is driven not by breakthroughs in military technology, but by the rapid redirection of low-cost, standardized, and highly replicable civilian supply chains toward wartime production[12] [10]. Some analyses further suggest that Russia's organizational model for drone warfare is shifting from centralized defense manufacturing toward decentralized, commercially oriented procurement, a transition that poses a profound challenge to the traditional military-industrial system [11].

3.3.3. The military conversion of the logic of commodified production

Considered together, the production capacity figures for Ukraine and Russia and the cost data presented in Table 3 support a theoretically significant conclusion: the fundamental reason FPV drone production can expand to millions of units within a short period during wartime is not the mobilization capacity of the military-industrial sector, but the rapid redirection of existing production capacity within consumer electronics supply chains toward military applications[13]. FPV drone production does not require the construction of new, dedicated defense production lines, the training of specialized defense industry workers, or the establishment of independent military supply chains. All the necessary infrastructure already exists within the consumer electronics industry[14].

The theoretical implication of this conclusion is that the transformation of FPV drones "from commodities to weapons" provides empirical validation of the concept of "disembedding from the logic of fixed capital" developed in Chapter 2. FPV drones achieve extremely low unit costs and high production flexibility precisely because they are "disembedded" from the logic of fixed capital: they are not designed to maximize service life, do not require specialized maintenance systems, and do not depend on highly specialized operators [2]. Their production processes are embedded in the commodity production logic of the consumer electronics industry rather than in the fixed-capital logic of military-specific equipment[15].

This chapter has examined the transformation of FPV drones "from commodities to weapons" across three dimensions: commodity characteristics, weaponization pathways, and wartime production capacity. The analysis demonstrates that the essence of this transformation is not a breakthrough in military technology, but the penetration of the logic of commodified production into the domain of military production. The core components of FPV drones are sourced from consumer electronics supply chains, the technical barriers to weaponization are extremely low, and wartime production expansion is driven by the rapid conversion of civilian supply chains to military use. Taken together, these empirical characteristics provide support for the

[12] See Note 6.

[13] See Note 6.

[14] See Note 6.

[15] See Note 6.

concept of "disembedding from the logic of fixed capital". Building on this analysis, the next chapter systematically presents empirical evidence and exchange-ratio data on "cost inversion", providing a quantitative basis for the theoretical analysis.

4. Empirical evidence of "cost inversion": data presentation and exchange-ratio analysis

The analysis in Chapter 3 demonstrates that the essence of the transformation of FPV drones "from commodities to weapons" lies in the penetration of the logic of commodity production into the field of military production. This chapter presents quantitative evidence of "cost inversion" from two perspectives: cost structure decomposition and exchange-ratio verification. It thus provides an empirical basis for the subsequent theoretical analysis.

4.1. Cost structure decomposition of FPV drones

4.1.1. Component-level cost analysis

The cost advantage of FPV drones is rooted in their component-level cost structure. According to an industry report published by Guolian Minsheng Securities in 2026, a complete FPV drone system consists of the following components: a carbon-fiber frame ($20–$50), brushless motors and electronic speed controllers (approximately $110), propellers ($3–$5), a flight controller board ($25–$50), a video transmission system ($30–$150), a radio receiver ($10–$30), a battery ($20–$40), and an optional mission payload. The total cost of a complete drone typically ranges from $200 to $400 [2]. Among these components, the flight controller board uses microcontrollers from STMicroelectronics' STM32 series; the video transmission system comes from consumer electronics brands such as DJI and Caddx; and the batteries are sourced from China's lithium battery industry chain. None of these components is specifically developed for military purposes. Rather, they are standardized products that have been validated through mass production in the global consumer electronics market [2].

4.1.2. Cost ranges for different configurations

The costs of combat FPV drones vary significantly depending on mission requirements and warhead types. A basic reconnaissance FPV drone costs approximately $200–$400; a standard attack model equipped with an RPG warhead or a warhead of equivalent destructive power costs approximately $400–$600 for the complete system; and a heavy attack model equipped with a larger-caliber thermobaric warhead or a tandem warhead costs approximately $600–$1,200 [2]. Actual usage data from the Russia–Ukraine conflict show that a large number of FPV drones cost approximately $500 each, while some sources report a cost range of $500–$1,200 [1]. At this price level, the procurement cost of an FPV drone is already lower than that of a mid-range smartphone [2].

4.2. Cost structure decomposition of high-value weapons platforms

4.2.1. Platform procurement costs

In sharp contrast to the low cost of FPV drones are the procurement costs of high-value weapons platforms. For main battle tanks, the procurement cost of the M1 Abrams varies according to the model and transaction terms. In December 2025, Australia delivered 49 M1A1 SA Abrams tanks to Ukraine at a total value of $245 million, equivalent to approximately $5 million per tank. Earlier reports, however, cited a total value of $164 million, equivalent to approximately $3.34 million per tank [2]. On the Russian side, the T-90M *Proryv* tank

has been assessed by the Main Directorate of Intelligence of Ukraine's Ministry of Defense at approximately $4.5 million[16]. Poland's procurement contract for 180 South Korean K2 tanks was valued at $6.1 billion, bringing the unit price to nearly $34 million[17].

In terms of air defense systems, a complete Patriot air defense missile system typically includes several launchers, radar vehicles, command-and-control vehicles, power-generation vehicles, and anti-missile interceptors, among other components. The cost of an entire system exceeds $1 billion. In January 2026, a video released by Russia's Rubicon drone unit showed an FPV drone successfully destroying an AN/MPQ-53 radar assigned to a Patriot air defense system. The unit price of this radar exceeds $100 million[18].

4.2.2. Full life-cycle costs

The costs of high-value weapons platforms extend beyond their initial procurement and include the entire support system required for their operation as military fixed capital. Research indicates that the operating and maintenance costs of heavy armored vehicle fleets account for approximately 70.81% of their total life-cycle costs and increase exponentially as the equipment ages. The M1 Abrams tank, for example, required additional modifications after its delivery to Ukraine, including the installation of anti-drone wire cages, the addition of reactive armor, and upgrades to its electronic warfare systems. Its crew members also had to undergo more than a month of training on the new equipment before the tanks could be deployed [2]. These supporting investments make the actual operating costs of tanks substantially higher than their procurement prices [6].

4.3. Data analysis and verification of exchange ratios

4.3.1. Per-unit exchange ratios

The per-unit exchange ratios between FPV drones and high-value weapons platforms provide the most direct quantitative evidence of "cost inversion". A study published in 2025 noted that FPV drones had become the primary driver of Russian tank losses, accounting for approximately 65% of such losses by early 2025. For T-90M tanks, approximately 50% of losses were ultimately caused by FPV drone strikes. Assuming that a $500 FPV drone destroys a tank worth $3 million, the exchange ratio is approximately 1:6,000[19]. If an FPV drone costing $400–$1,000 destroys an M1 Abrams tank worth $8–$10 million, the exchange ratio would still reach 1:1,000, even under the extremely conservative assumption that ten drones are required to destroy one tank [2].

4.3.2. System-level exchange ratios

At the systemic level, an assessment report published by RUSI in 2025 indicated that tactical drones accounted for 60%–70% of the total destruction of Russian military equipment[20]. A report by Ukraine's Defense Intelligence indicated that Russian forces lost more than 2,400 armored vehicles in the first quarter of 2026, with FPV drones accounting for approximately 61% of these losses. In an interview in March 2026, the commander of Ukraine's Unmanned Systems Forces, Brovdi, provided data showing that the unit had achieved a combat attrition ratio of 400:1, with an equipment expenditure of approximately $878 for each enemy combatant eliminated. Notably, the Unmanned Systems Forces account for only 2% of Ukraine's total military

[16] See Note 2.

[17] See Note 2.

[18] See Note 2.

[19] See Note 2.

[20] See Note 1.

personnel but are responsible for more than one-third of enemy losses[21].

Table 4. Exchange-ratio data for FPV drone strikes against high-value targets in the russia–ukraine conflict

Target	Target cost (USD)	FPV drone cost (USD)	Exchange ratio (conservative estimate)	Data source
M1 Abrams tank	8–10 million	400–1,000	Approximately 1:1,000	Defense Express [2]
T-90M tank	Approximately 4.5 million	Approximately 500	Approximately 1:9,000	Ukrinform[22]
Patriot radar	Over 100 million	Approximately 500–1,200	Approximately 1:83,000	The Paper[23]
Personnel targets (system-wide average)	—	878 (cost per kill)	Combat attrition ratio of 400:1	The Economist[24]

Table 4 presents the exchange ratios achieved by FPV drones against different types of military fixed capital. The data show that even under the most conservative estimates, the exchange ratio remains on the order of 1:1,000. In extreme cases, it can reach tens of thousands to one.

4.3.3. The extreme exchange ratio in operation spiderweb

Operation Spiderweb, conducted in June 2025, represents an extreme case of "cost inversion". Ukraine used 117 FPV drones to strike multiple Russian military airfields. Based on publicly available information, the cost of each drone was estimated at only $500–$1,200, bringing the total expenditure to no more than $60,000–$150,000. Among the targets was a Tu-95MS strategic bomber valued at more than $100 million [1]. The ratio between the attacker's total expenditure and the total value of the targeted assets reached several thousand to one or even higher. Ukraine claimed to have destroyed or severely damaged 41 strategic bombers. If this claimed result is partially verified, it would mean that an investment of less than $150,000 had caused asset losses worth several billion dollars [1].

4.3.4. Explanation of differences in data definitions

It should be noted that the data presented above involve several differences in statistical definitions. First, the cost of FPV drones varies considerably according to their configurations, ranging from $200 for basic models to $1,200 for heavy attack models. This study uses a range of $500–$1,000 as the representative cost in its calculations [2]. Second, the costs of high-value platforms can be measured in three different ways: procurement price, assessed value, and full life-cycle cost. This study primarily uses procurement prices while taking into account that full life-cycle costs are substantially higher [2, 6]. Third, exchange-ratio calculations involve different definitions of "destroyed" and "damaged", and statistical methods may vary across sources[25]. All data cited in this study are accompanied by their respective sources, and conservative estimates are used wherever possible. These differences in data definitions do not alter the fundamental conclusion of "cost inversion", but they indicate that the theoretical analysis should focus on its order-of-magnitude characteristics

[21] See Note 2.

[22] See Note 2.

[23] See Note 2.

[24] See Note 2.

[25] See Note 2.

rather than precise numerical values.

This chapter has systematically presented quantitative evidence of the "cost inversion" of FPV drones from two perspectives: cost structure decomposition and exchange-ratio verification. The analysis shows that the unit cost of FPV drones ranges from $200 to $1,200, whereas the costs of the high-value weapons platforms they destroy range from $3 million to over $100 million, producing exchange ratios of 1:1,000 or higher [2][26]. The data also show that FPV drones now account for 60%–70% of total equipment destruction, making them a dominant force in battlefield attrition[27]. These empirical findings provide the necessary quantitative foundation for the next chapter's theoretical analysis of the underlying mechanisms of "cost inversion" from the perspective of "disembedding from the logic of fixed capital".

5. Theoretical extension: the mechanisms, conditions, and theoretical significance of "disembedding from the logic of fixed capital"

Chapter 4 provides a detailed analysis of the quantitative evidence for the "cost inversion" of FPV drones, clearly demonstrating the exchange ratios between the unit costs of FPV drones and the costs of high-value weapons platforms they destroy. Building on the empirical evidence presented above, this chapter advances the discussion from a descriptive concept to an analytical category. It systematically examines the mechanisms and conditions of "disembedding" and discusses its theoretical significance for understanding transformations in contemporary modes of military production.

5.1. Theorizing "cost inversion": from a descriptive concept to an analytical category

5.1.1. The theoretical implications of the cost inversion phenomenon

In security studies, "cost inversion" is generally used as a descriptive concept to refer to the empirical fact that FPV drones can destroy high-value targets at extremely low unit costs. However, as a descriptive concept, "cost inversion" cannot answer a key question: why has this asymmetry reached an unprecedented scale? This study argues that answering this question requires elevating "cost inversion" into an analytical category within political-economic critique. Its theoretical significance lies in revealing the rupture in the logic of military fixed capital [6].

In his analysis of fixed capital, Marx pointed out that the value of fixed capital is "gradually transferred to the products through use". This transfer process presupposes that the material form of fixed capital remains intact over an extended period. Once this precondition is broken, the portion of value that has not yet been transferred cannot be recovered, thereby creating a rupture in the process of capital accumulation [6]. As military fixed capital, high-value weapons platforms operate according to the same underlying logic: their substantial research, development, and production investments are gradually recovered over relatively long service lives. The "cost inversion" of FPV drones indicates that this precondition has become increasingly difficult to sustain under contemporary battlefield conditions. An M1 Abrams tank worth $8–$10 million may be destroyed within just a few weeks of deployment by an FPV drone costing less than $1,000, causing its unrecovered capital value to vanish instantaneously [2]. One study has examined this phenomenon from the perspective of the "low-end reconnaissance-strike complex", arguing that weaker parties can rely on low-cost reconnaissance-strike integrated equipment to generate asymmetric cost attrition and continuously raise the

[26] See Note 2.

[27] See Note 1.

marginal costs of major powers' strategic operations [12]. This analysis confirms the structural characteristics of cost asymmetry, but its theoretical focus remains on international strategic competition and does not delve into the intrinsic contradictions of capital logic.

5.1.2. A comparative analysis with historical precedents

The use of low-cost means to counter high-value targets is not new in the history of guerrilla warfare. From landmines to improvised explosive devices, the strategy of using inexpensive means to deplete an adversary's costly resources has run throughout the history of modern conflict. However, the "cost inversion" associated with FPV drones differs qualitatively, rather than merely quantitatively, from these historical precedents [12].

In traditional guerrilla warfare, although low-cost weapons can inflict losses on high-value targets, such losses can be absorbed within the logic of military fixed capital. A landmine may destroy an armored vehicle, but this does not fundamentally alter the period over which the vehicle, as military fixed capital, recovers its value. The vehicle can still "recover" its capital value over an extended period through its combat effectiveness [6]. In other words, traditional asymmetric warfare consumes the use value of fixed capital rather than undermining its very form of existence as capital. The "cost inversion" associated with FPV drones is different. When a $500 drone repeatedly destroys tanks worth millions of dollars, what is undermined is not merely the tanks' combat effectiveness but also the economic rationale for their existence as military fixed capital. This is because the recovery of the value of military fixed capital depends on the probability that it will remain undestroyed throughout a relatively long service life. When this probability declines sharply due to saturation attacks by low-cost weapons, the economic logic of investing in high-value platforms faces a fundamental crisis [6]. One analysis points out that as the degree of cost asymmetry between offense and defense has increased from "several times to ten times" on the Nagorno-Karabakh battlefield to "tens to hundreds of times" in the Russia–Ukraine conflict, the defender's predicament has shifted from being "silenced under the overwhelming superiority of a technological gap" to having its "ammunition stocks exhausted by extreme cost asymmetry" [12]. This change indicates that the nature of asymmetry has undergone a qualitative transformation.

5.2. Mechanisms of "disembedding": how FPV drones escape the logic of fixed capital

5.2.1. Consumableization: refusing to enter the logic of fixed capital

The primary mechanism through which FPV drones become "disembedded" from the logic of fixed capital is their consumableization. Unlike tanks and air defense systems, which are designed to serve as military fixed capital over extended periods, FPV drones are conceived as disposable consumables from the outset [2]. The US Department of Defense has explicitly instructed the military services to treat small drones as consumables and to "modify or eliminate" policies that slow down procurement and deployment processes. The theoretical significance of this policy shift is that it confirms that the economic nature of FPV drones is closer to that of ammunition than to that of weapons platforms [2].

This distinction has fundamental significance in political economy. Ammunition is a pure value-consuming commodity: its use value is realized in a single act of consumption, without any need for value recovery. A weapons platform, by contrast, is fixed capital whose value must be gradually recovered through long-term use [6]. The "self-consumableization" of FPV drones allows them to escape entirely the burdens inherent in fixed capital: they do not require maintenance systems, spare-parts supply chains, or personnel training systems. Cost analysis shows that a complete FPV drone system costs between $200 and $400, whereas a standard Western artillery round costs between $3,000 and $8,000 [2]. This means that the economic nature of FPV drones is closer to that of ammunition than to that of weapons platforms: they are a form of "precision-guided ammunition" rather than "reusable weapons systems" [2].

5.2.2. Commoditized supply chains: a demilitarized production base

The second mechanism of "disembedding" is the fully commoditized nature of the production base of FPV drones. The production of traditional military fixed capital is embedded in specialized military-industrial systems, where a small number of integrated enterprises monopolize artillery ammunition production. Investment at each production site can amount to billions of euros, and production cycles are measured in months or years[28]. By contrast, FPV drone production is fully embedded in consumer electronics supply chains. Its core components—including flight-control microcontrollers, image sensors, and radio-frequency communication modules—are manufactured on the same product lines as those used for industrial robots, automotive electronics, and HVAC controllers, and all are sourced from the global consumer electronics market [2]. This difference means that the expansion of FPV drone production capacity does not depend on the mobilization capacity of the military industry, but rather on existing capacity within consumer electronics supply chains[29]. Ukraine's annual FPV drone production capacity of more than 8 million units, supplied by over 160 companies, exemplifies the military conversion of this commoditized supply-chain structure [1].

5.2.3. Lower operational barriers: restructuring training systems

The third mechanism of "disembedding" is the substantial reduction in operational barriers. The effective use of traditional high-value weapons platforms depends on highly specialized operators. An M1 Abrams tank crew member, for example, must undergo several months or even years of specialized training [8]. The operational threshold for FPV drones is considerably lower. According to the experience of Ukrainian drone trainers, training an FPV operator from scratch to a basic level requires at least three months, although trainees with experience in radio communications or engineering can acquire the necessary skills more quickly. At the training centers of Ukraine's Air Assault Forces, training for multirotor reconnaissance specialists takes no more than 15 instructional days [1]. Lower operational barriers mean that the generation of FPV drone combat capability does not depend on long-term specialized training systems; instead, rapid deployment can be achieved through relatively short-term training. This characteristic further weakens the connection between FPV drones and the logic of fixed capital [8].

5.3. Theoretical implications for modes of military production

5.3.1. The dialectical process of the self-negation of the logic of fixed capital

The "cost inversion" associated with FPV drones is an inevitable manifestation of the internal contradictions of the capitalist mode of military production [6]. The high-value nature of military fixed capital requires it to protect its own capital value. However, the emergence of low-cost attritional weapons has made such protection increasingly difficult. The essence of this contradiction lies in the self-negation of the logic of fixed capital as revealed by Marx: the more fixed capital pursues high value and advanced technological performance, the more pronounced its vulnerability becomes in adversarial environments; and the more it relies on technological superiority to maintain its survivability, the more likely it is to become a target for low-cost weapons [6]. The US Department of Defense's definition of "attritable" systems confirms the inherent tension in this logic. According to the classification of the Congressional Research Service, the cost ceiling for an attritable system is $10–$20 million per unit, while that for an expendable system is $3 million [2]. This classification itself demonstrates that even military planners are attempting to define the "attritability" of weapons through cost thresholds. Once a weapon exceeds a certain value threshold, it becomes "non-

[28] See Note 6.

[29] See Note 6.

expendable" and must therefore enter the operational logic of fixed capital. The distinctive feature of FPV drones is their extremely low cost, which places them within the cost threshold for "attritability" from the outset and thereby allows them to avoid the constraints of the logic of fixed capital entirely [2].

5.3.2. The case of the US marine corps' elimination of tanks

In 2020, under the framework of *Force Design 2030*, the US Marine Corps made a forward-looking decision to remove all M1A1 Abrams tanks from its force structure, reducing the number of tank companies from seven to zero. The decision sparked widespread controversy at the time, but the destruction of M1 Abrams tanks by FPV drones in the Russia–Ukraine conflict has since validated its foresight [2]. The Marine Corps' rationale for eliminating tanks was not that the Abrams was "useless", but rather that it reflected an assessment of what the Marine Corps should contribute to future joint operations: a lighter, more dispersed expeditionary force capable of deploying across islands, detecting enemy vessels, launching long-range missiles, and surviving in contested littoral environments. Weighing 67.6 metric tons, the M1A1 tank requires heavy transport, recovery vehicles, bridging support, maintenance capabilities, and substantial fuel supplies. Under conditions of dispersed deployment, these supporting requirements constitute a considerable logistical burden [2]. The theoretical significance of this case is that it demonstrates how military organizations have begun adjusting their force structures according to the logic of "disembedding": abandoning high-value platforms with substantial logistical dependencies that embody the logic of fixed capital, and shifting toward low-cost, distributable systems designed to be expendable [2].

This chapter has systematically developed the concept of "disembedding from the logic of fixed capital" through three dimensions: the theorization of "cost inversion", the analysis of disembedding mechanisms, and the implications for modes of military production. The analysis demonstrates that the "cost inversion" associated with FPV drones is not an incidental by-product of technological progress, but an inevitable manifestation of the internal contradictions of the logic of military fixed capital. Through three mechanisms—consumableization, commoditized supply chains, and lower operational barriers—FPV drones become "disembedded" from the operational logic of fixed capital, thereby systematically undermining high-value weapons platforms. The next chapter summarizes the central conclusions and theoretical contributions of this study.

6. From "cost inversion" to a theoretical extension of the critique of military political economy

Chapter 5 systematically developed the concept of "disembedding from the logic of fixed capital" through three dimensions: the theorization of "cost inversion", the analysis of disembedding mechanisms, and the implications for modes of military production. Building on the preceding analysis, this chapter revisits the central arguments of the study, clarifies its theoretical contributions, and discusses its limitations.

6.1. Review of the core conclusions

The central argument of this study can be summarized in three successive propositions. First, the "cost inversion" associated with FPV drones is not an isolated tactical phenomenon, but rather reflects a systemic structure of military economics. Tactical drones account for 60%–70% of total Russian equipment destruction[30], while the exchange ratios achieved by FPV drones against high-value platforms reach 1:1,000 or

[30] See Note 1.

even higher [2]. Second, the theoretical implications of this phenomenon cannot be adequately explained by the descriptive concept of "cost asymmetry" in security studies. Instead, they must be understood through the antagonistic relationship between "fixed capital" and "living labor" in Marx's theory of machinery [5, 6]. Third, the fundamental reason why FPV drones can systematically undermine high-value weapons platforms is that they become "disembedded" from the operational logic of military fixed capital through three mechanisms: consumableization, commoditized supply chains, and lower operational barriers [2][31]. As military fixed capital, high-value weapons platforms depend on relatively long service lives to gradually recover their substantial investments. However, with unit costs ranging from $200 to $1,200, FPV drones make it difficult to sustain such recovery periods under contemporary battlefield conditions [2, 6].

6.2. Theoretical contributions

6.2.1. Extending Marx's theory of machinery

This study extends Marx's theory of machinery from its analysis of the capitalist production process to an analysis of antagonistic relations in the process of military consumption [5, 6]. The validity of this extension rests on the structural homology between weapons systems and productive fixed capital: weapons platforms such as tanks and air defense systems likewise exhibit the characteristics of fixed capital, including high research and development investment, long production cycles, and complex maintenance systems [2]. Through this theoretical translation, Marx's analytical framework concerning machinery as fixed capital and the internal contradictions of fixed capital is transformed into a theoretical tool for understanding contemporary transformations in military technology. As some scholars have pointed out, Marx's thought on machinery possesses theoretical explanatory power that extends beyond the historical period in which it emerged, and its analytical logic can be reactivated and extended under new empirical conditions[32].

6.2.2. The theoretical significance of the concept of "disembedding from the logic of fixed capital"

This study proposes and systematically develops the analytical concept of "disembedding from the logic of fixed capital" [2]. The concept defines a mode of existence for weapons systems that differs from the traditional logic of military fixed capital: certain weapons systems break away from the form of high-value, long-cycle fixed capital and are transformed into low-value, expendable forms of circulating capital. The theoretical significance of this concept lies in its provision of a unified explanatory framework for understanding the FPV drone phenomenon. It brings the commodity attributes of FPV drones (consumer electronics supply chains), their technological attributes (single-use deployment and low operational barriers), and their economic attributes (cost inversion) within a single theoretical framework [2][33]. The US Department of Defense's classification of attritable and expendable systems according to cost thresholds provides empirical support for this concept from the perspective of military planning practice [2].

6.2.3. Methodological contributions to the political economy of the military

This study establishes a complete chain of argumentation extending from empirical phenomena to theoretical categories. It takes Operation Spiderweb as its empirical point of departure [1], uses cost structures and exchange-ratio data as empirical support, adopts Marx's theory of machinery as its analytical framework [5, 6],

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[31] See Note 6.

[32] Yao, Wenpei. (2026, June 25). Living labor, the collective worker, and intelligent machine systems: Contemporary confirmation and development of Marx's labor theory of value. Retrieved October 15, 2026, from https://zsyyb.cn/abs/20260 6.03778

[33] See Note 6.

and ultimately derives the theoretical category of "disembedding from the logic of fixed capital". The methodological significance of this approach is that it demonstrates how Marxist political-economic critique can provide explanatory analytical tools for understanding contemporary transformations in military technology, rather than remaining confined to classical analyses of the capitalist production process [6].

6.3. Research limitations and future directions

This study has three main limitations. First, its empirical materials are drawn primarily from the Russia–Ukraine conflict and publicly available reports, and the data are subject to uncertainty. The costs of FPV drones vary considerably according to their configurations; the procurement prices and full life-cycle costs of high-value platforms are measured using different definitions; and the statistical methods used to calculate exchange ratios vary across sources [2][34]. Second, the boundaries of the theoretical translation require further discussion. The extension of Marx's analysis of the relationship between machinery and labor in the production process to the antagonistic relationship between weapons systems in the process of military consumption requires more comprehensive theoretical justification regarding the limits of its applicability [5, 6]. Third, further empirical observation is needed to assess the long-term trajectory of the phenomenon of "disembedding". Whether the "cost inversion" associated with FPV drones constitutes a structural transformation in the mode of military production or is merely a transitional phenomenon under specific technological conditions remains to be determined through continued observation [2]. The study's final conclusions will be presented in Chapter 7.

7. Conclusion: theoretical prospects for a critique of military political economy from "cost inversion"

Taking the "cost inversion" of FPV drones in the Russia–Ukraine conflict as its empirical point of departure, this study has followed a chain of argumentation encompassing "phenomenon description, theoretical construction, empirical verification, and mechanism analysis" to progressively reveal the capital logic underlying this military-economic phenomenon. The findings demonstrate that the fundamental reason why FPV drones can systematically undermine high-value weapons platforms worth millions or even hundreds of millions of dollars at unit costs of just a few hundred dollars is that they become "disembedded" from the logic of military fixed capital through three mechanisms: consumableization, commoditized supply chains, and low operational barriers. The concept of "disembedding from the logic of fixed capital" proposed in this study brings the commodity, technological, and economic attributes of FPV drones within a unified analytical framework, providing a tool of political-economic critique for understanding contemporary transformations in military technology.

When "dead labor" negates itself in the form of consumables, Marx's analytical framework concerning the relationship between fixed capital and living labor needs to be reactivated [5, 6]. The "cost inversion" associated with FPV drones is not a military phenomenon that can be explained by "technological superiority", but rather a problem of capital logic that requires examination through political-economic critique. The predicament facing high-value weapons platforms as military fixed capital lies in the following contradiction: the more they pursue technological superiority to protect their own capital value, the more they become cost-effective targets for low-cost weapons [6]. The essence of this contradiction is the self-negation of capital logic

[34] See Note 2.

in the military sphere. Conducting a political-economic critique of this issue is not only a theoretical necessity for understanding contemporary military transformations, but also an inherent requirement for extending the analytical boundaries of Marxist political economy in the new era[35].

Looking ahead, this analytical framework can be further extended to expendable unmanned weapons systems such as loitering munitions and unmanned surface vessels, as well as to issues including civil-military integration and reforms in military procurement systems. Such extensions would open up broader theoretical horizons for the critique of military political economy.

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[35] See Note 32.