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The Application of Intelligent Missiles in System Breaking Operations

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Abstract

With the evolution of war forms towards intelligence, intelligent missiles have become the core equipment for system breaking operations. This article deeply analyzes the key characteristics of "node destruction and system paralysis" in system breaking operations, as well as the resulting demands for missile autonomous collaborative combat capabilities, anti-interference capabilities, and so on. At the same time, the application of core technologies such as intelligent missiles target identification, dynamic decision-making,and multi missile coordination in system-breaking operations is discussed. In addition, relevant suggestions are made for the challenges of perception reliability and real-time decision-making in complex battlefield environments.

Keywords

Intelligent Missile; System Breakdown; Precision Guidance.

1. Introduction

Intelligent missile is a new type of weapon system with human-like intelligence features such as autonomous perception, situational understanding, dynamic decision-making, and learning interaction, which can independently complete target detection, identification, tracking and precision strike tasks in complex and changing battlefield environment[1]. With the deep integration of sensor technology, information network and artificial intelligence, the intelligent process of weaponry is accelerating, and new combat platforms such as intelligent drones and autonomous anti-tank missiles have already achieved operational application[2]. Especially after more than 30 years of technology iteration, intelligent technology gradually breaks through the engineering bottleneck, is generally considered to be the revolutionary direction of missile weapon development after informationization, and its“algorithm-driven, autonomous adaptation” characteristics are reshaping the rules of modern warfare.

At present, although missile weapons continue to make breakthroughs in range, accuracy and other performance indicators, the effectiveness and survivability of traditional missiles in the face of the all-area anti-missile system of air and space integration and network linkage are facing serious challenges. The defending party has significantly compressed the operational window of missiles through multi-spectrum reconnaissance, layered interception and intelligent command and control of closed-loop operations. In this case, there is an urgent need to reconstruct the missile's offensive and defensive system through intelligent technology: on the one hand, the use of autonomous mission planning, real-time trajectory optimization, and multi missile co-operation and surprise defense capabilities to form an asymmetric advantage of “breaking the network with intelligence”; on the other hand, through dynamic learning of the battlefield environment and anti-jamming algorithm upgrades to achieve the “the more one fights, the stronger one becomes”.This paper focuses on the technological integration and tactical innovation of intelligent missiles in system breaking operations, and analyzes in-depth its capability demand, application mode and development bottleneck, aiming to provide

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theoretical support for the construction of a new combat paradigm of "node destruction and system paralysis".

2. Characteristics and Intelligent Requirements of System Breaking Operations

2.1. Current Research Status of Intelligent Missiles

Thanks to advanced information technology, computer technology and microelectronics technology, the United States is in a leading position in the research of intelligent weapons. The third-generation anti-tank missile of the United States is capable of comparing the image acquired by the detector with the image in the on-board database, thus recognizing various types of targets such as transportation vehicles and missile launchers, and selecting the target of attack autonomously [3].The new anti-ship missile LRASM also adopts intelligent technology, relying on advanced on-board sensors and data-processing capabilities to realize autonomous target detection, identification, navigation and terminal guidance without the need to relay guidance information. As an important part of the non-light sight Launching System, the patrol attack missile is equipped with intelligent functions such as area search, target surveillance, damage assessment, radio relay and autonomous attack, and is capable of realizing patrol attack.The tactical Tomahawk missile Block 4 is equipped with UHF satellite data link and UHF ground data link, which enables the missile to have the capability of real-time target selection, automatic terminal attack and real-time mission planning[4]. In addition, the UAV with intelligent autonomous control is able to complete evasion in a complex offensive and defensive confrontation environment, thus improving survivability.

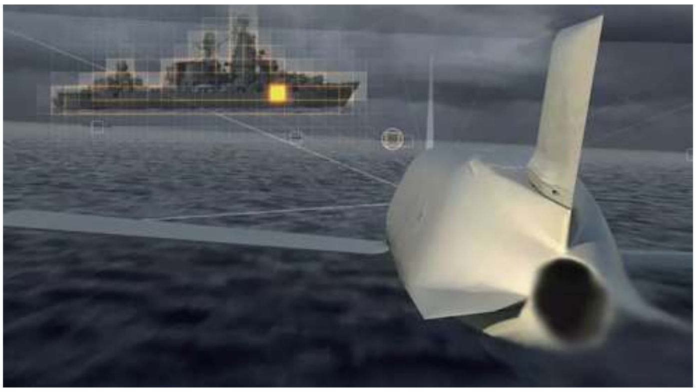

Figure 1. Schematic diagram of hull target selection by LRASM

The Russian Granite anti-ship missile is considered to be one of the earliest missiles with intelligent features. After service, with the improvement of basic technology, its level of intelligence has been improved, and it has such intelligent features as online replanning of trajectories, automatic target capture, multi-target distribution of strikes, autonomous locking and attacking, and it was the first to introduce the concept of"lead missile"[5]. There is a view that the Russia's Poplar-M and Yars missiles are expected to adopt a set of digital automatic control system, so that after the launch of the missile can be real-time control or modification of the attack mission, thus significantly improving the ability to break out of the defense.

Europe also attaches great importance to missile intelligence in the development of new missiles. In the development program of NSM Block 2 and JSM missiles, two-way data chain is listed as a key technology for verification and development[6]. The introduction of the data chain will serve as the basis for intelligent technologies such as inter-missile networking and coordinated attack, enabling the missiles to change tactical warfare in real time and enhance

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the ability of surprise defense. Israel is equipped with SPIKE NLOS through the addition of wireless data chain to support networked coordinated operations, can be remotely controlled and retargeted to new targets.

Figure 2. NSM launching process

In general, the intelligent development of foreign missile weaponry can be divided into several stages such as initial realization of features, gradual realization of functions, and continuous improvement of intelligent applications, etc. New missile weapons currently in the research and development stage are further improving the degree of intelligence to better adapt to intelligent warfare.

2.2. Characteristics of System Breaking Operations

The “system breaking” emphasizes the concentration of superior combat power, non-contact, non-linear medium- and long-range precision strikes as the main means, and combines with other combat modes to implement structural damage to the enemy's operating system and even the key nodes or key parts of the entire war system. In this way, the enemy's overall combat effectiveness can be reduced and weakened, shaking its will to resist, so as to achieve the combat goal quickly at a small cost[7]. The System Breaking operations highlights the winning mechanism of“precisely striking key nodes to paralyze the enemy's operating system”, and clarified the winning requirement of “destroying the enemy's operating system before launching subsequent combat operations”, it emphasizes the winning tactic of “combining various means of combat to carry out composite strikes”and embodies the winning guiding principle of “a high degree of autonomy in combat operations”.On the integrated battlefield, the system of confrontation is fast-paced, and it is necessary to abandon the traditional battlefield thinking mode of achieving combat effectiveness through“sustained consumption”and to fully implement the strategic idea of“quick victory”, it takes “quick victory”as an important criterion to measure the success or otherwise of strike-breaking operations, and grasps the initiative of system confrontation through the “pre-emptive” offensive to realize the comprehensive strike-breaking of the enemy's operating system.

System breaking operations paralyzes the enemy's operating system as its fundamental goal, and the key lies in the structural destruction of the enemy's key nodes of command and control, information transmission, and firepower strikes by means of precision strikes, information dominance, and cooperative linkage. Its core features are mainly reflected in the following aspects: First, with the help of high-precision strikes, the enemy's command center, communication hubs and other key targets to carry out precision strikes, directly destroying the physical entity and cutting off information links. Secondly, it relies on the battlefield sensing system for real-time data collection and dynamic analysis to build a situation map of the whole area and optimize the strike strategy.Thirdly, based on the distributed coordination mechanism, it realizes tactical cooperation among multiple platforms and types of troops, and breaks

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through the enemy's air defence system through dynamic reorganization and task allocation. Fourth, combining electronic warfare, network warfare and other non-kinetic means, the enemy's information system to implement “broken network” strikes, through electromagnetic interference or network intrusion caused by the “information island”, and quickly seize the right to control information. Fifth, dynamic adaptability, according to changes in enemy defense to switch combat style, for example, from single-point precision strike to multi-domain saturation attack, or through stealth configuration and dynamic adjustment to optimize the strategy of surprise.

2.3. Intelligent Requirements of Missiles for System Breaking Operations

System breaking operations take“node destruction and system paralysis” as their core objective, its dynamics, complexity and confrontation characteristics of the missile intelligence level put forward a variety of requirements[8]:

(1) Automatic target detection and identification capability. It is capable of utilizing various types of available information such as radio waves, visible light, infrared, laser, acoustic waves and even gases emitted by the target itself, and when the missile is close to the target, it captures such information and makes correlation and comparison with the information in the on-board datum library, so as to determine the target and its location and provide information support for the missile's end-to-end precision guidance and precise hit on the target.

(2) The ability to analyze and judge the battlefield situation. It is capable of comprehensively applying the information received by the missile from space-based, air-based or ground control stations, as well as the geographic information obtained by ballistic sensors and the acoustic wave, radio wave, infrared, laser and other information emitted by the enemy's weapons, and then, through the rapid processing of computers, determining the threats appearing in the battlefield environment, and rapidly analyzing the battlefield situation.

(3) Electronic countermeasures and intelligent anti-jamming capability. It is capable of overcoming the adverse effects of the geographical, meteorological and electromagnetic environments of the battlefield in combat missions, possessing a certain degree of enemy identification capability, effectively countering a large number of malicious interferences exerted by the enemy, and preventing interruption, induced deviation or deception by the enemy's jamming information, so as to ensure that target strikes can be realized in the complex battlefield environment.

(4) Autonomous flight trajectory selection capability. According to the target information, the battlefield environment information and the time to reach the target and other factors, it is able to change the scheduled flight trajectory, plan and select the most suitable flight path in real time, avoid the enemy's layer-by-layer interception, and maneuver autonomously to realize the strike on the designated target.

(5) Intelligent target strike capability. It is capable of receiving instructions from the C4ISR system to re-establish the strike target, and can change direction in flight to strike a new moving target; or it can observe the strike effect of the previous missile through the on-board sensors to confirm whether or not it has hit the target, so as to decide whether or not to carry out the strike again or to strike other targets.

(6) Monitoring and management of the status of the missile body. It is able to utilize distributed sensors to monitor and manage the working status of each subsystem of the missile, and when a subsystem of the missile system has a problem, it applies fault-tolerant control, system reconfiguration, self-repairing and other technologies to ensure that the missile weapon works normally and completes the combat mission.

3. Intelligent Missiles in System Breaking Operations

3.1. Intelligent Intelligence Processing and Target Recognition

Intelligent missile's intelligence processing and target identification capability in system breaking operations is the key foundation for the realization of“destroying nodes and paralyzing the system”. In the massive, heterogeneous and dynamic data environment of the information-based intelligent battlefield, missiles need to build a full-area perception network with the help of multi-source sensor fusion technology, and utilize knowledge map and deep learning algorithms to realize accurate screening and priority ranking of battlefield targets.For example, when striking the enemy command center, the missile can combine satellite communication signal characteristics, electromagnetic radiation source positioning data and geospatial information to quickly identify fortified underground command posts disguised as civilian facilities through migration learning models;for mobile air defense systems, the cross-modal correlation of synthetic aperture radar and infrared thermography is used to distinguish between vehicle thermal features and background noise, and to track their movement trajectories in real time[9].In addition, the introduction of small sample learning technology solves the problem of scarcity of military target data - the virtual battlefield environment constructed based on Generative Adversarial Networks (GAN) can synthesize the characteristics of new enemy weapons, so that missiles can still complete high-precision identification in the absence of real samples. For example, the U.S. Army's LRASM through multi-spectral sensors and artificial intelligence algorithms, can be in the complex electromagnetic interference in the independent identification of ship models and lock the bridge or powerhouse and other key parts of the ship, to achieve “be paralyzed in one shot” effect of the strike. This capability enables intelligent missiles to penetrate the information fog of the enemy's defense system and accurately lock the “nerve center” that supports the operation of the operating system, laying the foundation for the cascade diffusion of the subsequent destruction link.

3.2. Intelligent Decision Making and Strike Planning

In dynamic confrontation system-breaking operations, the decision-making system of intelligent missiles needs to change from “preset logic” to “autonomous evolution”. Through the combination of reinforcement learning frameworks and digital twin technology, missiles can preview thousands of attack scenarios in the virtual battlefield, accumulate confrontation experience and generate a library of adaptive strategies. For example, when breaking through a multi-layer anti-missile system, the missile can simulate the interceptor movement model in real time based on Monte Carlo Tree Search (MCTS) algorithm, dynamically assess the survival probability of different maneuvering strategies, and autonomously select the optimal path. At the same time, multi-objective optimization algorithms (e.g NSGA-II) can balance the contradiction between the timeliness of strikes, fuel consumption, and destructive effectiveness - when detecting the enemy's mobile command vehicle suddenly cutting into the battlefield, the missile can recalculate the trajectory in milliseconds to weigh the option of continuing to attack the original radar station or diverting to a high-priority moving target.The application of the Russian Dagger hypersonic missile on the Syrian battlefield has shown that its intelligent decision-making module can automatically adjust the order of attack based on real-time satellite intelligence: first paralyze the regional communication nodes with electromagnetic pulse missiles, and then precisely destroy the exposed air defense positions with kinetic warheads, this kind of“soft and hard kill synergy” decision-making logic significantly improves the efficiency of the system to break the attack.In addition, a distributed mission planning system based on blockchain technology allows the swarm to maintain synergy through a consensus mechanism even when communication is interrupted, ensuring

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that the destruction of some units does not affect the realization of the overall combat objectives[10].

3.3. Precision Guidance and Ballistic Optimization

In order to break through the closed loop of "reconnaissance, control and strike" of modern air defense systems, the guidance system of intelligent missiles needs to realize the dual breakthroughs of "environmental self-adaptation" and "unpredictable trajectory".In the terminal breakout phase, the missile is guided by a three-dimensional fusion of millimeter-wave radar, laser radar and infrared imaging, which allows it to build a centimeter-level accurate digital twin of the target, identifying the mechanical weak points of a building structure or a ship's power compartment.For example, in striking the underground command center, the missile uses the combined guidance of geological penetrating radar and inertial navigation, which can real-time correct the angle of incidence of the drilling warhead and the detonation delay to ensure that it will detonate in the predetermined cavity after penetrating the multilayered reinforced structure.For ballistic optimization, an adaptive control algorithm based on deep reinforcement learning enables the missile to solve the optimal trajectory under complex constraints online:when encountering sudden side wind disturbance, the control system can instantly adjust the aerodynamic rudder surface and vector nozzle to maintain the stability of the attack axis; for the interception of enemy directional energy weapons, it adopts the "quantum walking" trajectory generation technology to break the prediction model of the interception missile through random non-linear maneuvers.The U.S. Army's Storm Shadow missile demonstrated such capabilities in the test - its real-time analysis of enemy radar beam pointing through the on-board AI, the use of "spiral climbing - dive sudden defense" combination of Maneuver, so that the interceptor system's fire control solution error increased by 300%, the success rate of surprise defense increased to 92% [11].

3.4. Autonomous Coordinated and Multi Missile Attacks

Intelligent coordination of multi missile is the ultimate means to break through the enemy's system defense and trigger the cascade paralysis effect. Through the distributed autonomous cooperative architecture, the missile group can form a "combat cloud network" with group intelligence:based on the improved Contract Net Protocol (CNP), the missile cluster can dynamically allocate targets through an auction mechanism [12]. For example, when an enemy early warning radar is detected to be on, the three closest missiles automatically bid for the electromagnetic suppression mission, while the rest of the units are assigned a strike priority based on the threat gradient.This capability was demonstrated in simulated missile swarm during the NATO Dynamic Forward 2022 exercise:the first wave of missiles released foil jamming to cover the follow-on unit's breakthrough, the second wave used strobe infrared decoys to deflect the interceptors, and the third wave launched simultaneous attacks from different elevating angles to disable the enemy's "Patriot" system's fire channel.A more advanced mode of coordination involves cross-domain joint strikes -- air-launched missiles and submarine-launched cruise missiles sharing target information through space-based data chains to implement "cross-media coordinated hunting" of time-sensitive targets.In addition, based on the game theory of adversarial synergistic algorithms so that the missile group can predict the enemy's interception strategy and dynamically adjust the formation: when the enemy started electronic jamming, the missile group automatically switched to the anti-jamming communication protocol, part of the unit to sacrifice their own probability of breaking through the defense to act as a "bait" to cover the main missile group to carry out a fatal blow. This "autonomous evolution" of the synergistic logic, not only significantly enhance the efficiency of the breakout, but also through multiple waves, multi-dimensional, multi-effect composite attack, forcing the enemy defense system into a "lose sight of the other side" of the systematic collapse, and ultimately achieve The system breaking effect of "breaking the net with wisdom and suppressing quality with quantity" is finally realized.

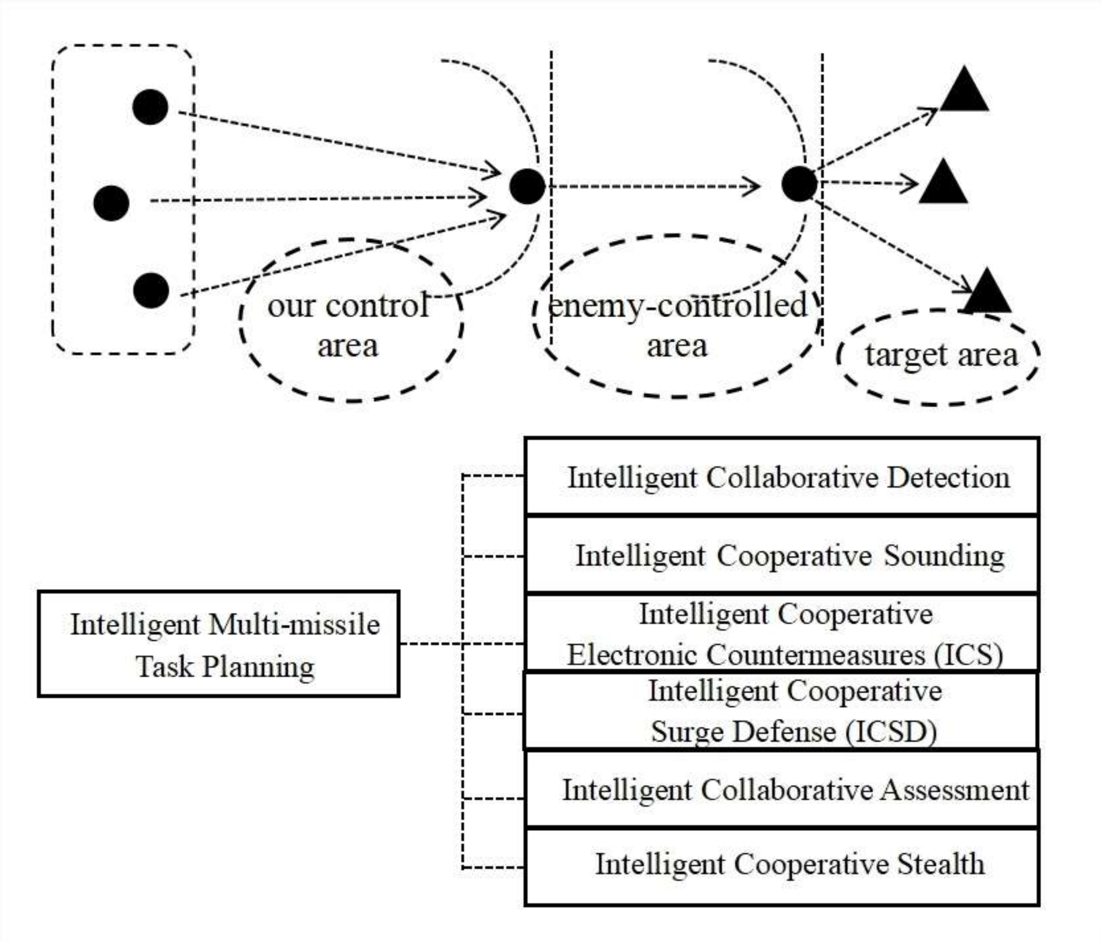

Figure 3. Schematic diagram of intelligent multi missile cooperative operation

4. Challenges and Recommendations for Intelligent Missiles Utilization in System Breaking Operations

4.1. Challenges

The use of intelligent missiles in system breaking operations still faces many challenges, and this paper mainly puts forward the following five points:

(1) Reliability challenges of multi-source heterogeneous information fusion. The battlefield environment is complex, with electromagnetic interference, false signals and camouflaged targets intertwined, and sensor data may be distorted by environmental noise or enemy active deception. For example, the enemy simulates the infrared and radar signatures of command vehicles by deploying thermal decoys or angular reflectors, which can lead to misjudgment of the target recognition algorithm; when the spatial and temporal datums of multiple sensors are inconsistent, the fused battlefield situational map may suffer from localization bias, which will in turn affect the strike accuracy [13].

(2) The conflict between real-time and security of autonomous decision-making. Although reinforcement learning and online optimization algorithms improve the dynamic planning capability, there is a conflict between the arithmetic power demand of complex models and the resource limitations of the on-board computing units. In the process of surprise defense, missiles need to complete threat assessment and path planning in milliseconds, while the

existing edge computing hardware is still difficult to simultaneously meet the requirements of high precision and low latency. In addition, the “black box” feature of the deep learning model may be utilized by the enemy to induce the missile decision-making system to output erroneous commands through the injection of antagonistic samples.

(3) Robustness of cooperative control is insufficient. Multi missile coordination relies on high-bandwidth, low-latency communication links, but adversaries can cut off inter-missile data links through directed-energy weapons or cyberattacks. For example, in the U.S. Army's Thundercloud 2021 exercise, a simulated group of missiles lost control of their coordinated formation due to communication delays, and some of the missiles deviated from the preset attack axis. In addition, distributed coordination algorithms have limited fault tolerance for node failures, and the destruction of a single missile could cause a significant reduction in the overall effectiveness of the formation.

(4) Bottlenecks in the effectiveness of man-machine coordination mechanisms. Despite the autonomous decision-making capability of missiles, commanders still need to intervene in key aspects (e.g., target authorization, damage assessment). However, information overload on the battlefield may lead to delays in human-computer interaction, for example, in saturation attack scenarios, it is difficult for the commander to verify the rationality of the target allocation of hundreds of missiles in real time, which may lead to false strikes or waste of resources.

(5) The balance between cost and scale is difficult. Intelligent missiles rely on high-performance sensors, anti-jamming chips and AI computing modules, and the cost of a single bomb can be 3-5 times that of traditional missiles. When deployed on a large scale, the high procurement and maintenance costs may exceed the military budget, while reducing the technical specifications will lead to a decrease in the probability of surprise defense, forming a “performance-cost” dilemma.

4.2. Relevant Recommendations

The complex and changing informationized intelligent battlefield in the future poses new challenges to missile weaponry, especially in system-breaking operating, intelligence has become an inevitable trend in missile development. In order to promote the in-depth application of artificial intelligence in missile system and enhance its core striking ability in system confrontation, the following four suggestions are put forward:

(1) Correctly recognize the advantages and limitations of artificial intelligence in missile system breakthrough. Artificial intelligence technology has significant advantages in information fusion, target recognition, autonomous decision-making, etc., which can effectively enhance the adaptability of missiles to complex battlefield environments and mission execution efficiency. In system breaking operations, intelligent missiles can analyze the enemy operating network structure autonomously, accurately strike key nodes, and realize the goal of paralyzing the enemy operating system. However, the current artificial intelligence technology still has problems such as strong dependence on training data and insufficient interpretability, so it is necessary to scientifically assess its applicable boundaries in military applications and reasonably guide its integration and development in missile systems.

(2) Build a missile intelligence standard system to support systematic combat requirements. In the process of integrating artificial intelligence into missile weapon systems, attention should be paid to the establishment of a unified technical standard and evaluation system, covering algorithmic performance, human-computer coordination mechanism, combat effectiveness verification and other aspects. Especially in the context of systematic combat, it is necessary to promote the construction of missile intelligence standards for military-civilian cooperation, promote the two-way transformation of technical achievements in the military and civilian fields, enhance the compatibility and interoperability of missile systems, and guarantee their efficient cooperation in the joint combat system.

(3) Construction of a specialized artificial intelligence database applicable to system-breaking operations. The effective operation of artificial intelligence models is highly dependent on high-quality data support. In view of the characteristics of the system-breaking mission, the construction of a specialized database covering typical combat scenarios, target characteristics, electronic intelligence, striking methods and other elements should be accelerated. Through deep learning, knowledge mapping and other technical means, intelligent identification and prioritization of key targets such as enemy command and control nodes, communication hubs and radar deployments should be realized, so as to provide missiles with more accurate strike recommendations and path planning support.

(4) Strengthening the training of composite talents for missile intelligence. With the rapid development of artificial intelligence technology, missile development is in urgent need of a group of high-quality talents who understand artificial intelligence theory and are familiar with missile system engineering. Relying on the strengths of universities, scientific research institutions and military enterprises, we should build an interdisciplinary personnel training system to strengthen the ability to tackle key technology areas such as mission planning, target identification and autonomous decision-making. At the same time, we should actively absorb the advanced achievements in the civilian field, combine with the actual needs of the system breakthrough operations, carry out research on cutting-edge technologies such as small-sample learning, multi-modal fusion, brain-like computing, etc., so as to push forward the continuous improvement of the missile intelligence level.

5. Summary

Intelligent missiles, as the core force of future system-breaking operations, are reshaping the offensive and defensive postures of modern warfare. With key technologies such as intelligent target identification, autonomous decision-making, precision guidance and multi missile coordination, missiles are able to carry out precision strikes and structural damage to key nodes of the enemy's combat system in complex confrontation environments, thus realizing the combat goal of “breaking the surface with a point and paralyzing the system”. However, intelligent missiles still face many challenges in terms of technology maturity, system security and adaptability to actual combat. In the future, we should focus on the construction of standard system, professional database, key technology breakthroughs and the cultivation of composite talents, etc., and continue to promote the in-depth application of intelligent missiles in system-breaking operations, so as to further enhance the strategic striking capability and system confrontation advantages in future high-end wars.

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