Advantage Competition of Air and Space in Artificial Intelligence Era

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Abstract: Air and space is one of the most intense fields of science and technology competition for powerful countries. This paper focuses on the competition to achieve mastery of air and space, and analyzes the impact of fast developing intelligent technologies from six basic contradictions of the war, including hiding and finding, understanding and confusion, network resilience and network degradation, hitting and intercepting, speed of action and decision-making, and shaping the perceptions of key crowd. On this basis, aiming at securing competitive advantage in the future, the development directions of intelligent technologies are proposed for the air and space competition.

Key words: air and space advantage; artificial intelligence (AI); basic contradictions of war

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0 Introduction

The development of artificial intelligence (AI) technology and its rapid application in the military technology field have profoundly changed the war. At the end of 2019, the U.S. military put forward "decision-centric warfare"[1], regarding the cognitive domain as the winning domain and emphasizing on relying on the cognitive advantage to obtain the operational advantage, which transcends the traditional physical domain and information domain. This concept marks that the U.S. military has entered the phase of intelligent war in military thinking.

Air and space advantage is an important method for major countries to carry out national strategy and compete in science and technology. The rapid development and quick application of intelligent technology speed up the evolution of air and space power, making intelligent technologies internally incentive to change the competition for air and space advantage[2].

1 New Trend of Air and Space Competition

Under the help of AI technology, it becomes possible to accomplish the dynamic perception and data mining of combat forces and their actions in all-time, all-around and all-dimensional. AI enables modern military personnel to break through the limit of logical thinking, physiological senses and physical existence[3-6]. Meanwhile, AI can be used to greatly improve the cognitive scope of time and space, enhance the control of all forces' actions in real time and achieve the mastery in multi-dimensional fields.

According to "the future of war" proposed by Scharre[7], the rapid mobilization, aggregation and attack of combat resources can suppress the opponent in many aspects and seize the advantage of air and space through six factors, which include concealment and discovering, recognition and confusing, network resiliency and disruptions, striking and intercepting, action speed and decision-making

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speed, and the views of key crowd.

1.1 Hiding and finding

The reconnaissance and counter-reconnaissance is the main line running through the whole process of air and space competition. The innovation and competition in the reconnaissance technology have always being fierce, and the application of intelligent technology has further intensified the contradiction[8].

Information hiding can be achieved by adaptive distribution of smart jamming, precision electronic attack, network defense and low-cost intelligent decoy. Aircraft hiding can be achieved by using smart stealth skin, active electromagnetic cancellation, controllable stealth and adaptive stealth technology in different environments[9].

From another point of view, it is also highly possible to achieve efficient reconnaissance by forming distributed, penetrating, multi-domain sensor network and information fusion, including technologies of distributed sensing, multi-sensor data fusion, elastic space surveillance, intelligent penetrating imaging radar, low-cost autonomous robot system, quantum computing[10], intelligent target detection[11], etc. The Algorithmic Warfare Cross-Functional Team in U.S. tried to use AI technology to analyze unmanned aerial vehicle (UAV) surveillance videos and searched for terrorists[12], and University of Missouri used AI technology to quickly identify anti-air missile positions from satellite images, shown in Fig.1.

Fig.1 Anti-air missile positions identifying from satellite images based on AI by University of Missouri

1.2 Understanding and confusion

It is very important to extract useful and accurate information from tremendous number of complex data. The competition of cognitive domain is also one of the most important aspects for the intelligent era. The AI technologies play an important role in improving the cognitive system by enhancing the ability of artificial recognition, quick response and goal-oriented planning[13].

In order to achieve the advantage of understanding, it is necessary to take two steps:

(1) Develop the human-computer hybrid decision-making technology. The decision process of human beings has the characteristics of creativity, flexibility and initiative of human brain, while fast speed, high precision and anti-fatigue[14] of machine. To combine and coordinate human-machine decision process, it is vital to improve the efficiency of battlefield information extraction and the command and control for missiles[15-17].

(2) Research the autonomous decision-making technology in order to support autonomous of unmanned systems. The long-range anti-ship missiles (LRASM) can achieve threat circumvent and target identification, and realize autonomous search, identification, target selection and precise attack[18].

1.3 Network resilience and network degradation

The network resilience and the mastery of electromagnetic spectrum are the premise of intelligent warfare. To achieve the advantage, it needs to take three steps:

(1) It is necessary to construct a basic network with low delay, large capacity and high reliability, in order to meet the requirements of information transmission and sharing in complex environment

from multiple perspectives such as intelligence support, command and control, and weapon coordination. In addition, the network should be decentralized, robust and with good anti-interference ability.

(2) Integrate platform and weapons into a "sensor-weapon kill-effecter" complex. The effectiveness of the combat system can be greatly improved due to the information sharing capability of the complex, which connects all the units in the battlefield from physical domain, cognitive domain, time domain and other cross domain[19].

(3) In terms of network degradation, AI technology can be used in the many fields such as signal sorting and recognition, electronic countermeasure, threat assessment and spectrum allocation. These applications are vital for the electromagnetic spectrum advantage of future warfare[20].

1.4 Hitting and intercepting

Hitting and intercepting make the core of military operations in air and space operation.

In the aspect of hitting, the adaptability to various targets is important for efficient mutilate ability. AI technology can be used to upgrade the guidance and control system by employing intelligent sensing, autonomous decision-making, adaptive control and multi effect damage. In addition, the low profile penetration can be achieved by the comprehensive application of multiple advanced technologies, which includes active cancellation stealth technology, low-to-zero electromagnetic radiation control and threat circumvent, etc[21].

In the aspect of interception, under the help of data fusion technology, the defense system can form a three-dimensional perception of the battlefield situation through its own multi-sensor fusion detection, as well as the early warning information network of the land, sea, air and space. To make proper countermeasures, the defender needs to have the ability to analyze battlefield situation, identify high threat target group and generate operation plan fast enough to obtain the advantage in the interception process, while maintaining high level of control precision and terminal damage effect.

1.5 Speed of action and decision-making

One of the most important characteristics of air and space competition is the action speed and the decision-making speed, in which AI technology plays an important part.

For decision-making process, with the assistance of collaborative algorithm and real-time online optimization of individual nodes, the observation-orientation-decision-action (OODA) cycle of operations can be greatly reduced while maintaining overall optimal performance, which is vital for the decision-making speed and quality[22].

The intelligent flight assistance software ALPHA developed by the University of Cincinnati can observe and react 250 times faster than humans. It can update the multi-aircraft combat plan within 1 ms and improve decision-making capabilities through self-learning.

For action process, to squeeze flight performance potential of a missile, AI technology can be used in real-time perception and analysis of the thermal environment and structural strain, and relative technologies include adaptive control, variable structure, intelligent heat insulation, etc[23].

1.6 Shaping perceptions of key crowd

Technology is important for combat advantage, but the ideology of human is always ultimate reason for war, which implies human's perceptions are the key to win the war. To shape the perceptions of key crowd, AI technology can be used to greatly improve the decision-making accuracy and the action speed, transmit the strong determination in critical moment and guide the war in the beneficial direction. By a strong deterrent effect, the views of key crowd can be affected, and the purpose of "subduing the enemy without fighting" is achieved. In the third offset strategy, the United States proposed to build the global surveillance and strike network, aiming to establish a surveillance and strike network that can process various threats with distributed deployment in a few hours and minutes[24]. The combination of the network with Joint Artificial Intelligence Center of the US Department of Defense can further the action speed and decision-making accura-

cy, achieve expansion and influence the situation anywhere in the world[25].

2 Future of Air and Space Competition

New technologies such as AI, autonomic technology, cluster and networking will have combined effects on the combat performance of weapon system. It will be the internal driving force for the evolution of weapon system, and determine the direction of future space technology.

2.1 Interdisciplinary approach of mechanization, digitalization and intellectualization

In the new era with the rapid development of military technology and the dramatic change of international situation, military intelligence is leading to a chain reaction[26]. And the development of mechanization, digitalization and intellectualization is deeply interrelated. The discipline integration clarifies the direction for military AI technology in air and space field.

Mechanization is the foundation of digitalization and intellectualization. It contains the most elements in the development of air and space force. Digitalization makes an interconnected system between mechanization and intellectualization, playing a vital part in the space system. On a good basis of mechanization and digitalization, intellectualization is the key to seize the advantage of air and space.

2.2 Improvement of command agility of system

In the competition of air and space superiority, the operation scale, organization form, planning complexity and confrontation agility have been greatly improved with the development of AI algorithm, data processing, computing power, etc.

In order to make the recognition more accurate and profound, the battle course should be parallel processed in the war game simulation under the surveillance of command and control system with AI technology. Processed with high-performance and high-efficiency algorithm, massive data will be quickly converted into useful intelligence and dispel the "Fog of War"[27].

Due to the fast and accurate processing, the system will partially replace human's role so as to speed up the operation planning and seize the opportunity in combat. By rapid response, the system will have the ability to constantly disrupt the enemy's campaign and deployment.

In the end, in order to support and coordinate multi combat forces, it is necessary to improve the agility of command and control by forming a better operational organization structure and resource allocation process according to the battlefield situation.

The key to win the decision-centric operation is to let commanders make faster and better decisions than the enemy, degrade the quality and speed of decision of the enemy at the same time and prevent the enemy from achieving its goals by creating multiple difficulties[28]. As "Fog of War" is inevitable, the decision-centric operation improves the adaptability and survivability of its own side by applying distributed formation, dynamic force combination and reorganization, reduction of electromagnetic radiation, counter command, and C2ISR operations. Meanwhile, it decreases enemy's operation uncertainty and command capability.

The decision-centric operation solves two major challenges: One is to deploy in a distributed way and hide their own deployment and intention, and the other is to maintain the ability to make quick and effective decisions. Autonomous system and AI offer great help in solving these two challenges[1].

2.3 Giving full play to advantages of missile weapons

Missile weapon is not only the carrier and manifestation of information and firepower, but also important means of attack and defense in modern war. Since its invention, the missile, with the characteristics of long range, high accuracy, high speed and strong fire power, has become a new epoch-making weapon after artillery and bombers. And the missile has always being the represent of the latest military technology all along. As the most advanced equipment of modern warfare, it is an effective weapon for asymmetric warfare and deterrent warfare[29].

With the development of stand-off combat system, missile becomes the primary method to attack

and defense in air and space competition. For supporting operations to play a major role in the battle, the concept of missile warfare emerges and the missile salvo becomes the basic mode of modern warfare.

According to the research plans arranged by the United States under the guidance of the third offset strategic military, they all embody the ideology of giving full play to the advantages of missiles and improving the overall combat ability by improving the perception ability and dynamic response speed of unmanned platforms with missile weapons. In a sense, the essence of space competition is missile competition.

2.4 Improvement of battlefield situation awareness ability

In the intelligent war, although "Fog of War" has not completely dissipated, the transparency is getting higher and higher. The mastery of information and intelligence will become the key to win the war. The idea of full range situation awareness is to connect the physical space and the information space of the battlefield, making the battlefield transparent.

However, with the development of electronic warfare technology, the forward-deployed forces' situation awareness gradually declines. With the advancement of distributed warfare process, the difficulty of long-range perception also increases. With the increased proportion of autonomous operations, the requirement of real-time information perception increases.

In this situation, relying on the space-based support system, it is necessary to give full play to the penetration advantages of unmanned platforms to carry out forward reconnaissance, forming a coordinated reconnaissance system of integration of heaven and earth and greatly improving our situation awareness and control capabilities.

2.5 Improvement of cross domain collaboration ability

In the era of intelligent warfare, the combat elements are highly integrated and the combat space is expanded unprecedentedly.

The intelligent weapon system no longer forms a rigid system, but dynamically constructs a self-organized and adaptive combat system according to the changes of the battlefield. The "kill chain" of single service operations is expanded into a "kill network" of multi service operations to realize multi domain joined operation.

Taking "cross domain firepower" and "all domain maneuver" as the core elements, each combat platform and weapon unit are integrated into a distributed "sensor-weapon kill-effector" complex as a node through cross domain collaboration, which is composed of "ISR, strike, maneuver and support"[30]. It can be used across different areas. The command and control system operated at the same level enables all combat units to work cooperatively with each other through fire power and information sharing to achieve the mastery of air and space operation. The cross-domain collaboration operations are shown in Fig.2.

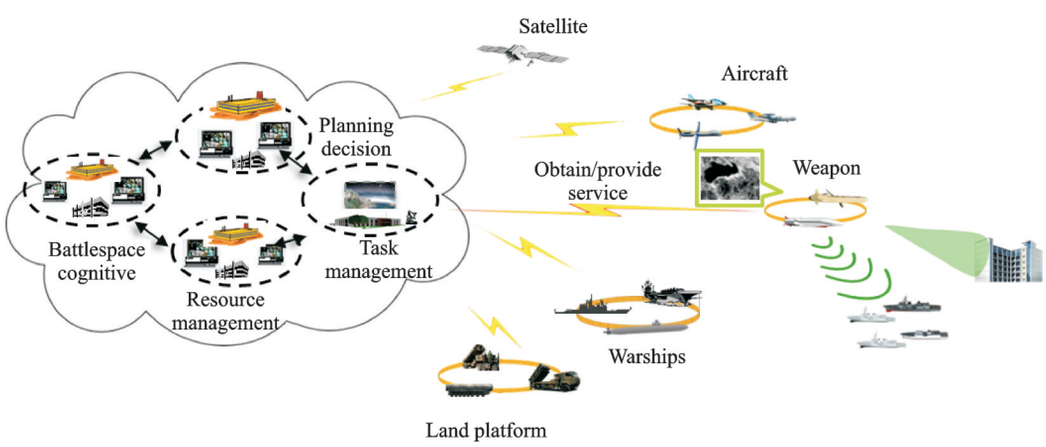

Fig.2 Schematic diagram of cross-domain collaboration operations

3 Conclusions

With information technology development, we have made preparations for the era of intelligent warfare.

(1) In the transformation from "information centric operations" to "decision-making centric operations" and from "control information superiority" to "control decision superiority", we have a deep recognition of the impact of intelligent technology on the air and space domain, and have a scientific and systematic layout for the development of air and space intelligent technology.

(2) Developing the air and space intelligent combat system with leading technologies will seize the air and space advantage in the future competition.

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Author contributions Prof. **WANG Changqing** designed the study, provided the core idea and wrote the main part of the manuscript. Mr. **XIAO Zuolin** conducted the analysis and wrote the part of the manuscript. Ms. **ZHANG Qian** contributed to background of the study and modified the manuscript. All authors commented on the manuscript draft and approved the submission.

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智能化时代的空天优势竞争

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摘要: 空天是强国竞争和科技博弈最为激烈的领域之一。本文聚焦空天优势竞争,从战争"隐藏与发现、理解与混淆、网络弹性与网络破坏、打击与拦截、行动速度与决策速度、关键人群的看法"6个基本矛盾入手,分析了智能技术发展对空天优势竞争的影响。在此基础上,针对未来获取优势竞争,提出了智能空天时代的发展方向。

关键词: 空天优势;人工智能;战争基本矛盾