Analysis of architecture framework and intelligent development of air-to-ground precision strike system

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Abstract: By the analytical method of system engineering, the air-to-ground precise strike system is set up. Using DoDAF (Department of Defense Architectural Framework, DoDAF), the concept of air-to-ground precision strike is built. The organization is definite and the capability requirement is analyzed. On the basis, the intelligent applications of command and control system, aircraft platform and guided munition are summarized. At last, some suggestion is put forward for the intelligent development of air-to-ground precision strike system.

1. Introduction

Air-to-ground precise system is an organic combination of information technology, precise weapon and air combat platform. It mainly consists of reconnaissance and surveillance platform, command and control system, air attack platform and precise guidance weapon system [1]. In other words, the air-to-ground precision strike system a large system composed of a variety of weapon and equipment systems with complementary functions, mutual connections and interactions in order to compete the air-to-ground strike combat task under the condition of integrated operation [2]. At present, the research on systems, especially equipment systems, such as architecture and system engineering [3], system modeling and simulation [4~7], has been booming at home and abroad.

Artificial intelligence (AI) is a new technical science that studies and develops the theory, method and application of human intelligence for simulation, extension and extension. The military application of AI can greatly improve the degree of autonomous control in future joint operations. Military intelligence is the further development of traditional military informatization and has become an important technology to effectively improve the form of informationized warfare.

In this paper, air-to-ground precise strike is taken as an example, and the structure framework DoDAF is adopted to preliminarily construct the air-to-ground precise strike architecture. High-level operational concept map, organizational structure, description of operational resource flow, decomposition of operational activities, and description of capability classification and dependency relationship are given. Then, according to the characteristics of air-to-ground precise strike mission, the application of artificial intelligence of important system members such as command and control
system, reconnaissance/strike platform and ammunition is discussed and analyzed. Finally, some suggestions are put forward for the intelligent development of air-to-ground precision strike system.

2. Air-to-ground precise strike combat architecture

2.1. High-level operational concept map

![Conceptual illustration of high-level operations OV-1.](image)

The OV-1 is a high-level graphical description of air-to-ground strike combat, which is more intuitive and easy for strategic decision makers to understand and communicate, including the description of key combat units, combat elements, battlefield environment, combat activities, combat modes and important combat capabilities. Through the analysis of the operational process of air-to-ground precise strike and with the combination of OODA operational ring, the operational concept map of high-level operations is obtained, as shown in figure 1.

2.2. Organizational structure

The OV-4 describes the command relationship of units in the process of air-to-ground precise strike, as shown in figure 2. In the example in the paper, at the task level, the combat commander, makes the task planning, decision-making and communication of the combat mission. Each command organization, including reconnaissance and surveillance formations, ground troops and attack platform formations, shall formulate operational plans and implement operational plans and implement operational plans according to the operational task assigned by the command and control center and their actual conditions.

![Organization diagram OV-4.](image)

2.3. Description of combat resource flow

In order to describe the information that needs to be exchanged from important nodes to other nodes in the operation of air-to-ground precise strike, the OV-2 combat resource floe description view, namely
the information flow view, is designed, and the types of information exchange between combat nodes are given to facilitate commanders’ decision-making and command.

**Figure 3.** Description of combat resource flow OV-2.

2.4. Decomposition of combat activities

Based on the high-level operational concept map and operational plan, the combat activities of air-to-ground precise strike are decomposed, as shown in figure 4.

Reconnaissance/surveillance: ground troops and unmanned reconnaissance aircraft formations carry out reconnaissance in the target area to look for enemy targets according to the reconnaissance/surveillance plan; when finding the enemy target, reporting the target information to the command and control center and request a strike.

Command and control: the battle commander makes the battle plan, checks the communication among the members of the system, and sends the battle mission plan to the attack platform formation.

Strike implementation: the attack platform formation flies to the target area, develops the guidance battle plan, and launches the ammunition to attack the target.

Damage assessment: ground troops, unmanned reconnaissance aircraft formation or attack aircraft formation conduct target damage assessment, and report the assessment results to the command and control center; the operational commander decides to strike again or end the mission.

**Figure 4.** Breakdown diagram of operational activities OV-5a.

2.5. Capability analysis of air-to-ground precise strike combat system

Combined with the above relevant operational views, the capability classification of air-to-ground
precise strike combat system is determined, which mainly includes reconnaissance and surveillance capability, communication capability, command and control capability, target attack capability and damage assessment capability, etc., as shown in figure 5. The interdependence among capabilities is shown in figure 6.

![Figure 5. Diagram of capability classification CV-2.](image)

![Figure 6. Diagram of capability dependencies CV-4.](image)

3. Related application of artificial intelligence in air-to-ground precision strike system

According to the characteristics of air-to-ground precise strike mission, command and control, reconnaissance/strike platform and ammunition are important units of the combat system.

3.1. Intelligent command and control

Command and control is the "nerve center" of military combat system. Command and control intelligence is the core of military application of artificial intelligence technology. In the future battlefield, command and control will play the role of “intelligent brain”. The one, whoever has a high level of command and control intelligence, will have a good command and control tactics.

The United States has been exploring the application of artificial intelligence in the military field for a long time [8]. The defense advanced research projects agency (DARPA) launched “deep green” plan in 2007 to embed simulations into command-and-control systems to improve the speed and quality of commanders' on-the-fly decision-making. In 2009~2014, DARPA has launched a large number of base technology research projects, such as “Insight”, Visual Data Analysis (XDATA), Deep Learning, Text Depth Excavation and Filtering (DEFT), to explore the key technology development about multivariate data automatic acquisition, processing information, extracting the key characteristics and mining association relationship.

In December 2015, the US Department of Defense proposed the third offset strategy, and proposed five key technology areas focusing on intelligence and autonomy. Among them, autonomous learning and human-computer interaction technology, using artificial intelligence technology, integrating human insight and high sensitivity of the computer, improves the commander's decision-making...
effectiveness. According to US DoD deputy secretary David Walker, these technologies can compress the commander's time in the observation-orientation-decision-action (OODA) loop, achieving the goal of joint command and control in multi-domain operations in order to gain control of future wars. In June 2016, Alpha AI, an artificial intelligence system developed by the University of Cincinnati, defeated the experienced retired US air force colonel 100% in simulated air combat. Alpha AI can quickly coordinate tactical plans in air combat 250 times faster than humans. The whole process, from sensor collecting information, analyzing and processing to making correct responses, takes less than 1ms. Alpha AI can avoid dozens of missiles and attack multiple targets at the same time.

3.2. Intelligent aircraft platform

The intelligent aircraft platform focuses on the UAV platform.

The US air force is the country who developed and used unmanned aerial vehicle (UAV) in actual combat, and through a series of specific plans, provided long-term, comprehensive and sustained guidance for the development of UAV (such as “roadmap for UAV system”, which defines 10 autonomous control level for UAV [9]). The UAVs in-service can be used for near field combat support, and providing seamless coverage for remote missions [10].

The US military's RQ-11 raven, RQ-16 desert spiders and other short-range drones can fly close to the ground and accompany ground troops. MQ-1B predator, MQ-9 god of death and other long-endurance UAS can achieve wide-area sustained coverage at high altitude. UAVs such as grey eagle, reaper and global hawk have initially possessed low-level autonomous maneuvering capability, which can independently complete taking off and landing, and have initially acquired the capability of replanning the flight path onboard. The X-47b is the first experimental carrier-borne stealth unmanned combat aircraft in human history, which is completely controlled by computer without manual intervention. It has completed a series of tests such as autonomous air refueling and autonomous aircraft carrier taking-off and landing. Although the project has been cancelled, it has shown a strong degree of autonomy and intelligence.

In addition, the F-35 carries ten millions of codes and is known as the “flying computer”.

3.3. Intelligent airborne ammunition

Intelligent airborne ammunition weapon is a intelligent development of traditional airborne ammunition, and is a kind of weapon of destruction with higher thinking ability. Intelligent airborne ammunition weapon applies artificial intelligence technology in subsystems, such as military command, combat system, weapon structure, navigation, guidance and control, warhead and fire control, making the ammunition work with local or complete autonomous control in the whole process from detection, penetration, tracking to destroying [11].

Intelligent airborne ammunition shall have the following characteristics [12]:

1. Automatic target detection and recognition capability
2. Battlefield situation analysis and judgment ability
3. Electronic countermeasures and intelligent anti-interference capability
4. Online task planning ability
5. Intelligent target strike capability
6. Missile body status monitoring and management capability
(7) Multi-ammunition cooperation ability

At present, some foreign missile products have preliminary intelligence characteristics. The most representative are the Long Range Anti-ship Missile (LRASM), the Naval Strike Missile (NSM), the TACTOM Missile (Tactical Tomahawk) and the Taurus KE PD350 Missile [13].

| Missile    | Automatic target recognition | Automatic threat avoidance | Collaborative navigation | Target Localization | Quadratic route planning on line |
|------------|-------------------------------|---------------------------|--------------------------|---------------------|---------------------------------|
| LRASM      | √                             | √                         | -                        | -                   | -                               |
| NSM        | √                             | ×                         | √                        | √                   |                                 |
| TACTOM     | √                             | ×                         | √                        | √                   |                                 |
| KE PD350   | √                             | ×                         | ×                        | ×                   |                                 |

| Missile    | Flying condition adjustment | Target value judgment | Vital area recognition | Damage degree control | -                               |
|------------|-----------------------------|-----------------------|------------------------|-----------------------|---------------------------------|
| LRASM      | √                           | √                     | √                      | -                     | -                               |
| NSM        | √                           | ×                     | √                      | √                     |                                 |
| TACTOM     | √                           | -                     | -                      | √                     |                                 |
| KE PD350   | √                           | ×                     | -                      | √                     |                                 |

√ presents having the capability, × presents not having the capability, - presents not knowing whether having the capability or not.

4. Suggestions on the intelligent development of air-to-ground precision strike system

(1) Using the thoughts, theories and methods of system engineering to make overall planning for the intelligent development of the air-to-ground precision strike system.

(2) Intelligent flight platform and intelligent ammunition should develop uniformly.

(3) Import advanced civil artificial intelligence technology achievement into military field, and upgrade and transform existing weapon equipment, enhancing the combat effectiveness of weapon rapidly.

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