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INTEGRATING ARTIFICIAL INTELLIGENCE INTO C-UAS SYSTEMS TO MATCH THE MODERN WARFARE ADVANCEMENTS

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ABSTRACT

A notable development in modern military actions is the widespread use of unmanned aircraft systems (UAS). In the course of current conflicts, combat involves the deployment of low-cost unmanned aircraft loaded with explosives. These aircraft navigate via global positioning system (GPS), to accurately reach targets located hundreds of kilometers away from their secure launch sites. Current command and control (C2) systems deployed to fight against enemy UAS do not possess the advanced know-how required to effectively protect troops and assets on this day frontline. To enhance their effectiveness, counter-UAS (C-UAS) systems must incorporate artificial intelligence (AI), and automated processes be a tower of strength to human factor in making decisions and empower the achievement of deter and defeat channels. This article highlights the need to integrate AI, and automated processes into C-UAS C2 systems. Incorporating these technologies will provide a combative lead in opposing nowadays and emerging enemy UAS hazards and procedures.

KEYWORDS: AI, automated processes, C-UAS, machine learning

1. Introduction

AI is a rapidly evolving field within science and engineering, encompassing a wide range of subfields. These range from broad areas like study and knowledge to specialized applications like chess playing, mathematical theorem testing, poetry composition, autonomous driving in traffic, and disease diagnosis. Given its applicability to all intellectual tasks, AI is a truly universal discipline.

That is why it is very difficult to have a general definition of this concept. During the last decades there have been many people that have tried to define AI to address thought processes and reasoning or behavior.

Definitions of artificial intelligence are as follows:

− "*The art of creating machines that perform functions that require intelligence when performed by people*." (Kurzweil, 1990);

− "*The exciting new effort to make computers think ... machines with minds, in the full and literal sense*." (Haugeland, 1985);

− "*The study of how to make computers do things at which, at the moment, people are better*." (Rich & Knight, 1991);

− "*Artificial intelligence is technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy*." (Stryker & Kavlakoglu, 2024).

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To conclude with, AI is in the same time a technology, an art, a new effort and a subject of study that will dominate the future.

Artificial Intelligence (AI) is becoming more prevalent in the military sector, enhancing efficiency and accuracy in field operations, predictive analysis, logistics, and more. Its capacity to process vast amounts of data in real time and learn independently gives AI significant potential in defense and national security. Moreover, AI provides substantial benefits to military capabilities, including improved speed and accuracy, enhanced battlefield awareness, and superior decision-making abilities.

By utilizing AI algorithms for predictive analytics and scenario modelling, the military can foresee emerging threats and swiftly adapt its strategies to maintain agile and responsive command and control. Due to the impact on evolution of future conflicts, UAS are registered as influential technology, with unpredictable effects in the doctrinal sphere (Ciolponea & Bârsan, 2022). Military strategists regard the AI capability as a crucial factor that could significantly influence the outcomes of future conflicts and address the UAS emerging threat.

2. C-UAS Procedure

The C-UAS procedure utilizes active defence measures through four key stages: detection, identification, decision-making, and defeat. This structured approach offers a valuable framework for assessing UAS threats across various operational settings and exploring the integration of automation to support operator responses.

2.1. Detect

The initial phase of the C-UAS methodology involves identifying air threats within the operational area. This is achieved using a range of radar detection and seeking techniques, encompassing sensors located in the air and on the ground.

2.2. Identify

When an aerial path is observed, it is to investigate it and it is established whether it is friend or foe. This is achieved by conducting Identification Friend or Foe (IFF) using radars equipped with IFF capability, coordination with airspace control agencies, or by assessing unfriendly attributes. Differentiating between friendly and hostile courses is an intricate task that relies on one of two methods: identification by electronic means or according to some well established procedures. The most trusted method is the identification by electronic means, as it does not depend on visual confirmation to recognize a suspect air path. Instead, digital identification utilizing physics and recognized hostile traits can be employed to determine if a path belongs to an enemy UAS. Procedural identification distinguishes friend from foe by analyzing an aircraft's geographic location, timing, and flight plan, often following a specific order.

2.3. Decide

During this phase, two key decisions are made. First, it is determined whether engagement is necessary based on factors such as rules of engagement, the geopolitical climate, and the tactical situation. Second, the method of interception is chosen. If the person that operates the device determines that an aircraft has a hostile behaviour, he/she choose whether to neutralize the threat with a kinetic or non-kinetic weapon. The threat's direction, altitude, distance, and speed are evaluated to determine whether engagement is warranted and to choose the most effective weapon for a successful response.

2.4. Defeat

In this phase, operators successfully execute kinetic or non-kinetic actions against identified hostile tracks. The effectiveness of these actions is determined through either visual confirmation of the intercept or digital verification.

If the hostile track is not neutralized, the person who operates the system continues to position further means until the threat is eliminated or reaches its intended target.

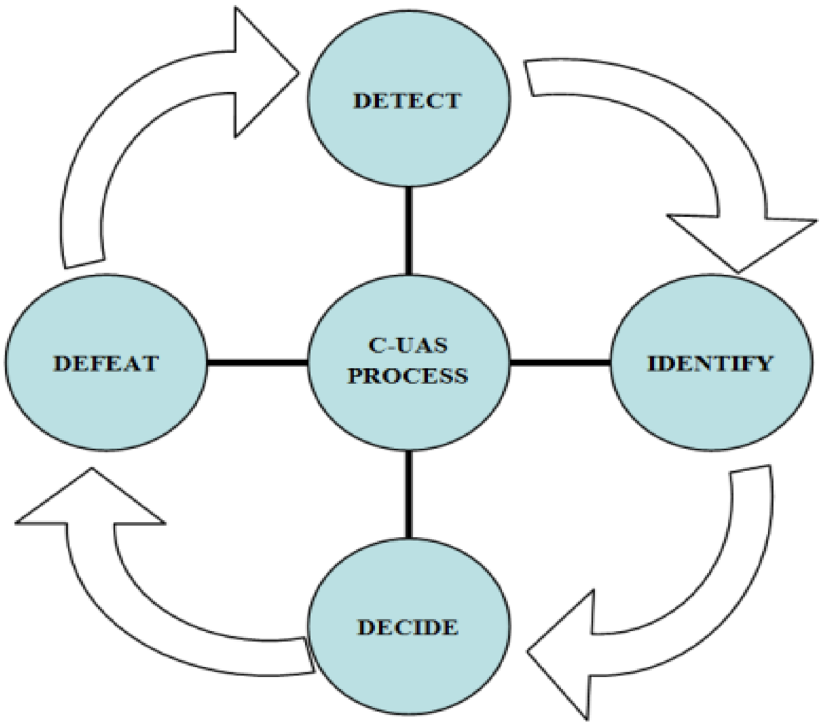

Figure no. 1: *Counter Unmanned Aircraft Process*
(Source: Graphic by authors)

3. Manual Engagement Challenges

Current command and control (C2) C-UAS systems rely on manual engagement processes during the identification, decision-making, and defeat phases, which greatly hinder the swift and effective neutralization of enemy threats – particularly when decisions must be made within seconds. Operators are required to manually analyze each radar track and individually activate defensive systems against hostile targets, making the process both time-consuming and susceptible to human error. Even the most advanced C2 C-UAS systems, like The Forward Area Air Defense Command and Control used by United States of America, rely on manual processes to counter the UAS threats.

This manual process hinders the ability to engage multiple targets simultaneously, which is essential in fast-paced combat situations. The time spent on manual engagements provides an opportunity for a swarm of UAS to breach defensive layers without resistance. C-UAS operators often experience task overload and a higher risk of human error as they juggle myriads of attacks conducted by UAS, oversee the paths of the own aircrafts that are operating in the area, chooses the most appropriate system to engage while coordinating ongoing battle.

Requiring manual intervention in the command and control system shifts focus away from critical aircraft identification, thereby increasing the potential for error on the account of human intervention and reducing efficiency in countering UAS threats.

Improvements in UAS attack speeds – exemplified by the Shahed drones – and the strategic use of terrain to delay radar interogation, further diminish the efficaciousness procedures conducted manually, potentially jeopardizing the success of counter-UAS interceptions.

Figure no. 2: *C2 interface used by US Army*
(Source: https://www.northropgrumman.com/what-we-do/land/forward-area-air-defense-faad)

4. The Need to Integrate AI Assistance into the Detection and Identification Phases

As this subchapter title states, the identification authority should not be passed to the AI and it should be kept within the humans, but relying on the machine substantial assistance. However, the AI ability to discover and identify enemy air paths while swiftly notifying humans will help alleviate the saturation of the systems, enabling those who operate the system to maintain ultimate authority over track identification. Integrating AI into this process will improve identification accuracy, shorten threat detection time, and provide ground forces with earlier warnings, ultimately preserving combat power.

AI should be incorporated into C2 systems to improve operational efficiency in detecting hostile air tracks. By offering continuous analytical capabilities, AI supports operators in interrogating air tracks and its key advantage lies in analyzing and recognizing patterns from past sources. The data needed by all the systems needs to be stored in classified archives, ensuring that AI identification systems can easily access it. This would enable the integration of air track data with a speed and accuracy beyond human capabilities.

If AI modus operandi is not integrated into command and control systems, the C-UAS command posts will be limited to the capabilities of human operators, falling short of the system's full potential. Without AI and machine learning tools, human operators face a week spot, increasing the likelihood of failing to speedily pinpoint routes and successfully intercept hostile ones, potentially allowing UAS to reach their targets. While manual interrogation and identification are possible, humans cannot match AI's precision, speed, and consistency in executing these tasks.

5. Implications to Include Automated Processes into the Decide-Defeat Phases

Strategists, warfighters, and technologists have heralded Artificial Intelligence (AI) as a potential tactical and strategic tool for outpacing adversary decision-making processes (Daniels2021). The essence of winning a fight against any hostile UAS is to outpace the enemy's Observe-Orient-Decide Act (OODA) loop. Traditional views suggest that combined teams of humans and machines, supported by AI-driven machineries, will respond faster than their adversaries in a war, securing key assets that may lead to victory. So why not shorten the decide-defeat loop as much as it can be done?

By integrating automated processes, the C-UAS systems will autonomously select the applicable response routine up to the time that the UAS is neutralized. This feature is going to reduce response times, enabling the operator to focus on detecting threats and managing airspace while the system independently selects and oversees the most effective interception strategy – completely free of human error.

Equipped with automated decision-making and target neutralization capabilities, the system enables the operator to oversee engagements with confirmed hostile targets. Meanwhile, the C-UAS system can simultaneously address multiple threats using an array of weapon systems, facilitating a coordinated combined arms defensive fire strategy. This automated neutralization system will improve UAS interception, shorten engagement durations, mitigate the errors of humans, and boost the possibility of successfully countering an attack conducted by UASs that operate in a swarm.

The real question is whether humans should or should not be included in the engagement phase against an UAS. "*Centrally, proponents of human control over AI-enabled weapons systems don't think that lethal targeting decisions should be left to AI. This is why the examples used to stress the importance of meaningful human control often focus on weapons systems that use AI for targeting decisions*" (Davidovic, 2023). Opponents of automated engagement frequently argue that operators should personally handle detected threats to guarantee compliance with international humanitarian law and rules for the use of force.

The existence of the "*Human out of the Loop (HOOTL)' mode in which an AI develops and executes solutions without human intervention should also be noted*" (Verney & Vinçotte, 2021). By doing so, the engagements will be faster and more accurate and the human intervention is conducted earlier during the identification phase so the target is already confirmed by a non-AI authority.

6. Next-Generation C-UAS Technology

The integration of UAS in military operations determines the conceptualization, and implementation of Counter UAS (C-UAS) measures, in all categories of forces, implicitly the automatic adoption of TTPs (techniques, tactics, and procedures) and standards (Ciolponea, 2022).

In order to keep up with the UAS developments, there is a need for the C-UAS assets to adapt to the modern era and AI is a reliable and enforceable solution since autonomous weapons systems act as a force multiplier (Etzioni, 2017).

In terms of detection, tracking and identification, a crucial factor in achieving faster and less labor-intensive air threat observation is automatic image recognition made possible by AI methods such as machine learning. The final step toward next-generation unmanned aircraft (UA) detection, tracking, and identification systems is automated sensor fusion, which combines data from every available resource and sensor to form a unified Common Operational Picture (COP). How this COP is presented to human operators requires careful attention. Additionally, all system observations and processes must be logged to support post-event operational analysis and forensic investigations (Dominicus, 2021).

Preparation plays a crucial role in enhancing the effectiveness of both current and future systems. It involves gathering information on the types of air vehicles used by potential adversaries and their operational methods. Additionally, training AI to recognize images and patterns in adversary operations is essential. Another important element of preparation is creating a sensor and effector deployment strategy that aligns with the local terrain and anticipated enemy positions and actions. It's also crucial to consider integration with other sensor networks and command and control systems. Ideally, future systems will include tools to streamline this planning, ensuring that a C-UAS system can be rapidly deployed when necessary.

Current operator decision support systems primarily offer a visual representation of the situation, typically through a two-dimensional topographical display. Some systems enhance this with auditory alerts to highlight new contacts or warn of potential threats. However, next-generation decision support should be significantly more advanced, continuously updating and prioritizing threats as the situation evolves. A truly effective system would also integrate available effectors, recommending the appropriate effector for each target based on the desired outcome. It should factor in the risks associated with deployment, including potential collateral damage and adherence to applicable rules of engagement (ROEs). Future decision support systems should shift from requiring human operators to be actively involved ("humans-in-the-loop") to a supervisory role ("humans-on-the-loop"). In scenarios where the risk of deploying an effector is minimal or the threat level is severe, fully autonomous decision-making and intervention may be viable.

Many first-generation C-UAS systems struggle with limited upgradability. As threats evolve rapidly, these systems fail to follow along with the increasing expertise of adversaries. Therefore, future C-UAS systems should be designed for easy expansion, allowing the integration of additional and diverse sensors and effectors. Furthermore, enhancements to the interfaces, decision support tools, and self-sufficiency should be integrated as they are on hand or enhanced as required.

7. Ways of Getting C-UAS Systems AI Ready

In order to have C-UAS systems AI capable, it will require the following enablers.

7.1. Data

AI cannot exist without data. The way data is collected, managed, and validated plays a crucial role in the success of AI projects. Proper implementation of these processes ensures the system functions correctly throughout both development and approval stages. The data environment, including the infrastructure, plays a crucial role in the success of the implementation.

7.2. People

They are the most important resource in the development and implementation of AI C-UAS systems. And here we refer not only to the soldiers that operate these machines but also to those who are involved in the acquisition and manufacturing processes or managing the databases. It will require years and years of training to acquire the skills and expertise needed to achieve final operational capability for this kind of systems.

7.3. Technology

There will be a need to increase the data processing power using the state of the art chips and implementing sophisticated security solutions. So there is a must to invest in technology in order to successfully implement the AI solutions into the C-UAS systems. Infrastructure plays a crucial role by providing hardware and networks distributed within the battle space.

7.4. Policies

There is a need for a clear policy on using AI in the military domain and particularly in the C-UAS missions. By having a clear policy and a set of rules, it will provide a safe and secure environment driven by the responsible use of AI.

8. Conclusions

Nowadays, the integration of AI into the C-UAS systems is a must and nations should accelerate the efforts in terms of research and development in order to achieve this goal.

First of all, by using the AI it will shorten the time of engagement and will allow a swift and effective nullification of enemy combat power. AI will empower humans that operate the systems to identify multiple targets in congested airspace while optimizing the peak performance of radars. With the availability of AI and machine learning technology, systems can adapt to evolving combat threats and enhance UAS interception success rates.

Secondly, failing to advance C-UAS C2 systems and relying on C-UAS processes with manual procedures, will give hostile actors a strategic edge on the battlefield. Recent events have demonstrated that low-cost UAS can effectively carry out precision strikes, posing a significant threat. Without intervention capabilities that match the speed and accuracy of modern digital technology, preventing large-scale destruction of combat power will be challenging, ultimately forcing combatant commanders to allocate additional resources to achieve their military objectives.

Last but not least, AI continues to evolve and warfare will remain centered around human decision-making. Educating leaders on the military impact of emerging technologies, while fostering a shared understanding among counties, will be the key to integrating tech-driven decision-making into future combat operations. If AI-powered technologies generate situations requiring human judgment and input, operators at all levels must develop a fundamental understanding of these systems' capabilities to use them effectively and trust their functionality. Since humans will continue to play a crucial role in the decision-making process for the foreseeable future, their involvement remains essential. Successfully combining human power of reasoning with machine cleverness and AI will either provide a significant military advantage or result in a cross to bear.

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