AUTONOMOUS COLLABORATIVE PLATFORMS (ACP): THE FUTURE OF AUTONOMOUS SYSTEMS

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The rapid progress of artificial intelligence and the advancement of digital communication technologies have facilitated the emergence of autonomous collaborative platforms (ACPs), systems capable of independently executing complex missions, cooperating with other platforms with or without a crew on board, and adapting to the challenges of the operational environment.

In the military sector in particular, ACPs are leading to the modernization of combat tactics, reducing risks for human personnel, optimizing resources, and expanding operational capabilities. The introduction of these technologies also brings new ethical and legal challenges, requires doctrinal changes, and their evolution is prompting a profound re-thinking of how combat actions are planned, coordinated, and executed, leading to a transformation of tactics, procedures, and the interaction between autonomous systems and human personnel on the battlefield.

Keywords: ACP; CCA; loyal wingman; artificial intelligence; collaborative;

INTRODUCTION

The pace of technological progress is constantly redefining how society functions, and the concept of *Autonomous Collaborative Platforms (ACPs)* is at the heart of this transformation. ACPs refer to intelligent systems capable of operating independently, collaborating with each other or with human operators, and responding quickly to challenges in their environment. These platforms not only automate tasks, but also bring a high level of adaptability and coordination, opening up new horizons for innovation and operational efficiency.

In a military context, ACPs will change the way combat operations are conducted, providing armed forces with tools to manage complex missions with minimal risk to human personnel. They can operate autonomously or in teams, integrating with other systems to ensure a rapid and effective response in different situations. These platforms can also operate in civilian sectors for the development of smart cities, transport optimisation and security surveillance, helping to reduce costs, improve quality of life and increase safety.

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The adoption of ACPs is driven by advances in artificial intelligence, high-speed communications systems, and the miniaturization of hardware components, which enable the development of increasingly autonomous and interconnected systems. Thus, autonomous collaborative platforms are emerging as new technologies of the future, with the potential to revolutionize the way high-risk missions are managed as well as many other tasks that can be handled by autonomous vehicles.

The research is based on an analysis of existing literature, focusing on relevant, current, and credible sources in the field of collaborative autonomous platforms. As this is a developing field, the main resources have been accessible online, including scientific articles, reports from international institutions, specialized websites, and ongoing projects. The approach adopted is interdisciplinary, combining technical, operational, and ethical perspectives to highlight both the challenges and opportunities associated with the development and implementation of ACPs.

CONCEPT DEFINITION

The term ACP refers to a new category of unmanned combat aircraft that use artificial intelligence (AI) to execute missions, from specific commands to general objectives with a high degree of autonomy. Autonomy can vary depending on the mission and can range from a *"loyal wingman"* working directly with another piloted aircraft to a fully autonomous platform that can receive mission updates from a human (Anderson, 2025, p. 35). The unmanned aircraft capable of executing *"loyal wingman"*-type missions are totally autonomous platforms at operational level (shooting, reconnaissance, jamming etc.), but they are directly monitored, guided and commanded by the pilot of the classical combat aircraft. In the United States of America, this concept is now known as the *"collaborative combat aircraft"* (CCA) (Venckunas, 2023), a term that is becoming increasingly used in the literature.

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These collaborative autonomous aircraft have been defined and cover five mission categories: collaborative combat aircraft (CCA), collaborative reconnaissance aircraft (CRA), collaborative bomber aircraft (CBA), collaborative mobility aircraft (CMA), and collaborative training aircraft (CTA) (Anderson, 2025, pp. 35, 36). The best-known category of ACPs is CCAs, which are designed to fight alongside piloted combat aircraft to increase lethality and survivability in high-risk missions. CCA is a US Air Force initiative aimed at the rapid development and deployment of highly autonomous unmanned aircraft capable of interacting and collaborating with fifth- and sixth-generation operational aircraft, such as the F-35 or the Next Generation Air Dominance (NGAD) program (Airforce Technology, 2024).

The US Air Force's Next Generation Air Dominance (NGAD) program marks a major paradigm shift in military aviation, adopting a *"system of systems"* approach. NGAD is not limited to the development of a sixth-generation fighter jet, but involves its integration into an extensive network that includes manned platforms, autonomous drones, and advanced command and control systems. The new sixth-generation aircraft in the NGAD program is estimated to cost approximately $300 million per unit, which has prompted the US Air Force to seek more affordable complementary solutions. As such, the concept plans to implement CCA-type platforms, which will operate both in tandem with piloted NGAD aircraft and independently, providing the necessary force on the battlefield at a much lower cost and increasing pilot safety (Ib.).

When unmanned aircraft systems operate autonomously in groups, in a coordinated manner, the notion mentioned in the literature is that of *"multiagent system"*. Colloquially, it is called *"swarm"*, which is a term used erroneously more often than not, especially in the situation when saturation attacks are executed, meaning that more single-use drones are launched against a defeated objective.

Unlike classic autonomous systems, which usually operate independently and perform predefined tasks, ACPs are designed to operate in an integrated ecosystem, where constant information exchange and cooperation with other platforms (autonomous or manned) become essential. Active collaboration is not limited to the transmission of simple directives, but involves complex real-time decision-making processes, assessment of the operational context, and optimal distribution of tasks among the members of the formation.

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The high level of autonomy of ACPs would allow them to interpret and execute complex commands without direct human intervention, quickly adapting to unforeseen situations, emerging threats, or mission changes. These platforms will not only respond to external stimuli, but will anticipate the evolution of tactical situations and make decisions to resolve them.

The flexibility of ACPs will consist of their ability to be quickly reconfigured for various missions, such as reconnaissance, surveillance, electronic warfare, logistics, support, or even direct combat actions. Thanks to their modular architecture and the possibility of integrating various sensors and payloads, the same platform can quickly switch from one role to another, depending on mission requirements. In addition, network collaboration allows them to act as part of an intelligent distributed system, sharing tasks, maximizing resource efficiency, and increasing the chances of success in complex and dynamic operational environments.

It should be noted, however, that, with the exception of CCA platforms, the other categories of collaborative aircraft (CRA, CBA, CMA, CTA) have not yet been developed or operationalized to a level that would allow for a detailed analysis of their performance and impact. Currently, these concepts remain at the project or theoretical stage, without concrete demonstrations or relevant examples of operational implementation. In the absence of an internationally accepted common standard, the tendency is to talk, in general, only about CCAs that can be quickly reconfigured to perform other types of missions.

CURRENT STAGE OF DEVELOPMENT

In recent years, autonomous collaborative platforms have become one of the most dynamic and contested areas of military technology. The development of these systems marks a fundamental change in the way air forces conceive their future strategies, promising a combination of efficiency, flexibility, and risk reduction for human crews. From single-use drones designed for high-risk missions to strategically valuable aircraft capable of operating in tandem with piloted aircraft, ACPs represent the response of the major powers to the challenges of the digital age and the competition for air supremacy. In a geopolitical context marked by increasingly intense rivalries, these platforms are no longer just technological experiments, but instruments of power.

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The Royal Air Force (RAF) has adopted an ambitious strategy to integrate collaborative autonomous platforms into its force structure by 2030. The goal is for these systems to operate alongside manned platforms to provide decisive military capabilities, both nationally and within coalitions. The RAF's strategy is not limited to technological development. It also targets organizational and cultural transformations to accelerate the adoption of ACPs and keep pace with technological progress and emerging threats. Thus, it has been considered that the RAF should work in collaboration with the Royal Navy, the Army, and the British industry to ensure the rapid and integrated development of new ACP capabilities.

The concept is to divide ACPs into three categories: Tier 1 – *"disposable"*: single-use drones for high-risk missions, Tier 2

– *"attritable"*: with chances of recovery, but loss is acceptable, and Tier 3 – *"survivable"*: platforms of strategic value, whose loss is unacceptable. These new autonomous platforms will be designed for a wide range of missions, from critical infrastructure protection, reconnaissance and surveillance to attack, logistical support, or electronic warfare. At the same time, official documents emphasize the need for organizational, operational, and cultural changes to harness the potential of ACPs and manage the associated risks (Royal Air Force, 2024).

A significant milestone for the development of autonomous collaborative technology in military aviation was the flight on 2 May 2024. US Air Force Secretary Frank Kendall participated in flight sessions with students from the Pilot Test School, including international students, highlighting the crucial role of the test and evaluation community in maintaining the technological advancement of the Air Force. During this visit, Kendall had the opportunity to fly the F-16 (X-62A VISTA), a test aircraft equipped with specialized software and machine learning algorithms to simulate and test autonomous air combat scenarios in real time. The most important feature of the X-62A VISTA is its ability to develop and test autonomous flight manoeuvres using integrated software agents that can react instantly to simulated threats. This technology has been developed in collaboration with DARPA's Air Combat Evolution (ACE) program (Gary, Mary, 2024). This event marked a milestone in the testing and validation of autonomous air combat capabilities based on artificial intelligence in real time.

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Moreover, the United States of America is investing heavily in the development of these types of platforms. Among the most important examples are the YFQ-42A (formerly known as the XQ-67A or Gambit), developed by General Atomics, and the YFQ-44A (Fury) from Anduril Industries, both of which were selected in 2024 for prototype development and testing phases under the US Air Force's official CCA program (Air Force, 2025). These unmanned aircraft are characterized by a high degree of autonomy, real-time collaboration with manned aircraft, and adaptability to a variety of roles, from combat, reconnaissance and electronic warfare missions to logistical support.

As part of the Royal Australian Air Force (RAAF) collaborative combat aircraft program, Boeing Australia has developed the MQ-28A Ghost Bat aircraft, specifically designed to operate in tandem with manned aircraft such as the F/A-18, EA-18G, F-35A, and E-7 Wedgetail, integrating autonomous behaviours and advanced communication and data fusion capabilities between platforms.

The Kratos XQ-58 Valkyrie is another example of *"loyal wingman"* experimental aircraft developed to meet Air Force requirements under the *Low-Cost Attritable Strike Demonstrator* program. The first flight of this unmanned platform was in March 2019. It was designed to assist fighter jets using artificial intelligence. Although Kratos was initially awarded a contract in 2021, the Air Force subsequently opted to continue working with General Atomics, the developer of the XQ-67A, considering that the XQ-58 was too small to meet all the requirements of the *"loyal wingman"* role (Spray, 2024). However, Valkyrie remains relevant due to its competitive cost and the fact that it was one of the first platforms to use AI to expand tactical capabilities.

There are also numerous initiatives in the Asia-Pacific region. As part of the Royal Australian Air Force (RAAF) collaborative combat aircraft program, Boeing Australia has developed the MQ-28A Ghost Bat aircraft, specifically designed to operate in tandem with manned aircraft such as the F/A-18, EA-18G, F-35A, and E-7 Wedgetail, integrating autonomous behaviours and advanced communication and data fusion capabilities between platforms (Donald, 2025). The MQ-28A Ghost Bat is considered a pioneer in the field of collaborative combat systems and has high potential for integration into the CCA program.

South Korea has also significantly accelerated its efforts to develop autonomous collaborative platforms and unmanned aircraft of the *"loyal wingman"* type, relying on integration between the local defence industry and the government sector. This strategy aims not only to accelerate the modernization of own military capabilities, but also to increase compatibility with Western systems, given the tense regional context and the need for interoperability at the level of strategic alliances. In early 2025, the first prototype of the *"loyal wingman"* stealth drone, LOWUS (Low Observable Unmanned Wingman System), was unveiled, designed to be operated primarily alongside the next-generation KF-21 Boramae aircraft. Developed by Korean Air in collaboration with the Agency for Defence Development (ADD), LOWUS marks an important step in the integration of the *"manned-unmanned teaming"* concept at the national level.

Equipped with radar signature reduction technologies and featuring an aerodynamic configuration reminding of American models, LOWUS is designed to perform reconnaissance, electronic warfare, and ground strike missions in support of manned aircraft. The prototype's maiden flight is scheduled for the end of 2025, and formation tests with piloted aircraft are expected to begin by 2027 (Newdick, 2025). By integrating these advanced unmanned aircraft, South Korea is strengthening its industrial autonomy and military capabilities.

Over the past decade, China has significantly accelerated its investment in advanced military technologies, positioning itself at the forefront of the global competition for air supremacy. One of the most dynamic and innovative segments of this effort is the development of *"loyal wingman"* drones as part of the CCA program designed to support and extend the capabilities of piloted fighter aircraft. Programs such as Feihong FH-97A (Saballa, 2024) and initiatives by Chinese aerospace industry giants reflect Beijing's ambition to catch up with other countries and establish itself as a leader in military autonomous aviation.

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Russia is actively developing advanced *"loyal wingman"* drone programs or collaborative autonomous platforms with the aim of increasing the efficiency and flexibility of its air forces. The best-known project is the S-70 Okhotnik-B stealth drone, designed to operate in tandem with the Su-57 fighter jet, providing escort, attack, and reconnaissance capabilities with a high degree of autonomy (Suciu, 2025). Moreover, Russia is exploring new concepts, such as Grom, a drone focused on strike and support missions, and is testing the integration of artificial intelligence for the autonomous control of multiple types of drones on the battlefield (Defense News Aerospace, 2024). Although the implementation stage of these projects is still under development, Russia aims to strengthen its technological capacity and reduce the gap with Western initiatives.

Europe is also investing heavily in the development of autonomous collaborative platforms for future generations of air forces, with a view to ensuring strategic competitiveness, technological autonomy, and interoperability with NATO allies. The most ambitious European project in this field is the Future Combat Air System (FCAS), initiated by France, Germany, and Spain. FCAS aims to build a *"family of systems"* that will include both a sixth-generation fighter jet and *"loyal wingman"* drones, called *"remote carriers".* These drones will escort piloted aircraft, carry out reconnaissance, electronic warfare, or attack missions, and will be integrated into a network for rapid information exchange and optimized decisions on the battlefield (Orbital Today, 2025).

The analysis of the current state of development in the field of autonomous collaborative platforms shows that they are far from being experimental projects, becoming central capabilities in the great powers' military architecture. From the USA and its Western allies to the Asian states, there is an accelerated and intense competition for the integration of such systems into the Air Force.

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HUMAN AND CULTURAL DIMENSION

While for engineers in test labs or aerospace companies the challenge of collaborative autonomous platforms is one of code, sensors and algorithms, for pilots, the revolution is more subtle and much more personal. Flying *"side by side"* with an autonomous drone is not just about adapting to new technology, but changing a professional culture built on the idea that the person in the cockpit is the ultimate arbiter of aerial combat. In 2024, the US Air Force's X-62A VISTA program brought this issue to the forefront when an experimental F-16, equipped with artificial intelligence software, performed autonomous manoeuvres in a dogfight scenario, while a human pilot in the rear cockpit served only as a *"safety net"* (Kohler, 2024). The tests clearly showed that artificial intelligence systems react and make decisions much faster than pilots, and the conclusions are that AI is already entering their space and doing so very quickly.

Many recognize the enormous tactical advantage of having *"loyal wingman"* drones that will assume the risks of the mission, enter enemy territory first, or perform time-consuming tasks. But on the other hand, there is a degree of instinctive reluctance toward autonomous systems that make decisions without always explaining the logic behind them. The adaptation process involves a transition from a model centred on direct human control to a collaborative model, in which the pilot acts as a combat manager, supervisor, and arbiter of decisions generated by autonomous algorithms.

DARPA's Air Combat Evolution (ACE) program explores how human pilots and autonomous systems can cooperate effectively in air combat missions. Unlike traditional tests, the focus is not only on the technical capabilities of autonomous platforms, but also on how human pilots adjust their behaviour and trust in the algorithm's decisions. In practice, the pilot becomes a combat coordinator, intervening for strategic or safety decisions, while autonomous aircraft handle tactical tasks that are impossible for the human in the cockpit to perform at such speeds (DARPA, 2024). As part of the program, pilots are exposed to scenarios in which drone autonomy can be activated or deactivated in real time, thus learning to delegate micro-decisions to AI. At the same time, DARPA monitors pilots' physiological responses, such as heart rate or stress levels, to assess their confidence in autonomous systems and identify any points of frustration or anxiety. The tests include air combat simulations where AI algorithms can execute faster and more aggressive manoeuvres than a human pilot could, providing a practical lesson on the limits and advantages of human-machine collaboration. The ultimate goal of ACE is not only to demonstrate that autonomous aircraft can fly on their own, but to create an air combat ecosystem in which pilots and autonomous platforms work together, increasing efficiency and reducing risk to humans. Moreover, the program faces cultural and ethical challenges: pilots must accept that AI can make faster decisions, and organizations must integrate this change without undermining trust in the human leader of the mission (Halpern, 2022).

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Therefore, the human and cultural dimension of introducing autonomous collaborative platforms is at least as difficult as the technical side. It requires professional training to transform pilots from direct executors into human-machine formation leaders, interfaces that briefly explain the algorithm's intent, and an organizational culture that accepts that AI can sometimes be faster. Essentially, the success of ACPs will depend not only on technological developments, but also on the willingness of a generation of aviators to share the skies with a new category of *"crewmembers".*

ETHICAL AND LEGAL CONSIDERATIONS

The implementation of autonomous collaborative platforms raises a number of ethical challenges, as there are currently no legal instruments that can address the challenges posed by these emerging technologies.

One of the most important concerns is the delegation of critical decisions to artificial intelligence systems, especially when ACPs operate in a military context where they can have lethal consequences. This delegation requires a clear definition of responsibility for the actions of the autonomous system. Who is responsible in the event of misjudgements, collateral damage, or human rights violations: the user, the developer, the operator, or even the platform (which has no legal personality)? Collaborative autonomous platforms are often *"black box"* systems, making it difficult to understand *how* and *why* certain decisions are made. This lack of clarity undermines user trust and makes human oversight difficult. It is essential that these systems should provide explanations so that their decisions can be understood and challenged when necessary. Trust in autonomous systems must be calibrated to avoid excessive trust and automation, which can lead to de-professionalization, meaning the degradation of the essential human skills needed for decision-making. Solutions such as *"override points"* (mandatory points of human intervention) and error detection training are essential (Merchán-Cruz et al., 2025).

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Regulation of autonomous platforms and artificial intelligence at the global level is far from uniform. In the United States of America, the traditional approach favours voluntary standards and manufacturer responsibility, which leaves room for rapid innovation but can create gaps in user safety and protection. In the European Union, a much stricter framework is taking shape through the AI Act, which classifies AI applications according to their level of risk and establishes clear obligations for transparency, auditing, and accountability. In contrast, China and other Asian countries have adopted centralized measures with strict rules on cybersecurity, data labelling, and the obligation to locate data within national territory (Consensus Labs, 2025). This diversity of regulations reflects cultural, economic and political differences, while also leading to fragmentation of the international legal framework. For companies developing or operating autonomous collaborative platforms, this context means legal uncertainty, additional compliance costs and difficulties in scaling projects globally. The lack of a common global framework also raises issues of harmonization of ethical and safety standards, especially in cross-border sectors such as autonomous transport, defence, or digital security.

FUTURE PROSPECTS

Autonomous collaborative platforms are at the beginning of a technological revolution that will profoundly reshape future combat operations.

One of the current trends is the development of drone swarms. Using the collective intelligence of swarms, ACPs can react quickly to changes in the operational environment, automatically redistribute resources, and influence tactical decisions in real time, significantly increasing mission efficiency and resilience. Inspired by the behaviour of social insects such as bees or ants, this intelligence is based on the decentralized coordination of a large number of aircraft which, through their interaction, exhibit emergent behaviour that is much more complex and efficient than the sum of their individual actions (SDI, 2024). In the context of ACPs, this approach allows multiple autonomous aircraft to cooperate in an adaptive and flexible manner, performing complex tasks such as reconnaissance, surveillance, or coordinated attacks together, without requiring direct control of each individual unit.

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Moreover, integration with *"legacy systems"* (classical systems) represents both a technical and economic challenge. In many industries, the current infrastructure was designed before the advent of autonomous platforms and was not designed to work with intelligent or self-adaptive entities. This lack of compatibility means that implementing new solutions requires significant investment in modernization, adaptation, and interoperability. The problem is exacerbated by the fact that many organizations operate with critical systems that cannot be quickly interrupted or replaced, forcing them to find *"plug-and-play"* solutions or middleware to facilitate communication between the old and the new (Geihs, 2020). These challenges are not only technical but also organizational: integrating collaborative autonomous aircraft requires adapting work processes, training staff, and defining new standards to ensure the coherent functioning of the entire system.

Cybersecurity remains a critical factor in the development and operation of collaborative autonomous platforms. As the number of connections and interactions increases, so do the attack opportunities available to malicious actors. Attacks can range from unauthorized access to data to taking control of autonomous components or systems, with potentially catastrophic consequences.

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A predictable development is the migration of ACPs to all operational environments (air, land, sea, and space), creating multi-domain networks for rapid information exchange and optimized decisions. Generative AI and adaptive algorithms will enable systems to constantly improve their performance, anticipate complex threats, and adapt to unpredictable changes. Therefore, the evolution of collaborative autonomous platforms is shaping up to be an accelerated process, in which technological progress must be accompanied by standardization, security, and sustainable integration in order to reach its full potential.

CONCLUSIONS

Autonomous collaborative platforms represent a technological revolution, bringing a significant leap in the efficiency and flexibility of military operations. The ability of these systems to operate both autonomously and in collaboration with piloted aircraft opens up new possibilities on the battlefield, fundamentally changing the way missions are designed and executed.

The widespread adoption of autonomous collaborative platforms will require profound changes in military doctrine and the structure of the armed forces, which are necessary for the integration of new technologies.

Ethical and legal challenges remain a major obstacle to the full implementation of these technologies. There is an urgent need to develop clear international legislative frameworks and regulations that define responsibilities and ensure transparency in how these autonomous systems make decisions.

Major investments by key state actors reflect the major strategic importance of ACPs in the race for air and technological supremacy. States that manage to integrate these technologies quickly and efficiently will gain a decisive competitive advantage in the field of security and defence. Thus, collaborative autonomous platforms are not only a technological innovation, but also a transformative factor that requires a balanced approach between progress and responsibility.

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