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Juan Camilo Correa Rubio
Lieutenant of the General Corps of the Air Force.
Head of the Systems Section (of the Transmission Company) of the Royal Guard.
Barracks "El Rey". Royal Guard. El Pardo (Madrid).

Email: jccorrearubio@gmail.com

Prospective analysis of the implications of using autonomous aerial systems in USAF Air Defence Interception Missions. From 2019 to 2035

Abstract

The introduction of robotics on the battlefield is no longer a concept from science fiction. Successful trials with autonomous weapon systems are giving way to a new Revolution in Military Affairs, set in the emerging era of robotics and nanotechnology. Through the technique of scenario building and analysis, four scenarios and their implications in air defence interception missions in US domestic airspace are examined. With 2035 set as the time horizon, in terms of this study the key concept within the autonomous UAS is the "loyal wingman".

Keywords

Autonomous UAS, USAF, Air defence, NORAD, FAA, Interception, loyal wingman.

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Introduction

In this research analysis, the possible progressive implementation of autonomous airborne weapons systems – and therefore equipped with artificial intelligence (AI) – in the United States Air Force (USAF) is evaluated through the construction and analysis of scenarios. With a time horizon of 2035, these scenarios have been limited to Air Defence (AD) interception operations. Having established the objective, the first step involves explaining why humanity is facing a Military Revolution (MR), discussing the current state of autonomous unmanned aircraft, and tracking the publications of other authors on this subject. Secondly, the methodology involved in scenario building and analysis will be explained and applied in the context of this study. Finally, it will be established which of the proposed scenarios is the most plausible.

At a time when Remotely Piloted Aircrafts (RPAs) are increasingly involved in certain military air operations, and are becoming more popular in the civilian sphere – both for private recreational use and for business activities – humanity has taken a step forward. This is a new reality in which the successful testing of unmanned autonomous aircraft (UAS) prototypes may lead to their being operated in conjunction with manned aerial platforms and RPAs. In the context of the USAF, this could materialise into one of the most important – if not the most important – mission of a nation's air force: the air defence of its territory, its critical areas and its citizens.

As with the RPAs, the incorporation of autonomous military UAS will require deconflicting and making the use of US airspace more flexible, through civil-military coordination, and the effective use of technical solutions[1]. This being a process of innovation, it can originate either from political authorities or from the military; for, contrary to what certain groups may think, the armed forces of a state, far from constituting itself as an isolated group and alien to its environment, interacts and interrelates with it. Consequently, its influences can have different origins, including society, political, economic and cultural situations, state institutions and, ultimately, the international arena[2].

UAS as a catalyst for an RMA

Robotics is clearly one of the most fascinating technological advances of recent decades: a science and technology that is present in many areas of society, and an area of research that is continually advancing, both for civil and military applications. The first successful tests of autonomous UAS represent a milestone, which, together with

1 CHEATER, Julian C. Accelerating the kill chain via future Unmanned Aircraft. Air War College 2007.

2 JORDÁN, Javier. «Un modelo explicativo de los procesos de cambio en las organizaciones militares. La respuesta de Estados Unidos después del 11-S como caso de estudio». Revista de Ciencia Política, n.º 1. 2017, pp. 203-226.

other military autonomous weapon systems, are beginning to revolutionise the very nature of warfare. However, to date this milestone does not depend exclusively on technological advances, but is also a function of other variables, which together are allowing humanity to witness a new era.

To speak of "revolutionise" or of an "era" extends beyond the mere use of these terms, and has important associated theoretical concepts. Authors such as Murray have identified RMs over the past half a millennium, these extended periods of time being characterised by social, economic and political factors that condition the general character of war, and which have their origin and end in turning points[3]. However, of the various authors who have written about revolutions, of particular interest are the Tofflers[4], for they identify three great waves – as they call the eras or revolutions – that are the origin of a fourth wave. These authors maintain that the first two waves belong to the past and that the present corresponds to the third, that of "post-industrial society". In this wave, communications, computer systems, globalisation, monitoring and tracking systems, etc. are key to business and military development[5]. However, it is the fourth wave, which the Tofflers identify with an emerging era of robotics and nanotechnology independent of the third wave[6], that is most relevant to this work and which is already beginning to bring about profound changes such as those discussed in the present analysis.

With regard to changes in the military field, they are not only the direct result of technological advances but, above all, of innovation processes systematically applied in all functional areas and military capabilities. In a broad sense, military innovation can be doctrinal, technological, or organisational, or a combination of all of these. If such innovation involves a profound change in any of these three aspects, a revolutionary change – which, moreover, will normally lead to transformations in some of the other two aspects of the triad – will generate a Revolution in Military Affairs (RMA). In conjunction with the above, a RM will normally comprise

3 BAQUÉS, Josep. «Revoluciones militares y revoluciones en los asuntos militares». In JORDÁN, Javier (coord.). Manual de Estudios Estratégicos y Seguridad Internacional. Madrid: Plaza y Valdés 2013, pp. 119-127.

4 Alvin Toffler was a futurologist and sociologist known for his works like Future Shock, The Third Wave or Power shift: Knowledge, Wealth, and Violence at the Edge of the 21st Century. Together with his wife, Heidi Toffler, he also produced works of a futurist tendency, notably: War and Anti-War: Survival at the Dawn of the Twenty First-Century, and Creating a New Civilization: The Politics of the Third Wave.

5 BALOCH, Qadar B.; KAREEM, Nasir. «Review of The Third Wave», by Alvin TOFFLER. The Journal of Managerial Sciences, n.º 2. 2007, pp. 115-143.

6 BAQUÉS, Josep. «Revoluciones militares y revoluciones en los asuntos militares». In JORDÁN, Javier (coord.). Manual de Estudios Estratégicos y Seguridad Internacional. Madrid: Plaza y Valdés 2013, pp. 126-127.

a series of RMAs[7]. Accordingly, the autonomous UAS can be qualified as an RMA within the RM that develops on the back of the Toffler's fourth wave. This fact will consequently imply – if the processes of investigation and experimentation prove successful – extensive transformations in the doctrine, organisation and resources of future military air operations.

Unmanned autonomous aircraft

Once again, the United States is at the forefront of military innovation, having achieved successful results in testing prototypes of autonomous and unmanned airborne weapons systems. As indicated in the previous section, this constitutes a genuine RMA that adds to the ongoing process of adaptation, integration and standardised operation of the increasingly used RPAs. It is therefore advisable that the civil and military authorities should begin to plan the implementation, use and regulations in the medium term, and even in the short term, of autonomous UAS. In addition, for the purpose of this study it should also be borne in mind that in order to carry out an AD mission a certain type of aircraft must be capable of performing air combat and winning it, if required.

If an autonomous UAS is to be capable of beating another aircraft, first and foremost the AI with which it is equipped must demonstrate that ability. The University of Cincinnati developed an AI dubbed ALPHA, based on genetic-diffusion systems, capable of beating a retired USAF experienced pilot, thus fulfilling the first system requirement, and of course representing a huge step forward in this field. Likewise, ALPHA was designed for use with Unmanned Combat Aerial Vehicles (UCAV) for research purposes[8], which is yet another indicator of the viability of this phenomenon. However, already a decade before, Captain Nidal of the USAF produced a thesis dealing extensively with the development of autonomous UAS through design, modelling and flight tests in simulation, using various mathematical and engineering tools[9].

However, the steps taken so far go beyond that thesis and ALPHA, with already autonomous UAS prototypes already in existence. Of particular relevance is PERDIX, the system used by the US Department of Defense, consisting of a swarm of micro-UAVs with shared AI. Launched from an F-18 US Navy capsule –103 drones in the case of the example – they embark on the flight coordinating with each other and

7 BAQUÉS, Josep. «Revoluciones militares y revoluciones en los asuntos militares». In JORDÁN, Javier (coord.). Manual de Estudios Estratégicos y Seguridad Internacional. Madrid: Plaza y Valdés 2013, pp. 119-127.

8 REILLY, M. B. «Beyond video games: New artificial intelligence beats tactical experts in combat simulation». University of Cincinnati Magazine. 27/06/2016. Available at https://magazine.uc.edu.

9 NIDAL, Jodeh M. Development of autonomous Unmanned Aerial Vehicle research platform: modeling, simulating and flight testing. Thesis. Ohio: Air Force Institute of Technology 2006.

deciding at each moment the best way to execute the assigned missions. This system stands out as a "collective organism", and is also very low cost compared to other weapon systems, as the micro-UAVs employed were manufactured using 3D printing[10].

Illustratiing the interest that this swarming technique arouses in researchers are the numerous studies on algorithms used for the collective decision-making of these swarms[11], as well as analysis in civil[12] and military publications[13] on the different modes of military operation, capabilities and limitations, countermeasures, command and control needed in these systems and other aspects related to their use.

However, autonomous micro-UAV swarms are not the only players in this RMA, as significant progress has also been made with considerably larger aerial platforms. In this respect, the success achieved in tests with autonomous F-16s is particularly innovative. This fighter and attack aircraft, the most manufactured and acquired in history, has been successfully "robotised", operating together with manned fighter planes under the concept of "loyal wingman". This consists of associating a certain number of autonomous aircraft (F-16) with a manned aircraft (F-35). In this way, a team is established in which the UAS is subordinated to the command of the pilot of the main aircraft, but carrying out the assigned missions autonomously, manoeuvring, attacking, defending and meeting again with its leader autonomously[14]. Also of note are projects related to autonomous Air-to-Air Refuelling (AAR) for unmanned platforms[15], the legal and ethical aspects of which have also been widely discussed by authors such as Gillespie & West[16] and Thurnher[17], among others.

10 UNITED STATES DEPARTMENT OF DEFENSE. Department of Defense announces successful micro-drone demonstration. Virginia: 2017 [consulted on 27 January 2019]. Available at https://www.defense.gov/Newsroom/Releases/Release/Article/1044811/department-of-defense-announces-successful-micro-drone-demonstration/.

11 FRANTZ, Natalie R. Swarm intelligence for autonomous UAV control. Thesis. California: Naval Postgraduate School 2005.

12 SCHARRE, Paul. «Robotics on the battlefield part II. The coming swarm». Center for a new American security 2014.

13 UNITED STATES AIR FORCE. USAF RPA vector. Vision and enabling concepts 2013-2038. Washington D.C.: 2014.

14 LOCKHEED MARTIN. U.S. Air Force, Lockheed Martin demonstrate manned/ unmanned teaming. Maryland: 2017 [consulted on 30 January 2019]. Available at https://news.lockheedmartin.com/2017-04-10-U-S-Air-Force-Lockheed-Martin-Demonstrate-Manned-Unmanned-Teaming.

15 BURNS, Brian S. Autonomous Unmanned Aerial Vehicle rendezvous for automated aerial refueling. Thesis. Ohio: Air Force Institute of Technology 2007.

16 GILLESPIE, Tony; WEST, Robin. «Requirements for autonomous unmanned air systems set by legal issues». The International C2 Journal, n.º 2. 2010, pp. 1-30.

17 THURNHER, Jeffrey S. No one at the controls: the legal implications of fully autonomous targeting. Rhode Island: Naval College of War 2012.

Whilst not intending to go into detail on the subject matter and scope of publications related to autonomous UAS, let us say, after consulting many academic databases and open sources, that most of these works are ambitious and generalist, with some attempting to cover a wide range of aspects of these systems. However, they do not go into the detail and specificity of these works with respect to a particular type of operation. A work with similar objectives to those of this research analysis – albeit more extensive as it is a thesis – is the work of Donald Brown, who, by means of analysis and scenario building, studies the implications of the use of different types of autonomous UAS in SEAD (Suppression of Enemy Air Defenses) missions[18].

The "loyal wingman" model

As we have seen in the previous section, there are currently two main models – at prototype stage – for the use of autonomous UAS using American technology: the swarm drones and the "loyal wingman". Without referring to specific prototypes, the phenomenon of swarming is the one that has received most attention in existing publications. This is due to the innovative nature of its robotic technology, its similarity to biological organisms and the incipient economy of scale in its development. This has been the case with Work and Brimley[19], and Scharre[20], among others. These authors highlight advantageous aspects of the use of autonomous UAV swarms such as:

– *Greater survival capacity.* As a set of micro-UAVs with shared AI, the shooting down or any inappropriate operation of one element of the cluster simply means that the remaining operational micro-UAVs continue with the fulfilment of the mission.

– *Suitability for certain missions.* They can act as a communications relay, perform logistical-military functions, carry out reconnaissance, surveillance, intelligence, jamming, and enemy saturation – the latter thanks to the multiple elements that make up the swarm.

– *Reduced size*. This makes it difficult to neutralise each individual micro-UAV and to detect it, for example, by means of primary radar.

However, despite all these advantages and characteristics – widely discussed in reference texts – for several reasons this study suggests that the "loyal wingman" should be the leading autonomous UAS for air defence interception missions.

18 BROWN, Donald. Bolts from Orion: Destroying mobile Surface-to-air Missile Systems with lethal autonomous aircraft. Alabama: Air Command and Staff College. Air University 2016.

19 WORK, Robert O.; BRIMLEY Shawn. «Preparing for war in the Robotic Age». Center for a new American security 2014.

20 SCHARRE, Paul. «Robotics on the battlefield part II. The coming swarm». Center for a new American security 2014.

First of all, the target date of 2035 must be borne in mind. This implies that the time frame in which conventional aircraft and RPAs will continue to exist is short to medium term. Therefore, the autonomous UAS – still in their most advanced state of development, but prototypes nevertheless – will not exist in exclusivity. Second, and related to the former, the possible threats that will have to be faced in this timeframe correspond to platforms of (relative) size. Consequently, in view of the possibility of having to neutralise them, similar systems – either (remotely) manned or autonomous UAS – are needed in terms of speed, manoeuvrability and armament. Thirdly, humanity is in a necessary transition, where, although the nation that we are concerned with here is at the technological forefront, possible airborne threats from other countries could appear. Many of them within the set timeframe will have available at most RPAs – including, for example, conventional fighters and attack aircraft. Fourth, in terms of similarity, a scenario such as that set out by Manson is considered unlikely[21], which conceives micro-UAV swarms capable of very high speeds, theoretically capable of beating conventional fighter planes and in general large aerial platforms. Even for the USA, and for this research analysis, it is estimated that this scenario falls outside the established time frame.

For all of these reasons, and as already mentioned in the previous section, scenarios will be built and analysed using the concept of "loyal wingman" as a starting point.

Construction technique and scenario analysis

Although it is not our intention to provide a detailed explanation of this technique or of prospective analysis in general, it is worth commenting briefly on its implications and its use in military-related studies.

In this context, as indicated in a study commissioned by the USAF from the RAND Corporation in the late 1970s, a "scenario" is the "description of the conditions under which a certain system under analysis, design or operation is supposed to operate". In this study, "system" means not only a specific weapon system, but also a combination of weapon systems with the facilities and logistics surrounding them, and even an organisation[22]. The system under analysis here is the "loyal wingman" operating on intercept missions, at the North American Aerospace Defense Command (NORAD).

For Brown, the construction of the scenarios in which to analyse a system is related to the four levels of decision-making it establishes, these being (1) operations management; (2) choice of tactical alternatives; (3) systems engineering, design and research; and finally (4) determination of major policies.

21 MANSON, Katherine. «Robot soldiers, stealth-jets and drone armies: the future of war». Financial Times. 16/11/2018. Available at https://www.ft.com.

22 BROWN, Sayom. «Scenarios in systems analysis». In QUADE, E. S.; BOUCHER W., I. (coords.). Systems analysis and policy planning: applications in defense. Santa Monica, California: The RAND Corporation 1968, pp. 298-310.

Therefore, for the purpose of this analysis, our main focus will be on levels one, two and four. In Level four we will be examining the "loyal wingman" in the US air defence system, which is the responsibility of the strategic command. Level two, because this analysis and the operation of this weapons system will be limited to interception missions in airspace for which NORAD is responsible – and not, for example, a conflict zone in the Middle East – and because, furthermore, a series of tactical considerations will be entered into for this type of mission, which will be explained later. And finally, level one, because we want to determine whether the combination of manned aircraft and "loyal wingman" is an efficient and effective mode of operation.

As one might expect, scenario building implies always being aware of one's own technological and economic aspects, but also those of the enemy, if needs be. Likewise, the functions and political implications of the system's performance must play a leading role. The political aspects, based on the construction of scenarios, must be consistent with the political-military context proposed. However, a realistic scenario –which is derived from such consistence – should not be confused with a high probability of its occurrence. The probability can be low, and it can still be a realistic scenario[23].

The ideas outlined so far can be supplemented by a previous study by the RAND Corporation. It establishes a series of general points to consider when building scenarios for research purposes related to the military and defence[24].

Along with the concepts developed in the works of Brown and DeWeerd, of particular relevance is the article *La técnica de construcción y análisis de escenarios en estudios de Seguridad y Defensa (The technique of construction and scenario analysis in Security and Defence Studies)*"[25] which provides a systematic approach to prospective analysis, recasting and synthesising the works of various authors. It offers a clear explanation of this technique, including the steps to be followed to carry out a complete prospective study. These steps will be developed further on and applied directly to the subject matter of this study.

Application of the technique to the *"loyal wingman"* model

As a prerequisite to establishing the final set of scenarios, and the further analysis of their implications, the initial scenarios have to be drawn up. To this end, through an initial five steps, a number of key elements must be delimited and identified, which will form the support base for this research. A correct analysis in these first phases will enable us to learn from the hypothetical future scenarios proposed.

Step 1. Defining the basic parameters of the analysis

As indicated in its title, this research analysis is limited in terms of geography and time, besides setting out the subject matter of the study. The analysis is centred on the

23 BROWN, Sayom. «Scenarios in systems analysis». En QUADE, E. S.; BOUCHER, W. I. (coords.). Systems analysis and policy planning: applications in defense. Santa Monica, California: The RAND Corporation,1968, pp. 302-307.

24 DEWEERD, Harvey A. Political-military scenarios. Santa Monica, California: The RAND Corporation 1967.

25 JORDÁN, Javier. «La técnica de construcción y análisis de escenarios en estudios de seguridad y defensa». Análisis GESI 24/2016. Grupo de Estudios en Seguridad Internacional 2016.

plausible use of autonomous UAS in air defence interception missions in US airspace, between now and the year 2035.

Step 2. Identifying the research requirements

As Jordan observes, this is an iterative process that is found throughout the application of the technique. Through its execution, the construction of the scenarios and their subsequent analysis will be refined. As a starting point, the need to consider possible scenarios is established and deduce in each of them the consequences of integrating the autonomous military UAS into the exploitation and use of American domestic air space. Specifically, those that in the future could be dedicated to air defence together with the RPAs already in use, and, of course, conventional aircraft. As already indicated, this study arises from the need to go beyond generalist studies with respect to the introduction of robotics in military airborne platforms, applying more specific, mission-oriented approaches.

Step 3. Identifying the main actors involved

Only three key players will be considered in this study: the USAF, NORAD and the Federal Aviation Administration (FAA). That said, another option would be to dive into the entire US institutional fabric, where other stakeholders would certainly appear. One of them could be the legislative power and the controls, commissions, and regulations that it approves and applies in relation to the use of UAS - including autonomous systems. Another could be the judicial power and the sentences it adopts with respect to complaints from any individual or legal entity on this matter. Of course, public opinion, which is constantly evolving, could also be considered. However, in this investigation the three agents mentioned at the beginning are considered the most suitable for the scenarios used, because of their close relationship with civil and military air operations, their own room for manoeuvre, and their status as American institutions.

- *The United States Air Force*. With the "loyal wingman" as the chosen autonomous UAS model in this study, the US Air Force, rather than the US Navy and its swarm clusters, will emerge as the major player. Of crucial importance in evaluating the USAF's position regarding the use of such systems are the strategic documents published by the Air Force. These present the vision and plans for the future of an organisation with autonomy within its jurisdiction, but which in turn is part of the Department of Defence (DOD). In this context, the acceptance and introduction of autonomous UAS into the Techniques, Tactics and Procedures (TTPs) of the USAF is not sufficient. The authorisation of the use of such platforms in military missions in domestic airspace is also needed, which is the responsibility of other actors. It is therefore logical to think also about the influence that the approval of the President of the United States (POTUS) has on this type of mission, as well as the indications that his advisors in matters of Defence and National Security give him. In particular, it would be up to the Secretary of Defense, if he so wished, to defend the continuation of the project within the objectives he would set for his Department[26].

- *The North American Aerospace Defense Command (NORAD)*. A nation's air defence involves many more resources than a combat aircraft. For this reason, it is also worthwhile to provide a general explanation of the US air defence system, the main components that make it up, and the mission of each one. This is not an exclusively US organisation, since it comprises the bilateral action and cooperation of the USA and Canada in terms of North American air defence. Its areas of responsibility are divided into three main zones: the Alaskan NORAD Region (ANR), the Canadian NORAD Region (CANR) and the Continental US NORAD Region (CONR). Although the ANR and CONR airspace also falls under US sovereignty, for the purposes of simplification and illustration we will refer solely to continental US (CONUS).

  Confirming the first lines above, in addition to the F-15, F-16 and F-22 used as fighter and attack aircraft – on alert for CONR defence – the area has an integrated air defence system. This also consists of command and control systems, early warning radars and other detection devices, several telecommunications systems, and US Army anti-aircraft artillery systems.

  NORAD's mission includes the warning and control of airspace, as well as the warning of maritime threats, an aspect that we will not enter into here. In terms of airspace, the tasks to be carried out continuously are detection, identification, validation and, where necessary, warning – of both civil and military aircraft, aerospace vehicles and missiles[27]. This whole package of technical and human resources, including the currently manned hunting and attack platforms, is what executes, when necessary, interception missions in air defence.

- *The Federal Aviation Administration (FAA)*. The FAA is an agency of the United States Department of Transportation (US DOT), whose corporate mission is to provide the world's most efficient and safest airspace management system. Through its operational arm, the FAA aims to safely and efficiently provide air navigation services in US airspace and in areas of US responsibility. This means providing such services to both commercial and private aircraft, as well as military aircraft – if they are subject to general aviation rules in their flight plan. The FAA, through its Office of Government and Industry Affairs,

26 UNITED STATES DEPARTMENT OF DEFENSE. Meet the team. Virginia: 2019 [consulted on 20 March 2019]. Available at https://www.defense.gov/Our-Story/Meet-the-Team/.

27 NORTH AMERICAN AEROSPACE DEFENSE COMMAND. About NORAD. Colorado: 2019 [consulted on 21 March 2019]. Available at https://www.norad.mil/About-NORAD/.

ensures that its actions are consistent with DOT guidelines. With respect to UAS, the FAA currently contemplates four main blocks of operators: those with recreational goals, those geared towards educational use, RPA certified pilots – including commercial operators – and finally those related to public safety and other government purposes[28]. As we have done with the USAF, for the purpose of this study its current strategic vision will be taken as a reference.

Steps 4, 5 and 6. Identify basic trends and their impact, identify key uncertainties and construct initial scenarios

As Jordán explains[29], compared to the option of building the initial scenarios from a matrix based on a combination of basic trends and key uncertainties (drivers), there exists the possibility of doing so using two orthogonal axes. In order to do so, it is necessary to be able to concentrate on the main drivers, to be clear about the subject of the study and to establish which are the main actors.

The objective of this study is not to build scenarios where the possible existence of autonomous UAS is analysed in a general fashion, but to concentrate on USAF developments. Thus, of interest in this context are autonomous UAS with military purposes intended for use in AD missions. Focusing on a particular type of mission does not necessarily imply that the aircraft in question is designed and intended exclusively for that type of mission. Accordingly, it can be multi-purpose like most fighter and attack aircraft today.

It will therefore be crucial for the scenarios to know whether the USAF, following the first real test successes of its prototypes, is going to continue improving and perfecting their capabilities. In this case, it will opt for the progressive implementation of these weapons systems in its operational organisation, in order to include them in a safe and controlled manner in the different tasks of the Air Force.

On the other hand, it is not only the improvement and maintenance of these prototypes over time that must be considered, but also the management of their area of operation. Since this study considers only AD missions, the area in which these systems will operate will be the US domestic airspace. In this way, it is not only that the USAF has them, but also that NORAD has to admit them as yet another of the various means at its disposal to fulfil its mission. Finally, the knowledge and acceptance of the FAA, as the state entity in charge by default of civil aviation matters in the United States, must also be obtained.

28 UNITED STATES DEPARTMENT OF TRANSPORTATION. Federal Aviation Administration. Washington D.C.: 2019 [consulted on 23 March 2019]. Available at https://www.faa.gov/.

29 JORDÁN, Javier. «La técnica de construcción y análisis de escenarios en estudios de seguridad y defensa». Análisis GESI 24/2016. Grupo de Estudios en Seguridad Internacional 2016,

Based on these considerations, two main drivers are identified to form the basis of the four scenarios. On the one hand, continuity in research, development and innovation (R&D&I) of autonomous UAS from the USAF. On the other hand, coordination and a level of mutual understanding between NORAD and FAA. In figure 1, both drivers and the four resulting scenarios are represented. In this way, establishing a relationship between the two most characteristic drivers of this study by means of two orthogonal axes, we can describe the fundamental elements of each of the four initial scenarios, which will be developed in the following section.

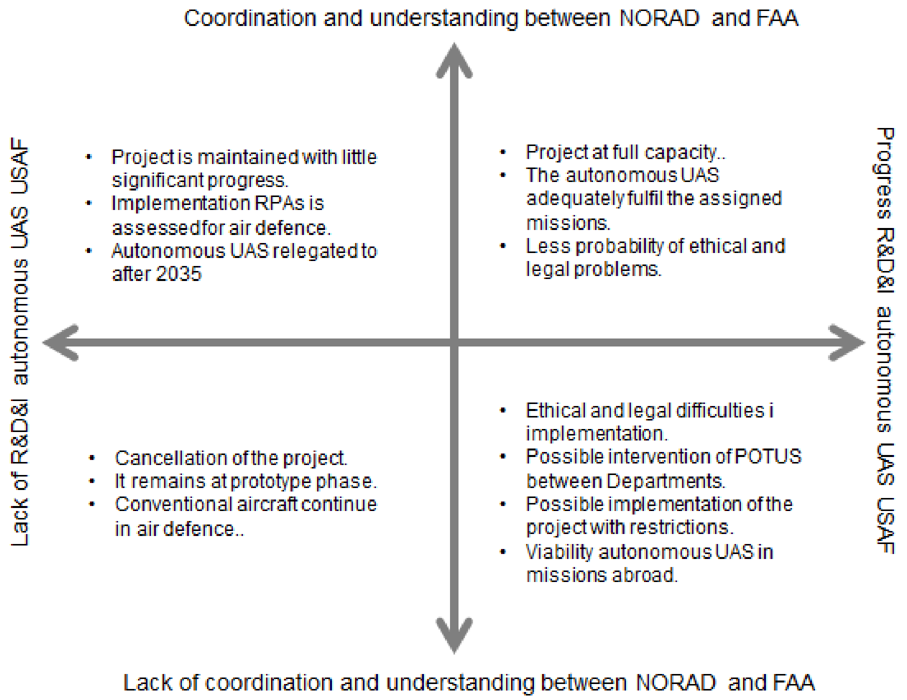

Figure 1: setting up of scenarios. Source: prepared by the author

Presentation of scenarios

Steps 7 and 8. Checking the internal consistency and plausibility of the scenarios, and establishing the final set of scenarios

Because of their importance, before showing a complete description of the four scenarios, we should clarify a series of concepts that have been named so far:

- *Air Defence.* According to *Annex 3-01 Counterair Operations*[30], defensive and offensive operations aimed at achieving and maintaining the desired level of control of certain airspace make up the counterair mission. In this way, the objective of the AD - or its synonym *defensive counterair* – is that of protecting its own forces and vital positions of interest from any air attack of enemy

30 UNITED STATES AIR FORCE. Annex 3-01. Counterair Operations. Alabama: 2016.

origin. In turn, AD can be divided into two main blocks of action: active and passive. The active block comprises defensive actions that seek to "destroy, nullify or reduce" the effectiveness of air attacks carried out by missiles and aircraft – including UAS. On the other hand, the passive block seeks to minimise enemy effectiveness through actions that fall into the following categories: detection and alert; chemical, biological, radiological and nuclear (CBRN) defence; camouflage, concealment and deception; physical protection of installations, reconstitution, dispersal, redundancy, mobility, infrared and electronic countermeasures and, finally, stealth technology[31].

It is also interesting to note that the desired control of airspace can be classified at the following levels: air parity, air superiority and air supremacy[32]. If the aim is to guarantee air defence in the airspace under US sovereignty, it is logical to think that superiority is not enough, but rather air supremacy, and that the actions included in passive defence are also practised as preventive measures. This last aspect, which does not exclude the active defence missions necessary to preserve air supremacy, will mainly depend on the level of real threat and the economic capacity of the nation.

Applied directly to US national security, through *Annex 3-27 Homeland Defense* in its joint doctrine, the USAF describes its fundamental mission: "to protect national sovereignty, territory, citizenship, and critical infrastructure from external threats or aggression, or others as determined by the President". Here, counterair operations play an important role, particularly the surveillance, control, warning and direction of air defence operations – including interception missions. For this reason, collaboration and coordination between the different USAF and NORAD Commands are essential to guarantee national security. This is due to the fact that the resources and personnel that the USAF contributes to NORAD, even though they depend organically on the Air Force, have a functional dependence and are under NORAD's operational control[33].

- *Interception operations*. This type of mission falls within the scope of the active AD. Thanks to an agile and robust command and control system, and through the integration of weapons systems – mainly combat aircraft and sensor systems – it is possible to detect, fix, pursue, and target an airborne threat, in order to destroy, nullify or reduce its effectiveness[34].

31 When applied to an aircraft, stealth technology seeks to make it invisible to the radar. To this end, shapes and materials are used in the construction of the aircraft, which by means of absorption and reflection allow for this to be achieved..

32 UNITED STATES AIR FORCE. Annex 3-01. Counterair Operations. Alabama: 2016, pp. 2-24.

33 UNITED STATES AIR FORCE. Annex 3-27. Homeland Operations. Alabama: 2016.

34 UNITED STATES AIR FORCE. Annex 3-01. Counterair Operations. Alabama: 2016.

Without going into detail about the complexity of US airspace, the aircraft using it, and the actions to be taken by these aircraft before, during and after a flight, we will now attempt to synthesise the sequence and actions of an intercept operation.

As we have seen above, CONUS is continuously monitored by a variety of sensors, with primary and secondary radars providing uninterrupted information on the general aerial situation (picture). In order to fly over the Air Defense Identification Zone (ADIZ), which covers an area larger than the United States' own airspace, both civil and military aircraft require clearance, even more so if the latter come from another jurisdiction. Such clearances set out a number of limitations and procedures to be followed by the cleared aircraft, such as the route to be flown, mandatory reporting points with air control, or restriction – and even prohibition – of overflying through certain areas and at certain altitudes. Failure to comply with the limitations to which the aircraft must be subjected will trigger alarms – via a sequence of procedures – and focus the interest of air traffic control on that aircraft.

Either at the request of FAA air traffic controllers, or by direct identification by NORAD, the latter will take over the detection, tagging, and tracking of that aircraft until further inquiry. If NORAD's procedures and controls so determine, they will, initiate an interception mission against that aircraft by means of a scramble[35]. In that operation, thanks to the military air control provided by NORAD's ground control interceptors (GCIs), the interceptor aircraft - a fighter and attack aircraft - will be guided by them to the aircraft of interest. Once intercepted, it will visually assess whether it is indeed who it previously claimed to be by radio, whether it poses a threat, or whether abnormal activity is perceived inside the aircraft. For the security of the intercepting aircraft – and bearing in mind that the aircraft of interest may be a non-U.S. military aircraft – if resources, availability and personnel permit, the interception will be carried out with an aircraft pairing. In this scenario while one of them identifies and approaches the aircraft of interest, the other maintains a position behind the possible threat, so that, in extreme cases, it can be neutralised. If there is no reason to proceed to such an extreme, once the interception has been made, the aircraft may be authorised to continue its established route, be forced to land at an airfield determined by NORAD, or be escorted to the ADIZ limit, amongst other actions.

Although relatively small documents, a nonetheless more detailed explanation of interceptions can be found in the Homeland Security Digital Library for the FAA and users who rely on their administration[36].

35 «Scramble» is a term in military aviation that refers to a military aircraft taking off in the shortest possible time.

36 NORTH AMERICAN AEROSPACE DEFENSE COMMAND. NORAD intercept procedures, Air Defense Identification Zone, & Temporary Flight Restrictions. Colorado: 2011 [consulted on 3

- *NORAD-FAA Coordination*. Coordination between civil and military aviation is essential for the safety of both types of aircraft, deconfliction[37] and flexibility in the use of airspace. The main reference document is the Memorandum of Understanding between NORAD and the FAA[38]. Based on the legal and normative texts on which both organisations are based, this document presents a series of general points aimed at establishing agreements. However, the ultimate goal, without prejudice to the responsibilities of either entity, is that air defence is guaranteed in CONR and ANR. Coordination, bilateral communication, and the establishment of procedures and liaison personnel between both entities are essential. This allows for the correct development of the duties of each entity, promoting and enhancing the exchange of information of interest, and an awareness that efforts aimed at guaranteeing national security are a priority.

  Among the various types of incidents that NORAD and FAA must be prepared to deal with, and one of the most interesting for the general public, is the hijacking of an aircraft, how the incident unfolds and its outcome. Of particular relevance were the hijackings of four commercial aircraft carrying passengers during the 9/11 attacks. The prevention and response to this type of incident involves the joint and coordinated efforts of FAA and NORAD. In such a situation, decision-making has to be swift, but also properly conveyed to higher levels. Consequently, each regional level must correctly apply – by means of established procedures – tactical solutions to the development of events. This entails maintaining uninterrupted communication, both horizontal and vertical – including civil-military – acting coherently to achieve the strategic objectives with respect to the incident. Any action by NORAD requires this level of coordination, which, in the case of the use of military interceptor aircraft, must be at a maximum[39].

  Put very simply, one could say that the limitations on flight rules to be met by a military interceptor aircraft on an air defence mission are minimal compared to general aviation rules. The interceptor aircraft will have priority in the use of airspace to successfully carry out its mission. However, it should be stressed that there must be continuous coordination between civil and mi-

April 2019]. Available at https://www.hsdl.org/?abstract&did=748300.

37 «Deconfliction» is a term used in aviation, referring to those actions aimed at reducing the risk of collision between users in a given airspace, based on the coordination of their movement. The action is extendable to military users, including not only aircraft, but also for example missiles, or artillery fire. In the context of this analysis, the aim is to avoid conflicts and dangerous situations between civil and military aircraft, without prejudice to their operation.

38 NORTH AMERICAN AEROSPACE DEFENSE COMMAND. Memorandum of understanding between NORAD and the FAA. Colorado: 1987.

39 RUTGERS UNIVERSITY. Law Review. The FAA and NORAD. New Jersey: 2011 [consulted on 2 April 2019]. Available at http://www.rutgerslawreview.com/2011/1-the-faa-and-norad/.

litary air control. As the main users are commercial airlines and their passengers, it is essential that the regulations are available to them for consultation and compliance. Among the general aviation regulations, of particular note is the section on FAA Air Traffic Plans and Publications[40]. Also, as an illustration of civil-military coordination, it is worth highlighting the NORAD summary sheets on intercepted civil aircraft[41], or the previously mentioned NORAD document in 2011[42].

Having presented the most relevant aspects of Air Defence, NORAD-FAA Interception and Coordination missions, each hypothetical scenario resulting from the analysis will be described below. The scenarios are ordered from lowest to highest in terms of implementation of autonomous UAS, for the type of mission that has been established.

Scenario 1: The fifth jet fighter generation.

The first scenario is based on the main premise that there is little investment by the USAF in R&D&I projects related to the design and use of autonomous UAS, and that there is a lack of coordination and tension between NORAD and FAA. Therefore, this is the worst scenario of the four that arise from the future use of these autonomous platforms in interception missions, and in general, in any type of mission.

In this scenario, the USAF is unable to secure the necessary funding and support to initiate or continue these projects. Despite successful initial trials, the projects are still in their infancy, as researchers have not been able to have them designated as high priority and consequently obtain the large financial resources they need to continue. Other costly programmes, such as the development of the F-22, the F-35, and different RPA models, are attracting the attention of military commanders, who are looking for ways to recoup the respective investments already made.

Although the RMA derived from the autonomous UAS has aroused interest and enthusiasm, no progress has been made in the development of these systems beyond the prototype phase, as it is considered that with the current resources and investments, the objectives set for 2035 can be met with certainty. Aware of its usual position of technological leadership, the USAF considers it unlikely that another nation will operationally integrate such weapons systems into its air forces within two deca-

40 FEDERAL AVIATION ADMINISTRATION. Air Traffic Plans and Publications. Washington D.C.: 2019 [consulted on 6 April 2019]. Available at https://www.faa.gov/air_traffic/publications/#manuals.

41 NORTH AMERICAN AEROSPACE DEFENSE COMMAND. Civil Aviation Resources. Colorado: 2019 [consulted on 21 March 2019]. Available at https://www.norad.mil/General-Aviation/.

42 NORTH AMERICAN AEROSPACE DEFENSE COMMAND. NORAD intercept procedures, Air Defense Identification Zone, & Temporary Flight Restrictions. Colorado: 2011 [consulted on 3 April 2019]. Available at https://www.hsdl.org/?abstract&did=748300.

des, making it even less likely that they will seek to use them against the United States. The successes achieved will serve as a basis for future investments, as the present moment is not appropriate.

The latter decision is reinforced by the friction and tension generated as a result of the RMA between NORAD and FAA. The latter considers it inadmissible to develop autonomous UAS operations in US airspace in the short and medium term, in particular if such platforms are intended to approach within a few metres of commercial aircraft carrying passengers. Although regulations already exist for the use of RPAs in sovereign airspace – as seen above – the use of RPAs for interception operations in the ADIZ has never been addressed. Thus, since no guidelines have been established for the execution of this type of mission with RPAs – in which there is a remote operation by an USAF pilot – it makes no sense to propose interceptions by autonomous platforms. The transfer of the FAA's stance to the USAF by NORAD strengthens and feeds the line of thought that the situation is not yet right for more rapid progress in autonomous UAS projects. Therefore, their use is already ruled out, not only in interception assignments, but also in other types of operations. In this way, manned combat aircraft will continue to ensure national air defence, on constant alert for any suspicious flying objects.

Scenario 2: Contained enthusiasm.

The second scenario arises from the consideration that, despite the fact that the USAF has made hardly any progress in R&D&I in terms of the development of autonomous UAS, there is harmony and willingness for dialogue in NORAD and FAA with respect to this new RMA. Although the USAF has other priorities in terms of project promotion and capital injection, it is aware that the development and application of autonomous platforms to real missions is a new technological-military race. It is therefore a new reality that should not be ignored, as there is a risk that nations with conflicting interests will gain an advantage in their development and employment.

Thus, projects are not suspended, but merely moved to a non-priority level. This means that, as far as resources allow, progress can be made on them. FAA's favourable attitude towards these new technologies makes it possible to create NORAD-FAA working groups at both tactical and strategic levels. The objective is to start designing the future implementation of these systems in interception missions, although it is acknowledged that this is unlikely to happen in the next two decades.

As an intermediate step, there is merit in starting with tests in segregated airspace, in which interceptions are carried out by RPAs associated as escorts to manned combat aircraft, thus establishing a previous level of "loyal wingman". In this way, while trials are being conducted, air defence alert aircraft will continue to be manned. In the event that the tests meet the appropriate conditions of safety and reliability, an interception will be carried out by the manned fighter jet and its RPA escort. The background and experience gathered from such interceptions will be of great help for the future implementation of the "loyal wingman" from autonomous UAS.

Scenario 3: Interdepartmental discrepancies.

The third scenario is based on progress being made in R&D&I, but, on the other hand, without adequate coordination and understanding between NORAD and FAA. Aware of the milestone reached and the race that has begun between the great powers, the USAF is capitalising on the success achieved with the prototype, directing more resources and efforts to achieve significant advances. The goal is the integration of the autonomous UAS into their operational weapon systems. Such proposals have been submitted to the FAA by NORAD, where, however, civil aviation has expressed the same reticence as in the first scenario, despite the relevant technological advances that the USAF has achieved in the short term.

They are similarly opposed to performing trials in segregated airspace, not even with RPAs, to test the feasibility of using autonomous UAS in interceptions in the ADIZ, which means that negotiations are stalled, considerably complicating the objectives of the USAF. Faced with such a situation, POTUS is forced to mediate between departments, suspending, as a precautionary measure, the use of these weapons systems except for the purpose of testing. In addition, there are protests from certain groups and demands regarding the ethics and legality of the use of autonomous robots, especially in national territory. The suspension will be applicable until detailed reports on the operation of autonomous UAS in missions abroad allow for the provision of reliable data that the systems are safe. If it is demonstrated that they perform such missions and others in an appropriate manner, POTUS may reconsider its position. Until then, interception missions will be carried out as in the first scenario.

Scenario 4: The mixed binomial

The fourth scenario is ideally suited to the "loyal wingman", thanks to the advances in R&D&I achieved by the USAF, and also to the coordination and understanding between NORAD and FAA. This latter aspect, which gives priority and establishes working tables, agreements, procedures and regulations for the implementation of autonomous UAS by the government and its institutions, allows the general public to accept the new reality, which at the same time is fascinated by it. In this case, the chances of certain groups presenting and managing to hinder the project through ethical and legal approaches are substantially lower.

The USAF's major technological investment has resulted in the combination of a manned fighter plane and a "loyal wingman" for interception missions. This makes it possible for aircraft such as the F-35 to carry more than one autonomous escort for more difficult or risky missions. The concept of the "loyal wingman" is not only associated with the F-35, but also with the F-22, or even another manned F-16, among other platforms. The same considerations could apply to the autonomous UAS itself.

Not surprisingly, the integration of the autonomous platforms into the USAF affects its entire structure, bringing its advantages to various types of missions both at home and abroad. This means, for example, that a logistics aircraft on a transport mission can also benefit from a robotic escort. The progressive implementation and the multiple experiences obtained in the different missions in which one or more "loyal wingman" is used, set the foundations for future projects. One must highlight the possibility of seeking total autonomy for the autonomous UAS, with the technological and security implications that this will entail in order to guarantee the success of the missions in which it participates.

Step 9. Analysing the implications of each scenario

Implications of Scenario 1

With the F-22 and F-35 – two of the pioneering aircraft of the fifth generation of fighter and attack aircraft – in full operation, and considering the demanding investment that the USAF has had to make and must maintain, it is unlikely that military commanders will venture into another multi-million dollar project aimed at R&D&I in autonomous UAS. The question is not whether these novel weapon systems are viable *per se*, but, firstly, the ability to defray the investments made so far, and, secondly, whether the USAF, even if the bold investment in the "loyal wingman" is successful, will be able to acquire the appropriate number of such platforms to make the expenditure justifiable[43]. As Glade points out[44], aircraft automation implies a significant increase in the cost of the weapons subsystems that make up the aircraft, which favours traditional platforms and, to a lesser extent, RPAs.

Conversely, the very presence of humans on the platforms also entails higher costs associated with pilot protection systems – besides increasing the weight of the aircraft – and conditions its performance due to acceleration limits, gravitational forces and pilot fatigue. Therefore, autonomous UAS may represent a partial solution to the enormous monetary effort required by modern manned platforms today[45].

The considerable investment involved in the training of military pilots, the departure of many servicemen to join the labour market after completing the minimum number of years of service, the large number of air bases to be served, and the availability of conventional platforms on them, are some of the various factors affecting the USAF operation. This may mean that, in "peacetime", certain interception operations do not meet the minimum security requirements, due to the fact that the mission is carried out by a single manned aircraft – instead of two – and is poorly armed. Nor-

43 BROWN, Donald. Bolts from Orion: Destroying mobile Surface-to-air Missile Systems with lethal autonomous aircraft. Alabama: Air Command and Staff College. Air University 2016, p. 45.

44 GLADE, David. Unmanned Aerial Vehicles: implications for military operations. Alabama: Air War College 2000.

45 PIETRUCHA, Michael W. «The next lightweight fighter. Not your grandfather's combat aircraft». Air & Space Power Journal. 2013, p. 40.

mally, such a situation would not pose any major concerns, but when the aircraft to be intercepted does indeed pose a threat, a single interceptor would be more vulnerable as it would not have an escort to protect it while identifying the suspect platform.

Finally, the perception of the USAF's military superiority with the F-22 and F-35, along with the FAA's unwillingness to negotiate the operation of autonomous UAS in the ADIZ, may prove dangerous, as what is advantageous today will become obsolete tomorrow, if R&D&I and the use of RMAs are not pursued.

Implications of Scenario 2

Although autonomous UAS are not a priority in this scenario, the US authorities should avoid falling into the complacency and overconfidence of the previous analysis. On the one hand, progress, although long-lasting, must be of a high quality and reliable, to prevent, for example, poor security in telecommunications and electronic countermeasures from leading to a loss of control of the systems[46] On the other hand, the stance that potential opponents adopt regarding these systems must be taken into account. Growing concerns about the possible effects of an AI-based arms race[47] can be appreciated, for example, in China's demonstrations of civil uses. These show the great potential of this nation to participate fully in such a race[48].

One of the keys to progress in the integration of the autonomous UAS is the goodwill of NORAD-FAA. Working tables, coordination measures, concessions, agreements, flexible use of airspace and the generation of regulations are, among others, a necessary condition but not sufficient for this venture. In the absence of further definition, the testing and subsequent operation of RPAs as "loyal wingman" clearly represents progress, as well as valuable experience for the future full implementation of the autonomous UAS.

However, in view of the advantages of RPAs over conventional aircraft – greater autonomy, smaller size, diminished possibility of detection by the enemy and the ability to take greater risks[49]– the staffing problem persists. This is because interception will continue to require two pilots – even if one operates remotely – in order to meet adequate security conditions. On the other hand, the UAS – whether RPA or autonomous – will be required to ensure that their sensors, information processing and decision-making are reliable according to the sensitivity of the mission; among other

46 WORK, Robert O.; BRIMLEY Shawn. «Preparing for war in the Robotic Age». Center for a new American security 2014, p. 23.

47 ROMANIUK, Scott N.; BURGERS, Tobias. «China's swarms of smart drones have enormous military potential». The Diplomat. 03/02/2018. Available at https://thediplomat.com.

48 ROMANIUK, Scott N.; BURGERS, Tobias. «China's swarms of smart drones have enormous military potential». The Diplomat. 03/02/2018. Available at https://thediplomat.com.

49 GLADE, David. Unmanned Aerial Vehicles: implications for military operations. Alabama: Air War College 2000, pp. 12-14.

reasons, because its operation can affect dozens of civilians. For this reason, automation is preferable, because of the semi-direct control that the manned plane has over an autonomous aircraft, and because of the minimum delay in communications.

Finally, with the lack of R&D&I available in this scenario, in order to climb up the USAF's priority level, autonomous UAS must be economically more cost-effective compared to traditional aircraft. Limited capacity designs such as those of Pietrucha[50] can gain ground. The type of aircraft proposed reflects a concept of "loyal wingman" viable in the short term, and capable of participating in operations with guarantees of success. This aircraft would shorten the deadlines for the deployment of autonomous UAS, which could be available before 2035, and even be used directly without going through an intermediate phase of greater RPA involvement.

Implications of Scenario 3

In its strategic documents, the USAF contemplates the development and use of autonomous UAS, even demonstrating very concrete possible scenarios[51]. The aim is for these systems to be highly adaptable and flexible and to increase capabilities in environments with all kinds of risks, in order to enjoy an advantageous position vis-à-vis their adversaries. Such platforms are expected to fulfil all kinds of missions, such as intelligence, surveillance and reconnaissance, SEAD, air-to-ground attacks, casualty evacuation, logistics, and others. In turn, they describe the technical needs, support and prospects for these systems to accomplish such missions, either exclusively or as components of a larger team. To this end, they consider, among others, the concepts of swarming and "loyal wingman"[52].

Nevertheless, the USAF is aware that legal, ethical and doctrinal aspects cannot be ignored[53]. Mirroring the different opinions expressed in the third scenario, Guetlein [54] argues that, even when achieving a very high level of sophistication in autonomous weapons, the human component will always intervene. He states that their low tolerance of their own casualties and collateral damage may favour robotics. Furthermore, it advocates the development of conceptual and doctrinal approaches, testing in controlled environments, and TTPs that take for granted that such systems will be inte-

50 PIETRUCHA, Michael W. «The next lightweight fighter. Not your grandfather's combat aircraft». Air & Space Power Journal. 2013, pp. 39-58.

51 UNITED STATES AIR FORCE. Air Force future operating concept. A view of the Air Force in 2035. Washington D.C.: 2015, p. 20.

52 UNITED STATES AIR FORCE. USAF RPA vector. Vision and enabling concepts 2013-2038. Washington D.C.: 2014.

53 UNITED STATES AIR FORCE. America's Air Force. A call to the future. Washington D.C.: 2014, p. 19.

54 GUETLEIN, Mike. Lethal autonomous weapons. Ethical and doctrinal implications. Rhode Island: Naval War College 2005.

grated into real military operations. Nonetheless, it conditions the implementation of these, primarily, on the trust they create in military commanders.

Thurnher[55] adopts an approach that focuses on the arms race. Leaving the legal discussion to one side, he asserts that the United States must remain at the forefront of the development and use of autonomous weapons systems, or other nations will take over. In contrast, Mousazadeh et al. [56] attach greater importance to the legal framework, believing that the use of autonomous UAS is unlikely to meet the criteria of international humanitarian law. On the other hand, similar to Guetlein, Gillespie & West[57] suggest that, regardless of the level of autonomy that weapons systems achieve, the authorisation to carry out an attack should arise from an appropriate hierarchical command and control structure, identifying the need for human decision-makers at critical points. This idea is also shared by the USAF itself, which conceives of the mixed use of conventional, remotely operated and autonomous weapons systems, reserving the management of critical tasks to military personnel[58].

Due to the wide variety of missions, the requirements to be met by autonomous platforms will vary. The difficulties in achieving a high level of effectiveness and efficiency for specific missions makes the development of multipurpose platforms much more complex, although missions with similar characteristics can be fulfilled by the same platform. Favourable statistics on the use of "loyal wingman" in foreign operations will be decisive for obtaining presidential authorisation to use autonomous UAS in interception missions in US airspace. Therefore, minimum failure levels will be required, as well as the successful completion of escort functions, both in interceptions, air-to-air combat, or in SEAD. Conditioning such a decision, the idea defended by Cheater will surely be key[59], according to which the algorithms that form the AI of the autonomous UAS, must be designed in such a way that the system acts in one way if it is in a civilian domestic environment, and in another way if it is in combat. Within such statistics, the command and control requirements must also be satisfied to ensure that operations are in compliance with the law. The total absence of humans in the decision-making process is outside the established timeframe.

55 THURNHER, Jeffrey S. No one at the controls: the legal implications of fully autonomous targeting. Rhode Island: Naval College of War 2012.

56 MOUSAZADEH, Reza et al. «Analyzing the legal dimensions of Unmanned Combat Aerial Vehicle in the International Law». Journal of Politics and Law, n.º 10. 2016, pp. 1-11.

57 GILLESPIE, Tony; WEST, Robin. «Requirements for autonomous unmanned air systems set by legal issues». The International C2 Journal, n.º 2. 2010, pp. 5-6.

58 UNITED STATES AIR FORCE. Air Force future operating concept. A view of the Air Force in 2035. Washington D.C.: 2015, p. 21.

59 CHEATER, Julian C. Accelerating the kill chain via future Unmanned Aircraft. Air War College 2007, p. 22.

Implications of Scenario 4

The fact that the fourth scenario brings together the best conditions for the development of the project does not mean that there are no expectations that the autonomous UAS should meet. Some (partially) ambiguous statistics regarding the reliability of the systems may trigger the kind of mistrust displayed in the third scenario. The integration of these systems in the USAF – and by extension in NORAD – will modify the doctrine and affect operations[60]. In order to develop these, the autonomous weapon system, in this case the "loyal wingman", needs to be reliable. It must therefore be robust against hacking, safe against cyber-attacks and electronic warfare, and have advanced computing and autonomy. In addition, it is crucial to have AI techniques capable of acting according to rules of engagement and other discriminating factors[61]. Similarly, it would be important that, by linking a "loyal wingman" to a pilot of another aircraft, the AI of the associated autonomous UAS should learn and retain in its "know-how" the tactical considerations and modus operandi of the missions carried out by the pilot, in order to optimise the performance of the team. In this way, what is really important is that the AI corresponding to a given pilot is loaded – as if it were software –into the autonomous platform that is going to escort him for a given mission[62].

In interception, the most sensible way to reduce the human risk would be for the autonomous UAS to carry out visual recognition, while the manned aircraft has a shot at the intercepted aircraft. This would require the UAS to have the ability to interpret the information it collects – for example, by using cameras that record in various spectrums – alerting the pilot and taking action if necessary. Another option is that the information collected should be transferred directly to the monitor of the manned aircraft – notwithstanding the fact that the UAS will act without waiting for orders from the crew, even if only in defensive actions. However, switching positions should not be ruled out, allowing the crew to make visual reconnaissance, while the UAS remains alert behind the intercepted aircraft. In this case, the "loyal wingman" would be given freedom of action – under the rules of engagement – if the situation so required.

Here too, NORAD-FAA coordination will be crucial. In this sense, it should be noted that the civil sector already acknowledges that humanity is "on the edge" of a new great era in aviation, with a leading role for the UAS, including autonomous

60 PALMER, Adam A. Autonomous UAS: A partial solution to America's future airpower needs. Alabama: Air Command and Staff College 2010, p. ii.

61 WORK, Robert O.; BRIMLEY Shawn. «Preparing for war in the Robotic Age». Center for a new American security. 2014, pp. 22-25.

62 BROWN, Donald. Bolts from Orion: Destroying mobile Surface-to-air Missile Systems with lethal autonomous aircraft. Alabama: Air Command and Staff College. Air University 2016, p. 48.

systems. This is why it is committed to the integration of such systems, guaranteeing safety in airspace at all times[63].

Finally, faced with the possibility that this scenario will lay the foundations for fully automated platforms, a number of different positions exist. Pietrucha[64] advocates that autonomous UAS represent a "force multiplier, but not a replacement" for experienced and well-trained crews, setting the RMA limit on the fledgling "loyal wingman". A more optimistic position, foresees the assumption of more and more types of missions by autonomous UAS, with the corresponding progress in doctrine, TTPs and technology. However, it also argues that aviators will continue to play a key role, thus advocating a mixed team of manned aircraft, RPAs and autonomous UAS[65].

Conclusions

The emerging era of robotics and nanotechnology is encouraging the use of robotics on the battlefield. Autonomous weapon systems are an RMA that cannot be ignored, and are making their way into the various branches of the US Armed Forces. In the case of interception operations in Air Defence, the battleground is the sovereign airspace and of responsibility of the United States, and the autonomous weapons systems of interest are those that would operate in that environment.

Using the technique of scenario building and analysis, we have carried out a future-oriented analysis of the implications that the use of autonomous UAS may have on the type of operation described. Enhancing the use of such systems will depend mainly on the decisions and agreements reached between the USAF, NORAD and FAA. The four proposed scenarios are only some of many others that can be proposed and analysed. However, they are deemed to be characteristic of the different degree of implementation of such autonomous systems within NORAD's mandate.

As far as their use is concerned, the automation of the aerial platforms has given rise to two different models: swarming, and the "loyal wingman". The former seems to have aroused more interest among researchers in the military aerospace field, mainly because of its low cost and greater survival capacity. However, with a 2035 target date, the "loyal wingman" is considered to be the ideal model for air defence interception missions. The achievements to date, the need to continue to effectively address major platforms, and the differences in military organisation, doctrine and technology between the various nations, all justify this.

63 FEDERAL AVIATION ADMINISTRATION. FAA Strategic Plan. FY 2019-2022. Washington D.C.: 2019, pp. 1 and 7.

64 PIETRUCHA, Michael W. «The next lightweight fighter. Not your grandfather's combat aircraft». Air & Space Power Journal. 2013, p. 40.

65 PALMER, Adam A. Autonomous UAS: A partial solution to America's future airpower needs. Alabama: Air Command and Staff College 2010.

A transition from conventional military aircraft to fully autonomous UAS, involving a hybrid operation, is therefore necessary. The ethical and legal concerns of some authors regarding total autonomy, as well as the ideas expressed in the USAF strategic documents, advocate a human presence at critical points in the decision-making process. The total automation of such systems, as well as their operation on the battlefield without any supervision, exceeds the established time horizon.

All this makes the last scenario the most plausible of the four. The relative simplicity of a peacetime interception mission should not present many difficulties in implementing the manned fighter/attacker combination with the "loyal wingman" in such missions. Favourable results will also allow for its implementation in more complex missions.

In view of the establishment – not without its difficulties – of the joint operation, the United States, as an important and influential component of NATO, must be able to exploit this RMA, heading up a progressive and across-the-board transition among the members of the Alliance. As a clear reference of doctrine and TTP's, the US commitment will be key to strengthening NATO, and securing an advantageous position in comparison with other alliances.

In short, given the leading doctrinal and technological position in which the United States has regularly found itself, the arms race that has already begun, and the level of importance that this nation attaches to national security, these all generate a propitious environment for the emergence of robotics on the battlefield. Consequently, the USAF should not miss out on the opportunity to continue developing and improving this fascinating project.

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