**"Mircea cel Batran" Naval Academy Scientific Bulletin, Volume XX – 2017 – Issue 1**
**The journal is indexed in: PROQUEST / DOAJ / Crossref / EBSCOhost / INDEX COPERNICUS / DRJI / OAJI / JOURNAL INDEX / I2OR / SCIENCE LIBRARY INDEX / Google Scholar / Academic Keys/ ROAD Open Access / Academic Resources / Scientific Indexing Services / SCIPIO / JIFACTOR**

# UNMANNED AERIAL SYSTEMS IN MILITARY ENVIRONMENTS: THE BENEFITS OF INTEROPERABILITY

**Rodolfo Santos CARAPAU[1]**
**Alexandre Valério RODRIGUES[1]**
**Mario Monteiro MARQUES[1]**
**Victor LOBO[1]**
[1] CINAV, Portuguese Navy Research Center, Almada, Portugal, E-mail: santos.carapau@marinha.pt

***Abstract:*** *Nowadays, the use of Unmanned Aerial Vehicles (UAVs) is a growing presence in both civilian and military environments, which has resulted in an opportunity to explore this technology, its benefits and how they can be improved. This paper aims to present a study focused on the impact of UAVs in military environments and how interoperability can further develop the benefits of the use of unmanned systems. It presents the importance and motivation for the use of UAVs, developing to a description of an UAV and its supporting structure. Afterwards, the study presents the primary military UAV applications, as well as studies that have been conducted to develop UAV capabilities in performing tasks such as surveillance, reconnaissance, search and rescue, and hazardous materials detection. Following the study of UAV in military scenarios, an approach to interoperability of unmanned systems is presented: its concept, and a project that has proved its reliability, converging to the benefits of interoperability. Overall this study hopes to improve awareness regarding unmanned systems and how it can play a key role for the future of military technology.*
***Keywords:*** *Interoperability, Unmanned Aerial Vehicle, Military.*

## I. INTRODUCTION AND MOTIVATION

The creation and development of Unmanned Aerial Vehicles (UAVs) has provided a valuable opportunity to develop tasks such as search and rescue (SAR), surveillance, reconnaissance, inspection, patrolling, hazardous materials detection, among many other tasks. Particularly in military scenarios, the danger is more significant, which motivates the use of UAVs to perform certain missions, since its use promotes the safeguard of human lives. This is one of the main motives that has promoted innovation regarding unmanned systems (UxS), and the development of applications for UAVs. For example, for a Navy, the creation and development of UAV applications such as buoy deployment and monitoring, missile decoy, communication relaying, and protection against coastal attacks prove to be a valuable asset [1]. Other applications regarding the detection of hazardous materials, SAR, surveillance and border patrolling, have been the target of projects like GammaEx, SEAGULL, and *Protection of European Seas and borders through the intelligent use of surveillance* (PERSEUS), involving military entities.

Although the deployment of an UAV grants an edge in the performance of a mission, the deployment of several different unmanned systems working together would result in an improvement of the operational capability. The successful achievement of a feat of such dimension can be made possible through the integration of interoperable systems that work together to achieve common objectives. This involves the creation of standard software and protocols that support unmanned systems in order to guarantee smooth and reliable services and information exchanges. Projects like *Deployable SAR Integrated Chain with Unmanned Systems* (DARIUS) have implemented such concepts to develop crisis emergency response systems that synergize UxS with control systems and multi-national emergency services.

According to this motivation, this study aims to achieve the following objectives:

- Demonstrate the importance of UAV for military applications;
- Relate the concept of interoperability with unmanned systems;
- Explaining the benefits of interoperability associated to the use of unmanned systems;

This paper is organized according to the following structure: section II provides an overall view of UAVs operating in military environments by defining "UAV" and the basic architecture and components of an Unmanned Aerial system (UAS), presenting a timeline of UAV development motivated by military conflicts, followed by the enumeration of several military tasks that UAVs can perform, and finally presenting projects that have developed these capabilities; section III combines the concept of interoperability with unmanned systems by presenting definitions of interoperability, and technology/projects that motivate interoperability between unmanned systems, in order to determine the primary benefits of interoperability; finally a conclusions section that reviews that study as a whole.



**DOI: 10.21279/1454-864X-17-I1-006**

“Mircea cel Batran” Naval Academy Scientific Bulletin, Volume XX – 2017 – Issue 1
The journal is indexed in: PROQUEST / DOAJ / Crossref / EBSCOhost / INDEX COPERNICUS / DRJI / OAJI / JOURNAL INDEX / I2OR / SCIENCE LIBRARY INDEX / Google Scholar / Academic Keys/ ROAD Open Access / Academic Resources / Scientific Indexing Services / SCIPIO / JIFACTOR

## II. UAVs IN MILITARY ENVIRONMENTS

UAVs are vehicles that operate by air, don’t carry an onboard pilot or crew, and can be controlled by an onboard electronic equipment, or by a ground control station, through the use of waypoints, pre-established goals, or through manual teleoperation [2], [3]. They can be classified according to their weight and size (small, medium and heavy), operating altitude (low, medium or high) and design (fixed wing, rotary wing, flapping wing and blimps) [1] [4]. An UAV is part of an Unmanned Aerial System, which can be divided in three main parts:

- Command and Control includes the ground control station (GCS), communication subsystem, launch and recovery, and support equipment;
- Datalink establishes a communication link (uplink: land-to-air, downlink: air-to-land) between the communication subsystems of the ground control station and the vehicle;
- The Vehicle includes the payload, a navigation subsystem, sensors, a communication subsystem, power and propulsion.

The creation and development of UAVs dates back to the Nineteenth Century, and were always enhanced by military conflicts. Events such as World War I and II, Cold War, Vietnam War and Gulf War served as catalysts for the development of unmanned systems. Figure 1 displays a timeline describing the creation and evolution of UAVs, matching the main historical developments of UAVs with the time period of the previously mention conflicts, and mentioning the most recent development of small and micro UAVs [5] [6].

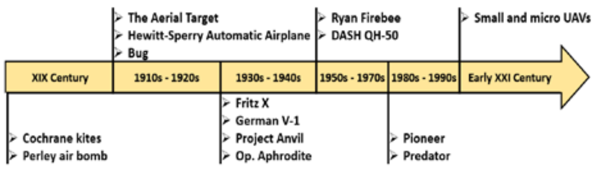

Figure 1 - Timeline of UAV evolution.

In military environments, the advantage of using the operating capability UAVs provide, can be demonstrated through a variety of missions and tasks that UAVs can perform. According to Rosa [7], such tasks can be:

- Intelligence and reconnaissance;
- Mine countermeasures;
- Anti-submarine Warfare;
- Inspection/identification;
- Oceanography/hydrography;
- Communication;
- Navigation;
- Payload delivery;
- Enemy Influence Activities;
- Time critical strike;
- Maritime Security;
- Surface Warfare;
- Special Operations Forces Support;
- Electronic Warfare;
- Maritime Interdiction Operations Support;
- Aerial Warfare;
- Transport cargo or passengers;
- Extraction;
- Insertion;
- Surveillance;
- Search and rescue;
- Analysis of damage attack;
- Border patrol.

In order to develop the capabilities and performance of UAVs, when executing some of the previous tasks, projects like GammaEx, SEAGULL, and Perseus, were created.

The GammaEx project is being conducted by the Portuguese Navy and Army, IST (*Instituto Superior Técnico*), I-SKYEX and ISQ (*Instituto de Soldadura e Qualidade*), and it aims to develop UASs to integrate an emergency response system to chemical, biological, radiological and nuclear (CBRN) threats or incidents. It involves the creation of UAVs (Figure 2) that carry CBRN sensors, and that are compliant with the ATEX (*ATmosphères EXplosibles*) directives. This system focuses on the deployment of GammaEX UAVs (Figure 2) in maritime and land scenarios, being a CBRN onboard a ship or in an off-shore platform, or inside a warehouse or any other building [8].

Figure 2 - GammaEX UAVs: a M6 hexacopter on the left and a tricopter on the right [8].

Another effort in developing UAVs is the SEAGULL project. SEAGULL is a project developed by the Portuguese Navy and Air Force, Critical Software, IST and FEUP (*Faculdade de Engenharia da Universidade do Porto*), and it focuses on developing intelligent systems to support maritime situation awareness based on unmanned aerial vehicles. Motivated by the current Portuguese maritime search and rescue area, as well as the current EEZ (Exclusive Economic Zone) and continental platform extension, the project aims to create an intelligent



DOI: 10.21279/1454-864X-17-I1-006

maritime surveillance systems by outfitting UAVs with optical sensors to perform: detection and geo-referencing of oil spills or hazardous and noxious substances, system tracking (vessels, shipwrecks, lifeboats, and other), recognizing behavioral patterns, and monitoring parameters and indicators of good environmental status. The implementation of this project provides an edge to the Portuguese Navy and Air Force when performing patrolling missions, SAR and surveillance on maritime environments due to the extended area coverage that the SEAGULL UAV (Figure 3) provides (at a small cost) [9].

Figure 3 - Portuguese Air Force ANTEX-M UAV used in the SEAGULL project [9].

Regarding UAVs operating in maritime environments, the *Protection of European Seas and borders through the intelligent use of surveillance* (PERSEUS) project also improves the use UAVs. PERSEUS is an INDRA project, financed by the European Union (EU) 7$^{th}$ *Framework Programme for Research and Technological Development* project that supports maritime border control and that aims to create and develop an EU maritime surveillance system that integrates national and communitarian installations, as well as new technologies. PERSEUS counts with the collaboration of several entities, some being non-European countries and agencies, military entities, NATO (North Atlantic Treaty Organization), and the International Maritime Organization. In its maritime validation scenarios, PERSEUS has deployed the tactical UAS ATLANTE (Figure 4 (a)) (with a connection between the GCS and the PERSEUS system) to enhance the surveillance awareness picture, and the ANTEX-M X02 UAV (Figure 4 (b)) to enhance detection, identification and tracking capabilities, which proves to be a contribution to the growth of the operating capability and reliability of UAVs [10].

Figure 4 - UAVs deployed in PERSEUS: on the left (a) the ATLANTE UAV; on the right (b) the ANTEX-M X02 UAV [10].

Overall, UAVs prove advantageous when deployed in military environments, since they reduce the risk of endangering human lives; involve less costs when compared to their manned counterparts; several vehicles can be deployed at the same time without the need of multiple pilots; its performance isn't affected by dull tasks; and prove a valuable extension to a unit's operational capability. This potential can be further developed when paired with other unmanned systems (UxS) (ground, surface, and underwater), which promotes the study of interoperability between unmanned systems.

## III. INTEROPERABILITY OF UxS

The implementation of the concept of interoperability in a system allows for the development and expansion of its capabilities through the interaction with multiple other systems, which perform different tasks, in order to effectively achieve a common goal. This is a broad concept that can be applied in a variety of fields of study. According to NATO, interoperability is defined as the ability that two or more nation's forces have to train, exercise and execute, effectively, assigned missions and tasks [11]. Regarding UxS, the United States of America (USA) Department of Defense (DoD) [12] defines the concept has the ability that systems, units and forces have to provide and receive services from other systems, units and forces, in order to develop the joint operation effectiveness. The *Institute of Electrical and Electronics Enginners* (IEEE) [13] and the *National Institute of Standards and Technology* [14] have common interpretation of the definition of interoperability, which translates on the ability that different system's parts, or components, have to operate together effectively and successfully, obtaining a result that translates on a user's effort reduction. The *National Institute of Standards and Technology*'s definition adds that interoperability can be categorized in levels, types and degrees, and both entities add that interoperability can be achieved through the use of standards.

Standards are documents, software, hardware, etc., that define characteristics, parameters and rules of communication and interaction of a product or service. The creation of standards allow for the development of protocols, structures, and architectures that promote common operation, prevents incompatibility issues, and



DOI: 10.21279/1454-864X-17-I1-006

create a workspace that enhances the development of a system. Although the implementation of a standard may prove a challenge, its use allows for a reduction of time and costs associated to technological development, reduction of risk associated to the use of alternate technology, process productivity and effectiveness growth, and the use of standards motivates its own development, promoting reliability and guaranteeing its quality.

Regarding the development of UxS, there are several protocols and software that demonstrate the potential to be established as standards, due to their current use and functionalities. For example, the *NATO Standardization Agreement 4586* (STANAG 4586), *Micro Air Vehicle Communication Protocol* (MAVlink), and the *Robotic Operating System* (ROS).

The development of interoperability and standards has been achieved through projects that rely on cooperation and interaction between several UxS and the operator, to perform tasks associated to military intervention, like: search and rescue, reconnaissance, patrolling, payload transportation, among other tasks. These were some of the goals of projects like *Deployable SAR Integrated Chain with Unmanned Systems* (DARIUS).

The DARIUS project focuses on the intervention of unmanned systems, from multiple agencies, in various environments where SAR scenarios are being played, contributing to the development of interoperability between unmanned systems, and determining the requirements for further SAR unmanned systems. The development of DARIUS aims to benefit its users by enabling the control of multiple unmanned platforms, sharing of unmanned platforms (as well as collected information) across different users within the same operation, and the integration of unmanned systems in command and control and communication chains. DARIUS's organization defines three separate operational levels (coordination, tactical and execution) that work together to provide a response to crisis scenarios (earthquake, forest fire, maritime disaster, among others) through the intervention of multiple agencies in a multi-national level, and thus following the system architecture defined in Figure 5.

Figure 5 - DARIUS system architecture [15].

Overall, DARIUS aims at developing a fast and easily deployable crisis response using UxS and rescue systems, integrating UxS in existing command and control platforms, establishing a communication network between the whole system while using UxS for communication relaying, developing UxS navigation capabilities through harsh environments, and providing adequate interaction between the UxS, its payloads, the emergency first responders and the crisis victims [15].

According to the technological efforts that support interoperability and the projects that thrive upon it, it is important to state that the main benefits interoperability provide are:

- Reduction of operational costs and complexity;
- Reduction of compatibility issues;
- Successful cooperation and interaction between different systems;
- Promotes the creation and the growth of heterogeneous structures;
- Promotes joint collaboration and the creation of joint technology;
- Enhances the operational capability of a system (p.e. NATO).

Although interoperability provides several benefits, there are some limitations caused by standards with low accessibility and challenges related to information security requirements.

## Conclusions

The creation and development of UAVs has provided an opportunity for worldwide military entities to extend their operational capability while performing a number of different tasks and missions. This opportunity has motivated the creation of projects that studied the potential of UAVs, resulting in the creation of more UAVs and on the identification of requirements to implement, according to the task at hand. Regarding the advantages that the use of UAVs provide, it is crucial to further explore and develop these benefits through the creation of systems that promote interaction and cooperation between UAVs and other unmanned vehicles. Fortunately, the projects that delved in these concepts have proven successful, which further motivates the creation of new projects. Through the study of the capabilities of an UAV and the growing impact this technology has caused in military environments, this paper has resumed the potential of UAVs



DOI: 10.21279/1454-864X-17-I1-006

used to perform certain tasks, and has elevated the benefits of interoperability in the development of technology regarding unmanned systems.

**Bibliography**

[1] R. Austin, *Unmanned Aircraft Systems*. 2010.
[2] H. Bendea, P. Boccardo, S. Dequal, F. G. Tonolo, D. Marenchino, and M. Piras, 'Low cost UAV for post-disaster assessment', *Proc. XXI Congr. Int. Soc. Photogramm. Remote Sens. Beijing China 311 July 2008*, vol. XXXVII, pp. 1373–1380, 2008.
[3] J. Cosic, P. Curkovic, J. Kasac, and J. Stepanic, 'Interpreting Development of Unmanned Aerial Vehicles using Systems Thinking', *Interdiscip. Descr. Complex Syst.*, vol. 11, no. 1, pp. 143–152, 2013.
[4] S. G. Gupta, M. M. Ghonge, and P. M. Jawandhiya, 'Review of Unmanned Aircraft System', *Int. J. Adv. Res. Comput. Eng. Technol.*, vol. 2, no. 4, pp. 2278–1323, 2013.
[5] J. F. Keane and S. S. Carr, 'A Brief History of Early Unmanned Aircraft', *John Hopkins APL Tech. Dig.*, vol. 32, no. 3, pp. 558–571, 2013.
[6] J. D. Blom, *Unmanned Aerial Systems: a historical perspective*. 2010.
[7] G. C. Rosa, M. M. Marques, and V. Lobo, 'Unmanned Aerial Vehicles in the Navy: Its Benefits', *Sci. Bull. Nav. Acad.*, vol. 19, no. 1, pp. 39–43, 2016.
[8] M. M. Marques, V. Lobo, J. Gouveia-Carvalho, A. J. M. N. Baptista, J. Almeida, C. Matos, R. S. Carapau, and A. V. Rodrigues, 'CBRN remote sensing using Unmanned Aerial Vehicles : Challenges addressed in the scope of the GammaEx project regarding hazardous materials and environments', *6th Int. Conf. Risk Anal. Cris. Response*, 2017.
[9] M. M. Marques, V. Lobo, R. Batista, J. Viegas, A. P. Aguiar, J. E. Silva, J. Borges de Sousa, M. F. Nunes, R. A. Ribeiro, A. Bernardino, and J. S. Marques, 'An Unmanned Aircraft System for Maritime Operations : System architecture , automatic detection , and sense and avoid subsystems', pp. 1–13.
[10] INDRA, 'PERSEUS - PERSEUS Demonstarion Campaigns', 2014.
[11] NATO, 'Interoperability for joint operations', no. July, p. 9, 2006.
[12] U.-D. of Defense, 'Unmanned Systems Integrated Roadmap', *Dep. Def.*, no. 2038, p. 168, 2013.
[13] IEEE, 'IEEE Standard Glossary of Software Engineering Terminology', Standards Coordinating Comitee of the Computer Society of IEEE - Standards Board, 1990.
[14] H.-M. Huang, 'Autonomy Levels for Unmanned Systems ( ALFUS ) Framework Volume I : Terminology National Institute of Standards and Technology', *Framework*, vol. I, no. October, pp. 0–46, 2008.
[15] P. Chrobocinski, E. Makri, N. Zotos, C. Stergiopoulos, and G. Bogdos, 'DARIUS project: Deployable SAR integrated chain with unmanned systems', *2012 Int. Conf. Telecommun. Multimedia, TEMU 2012*, pp. 220–226, 2012.



**DOI: 10.21279/1454-864X-17-I1-006**