Portuguese Air Force Research, Development and Innovation Centre (CIDIFA): RD&I in the Area of Autonomous Unmanned Aerial Systems

José Passos Morgado
Colonel. Head (interim) of the Communications and Information Systems Directorate, in the Logistics Command of the Portuguese Air Force.

Aurélio Casaleiro dos Santos
Major. Deputy Director of the Portuguese Air Force Research, Development and Innovation Centre.

João Vieira Caetano
Captain. Researcher and Unmanned Aerial Vehicle Operator at the Portuguese Air Force Research, Development and Innovation Centre.

Abstract
The article describes the Portuguese Air Force Research, Development and Innovation (RD&I) programme, carried out since 2006 by its RD&I Centre (the CIDIFA), in the domain of Unmanned Aerial Systems. It focuses especially on the set of activities that ultimately led to the operationalization of the UAS in this branch of the Armed Forces, for maritime surveillance and search and rescue missions.
Portugal has an extensive maritime domain, which assumes a substantial economic role in the country. As a result, maritime surveillance and monitoring activities, which are considered a priority, are deemed to be effectively carried out by UAS at the service of the Portuguese Air Force and Navy.
Motivated by the successful results of the RD&I programme, as demonstrated by the high technological maturation already achieved, the CIDIFA will lead the process of industrialisation of the UAS, in collaboration with the National Defence Technological and Industrial Base.

Resumo
O Centro de Investigação, Desenvolvimento e Inovação da Força Aérea Portuguesa: Investigação, Desenvolvimento e Inovação na Área dos Sistemas Aéreos Autónomos Não-Tripulados

Descreve-se, neste artigo, o programa de investigação, desenvolvimento e inovação (ID&I) que a Força Aérea Portuguesa, através do seu Centro de Investigação, Desenvolvimento e Inovação (CIDIFA), vem desenvolvendo, desde 2006, no domínio dos Sistemas Aéreos Autónomos Não-Tripulados. Em particular, são focados os aspetos relacionados com a operacionalização deste tipo de tecnologia, no contexto daquele Ramo das Forças Armadas, para utilização no âmbito da vigilância marítima e da busca e salvamento.
Tendo em conta a grande extensão do domínio marítimo Português, bem como a sua importância a nível económico, torna-se prioritário proceder à sua vigilância e monitorização, atividades que, tendo em conta as caraterísticas dos dispositivos UAS, podem ser levadas a cabo, de modo altamente flexível e eficiente, utilizando este tipo de tecnologia. Em conformidade, considera-se da maior prioridade que as nossas Forças Armadas e, em particular, a Força Aérea e a Marinha, venham a utilizar estes sistemas para a vigilância e a monitorização do Espaço Marítimo Português, em complemento dos atuais meios tripulados.
Mostra-se que o programa acima referido atingiu já níveis de maturação tecnológica muito elevados, o que lhe permitirá, a nível nacional e em colaboração com a Base Tecnológica e Industrial de Defesa, liderar o processo global envolvendo todas as valências conducente à industrialização daqueles sistemas.

2017
N.º 146
pp. 85-103

Introduction

To achieve the objectives of the Portuguese Air Force (PtAF) in the domain of Unmanned Aircraft Systems (UAS) it is necessary to develop the operational capability of such systems, envisioning their application for maritime surveillance and Search and Rescue (SaR) missions, as a type of operation that complements the current fleet of manned aircraft in these specific missions. By teaming up with the National Defence Technological and Industrial Base (NDTIB), the PtAF will benefit from having: (1) a considerable increase in the operational capability of its means and aircrafts; (2) a cost effective operational capability and mission strategy; and (3) the ability to potentiate the growth of the NDTIB, and the development of a "Defence Economy" in Portugal.

In fact, the previous statement is aligned with the "*Strategic Vision*" of the PtAF, presented in its manual MFA 500-12, published under the title of "*Strategic Vision for Autonomous Unmanned Aircraft Systems*". This document details the framework for the development and operationalization of UAS by "setting the ground for a strategic vision for the development, integration and usage of UAS in the PtAF, with the goal of attaining a fully operational capability of these systems, therefore guaranteeing the successful execution of both military and public interest missions" (EMFA, 2013, pp. 1-2).

In order to plan and carry out the objectives highlighted in the MFA 500-12, the PtAF entrusted its Research, Development and Innovation Centre (CIDIFA) with the responsibility of establishing active collaboration with the NDTIB to design, produce and operationalize the use of UAS capabilities – up to NATO classification standard Class-II[1] – to integrate the operational fleet of this branch of the Armed Forces, complementing the manned aircraft fleet capabilities in the maritime surveillance and SaR (Borrego and Morgado, 2015). The CIDIFA is integrated

1 The taxonomy used in this article follows the North Atlantic Treaty Organization (NATO) classification for UAS (NATO, 2010). In this context, UAS are classified in three classes: (1) Class-I, which includes the systems with a maximum take-off weight (MTOW) under 150kg, further divided into 3 levels: nano and micro (<2kg), mini (2-20kg) and small (>20kg); (2) Class-II, which corresponds to tactical systems with MTOW between 150 and 600kg, characterized by their ability of being deployed from unprepared runways with auxiliary launch and recovery systems. Their operational altitude (up to 10.000ft) and range are better suited for tactical use (e.g. Shadow), and benefit from having a lighter logistic and support need, when compared to the higher class; (3) Class-III, corresponding to strategic UAS, with MTOW greater than 600kg. Such systems have a large operational range and endurance, capable of operating up to 45.000ft (MALE – Medium Altitude Long Endurance, e.g., the Predator series) and up to 60.000ft (HALE – High Altitude Long Endurance, e.g. Global Hawk), carrying out assignments across the entire spectrum, requiring, however, prepared runways for the launch and recovery, as well as complex logistics and support components.

in the Engineering and Programs Directorate of the Command of Logistics of the PtAF.

It is worth mentioning that the CIDIFA stemmed from the Portuguese Air Force Academy Research and Development Centre (CIAFA), which gathered and fostered the research, development, integration and operationalization of UAS since 2006. The CIDIFA, currently gaining a position of excellence in the development and operationalization of UAS in Portugal, focuses on establishing effective collaborations with the NDTIB on attaining the industrialization of the aircraft systems developed within the PtAF, envisioning their future commercialization, both at a national and international levels, therefore contributing to a "Defence Economy" in this field (Governo, 2015, p. 53).

This article aims at providing a background and insight into the activities that have been developed within the PtAF, through the CIDIFA, in the area of UAS. It focuses on presenting the phases of development, as well as the ongoing national synergies and NDTIB collaborations for the industrialization and operationalization of UAS technology with the goal of further increasing the operational capabilities of the PtAF fleet in the context of maritime surveillance and SaR.

Framework of the CIDIFA: Research, Development and Innovation Activities in the Field of UAS

The Research, Development and Innovation (RD&I) activities carried out by the PtAF in the area of UAS were initially created at the Portuguese Air Force Academy (AFA), in September 2006. Such activities were integrated in the first RD&I centre of the PtAF, the AFA Research Centre (CIAFA), created in 2009.

In 2015, the RD&I activities where transferred from the AFA to a more centralized – and specially created – Research, Development and Innovation Centre (CIDIFA), under the Engineering and Programs Directorate of the Logistics Command of the PtAF. This transfer involved a transfer of all resources from the CIAFA to the CIDIFA, ranging from human resources to technology, including the ongoing high impact projects.

This change took place in order to increase the efficiency of the ongoing research projects, to further potentiate and facilitate the synergies with the NDTIB, ensuring a faster transition of technology to the industry, as well as bringing the UAS one step closer to the integration in the PtAF operational fleets.

The mission, strategy and structure of the CIDIFA, and its collaborations, both at national and international levels are detailed below, as well as the main technological, operational and doctrinal accomplishments of that Centre, with a special focus on the considerable body of work carried out since 2006. The final section concludes this article with the main achievements and future goals of this strategy.

Mission, Strategy and Structure of the CIDIFA and its Main Collaborations at National and International Levels, in the Field of UAS

<u>Mission</u>

The CIDIFA is the main RD&I Centre of the PtAF and its mission is to: (1) develop aeronautical projects, both at a national and international levels, ensuring that the technology is developed and delivered with a high level of maturation, i.e., a high Technology Readiness Level (TRL[2]), with the ultimate goal of transferring the technology for its operational use; (2) be the link between the PtAF – and consequently the Portuguese MoD (National Defence Ministry – MDN) – and the NDTIB, the European Defence Agency (EDA) and NATO, in the activities of RD&I in the domain of aeronautical Defence; and (3) promote the operationalization of the UAS technology within the PtAF, as well as within other branches of the Armed Forces and civil entities, whenever possible.

Although the CIDIFA is designed to provide a RD&I structure with the capability of performing and carrying out projects in a broad aeronautical sense, it is especially fit to be a Reference Centre in the area of UAS, both at national and international levels. In this context, the CIDIFA focuses in the areas of scientific, technological and operational development of UAS, keeping a close connection with the doctrinal and the operational Divisions of the PtAF, respectively, the Division for Operations of PtAF (DIVOPS-EMFA) and the Air Command (CA), for military and dual application missions.

<u>Strategy</u>

The main technological and operational developments were carried out from September 2006 – initially within the CIAFA and carried on by the CIDIFA – essentially oriented for the industrialization and the commercialization of UAS, referred to as technology transfer. These activities were heavily leveraged in January 2009, following the approval of an RD&I project financed by the MDN: the PITVANT project[3].

2 This parameter is used by the US Department of Defense to measure the level of maturation of technology currently under development. The TRL levels of a given technology may vary between 1 and 9, where the former indicates that only the basic (design) principles are observed and the latter which is where the technology is approved under operational and real-life testing. The CIDIFA aims at having its technology development cycle deliver technology with TRL comprised between 7 and 9. (7 – prototype systems for demonstration in operational environment; 8 – full system approved for tests and demonstrations; 9 – approved system for operational environment). For more details, see Mankis (1995).

3 For a detailed description of the PITVANT project, see Morgado and Sousa (2007), Morgado (2008), Morgado and Sousa (2009), Morgado *et al.* (2013), Morgado (2015), Borrego and Morgado (2015b), Borrego and Morgado (2015c).

At the core of the PITVANT project was the need for implementing a RD&I methodology, specially centred in the development of UAS. Accordingly, the project strategy and its execution focused on concentrating the technical and technological resources onto the sole goal of developing, integrating and operationalizing UAS technology within the PtAF, namely for maritime surveillance and SaR missions. In parallel, other dual type, i.e., non-military mission scenarios, were also studied, to ensure the successful integration of UAS systems with different operators in Portugal.

The management, standardization and integration capabilities are also strategic cornerstones for the CIDIFA. These three areas have the power to sustain and guarantee the efficient execution of ongoing projects, as well as the ability to go beyond the initial objectives and surpass the requirements. In this regard, efforts are persistently made, since the beginning of the CIDIFA, in terms of standardization and agreement, ensuring that the ongoing projects: (1) follow correct project management (IEEE, 2011)[4]; (2) guarantee a sustained project management, according to systems engineering (IEEE, 2005); (3) guarantee the required interoperability of systems and subsystems under development (STANAG-4586, 2012); (4) guarantee the instruction and training of the UAS operators (NATO ATP-3.3.8.1, 2016); (5) make the required progresses in order to ensure the airworthiness certificates for all systems (STANAG-4671, 2009).

Furthermore, the CIDIFA successfully implemented what can be seen as the perfect collaboration between academic research and the operationalization of the developed technology. This collaboration worked in a (nearly) perfect manner, as proven by the successes of all projects developed in this Centre. In particular: (1) the CIDIFA collected information from the Operational and Doctrine Directorate Divisions about the needs of the PtAF and the country in terms of UAS suited missions; (2) reformulated those needs into a list of operational requirements; (3) addressed the operational requirements by developing academic and technological short term projects and scientific theses; and (4) used the outputs of the research to develop, integrate, test and improve the technology; and (5) provide the results to the *Operational* and *Doctrine Divisions*. This proved to be a win-win situation for the PtAF, its RD&I projects and, consequently, all external (to the PtAF) collaborations.

In the context of work methodology, the research areas the CIDIFA is currently focusing on are: (1) aeronautical design, materials and aircraft construction; (2) software engineering; (3) decision and control systems; (4) vision and image processing; (5) system navigation and data fusion; (6) maintenance and reliability; (7) aircraft certification; and (8) operations.

4 IEEE – Institute of Electrical and Electronic Engineering.

In addition, it should be stressed that the CIDIFA works closely with the National Aeronautical Authority (AAN) in order to assure that all UAS technology produced and tested in this Centre is certified and airworthy, satisfying all mandatory regulations and legislation, therefore ensuring a more effective integration and operationalization of the systems.

In accordance with the intentions of the PtAF, expressed by in its MFA 500-12, the CIDIFA focused its efforts on developing UAS technology with high TRL, in order to enable its integration in the PtAF fleet, as well as to allow the PtAF to act as a contractor for UAS missions for external entities or agencies.

Structure

The CIDIFA is subdivided into the following five interdependent centres, which provide the required structure to execute, with maximum flexibility and resource savings, the technological and operational activities mentioned above.

The Nucleus of Research, is the entity primarily responsible for the coordination and execution of the RD&I, as well as for the preparation of the project proposals to be submitted to external (to the PtAF) financing entities. The projects have been typically financed by the Portuguese MoD, the 7th Framework Program and the QREN (Quadro de Referência Estratégica Nacional, National Strategic Reference Framework). This nucleus is now preparing project proposals to be submitted to the Horizon 2020 and Portugal 2020 programs.

The Nucleus of Operation, responsible for the testing and operation of the UAS. A considerable portion of the field tests were carried at the CIDIFA operational test site, located at Ota, about 40 km North of Lisbon. This test site, one of the best test sites in Europe, is equipped with building infrastructures, logistic and catering support, runway, and segregated airspace (picture 1).

Besides the validation tests, the operational and integration demonstrations are performed by this nucleus at different locations, both in the mainland and offshore regions of Portugal (e.g., Portimão and Santa Cruz aerodromes and Porto Santo Island international airport).

The Nucleus of Production and Quality, responsible for the manufacturing and integration of the different parts that compose a UAS. This nucleus works in close connection with the AAN, providing all ground, connection, communication and failsafe testing results to that authority, for the emission of the certificate.

The Project Management Department, in charge of the legal, administrative, management and support tasks, both for ongoing projects, as well as new project proposals.

Picture 1 – Nucleus of Operation: a) Main test site, at Ota (white circle – support, hangar and squadron building; black circle – advanced ground launch and recovery station); b) Hangar building; c) UAS Operation team, with mobile command and ground control station (GCS); d) Team training and instruction at the GCS; e) Flight testing of a UAS prototype Class-I (MTOW of 25 kg) (take-off); f) Flight testing of a UAS prototype Class-I (MTOW of 150 kg) (landing)

a)

b)

c)

d)

e)

f)

The Aeronautics Laboratory, located at the AFA campus, in Sintra, is the main facility of the CIDIFA for the development, manufacturing, integration and ground testing of all sub-systems and final systems. It possesses the technical and physical infrastructures required for the previous activities (e.g., wind tunnel, computer numeric control machinery, composite preparation, assembly and oven facilities) (picture 2).

Picture 2 – Aeronautics laboratory: a) Wind tunnel; b) UAS manufacturing facility

a)

b)

National and International Collaborations

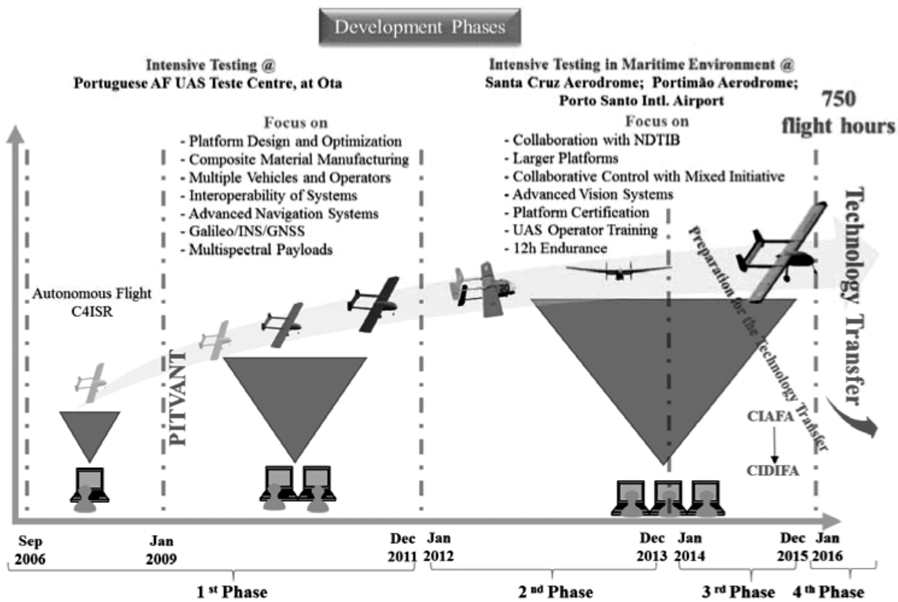
The CIDIFA has maintained active collaborations, on a basis of reciprocity and complementarity, with several national and international entities of great prestige in the area of UAS. Within these entities, we highlight:

At government level, the Portuguese Navy (Marinha Portuguesa – MP), the Portuguese Army (Exército Português – EP), the National Republican Guard (Guarda Nacional Republicana – GNR) and General Directorate for the Policy of the Sea (Direção Geral de Política do Mar – DGPM). At NDTIB level, connected with Academic and RD&I entities: the Higher Technical Institute (Instituto Superior Técnico – IST), the Faculty of Sciences of the Lisbon University (Faculdade de Ciências da Universidade de Lisboa – FCUL), the Faculty of Engineering of the Oporto University (Faculdade de Engenharia da Universidade do Porto – FEUP), the Beira Interior University (Universidade da Beira Interior – UBI), the National Laboratory of Civil Engineering (Laboratório Nacional de Engenharia Civil – LNEC), and more recently the Institute for Telecommunications (IT). At NDTIB level, connected with business and corporate entities: the Centre for Excellence and Innovation of Automotive Industry (CEiiA), the following companies: Critical Software, UAVision, Deimos-Engenharia, OPTIMAL, INOVAWORKS, INESC-Inov, Portugal Telecom Innovation and Systems (PTInS) and Energias de Portugal – Inovação (EDP – Inovação). And prestigious international entities such as the University of California at Berkeley, University of Salzburg, University of Munich, Delft University of Technology, the University of Warsaw, and, more recently, the European Maritime Safety Agency (EMSA) which has its headquarters in Lisbon.

Main Achievements of the CIDIFA: Development Phases

The doctrinal, technological and operational developments, as well as the transfer of technology at the CIDIFA were implemented in four consecutive phases, as presented in figure 1.

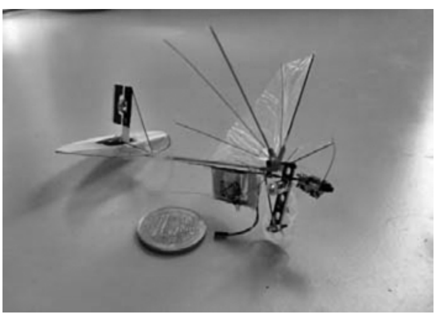
Figure 1 – Development Phases carried out by the CIDIFA



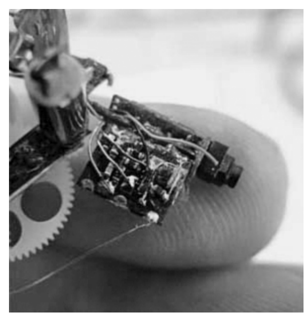
First phase (September 2006 to December 2011) – mainly defined as the ground setting phase, this first implementation phase is characterized by the definition of the initial structure, integration and standardization framework. Over the course of five years, the CIDIFA (formerly CIAFA) gained and consolidated the technological and technical know-how in the design, production and operation of UAS that fall within the first three classification levels, inside Class-I (see pictures 1 e) and f), with MTOW <150kg, see UAS NATO taxonomy mentioned in footnote 1). Over 250 flight tests were conducted, up to 3,500ft, with UAS prototypes developed at this research centre. The instruction and training of the operational team (see picture 1 d) set the ground for the exploration of different concepts of operation (ConOps) that were tested for the first time in Portugal (e.g., night flight, multi UAV operation in the same airspace, catapult launch, UAV handover between different GCS, auto-

matic ground and maritime target tracking and path following, SatCom with flights beyond line of sight (BLOS)). All tests and demonstrations were performed within PtAF Air Force bases, namely at its Ota UAS test site.
In parallel with the development of fixed wing UAV, the CIDIFA initiated the development of state of the art Flapping Wing Micro Air Vehicles (FWMAV), in a close collaboration with Europe's largest Aerospace University – Delft University of Technology (TUDelft). The PtAF focused on the development of novel and miniaturized micro and nano UAS[5] inspired in nature, for intelligence and defence-related missions. This collaboration was supported over the course of phases 2 and 3 (described below), resulting in over 20 scientific publications and the development of novel FWMAV capable of stealth autonomous flight, live video streaming and obstacle avoidance.

Picture 3 – a) DelFly Micro, with only 3 grams; and b) onboard camera and live video streaming hardware (DelFly, 2014)



a)



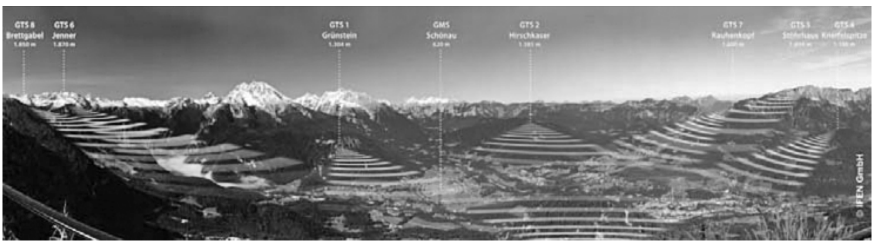
b)

Second phase (January 2012 to December 2013) – during this two-year phase, and as a direct consequence of the excellent results achieved in the first phase, the development and testing focused on achieving an even higher maturation and TRL. For the first time, real mission scenarios were tested in a maritime environment. In particular, the UAS were launched and operated from aerodromes located at strategic points close to the shoreline, focusing on maritime surveillance and SaR, in what can be referred to as a symbiotic cooperation with the Portuguese Navy.
The operation in maritime environment assumes a prime importance on the course of the CIDIFA activities, starting from this phase, envisioning a quick and efficient integration of UAS in the maritime surveillance and SaR missions carried out by the PtAF.

5 See UAS NATO's taxonomy mentioned in footnote 1.

Noteworthy, during this phase a CIDIFA's UAS prototype was used in flight testing in the Berchtesgaden Galileo test site (see picture 4), in the South of Germany, to assess the precision of this global positioning system for aerial vehicles. These were pioneering UAS tests performed in these European facilities.

Picture 4 – a) Panoramic view of the Berchtesgaden test site (IFEN, 2017); and b) CIDIFA UAS prototype during flight testing



a)

b)

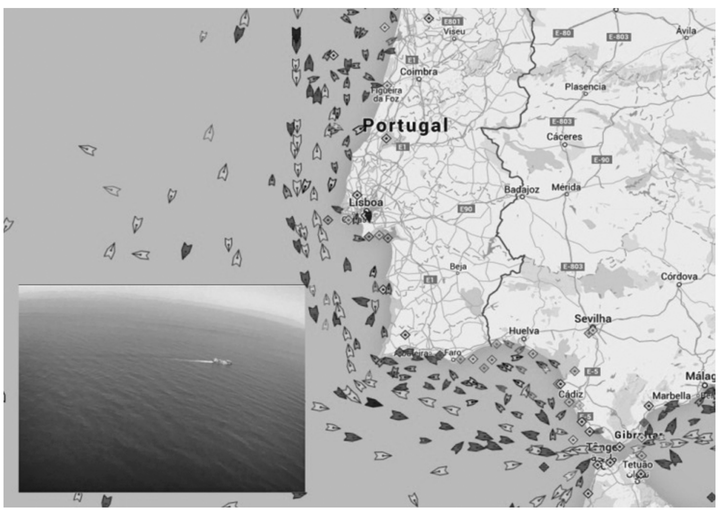
Over 500 flight hours were accumulated during this phase, representing the greatest operational leap of UAS within the CIDIFA and Portugal. Also during this phase the CIDIFA participated in the Portuguese Navy's operational exercises, the Rapid Environmental Picture[6] (REP), with the operation/testing of UAS in the context of maritime surveillance. Furthermore, the CIDIFA operational facilities were adapted to the mobility requirements imposed by the missions at hand. In particular, new mobile ground control stations (see picture 1 c) were acquired to support the operation of larger UAV and rapid deployment concepts of operation.

In terms of high impact operational developments, the second phase is characterized by the development of vision-based control strategies, automatic target detection using the combination of stochastic determination programming and vision,

6 For more information, see Morgado *et al.* (2013, pp. 147-160).

Galileo testing, and the integration of high precision differential GPS systems – which allow for fully automatic precision landings. Furthermore, this second phase was characterized by UAS operations over the maritime shipping corridor, offshore of mainland Portugal, using the information from the Automatic Identification System (AIS) – see picture 5. It was also possible to have the UAS Command and Control (C2) station on board of Navy ships, with direct live video link, as well as successful automatic hydro-carbonates spot detection tests, in cooperation with EMSA and the Maritime Police.

Picture 5 – Maritime Navigation Corridors off the shore of Mainland Portugal; overlap of the detection and localization of a cargo ship at about 40km from the shore line, obtained from a CIDIFA Class-I UAS (CIDIFA and Google Data, 2015)



Third phase (January 2014 to December 2015) – This phase can be described as the maturation phase, where the technology was subjected to operational testing within real mission environments, in different locations in the country. In particular, we witnessed a leap in terms of collaboration for operational exercises and missions, namely with EMSA, DGPM, CEiiA, EDP, UAVision, OPTIMAL and TUDelft.

In particular, the following set of activities were conducted, at different scenarios and with different collaborations: (1) planning and execution of the *Sharpeye* exercise, which was designed to be the biggest and most important UAS exercise in Portugal – performed on a yearly basis[7]; (2) integration of UAS collected data on the

7 For more information, see Borrego and Morgado (2014).

Picture 6 – Class-I UAS (UAS30) developed in collaboration with CEiiA (from NDTIB) for the monitoring of electrical power lines: a) take-off; b) net recovery; c) UAS30 at the EDP's electrical line interference laboratory; d) assessing the electrical interferences on onboard sensors and control systems

a)

b)

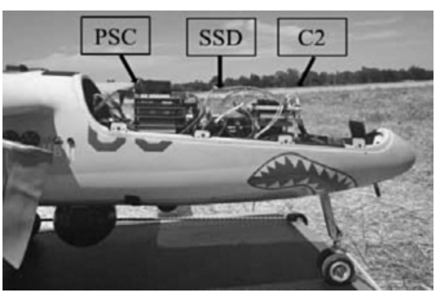
c)

d)

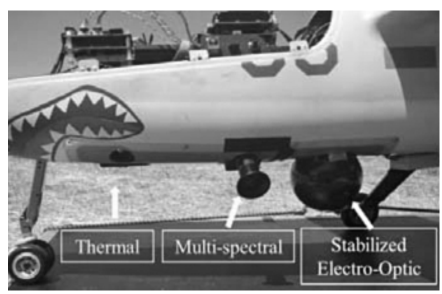
Integrated Maritime Data Environment (IMDatE) and the NIPIM@R information systems, respectively belonging to the EMSA and the DGPM, the latter developed by National entities, among which Inovaworks (from the NDTIB) should be highlighted. It is worth emphasizing that the NIPIM@R is implemented to provide the EU maritime situational awareness to aid on the operational decision making, under the Common Information Sharing System (CISE), making it a fundamental tool for the operationalization of the EU Maritime Police (Richardson, 2015, p. 82) and (Ribeiro, 2016); (3) instruction and certification of PtAF Operators, with direct involvement of the Directorate of Instruction, Centre of Psychology and the Centre of Aeronautical Medicine of the PtAF, under the syllabus described in the official Instruction Program (PDINST) 144-19 and 144-20 (PDINST, 2014); (4) design, construction and testing of a Class-I UAS, the UAS30, in close collaboration with CEiiA and EDP-Inovação, specially designed for low level and low speed inspection of medium voltage electricity lines (see picture 6); (5) the technical study for the creation of a UAS test infrastructure in Portugal, open to European countries, for the instruction, training and testing of UAS systems and teams up to Classe-III systems; (6) collaboration with UAVision, in the flight testing of their commercial Class-I UAS; (7) development of an onboard computational architecture, fundamental for the future integration of new onboard sensors, including hyper-spectral thermal cameras and radar (see picture 7); (8) integration and testing of a Synthetic Aperture Radar (SAR), from the Warsaw University of Technology; (9) operational testing of the UAS capabilities for terrain military force detection and maritime targets using SAR technology in the ZARCO operational exercise, organized by the Portuguese Armed Forces (see picture 8).

This third phase was marked by the accumulation of almost 700 flight hours and the debut of a consortium between the PtAF and the NDTIB for the design, production and operationalization of a Class-II UAS. Furthermore, strict maintenance and reliability planning was developed and implemented within the structure of the CIDIFA.

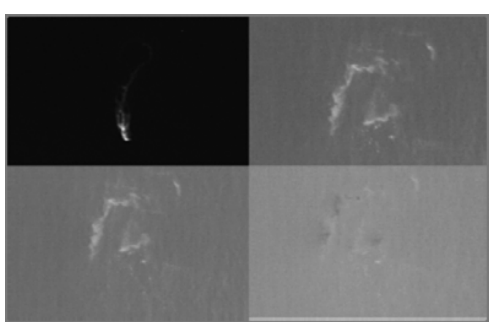
Picture 7 – a) Hardware Architecture, with Payload System Computer (PSC), Command and Control System (C2) and the solid state drives (SSD) for onboard HD recording; b) view of the payload bay, with onboard cameras; c) fish oil spill captured with the electro-optic and the hyper spectral cameras



a)



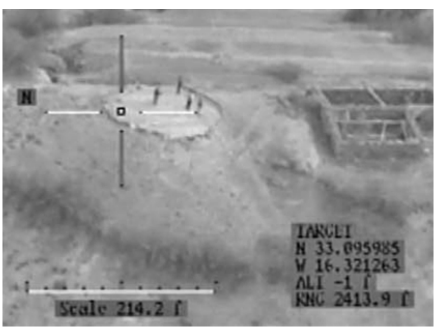
b)



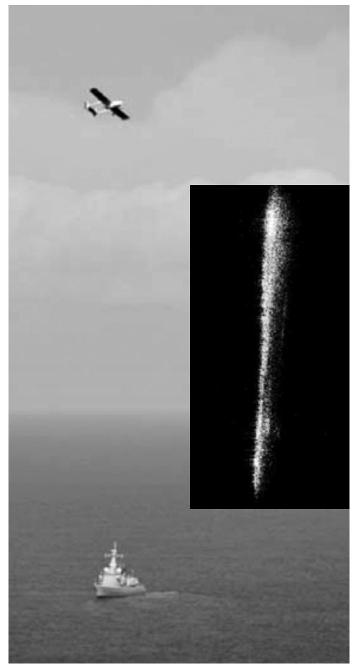
c)

Picture 8 – Images of the ZARCO exercise, in Porto Santo. a) take-off of a CIDIFA UAS prototype (just under 150kg) from the Porto Santo international airport equipped with electro-optic and Warsaw University's SAR payloads; b) optical image of forces in the field; c) pass over the Navy ship Bartolomeu Dias, and respective radar imagery (radar imagery is copyright from Warsaw University of Technology)

a)



b)



c)

Fourth Phase (January 2016 – ongoing) – in this phase, the CIDIFA aims at promoting the technology transfer of the UAS Class-I and Class-II developed and thoroughly tested in the previous phases. In particular, for the Class-I, the CIDIFA aims at promoting the industrialization and commercialization of the UAS30 (see picture 6), for civil activities, *viz a viz* compound and perimeter monitoring, inspection of critical infrastructures, e.g., power lines, dams, industrial parks, railways or shorelines, as well as aerial footage or air pollution monitoring – in this regard, the CIDIFA is currently preparing project proposals for the "*Portugal-2020*" funds, in collaboration with different non-governmental industries.

Moreover, on the UAS30 system type, the CIDIFA will promote testing in the context of the other branches of the Armed Forces, particularly for maritime monitoring, artillery shooting calibration, detection of unexploded ordnance (UXO) and support for demining activities, with operational tests on those activities planned for 2017 and 2018 within the TROANTE project[8]. In the context of security forces, the UAS30 has a strong potential for crisis situation monitoring, ensuring the surveillance of public gathering and crowd control, as well as the surveillance and control of borders.

In the case of Class-II systems, the PtAF is planning its production, in collaboration with the NDTIB, under the guidelines of the DIVOPS-EMFA directives, with the goal of integrating this system in the PtAF operational fleet by 2018/2019, for maritime surveillance and SaR support. Should this be deemed as a successful and cost efficient solution, the exporting of such systems for external markets is also considered to be a valid option.

Envisioning the transition of technology, the PtAF will provide, in collaboration with the NDTIB companies UAVision and Deimos-Engenharia, services of maritime pollution (atmospheric) monitoring for the EMSA, already starting at the first semester of 2017. In fact, the EMSA, is promoting this type of UAS application due to the following facts (EMSA, 2016, p. 29):

a) Atmospheric pollution caused by passing cargo ships that use basic oil derivatives, found to be extremely noxious – in particular the ones that contain sulphur. Furthermore, recent research has revealed that maritime traffic contributed to about 60,000 early deaths for populations living close to the coastline, with a special incidence in Europe and South Asia (Antunes, 2014);
b) The evidence identified in a) has resulted in the creation of Controlled Emission Zones in the North and Baltic seas, in which the navigation of polluting vessels and ships is highly controlled and restricted;
c) Aligned with a) and b), the EU has established the maximum levels of sulphur in the fuel emissions of the ships that navigate in European seas in its directive 2012/33 of 21 November 2012.

These facts suggest the urgent need to conduct monitoring and surveillance tasks of off coast ship corridors in Europe, as identified by the EMSA. To address these concerns, this agency launched an international public call, in the first semester of 2016, with the goal of selecting a limited group of service providers for this type of mission, in which a consortium led by the PtAF – in collaboration with Deimos and UAVision – was selected first, among several other European entities and consortiums. This is the realization of the dual capability of the PtAF Unmanned Aircraft Systems, and solid proof that the strategy adopted by the CIDIFA was the most efficient way of congregating Academia, Research Centres and Industry capabilities for the in-house development of systems capable of responding to military and civil mission requests, both in National and international settings.

8 For more information about the TROANTE project, see Morgado and Ruivo (2014).

At the acme of this fourth phase, we highlight that the CIDIFA is promoting the creation and development of a *National Strategy* which foresees the creation of a true *Defence Economy* in Portugal, as far as UASs are concerned, which aims at providing the means for (Morgado, 2016): (1) answering to the requirement established by the "National Strategy for the Sea" (ENM13-20) and the extension of the National Continental Platform; (2) the creation of a UAS testing framework and structure in Portugal, open to Europe and NATO; (3) the foundation of a Centre for Integrated Development of UAS in Portugal, to provide the common ground for the collaboration of national and international industries, research centres and end users.

Conclusions

This article presented, for the first time, the Research, Development and Innovation strategy of the Portuguese Air Force Research, Development and Innovation Centre in the context of Unmanned Aircraft Systems. This strategy was guided by the persistent will to satisfy the needs and aid in the missions of both military and civil operational organisations.

In particular, the research conducted in the CIDIFA stemmed from the PITVANT project in 2009, with the goal of creating collaborative control strategies of small tactical UAS, which evolved to the current remarkable landmark of more than 750 flight hours logged by Class-I UAS, with MTOW ranging between 12kg and 150kg. Furthermore, the CIDIFA set the ground for the development of a Class-II UAS with MTOW up to 600kg, envisioning its operational use in the context of the PtAF as early as 2018/2019. This strategy focused on an active collaboration with NDTIB, as well as national and international academic and industrial organizations, with the ultimate objective of promoting the transfer of technology in the short term.

The effective strategy developed by the CIDIFA has proved to be capable of serving as the basis for the planning of a National Strategy that fosters the establishment of a "Defence Economy" in Portugal in the field of UAS. In fact, and as has been shown in the present article, Portugal currently has privileged conditions for the Industrialization, Commercialization and Testing of this kind of technology.

It is now important, in light of the experience and knowledge acquired in the meantime, to promote and develop a "National Strategy" in the field of UAS focusing on: (1) the National Strategy detailed in ENM13-20 and the extension of the concomitant Continental Shelf; (2) the establishment of a Test Framework for UAS in Portugal open to Europe and NATO, taking advantage of the unique conditions that Portugal has for this kind of tests in the European context; and (3) the creation of an Integrated Development Centre for UAS, under the auspices of the PtAF. Furthermore, the definition of the "National Strategy" will guarantee the creation of a true *Defence Economy* in Portugal in the UAS context.

References

Antunes, J., 2014. O Snipping, o Ambiente e a Poluição Atmosférica da Costa Portuguesa. *Revista de Marinha*, nº980, Jul/Ago, pp. 34-38.

Borrego, J. and Morgado, J., 2015a. PITVANT – Génese das Atividades de ID&I na Academia da Força Aérea. *Revista da Força Aérea Mais Alto*, nº415, May/Jun, pp. 21-28.

Borrego, J. and Morgado, J., 2015b. Sistemas Aéreos Autónomos Não-Tripulados: Génese, Evolução e Futuras Oportunidades no Âmbito das Atividades de ID&I na Academia da Força Aérea. *Revista da Força Aérea Portuguesa Mais Alto*, nº413, Jan/Feb pp. 25-32.

Borrego, J.; Morgado, J.; Quadros, G. and Bustorff Silva, N., 2015. Conhecimento Situacional Marítimo: o Projeto SEAGULL. *Revista de Marinha*, nº987, Sept/Oct, pp. 20-25.

DelFly, 2014. *DelFly.* Available at www.delfly.nl

EMFA, 2013. *Visão Estratégica para Sistemas Aéreos Autónomos Não-Tripulados.* Lisboa: Força Aérea.

EMSA, 2016. *Work Programme 2016.* Lisbon: European Maritime Safety Agency.

Governo, 2015. *Programa do XXI Governo.* Lisboa: s.e.

IEEE, 2005. *Standard for Application and Management of the Systems Engineering Process (std 1220).* Lisboa: Institute of Eletrical and Electronic Engineering.

IEEE, 2011. *Adoption of the Project Management Institute (PMI(R)) Standard – A Guide to the Project Management Body of Knowledge (PMBOK(R) Guide) (std 1490).* Lisboa: Institute of Eletrical and Eletronic Engineering.

IFEN, 2017. IFEN. Available at http://www.ifen.com/

Mankins, J., 1995. *Technology Readiness Levels.* Advanced Concepts Office, Office of Space Access and Technology NASA.

Morgado, J., 2008. *Programa de Investigação e Tecnologia em Veículos Aéreos Não-Tripulados da Academia da Força Aérea.* Sintra: Lição Inaugural do Ano Letivo 2008/2009 da Academia da Força Aérea.

Morgado, J., 2009. O Programa de Investigação e Tecnologia em Veículos Aéreos Autónomos Não-Tripulados da Academia da Força Aérea. *Cadernos do Instituto de Defesa Nacional*, 2(4), pp. 9-24.

Morgado, J., 2015. Centro de Investigação da Academia da Força Aérea: Atividades de Investigação, Desenvolvimento & Inovação na Área dos Sistemas Aéreos Autónomos Não-Tripulados. *Boletim Informativo, Cidadania e Defesa da Associação de Auditores dos Cursos de Defesa Nacional*, nº53, pp. 16-21.

Morgado, J., 2016. *Sistemas Aéreos Não-Tripulados nas Vertentes Militar, de Segurança e Civil: Definição de uma Estratégia Nacional.* Lisboa: s.e.

Morgado, J. and Ruivo, N., 2014. *Proposta de Projeto, submetida à Direção Geral de Recursos da Defesa Nacional do Ministério da Defesa Nacional, pela Força Aérea Portuguesa: Desenvolvi-*

mento de Tecnologia UAV para Utilização de Âmbito Conjunto e Dual (TROANTE). Sintra: Academia da Força Aérea.

Morgado, J. and Sousa, J., 2007. *Proposta de Projeto, submetida à então Direção Geral de Armamento e Equipamentos de Defesa do Ministério da Defesa Nacional, pela Força Aérea Portuguesa: Projeto de Investigação e Tecnologia em Veículos Aéreos Não-Tripulados.* Sintra: Academia da Força Aérea.

Morgado, J.; Vicente, J. and Nunes, M., 2013. "Da Investigação, Desenvolvimento & Inovação à Industrialização e Comercialização das Tecnologias UAS Levadas a Cabo no Centro de Investigação da Academia da Força Aérea". In: J. Vicente, A. Baltazar, J. Nogueira and F. Leitão, eds., *A Transformação do Poder Aeroespacial.* Lisboa: Instituto de Estudos Superiores Militares, Fronteira do Caos, pp. 121-190.

NATO, 2010. *Strategic Concept of Employment for UAS in NATO.* Kalkar: Joint Air Power Competence Centre (JAPCC).

PDINST, 2014. *Formação de Operadores de UAV (144-19 e 20).* Alfragide: Programa da Direção de Instrução do Comando de Pessoal da Força Aérea.

Ribeiro, J. F., 2016. *O Mar como Fator de Desenvolvimento e Afirmação de Portugal.* Lisboa: Conferência proferida no IUM, no dia 1 de março de 2016, ao CPOG-2015/2016.

Richardson, J., 2015. "The Complexities of EU Maritime Security Policy". In: P. Borges Graça, ed., *New Challenges of the Atlantic. An Approach from Portugal.* Lisboa: Institute of Social and Political Sciences of the University of Lisbon, pp. 79-86.

STANAG-4670, 2014. *Guidance for the Training of Unmanned Aircraft Systems (Uas) Operators – ATP-3.3.7 (4670).* Brussels: NATO/NSA.

STANAG-4586, 2012. *Standard Interfaces of UAV Control Systems (UCS) for NATO UAV Interoperability (4586).* Brussels: NATO/NSA.

STANAG-4671, 2009. *Unmanned Aerial Vehicles Airworthiness Requirements (USAR) (4671).* Brussels: NATO/NSA.