Portuguese Air Force UAV Development, Certification and Operations in Maritime Environment

João Vieira Caetano
Portuguese Air Force Academy
2715-021 Sintra, Portugal
PORTUGAL

jvcaetano@academiafa.edu.pt

José Passos Morgado
Portuguese Air Force Direction of Communications and Information Systems
Lisbon
PORTUGAL

jamorgado@emfa.pt

ABSTRACT

This article describes the Portuguese Air Force Research, Development and Innovation (RD&I) programme for de development of Unmanned Aircraft Systems. If focuses on the set of activities that have led to the operationalization of the UAS in this branch of the Armed Forces, in particular for Maritime Surveillance and Search and Rescue missions.

With the tenth largest maritime domain in the world, Portugal has an added responsibility in terms of maritime surveillance and sea monitoring activities. As a result, Portugal must aim at developing and integrating UAS in its maritime surveillance means, with the ultimate goal of assuring a high persistence in these activities with efficient costs.

Under this scope, the Portuguese Air Force has focused on developing novel UAS systems. This task was attributed to the Portuguese Air Force Academy Research Centre (CIAFA), which bet on the development of Class-I UAS, through the integration of novel equipment on-board of specially developed platforms.

The CIAFA collaborates with national industries and academia, with special focus on companies from the National Defence Technological and Industrial Base (NDTIB). In order to be able to fly and operate the UAS, the CIAFA thoroughly tests and produces detailed documentation to be submitted to the Nacional Aeronautical Authority for the approval of specific types of operations. Once approved, the Authority issues a Special Airworthiness Certificate that certifies the flights of the UAS under the conditions and mission scenarios determined on the initial request.

The operations have focused on maritime environments, with the use of electro-optic, infra-red, multi-spectral and thermal sensors, as well as synthetic aperture radars. Powerful on-board processing is used to automatically detect vessels, which contributes to an improved efficiency of he mission, as well as a reduced level of attention and tiredness of the UAS operators.

1. INTRODUCTION[1]

To achieve the objectives of the Portuguese Air Force (PoAF) in the domain of Unmanned Aircraft Systems (UAS) it is necessary to develop the operational capability of such systems, envisioning their application in 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 Defense

[1] The information in this section was first published in [7].

Technological and Industrial Base (NDTIB), the PoAF will benefit from having: i) a considerable increase in the operational capability of its means and aircrafts; ii) a cost effective operational capability and mission strategy; and iii) the ability to potentiate the growth of the NDTIB, and the development of a Defense Economy in Portugal.

In fact, the previous statement is aligned with the Strategic Vision of the PoAF, 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 PoAF, with the goal of attaining a fully operational capability of these systems, therefore guaranteeing the successful execution of both military and public interest missions" [1].

As a result, the present manuscript aims at providing insight into the development and operation of UASs by the Portuguese Air Force. It details the process of development, integration, testing, safety assessment, special airworthiness license and, ultimately, the operation of specially designed unmanned aircraft systems.

2. A STEP INTO THE DEVELOPMENT OF THE SYSTEMS

The main technological and operational developments were carried out from September 2006, essentially oriented towards 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 Portuguese Ministry of Defence: the PITVANT [2] project.

The management, standardization and integration capabilities were, and still are, strategic cornerstones and 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 in terms of standardization and agreement, ensuring that the ongoing projects: *i*) follow correct project management [2]; *ii*) guarantee a sustained project management, according to systems engineering [3] ; *iii*) guarantee the required interoperability of systems and subsystems under development [4]; *iv*) guarantee the instruction and training of the UAS operators [5]; *v*) make the required progresses in order to ensure the airworthiness certificates for all systems [6].

In accordance with the intentions of the PoAF, expressed by in its MFA 500-12, the Portuguese Air Force Research, Development and Innovation (CIAFA) focused its efforts on developing UAS technology with high Technology Readiness Levels (TRL), in order to enable its integration in the PoAF fleet, as well as to allow the PoAF to act as a contractor for UAS missions for external entities or agencies.

The doctrinal, technological and operational developments, as well as the transfer of technology at the CIAFA were implemented in four consecutive phases, as presented in Figure-2-4-1[3]. Further information about maritime operations is presented in Section 4.

[2] *Further information in* [16].

[3] The information in this section was first published and is adapted from [7].

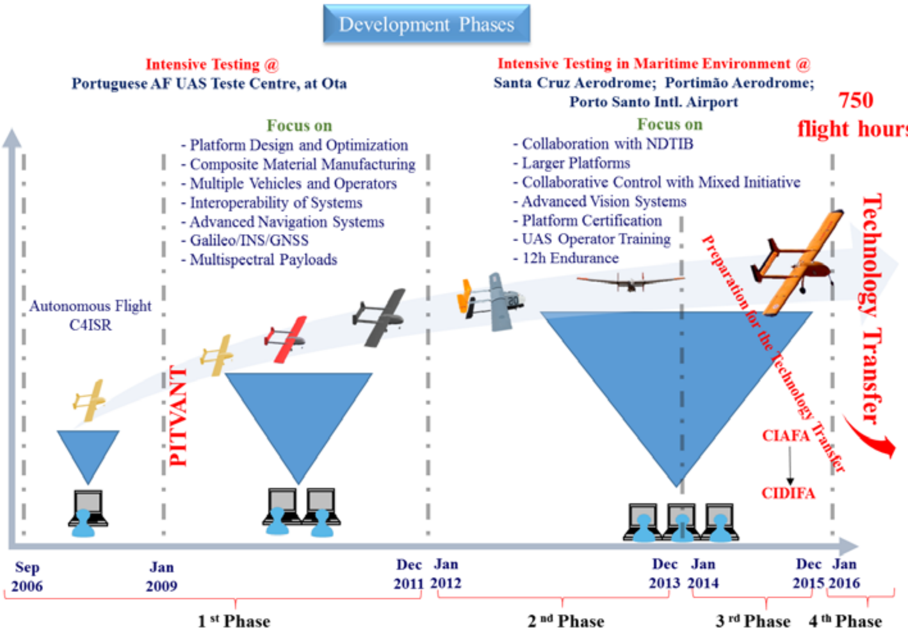


Figure 2-4-1: Development phases that have led to the operational capability and demonstration in maritime

The operation of the systems is assured by a specific team of UAV operators, who were specially instructed and trained to perform the tests and operational missions. All members of this team have been certified and instructed at the Portuguese Air Force UAS Operator's course. This course includes 414 hours of instruction and training in different fields of aeronautics, legislation, operations and meteorology, and can be compared, in terms of theory, to a pilot's course. After the theoretic part, all operator students are trained in the final UAS by their respective instructors. At the moment the PoAF has 16 certified operators.

Currently there are four types of UAV used by the Portuguese Air Force, ordered by span length and Maximum Take-Off Weight (MTOW) in Table 2-4-1.

Table 2-4-1 UAV configurations used in the PoAF and respective general characteristics.

UAV	Span (m)	MTOW (kg)	Cruise Speed (kts)	Endurance (h)	Engine (cc)	Ceiling (ft)
X02 Alfa	2.5	13	40	4	20	6000
X02 Alfa-Extended	3.5	25	50	15	28	12000
UAS30[4]	4.5	35	32	4	35	12000
X03 ANTEX	5.7	149	55	2	240	16000

[4] Manufactured by CEiiA – Center for Automotive and Aeronautic Excellence

a)

b)

c)

d)

Figure 2-4-2: a) X02 Alfa; X02 Alfa-Extended; UAS30; X03ANTEX.

3. AIRWORTHINESS CERTIFICATION

The European Military Airworthiness Authorities (MAWA) was created in 2008, under the guidance of the European Defense Agency (EDA), with the objective of standardizing the regulations and respective regulatory framework of the Agency's member states [8]. At the time being, the development, manufacture and operation of UAS requires these systems to demonstrate an Equivalent Level of Safety (ELOS) that is similar to the existing manned aircraft [9].

In Portugal two entities share the responsibility of regulating and certifying the Unmanned Aerial Vehicles under 150kg MTOW: a) for civil UAV – the National Civil Aviation Authority (ANAC); b) for military UAV – the National Aviation Authority (NAA) [10].

3.1 Special Airworthiness Licence

In Portugal, the Circular 1/2013 defines the requirements that must be met by the military UAS to be authorized to operate, i.e., to obtain a Special Airworthiness License (SAL). This document was created by the regulatory entity, i.e., NAA, and is applied to all UAV in the Portuguese Air Force fleet and all UAV operated by the PoAF's operators. For a UAS to receive a SAL it must comply the following requirements [11]:

- UAV registered at the NAA;
- Airspace reservation by the entity responsible for the UAV operation;
- Request for issuance of SAL stating the scope or purpose of the flight, duration and location by the entity responsible for the UAV operation;
- Proof of UAV configuration control;
- Historical record of operation of the UAV;
- Technical operating instructions of the UAS;
- Risk or safety analysis of the operation;
- Continued Airworthiness Instructions (maintenance requirements for the UAV);
- Certified personnel – qualifications to operate that specific UAV;
- Proof of implementation of STANAG 4670;
- Usage of communication bands at frequencies that have been previously approved;
- Maintenance manuals, which include the maintenance actions to be taken at given flight hours, as well as the plan of periodic inspection of the systems;
- Existence of a system to report any accident or incident to NAA.

3.2 Process for Safety Assessment

A safety assessment of UAS encompasses the procedures that verify if the subsystems and architecture of the UAS can assure safe operations. This process analyses all systems and subsystems of the UAS, assessing the interconnection of all components. Moreover, it analyses the failure modes and failure chains that can lead to unsafe situations during the operation, while it evaluates the system modes and operation procedures to assess the existence of failsafe and risk mitigation.

As a result, the process of safety assessment is performed on the UAV, ground control station, data links, autopilot (and respective levels of autonomy), operational environment and interoperability with air traffic control [12]. Despite being mostly qualitative, it can also be implemented quantitatively by applying [12]:

- A Functional Hazard Assessment (FHA) – set of procedures that identifies and classifies the potential for functional failure of sub-systems and components according to their severity;
- Preliminary System Safety Assessment (PSSA) – a systematic assessment of the system's architecture and classification of failure conditions;
- System Safety Assessment (SSA) – systematic process to verify if the main safety requirements are met.

Following the previous steps, after the FHA one must proceed with the PSSA to determine how failures can originate functional risks for a specific UAV and how the safety requirements should be met. In particular, the PSSA is oriented by the following methodology [6]:

- Outline of a thorough list of aircraft and system level safety requirements;
- Assess if the architecture and respective system is expected to meet the safety requirements;

- Derive the safety requirements for the design of lower level items, e.g., software, hardware and flight maintenance tasks.

The last step is to implement the SSA, which will state the safety requirement and correct installation of each subsystem and component, as well as issue maintenance tasks that guarantee the correct operation of the system. As a result, at the end of the SSA (and the complete process) it is possible to:

- Verify if the design requirements established in the system level FHA are met;
- Adjust and (probably) validate classification of the UAS failure effects;
- Verify that the safety requirements are met;

As an example of the results obtained using the described methodology we have that, for one specific UAV developed at CIAFA it was verified that, despite not having redundant systems for the propulsion and autopilot, the UAS complied with the minimum safety requirements defined in STANAG 4703 to operate in segregated airspace by introducing mitigation actions and processes for the most severe failure modes.

4. MARITIME OPERATIONS

4.1 Mission Scenarios and Operations

Over 1100 flight hours were accumulated using the UAS developed and flown at CIAFA, which represents the greatest operational leap of UAS in Portugal. Also, the CIAFA participated in the Portuguese Navy's operational exercises, the Rapid Environmental Picture[5] (REP) and Sharpeye with the operation/testing of UAS in the context of Maritime Surveillance.

In order to cope with the system developments, the CIAFA operational facilities were adapted to the mobility requirements imposed by the missions at hand. In particular, new mobile Ground Control Stations (see Figure 4-1) are used to support the operation of larger UAV and rapid deployment concepts of operation. Furthermore, UAS operations were conducted over the maritime shipping corridor, offshore of mainland Portugal, using the information from the Automatic Identification System (AIS), see Figure 4-2

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 European Maritime Safety Agency (EMSA) and the Maritime Police. This capability has the potential of transmitting the information that is captured onboard to national and international entities or agencies, therefore satisfying the interoperability and inter-nation information dissemination requirements.

Alongside with the operational vector, other technological feats were obtained in maritime environment, e.g., a) the development of an on-board computational architecture, fundamental for the future integration of new onboard sensors, including hyper-spectral thermal cameras and radar (see Figure 4-3); b) the integration and testing of a *Synthetic Aperture Radar* (SAR), from the Warsaw University of Technology, which allowed to detect the wake and silhouette of vessels at sea; and c) 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 Figure 4-4).

[5] For more information, the reader is referred to [17].

a)

b)

c)

d)

Figure 4-1: a) UAS Operation team, with mobile command and ground control station (GCS); b) Team training and instruction at the GCS; c) Flight testing of a UAS prototype Class-I (MTOW of 25 kg) (take-off); d) Flight testing of a UAS prototype Class-I (MTOW[6] of 150 kg) (landing) (adapted from [7]).

[6] Maximum Take-off Weight

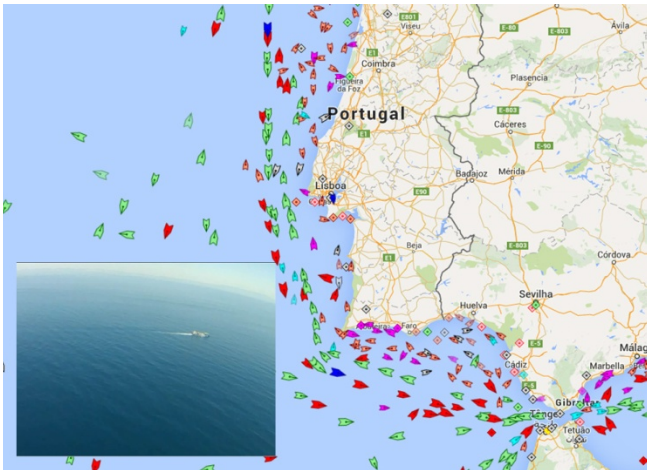
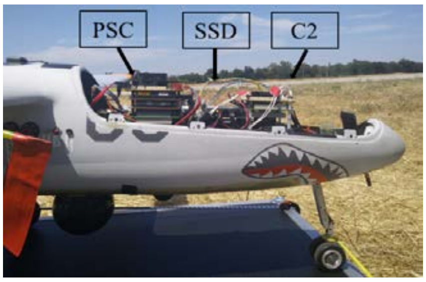
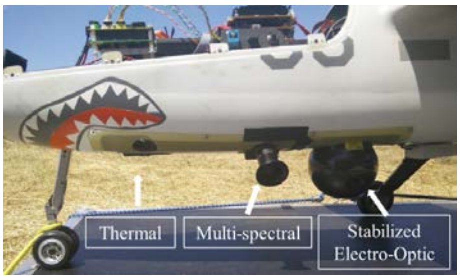


Figure 4-2: Maritime Navigation Corridors off the shore of Mainland Portugal; overlap of the detection and localization of a cargo ship at about 40km from the shore line, obtained from a CIAFA Class-I UAS. Sources: CIAFA and Google Data, 2015.



a)



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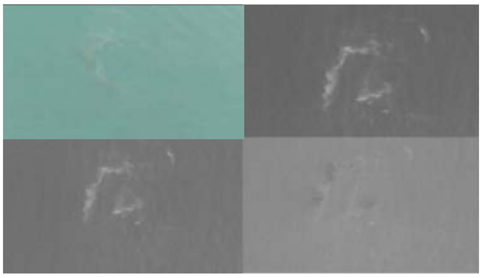

c)

Figure 4-3– a) Hardware Architecture, with Payload System Computer (PSC), Command and Control System (C2) and 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.

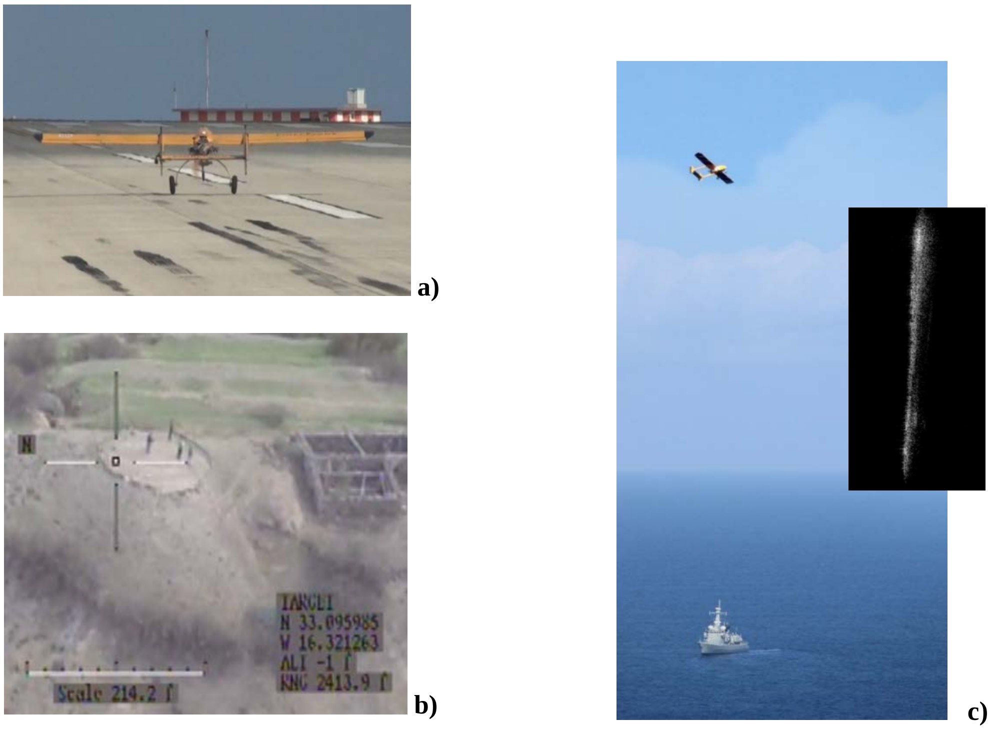

Figure 4-4 – Images of the ZARCO exercise, in Porto Santo. a) take-off of a CIAFA UAS prototype (150kg) from the Porto Santo international airport equipped with electro-optic and Warsaw University's SAR payloads; b) optical image of forces in the field; c) pass over the Navy ship Bartolomeu Dias, and respective radar imagery (radar imagery is copyright from Warsaw University of Technology).

4.2 International Operations

In collaboration with the NDTIB companies UAVision and Deimos-Engenharia, the PoAF now provides services of monitoring maritime pollution and illegal activities for the EMSA and partner countries. In fact, the EMSA is promoting this type of UAS application due to the following facts [13]:

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 [14];

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.

d. Need for border control and monitoring of sea pollution and illegal activities.

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 PoAF – in collaboration with UAVision and Deimos – was selected first, among several other European entities and consortiums. This is the realization of the dual capability of the PoAF Unmanned Aircraft Systems, and solid proof that the strategy adopted by the CIAFA 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 a National and international settings.

Following a request from Croatian Authorities to the EMSA, the Portuguese consortium provided the "eye in the sky" solution for maritime pollution and maritime surveillance in the Adriatic Sea – with flights over and around several Croatian islands. The solution was brought about using the UAS Wingo OGS42, which is manufactured by the Portuguese company UAVision[7], vd. Fugure 4-5 – this UAS is composed of the UAV and payload in subfigure 4-5 a) and the ground control station in subfigure 4-5 b). The general characteristics of the system are detailed in Table 4-1.

Table 4-1 – General characteristics of OGS42 UAV

UAV	Span (m)	MTOW (kg)	Cruise Speed (kts)	Endurance (h)	Engine (cc)	Ceiling (ft)
OGS42	4.2	40	51	6	70	15000

a)

b)

Figure 4-5 – Wingo OGS42 Ogassa UAS: a) OGS42 UAV; b) Ground Station and Control Software; c) Communication Relay and Datalink Antennas

With civil interest in sight, the Portuguese Air Force will be performing an operational assessment for the application of such systems for missions in Portugal, during the hot season, from June to September, monitoring forest fires and providing the Portuguese Civil Protection Association – and, therefore, firefighters – with the same "eye in the sky" perspective. Such an operation would have manned and unmanned aircraft in the same airspace and will be the optimal demonstration of the use of air and ground means for homeland protection.

5. CONCLUSION

Portugal, with its tenth largest maritime domain in the world, has bet on the development of Unmanned Aircraft Systems (UAS) to complement the missions of manned aircraft of the Portuguese Air Force in the monitoring and search and rescue missions. In this regard, the Portuguese Air Force Academy Research Centre has developed, since 2006, novel UAS for maritime operations and currently counts with over 1100 hours of flight on such systems.

[7] More info at uavision.com

A set of Safety Certifications processes were put into place to satisfy the National Aviation Authority (NAA) requirements for the issue of Special Airworthiness Licenses for the UAS. Besides guaranteeing the requirements, these procedures allow for the development of risk mitigation strategies and operational procedures, as well as maintenance tasks, which have led to the excel results observed so far.

Together with the boosting of the National Defence Technological and Industrial Base companies in the field of UAS, the apex of the effort conducted by the Portuguese Air Force is the operationalization of these means in national and international homeland, land and maritime surveillance missions.

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