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UNMANNED AERIAL VEHICLES: SYSTEM ARCHITECTURE AND PROTOCOLS

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

***Abstract**: Unmanned Aerial Vehicles are nowadays a very important tool in any military organization. Especially in the navy, they can be used for many missions, in order to increase their success and efficiency, reducing at the same time the risk with personnel. This paper focus in the UAV importance, especially in the navy. Also, it introduces UAV system architectures, and how they can be helpful in the Navy, introducing an interoperability approach for these systems' protocols.*
***Keywords**: Unmanned Aerial Vehicle, Architecture, Protocol*

I. Introduction

UAVs (Unmanned Aerial Vehicles) employment is not recent. In fact, these systems were developed in a large scale during World War I, but the vehicles were not efficient or accurate enough to have utility in the field. Thus, this early UAVs were not recognized as an essential tool in the military [1]. On the opposite, the level of growth registered nowadays is extremely fast.

Although the boom development was during World War I, these systems already had already appeared as far back as in the era of Pythagoras. This important contribution is documented, and its creation was attributed to Archytas (a known mathematic, strategist and philosophe, and mentioned by some as the first engineer)[2] . This mechanism, which is represented in Figure 1 was named "Pigeon", as it was built inspired in these birds. Therefore, it was a mechanical vehicle that could fly moving its wings, using accumulated steam energy. It was only tested once, and it flew for about 200 meters, falling after that on land, and could not fly again.

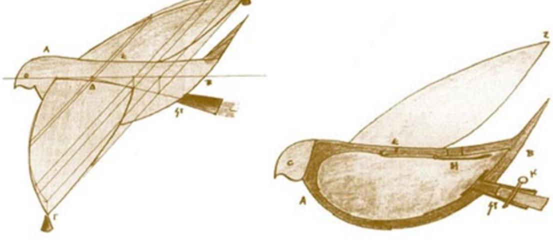

Figure 1 - "The Pigeon"

Nowadays, with the unprecedented registered growth level, UAVs are very complex, and they are being used in many tasks, either for civilian or military purposes. These systems may have various architectures and dispositions, e.g. fixed-wing aircrafts, where there are very heavy ones and lighter as well, and also rotary-wing, like quadcopters, which have vertical take-off and landing[3].

UAVs are complex, but they are introduced in a larger system, as they need to be controlled by a station, which is commonly named GCS (Ground Control Station). In order to maintain communication between the UAV and GCS, there are protocols, which will be also referred in this paper.

This paper is organized as follows. Section II introduces the importance that his vehicles have for the military, specifically, for the Navy. The UAV system architecture is represented in section III. Section IV specifies one of the subsystems represented in the above section, which is related to communications. In section V, conclusions are presented, so as future work that can be done in this field.

II. Importance of UAVs

As previously mentioned, UAVs are an important asset in almost any environment, and they can be included in several tasks. Specifically, for the military, there are various missions that these systems can ensure, reducing costs, or even in some cases, the risk to personnel[4].

Therefore these systems can be used in a great variety of missions, which can be divided according to their purposes: civilian and military. In regards to civilian tasks, UAVs can be used, for example: in aerial photography; in scientific exploration, helping researchers to gain understanding in difficult environments, such as in space; in traffic monitoring and management, in order to obtain traffic information and status. As for military tasks, these systems can be used, for example: in search and rescue missions, in order to search and provide aid to people that are in danger; in special operation forces support, for example in reconnaissance; in payload transport, providing a method to deliver payload in a variety of hostile areas.

There are already multiple project that prove the potential of UAVs for search and rescue missions.

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One of them is ICARUS (Integrated Components for Assisted Rescue and Unmanned Search Operations). This is a large European research project that has 24 partners from 10 countries, and it had good results in the EuRathlon Grand Challenge [5], which is a competition that involves various robot teams, whether they are land, sea or flying operating robots, as it is represented in Figure 2. ICARUS was a project that counted with 8 different platforms whether they are for air, ground or sea, integrating them into a single command and control system.

Figure 2 - Cooperation between robots in the ICARUS project

The SUNNY project is another example of UAV systems importance. It has 18 partners and it aims to develop solutions for intelligent surveillance of borders, both land and sea, in order to detect illegal entry. This project will allow coverage and monitoring of a large maritime and terrestrial border area in an efficient way.

III. UAV System Architecture

Although the vehicle is already a complex system itself, the UAV system is much more than that. There are several conceptions for the design of an UAS (Unmanned Aircraft System). For Austin, the system can be divided in the control station, payload, air vehicle, navigation systems, launch, recovery and retrieval equipment, communications, interfaces, support equipment and transportation [6]. Gupta introduces a more general model, dividing the UAS in the vehicle, datalink and communications, and command and control.

A. Vehicle

The vehicle can be divided into five different subsystems: payload, navigation, sensors, power and propulsion, and communications.

Sensors that need to be integrated in order to facilitate or allow the vehicle to achieve success in a certain task are called the payload. This equipment does not take part in the original design of the vehicle, as it is incorporated according to each mission. Examples of payloads are specific cameras or radars.

Navigation concerns all the processors and sensors that are necessary to collect data for navigation purposes, in order to control the vehicle. UAVs may use navigation systems such as inertial navigation, GPS, radio navigation, acoustic navigation, among others.

The basic operation of a sensor is to receive physical stimulus and responds with a signal. Therefore, they are obviously incorporated in the vehicle, in order to provide data to the processors. Sensors can be classified according to their areas, for example, chemical, current, temperature, acoustic, capacitive, among others.

Power and propulsion can be divided in: energy source, energy transformer, powerplant, propulsion effecter and control effecter [7]. The energy source is intended to be the means that will allow the vehicle to fly, e.g. gasoline, diesel fuel, solar energy, among others. An energy transformer changes converts the energy source into heat or electrical current. The powerplant transforms the heat or electrical current into motion, as the propulsion effecter turns the motion into vehicle movement, e.g. a propeller, converting motion into wind. Finally, the control effecter is connected to each of the subsystems mentioned above, and regulates all the aspects that concern the propulsion.

B. Datalink and communications

This sub-chapter concerns to the actual communication between the UAV and GCS. Basically, it consists in transmitting command and control operators to the UAV and to receive data in the GCS. The type of environment, maintenance costs and also task nature are some parameters that can define which communication system should be implemented. Also, they have to be robust, because a loss of communication can result in damaging or losing the vehicle.

Therefore it is important to choose the right type of datalink. There are several parameters that should be taken into account, e.g. bandwidth, latency and data package loss rate. These parameters depend on the type of mission. For example, if an UAV only needs to transmit simple data such as position or current mission status, the datalink should have a low bit rate. On the contrary, if an UAV needs to transmit video streaming, the bit rate should be high.

Communication between the GCS and UAV can be done in three different manners: by radio, optical fiber and laser beam. Laser communication was only tested, as it is not used for these communications. This happens because of atmospheric absorption, which reduces range and reliability. Optical fiber is another scenario for this communication. However, it needs physical connection between GCS and the vehicle, resulting in the fact that it is not used. Therefore, radio communications are the reliable option for these systems. There are several types of radio communications, such as wireless Ethernet or

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radio modems, which use open frequency bands. Also, there are studies that introduce the use of GSM (Global System for Mobile Communications) between UAVs and the GCS, because they have advantages when comparing to the other systems [8].

There are protocols that define the communication interface between the GCS and vehicle. Some examples are MAVLink (Micro Aerial Vehicle Communication Protocol), STANAG 4586, JAUS (Joint Architecture for Unmanned Systems), ROS (Robot Operating System), among others. The main differences between them is the specific environment, type of missions that vehicles will operate and type of vehicles, whether they are land, sea or air vehicles. An approach for protocols' interoperability is introduced in section IV.

C. Command and Control

C2 (Command and Control) can be divided into the control station, support equipment, launch and recovery and communications.

The control station is the interface between the operator and the vehicle. It is commonly named CS (Control Station) or GCS, and it may be on land or sea. It is used to control the UAV, transmitting information such as waypoints or even to monitor movements. It is also important to receive information, such as video and images[9].

In this approach, we introduce launch and recovery in the C2 system. There are already several methods to ensure the launch and recovery of UAVs. However, it depends on the type of environment of the mission. For example, this process can be more difficult in a moving ship. It also depends on the type of vehicle. In a rotary winged UAV, e.g. a quadcopter, this is not a difficult challenge, as it is done by a vertical take-off and landing system. On the opposite, fixed-wing UAVs present a greater challenge. The launch of these vehicles can be done by hand if it is a small UAV. However, if it has bigger dimensions, the process is complex. When it comes to launching, it can be for example in rocket assisted take-off, bungee cord, which is presented in Figure 3, hydraulic launchers and even pneumatic launchers. The recovery process can be done for example, by net recovery, arresting line, skyhook, windsock or even with a parasail[10].

Figure 3 - Bangee Cord launching system [10]

Support equipment is all the necessary tools and consumables that are important to have in order to support the UAS. It comprehends operating and supporting manuals, tools, e.g. battery chargers, subsidiary and transportation equipment.

IV. Protocols

As previously stated, there are several protocols that define communication and interfaces between the GCS and UAV. Most of them are message-based protocols and the difference between them is the type of environment where the UAV will operate, e.g. sea or air, the type of vehicle, and also the doctrine, because if it is for military systems, it should have specific messages.

Therefore it is also introduced an approach for protocols' interoperability, between two: MAVLink and STANAG 4586.

MAVLink protocol is based on a messages library, focused in MAVs (Micro Aerial Vehicles). It was developed in 2009 by Lorenz Meier, and it is one of the most used protocols, as it uses lightweight communications and it is an open-source protocol. Messages, which are commonly named packets, have fixed format and use correction codes, in order to ensure their structure.

STANAG 4586 is a NATO (North Atlantic Treaty Organization) protocol that creates interfaces and allows interoperability between different countries' UAS. It is a complex and complete protocol, as it is specialized in the military doctrine. However, this and also the fact that it is not open-source, makes it not so used, when comparing with other protocols, like MAVLink.

The proposed approach allows interoperability between MAVLink and STANAG 4586. The system is a bridge that will be introduced in a Raspberry Pi computer, so that it can be esily connected to any UAV. It will allow vehicles using MAVLink to communicate with STANAG 4586 GCSs.

This type of bridges is not unique in the scientific community. In fact, it was already used in several project, such as ICARUS. Because it had several

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vehicles, a JAUS to ROS bridge was created, allowing interoperability between them.

Conclusions and future work

To conclude, this paper addressed the importance of UAVs and the basic architecture that these systems should have, introducing an interoperability approach.

Nowadays, UAVs are important assets in almost any organization. Especially in the military, they can operate in difficult environments, reducing the risk to personnel and even costs. The UAS architecture is also very complex, and it depends on the type of mission and environment.

Protocols are essential in order to have efficient communication between the UAV and GCS. The proposed bridge will be an important tool, so that interoperability between MAVLink and STANAG 4586 can be achieved.

For future work, other bridges are proposed, for example, between JAUS and MAVLink, or even JAUS and STANAG 4586. These systems are important, in order to have interoperability and multiple vehicles and GCSs communicating with each other.

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