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University Degree in Data Science and Engineering and Telecommunication Technologies Engineering
2024 – 2025

Bachelor thesis

Applications of Autonomous Drones for Non-Terrestrial Networks in Remote Areas

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Leganés, 2025

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ABSTRACT

this is an abstract

Keywords: keyword1, keyword2, keyword3

ACKNOWLEDGMENTS

Thanks

AGRADECIMIENTOS

Gracias

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Part I

Introduction

1. MOTIVATION

2. STATEMENT OF THE PROBLEM

primary problem: the use of autonomous drones for remote areas is not widespread due to the lack of infrastructures, software and cheap drones.

moreover, the lack of specific knowledge and the steps to create a drone from scratch is a high barrier of entry for many people.

exisitng solutions as the dji drones are expensive and not open source, and not customizable which limits the potential of the drones. moreover the modularity of the drones is limited so the applicaitons are just a subset of the potential applications for example reconnaissance, surveillance, agriculture, etc.

Moreover, working in remote areas is often not possible due to the lack of infrasturctures, such as roads, electricity, internet, etc. This makes it difficult to use drones in these areas.

as this problem is broad, it needs to be narrowed down to a specific problem that can be solved in this thesis. The environment that will be modeled in this thesis will have the following characteristics:

TODO: complete the list of characteristics of the environment that will be modeled in this thesis

- internet connection via 4G or 3G will be available

3. OBJECTIVES

The main goal of this thesis is to develop a open-source, modular and customizable drone that can be used in remote areas. The drone will be able to fly autonomously and will be able to communicate with a ground station. The drone will be able to be controlled remotely and will be able to be programmed to perform specific tasks. The drone will be able to be used in a variety of applications, such as reconnaissance, surveillance, agriculture, humanitarian aid, etc.

Moreover, a software platform will be developed that will allow the drone to be programmed to perform reconnaissance tasks and the software will be designed to support multiple drones to create a swarm of drones that can be used to perform reconnaissance tasks in a coordinated way.

The drone will be designed to be easy to assemble and disassemble and will be designed to be easy to repair and maintain. The drone will be designed to be cheap and will be designed to be easy to customize and modify.

4. DOCUMENT STRUCTURE

5. METHODOLOGY APPROACH

TODO: need to rephrasea all this The methodology approach used in this thesis is based on the V-model as outlined by the International Council of System Engineering (INCOSE) standard for project development. The V-model is a rigorous and structured approach to project development that ensures that all aspects of the project are considered and that the project is completed on time and within budget. It is achieived by a thorough development process, facilitating clear validation and verification of initial requirements at each stage.

The methodology is divided into seven parts:

1. Identification of Solution Requirements: Before taking any actions, it is crucial to understand what can be achieved and the rationale behind it. To this end, the author has focused on deriving valuable insights from the reviewed literature in the State of the Art (SOT A) and identifying critical scenarios. Subsequently, and in conjunction with the thesis objectives and the applicable regulatory framework, a list of solution requirements is created. This list will later serve as a benchmark for validating the proposed solution.

2. Identification of System Requirements: Technical requirements are formulated to meet the previously established solution requirements. This includes a high-level overview of the proposed solution's components, the rationale for their selection, and their interconnections.

3. Identification of Component Requirements: Building on the high-level architecture of the solution, a more detailed approach is outlined for each component, considering their specific power and data transmission needs. This results in a detailed architecture of the solution.

4. Manufacturing and Implementation: The proposed solution is manufactured using available tools, while simultaneously integrating the necessary electrical components.

5. Component Verification: Each component's functionality is verified in standalone mode, with detailed information provided on the verification process.

6. Integration Testing and Flight Testing: The methodology for conducting flight tests and post-flight analysis is described. System integration is performed by checking communication between module pairs to ensure that data can travel freely and be used effectively.

7. Deployment and Preparation for Future Upgrades: Validation of the initial requirements is conducted to ensure that all solution requirements have been addressed. This step also includes preparations for potential future upgrades.

Part II

State of the art

6. OVERVIEW OF UNMANNED AERIAL VEHICLE SYSTEMS

7. HISTORICAL DEVELOPMENT

8. TYPES & TECHNOLOGIES

9. MODERN TRENDS

Part III

Methodology

10. REQUIREMENTS

Based on careful analysis

11. DESIGN

12. IMPLEMENTATION

Part IV

Results

Part V

Conclusions

13. CONCLUSIONS

14. FUTURE WORKS

15. SOCIO-ECONOMIC ENVIRONMENT

16. REGULATORY FRAMEWORK

rewrite the whole chapter The regulatory framework for drones is a complex and evolving field. The use of drones is regulated by a variety of laws and regulations, which vary from country to country. In general, the use of drones is regulated by aviation authorities, which are responsible for ensuring that drones are operated safely and responsibly.

16.1 Relevant Institutions

16.1.1 European Union Aviation Safety Agency (EASA)

The European Union Aviation Safety Agency (EASA) is the authority responsible for harmonizing aviation safety standards across all EU member states. EASA's primary objective is to ensure a consistent and high level of safety in civil aviation operations throughout the European Union. This is achieved through the establishment and enforcement of common regulations applicable to all member states. In particular, for the standardization of U AS, EASA has implemented Regulations (EU) 2019/947 and (EU) 2019/945.

16.1.2 Spanish Aviation Safety and Security Agency (AESA)

The Spanish Aviation Safety and Security Agency (AESA) serves as the national regulatory body in Spain and is tasked with overseeing adherence to civil aviation standards within the country's aerospace sector. AESA plays a critical role in promoting the development and application of aviation legislation, ensuring that the Spanish civil aviation system upholds the highest standards of safety, quality, and sustainability. In cases of non-compliance with aviation regulations within Spain, AESA has the authority to enforce sanctions.

16.2 Applicable Legislation

16.2.1 Implementing Regulation (EU) 2019/947

The Implementing Regulation (EU) 2019/947 is an European Union regulation that establishes the operational rules and requirements for (U AS). It provides a legal framework for the use of U AS across different categories of operations. The regulation outlines the operational requirements and procedures for U AS operators, including the need for operational authorizations and risk assessments when applicable. It sets standards for remote pilot competency, operational procedures, and safety management necessary to conduct U AS flights safely and effectively.

Additionally, the Implementing Regulation (EU) 2019/947 integrates with the Delegated Regulation (EU) 2019/945 by defining operational requirements in relation to the U AS classes established within. It details the specific operational limitations and conditions for each class of U AS, including requirements for the handling of U AS in classes C0 through C4, and includes provisions for the safe integration of new U AS classes introduced by the amendment in Delegated Regulation (EU) 2020/1058, classes C5 and C6.

This regulation also addresses the procedures for U AS operators from third countries (non-EASA member states) seeking to operate within the Single European Sky (SES) airspace, ensuring that their operations align with EU standards and safety regulations.

16.2.2 Delegated Regulation (EU) 2019/945

The Delegated Regulation (EU) 2019/945 is an European Union regulation that sets the rules and standards for U AS. It defines the types of U AS that require certification in terms of design, production, and maintenance. The regulation also establishes guidelines for the commercialization of U AS intended for use in the Open category, as well as for remote identification accessories (e.g. Drone Remote ID).

It also outlines the requirements for the design and manufacture of U AS intended for use under the conditions defined in the Implementing Regulation (EU) 2019/947.

16.2.3 Royal Decree UAS 517/2024

Its purpose is to establish the legal framework for those issues where the Implementing and Delegated Regulations from EASA either grant member states (e.g., Spain) the authority to regulate or do not directly address these aspects.

16.2.4 Regulation (EU) 2024/1689: Artificial Intelligence Act

The Artificial Intelligence Act (AI Act) of the European Union entered into force on the 1st of August 2024 [1] and aims to ensure AI systems are safe, transparent, and ethical while fostering innovation and protecting fundamental rights [2]. It categorizes AI systems by risk, imposing strict requirements on high-risk applications, such as those in aviation, which may impact public safety and fundamental rights. These requirements include robust risk management, transparency, human oversight, and data governance, ensuring AI systems are reliable and secure.

The AI Act introduces significant compliance obligations that could increase development costs and time. High-risk systems must meet strong standards to access the EU market, which may challenge innovation but ultimately aims to build trust and facilitate the broader adoption of AI technologies within the EU.

16.3 Operational Categories

Regarding U AS, the Implementing Regulation (EU) 2019/947 defines three distinct categories [3]:

- **Open Category:** This is the least restrictive category and is designed for low-risk operations. It includes activities such as recreational flying and commercial operations that pose minimal risk to people and property. Operators must follow specific operational limitations (e.g., flying below 120 meters, maintaining V LOS). U AS must be under 25 kg, and the pilot must ensure the drone does not fly over people or in restricted areas. No prior authorization is required, but registration and training as a remote pilot are compulsory for all operations, with the exception of drones weighing <250 g that do not fit a camera/sensor.

- **Specific Category:** This category covers medium-risk operations where a more detailed assessment is needed. It includes operations that might involve flying over people or in restricted areas but with mitigation procedures in place. Operators must conduct a risk assessment and obtain an operational authorization called Standard Training Scenarios (ST S) from AESA. The requirements for U AS and pilot qualifications can vary based on the specific risk assessment and operational procedures defined in the risk assessment.

- **Certified Category:** This category is designed for high-risk operations that are more complex and involve significant risk to people and property, such as those similar to manned aviation operations. It involves stringent requirements similar to those for manned aviation. UAS must meet specific certification standards, and operators need to comply with strict safety regulations. It often includes requirements for advanced training and operational procedures, similar to those for commercial air transport.

16.3.1 Open Category

This work will focus on civil U AS that fall under EASA's Open Category, although some of the work done may be applicable to other categories with the proper regulatory adjustments. Within the Open Category, there are three subcategories that differentiate themselves based on the associated risk, aircraft weight, and operational limits:

1. A1: UAS with an MTOW of less than 250 g that can fly over people but not over assemblies of people.
2. A2: UAS with an MTOW of less than 4 kg that can fly close to people, but must maintain a horizontal distance of 30 meters (5 meters in low-speed configuration).
3. A3: UAS with an MTOW of less than 25 kg that must maintain a horizontal distance of 150 meters from residential, commercial, industrial, or recreational areas.

TODO: add figure with the different categories

Some additional rules that apply to all three subcategories are stated below:

- The height of 120 meters above ground level should not be exceeded, as the lower limit for general aviation is 150 meters. Therefore, there is only a 30-meter separation between manned aviation and UAS.
- The operator must always fly in Visual Line Of Sight (VLOS), unless the aircraft is in *follow me* mode or the pilot is using First-Person View (FPV) goggles.
- The operator must be registered if the UAS weighs more than 250 g or if the aircraft is equipped with a camera or sensor.
- The aircraft must have a remote identification ID[4], which comes by default in all C1-C6 categories with the exception of C4 and privately built aircraft.

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