PROJETO DE AERONAVES
AIRCRAFT DESIGN – 10403

2017/2018

SEA WATER EXPLORER

UAV-17

Project Description

CONTENTS

1. INTRODUCTION ... 3
2. REQUIREMENTS ... 4
2.1. Mission ... 4
2.2. Performance ... 4
2.3. Propulsion ... 4
2.4. Wings ... 5
2.5. Fuselage ... 5
2.6. Tail ... 5
2.7. Landing Gear ... 5
2.8. Payload ... 5
2.9. Weight and Balance ... 5
2.10. Controls and Systems ... 5
2.11. Design Airworthiness Requirements ... 6
3. TASKS ... 6
3.1. Concept of Operations ... 6
3.2. Layout ... 6
3.3. Aerodynamics and Stability ... 6
3.4. Propulsion and Performance ... 7
3.5. Systems ... 7
3.6. Structure and Materials ... 7
3.7. Time plan ... 7
3.8. Work Requirements ... 7
4. ASSESSMENT ... 8
4.1. Test ... 8
4.2. Presentation ... 9
4.3. Report ... 9
4.4. Exam ... 9
4.5. Grade ... 9
5. REFERENCES ... 9
5.1. Text Book ... 10
5.2. Aircraft Design Books ... 10
5.3. Other Books ... 10

1. INTRODUCTION

The international aerospace sector has increasingly used in recent years unmanned aerial vehicles (UAV - Unmanned Aerial Vehicle) for missions of various types, such as: aerial photography, military reconnaissance, atmospheric research at high altitude, radio communication, surveillance, fire detection, technology development, etc.. Despite the technology involved, UAVs have dimensions smaller than manned aircraft, making their operation more flexible and more economical. The increasing automation and communication capabilities and the evolution of available materials has allowed the operation of these aircraft at distances and altitudes greater than ever, increasing their potential by making them equal, or even superior, to other aircraft that need to carry on board systems for crew support. For short distance surveillance applications, the investment required for the development and operation of a UAV is comparatively lower than equivalent manned aircraft so that its use in these tasks results in a cost-benefit ratio much more attractive. The UAV sector is the only sector of the aerospace industry with significant growth in the last 30 years, with an average growth rate of over 14% per year.

The UAV sector is rapidly flourishing and in many cases it is a source of concepts and technologies for manned aircraft. Currently, most UAVs in operation have military applications. The use of UAVs in civil applications is, however, growing rapidly with the appearance of new concepts of operation and the creation and maturation of appropriate legislation. Portugal needs to stay in this important aerospace area in order to be more autonomous in the development of technological means essential to the sustainability of its resources and its regional and national economic maturity, to employ its qualified manpower and to be a competitive exporter of technology.

Portugal also needs the use of UAVs in various areas of activity. Monitoring of forest areas which in recent years have succumbed to fires is an important example. The application of surveillance unmanned aerial vehicles allows a high degree of uptime and availability in the tasks of this nature and is a complementary means of ground surveillance and satellite monitoring already in use. The application of new UAV concepts to new civil scenarios that can be economic viable is also important.

In the past few years electric propulsion for aircraft has seen tremendous developments and a widespread use. Its application ranges from the model aircraft, UAVs, sailplanes and ultralight aircraft. Because batteries have a limited energy density, resulting in flights of short duration, the use of fuel cells for battery charging is an interesting option that has already been exploited. Conventional propulsion with a piston engine allows flights with longer duration and with the help of an alternator coupled to the engine batteries, that provide on-board power for systems, can be recharged in flight. To avoid consumption of gasoline to produce electricity, the incorporation of photovoltaic cells on the aircraft can provide part or all of the electrical energy required on board. In some situations a hybrid propulsion system may be preferred.

The main objective of this subject is to show students what the conceptual design of an aircraft is and what steps are necessary to follow given mission and performance requirements, design constraints, design methods and the need for optimization. To achieve this, the knowledge gained will be applied to the design of a new aircraft subjected to specific requirements. The optimization of the project is of extreme importance in the development of a new aircraft.

This project description presents the requirements that the aircraft must respond to in terms of mission, configuration, performance, systems, materials and design standards. It also describes the necessary tasks to be performed during the semester and the work plan to follow. This project requires dedication and continuous work to ensure that deadlines are met and results lead to a good design.

2. REQUIREMENTS

The current requirements follow a need for an autonomous UAV with the capability to fly efficiently over a relatively long distance over water, to land on water and remain on station for a long period of time to collect various scientific-related data before taking off and returning home. The requirements for this aircraft are listed below and during the course of the project they must be respected. Possible changes in the requirements will be discussed and agreed upon by the teacher and all the elements involved in the project.

It is required to perform the conceptual and preliminary design of a UAV taking into account some specific design requirements. The aircraft must have good flying qualities to allow easy and precise flying. The vehicle's structure and aerodynamics must be carefully designed to achieve low power consumption levels. Simplicity, robustness and ease of repair are essential to maintain high levels of operational readiness of the UAV.

2.1. Mission

The UAV must be designed for the following mission: it must be launched from a small place such a ship deck or a pier, then climb to a cruise altitude no less than 100 m, cruise for at least 100 km over water to the destination point, descend and land on water and remain on station for a period of one week collecting various scientific-related sea data; then take off by its own means, cruise back to base and land on the same ship deck or pier.

2.2. Performance

The vehicle must show the following performance figures (ISA conditions):

Take-off	from ship deck or pier
Cruise speed	above 70 km/h
Maximum speed	at least 100 km/h
Flight operational radius	at least 100 km
Data link range	at least 150 km (or satellite)
Service ceiling	1000 m
Landing	on ship deck or pier

2.3. Propulsion

Electric motors and/or piston engines may be selected for this UAV. The possibility of using a hybrid propulsion system should be considered for improved flexibility and increased range. The propellers must be selected to match the motor/engine performance and according to the UAV performance required. The aircraft can either have tractor or pusher propellers and can have as many propulsion units as required. In selecting the motor/engine, careful attention must be given to its durability and reliability. Proper cooling of the motor/engine must be provided. Tilting of the motors/engines may be considered (or not) to fulfil the operational needs. Proper protection from sea water must also be implemented.

2.4. Wings

The wings must be well designed, both aerodynamically and structurally, so that the overall efficiency of the vehicle is high and to allow the required mission to be accomplished with low energy requirements. According to the mission, the wings must be designed for high lift-to-drag ratio. The structure should use high specific strength and high specific stiffness materials to allow for an empty weight as low as possible. A tilting wing may be considered in conjunction with the tilting motors/engines when applicable.

2.5. Fuselage

The fuselage should be slender and light, yet possessing the necessary internal space for systems and payload. It should have high tolerance on payload weight and position. Equipment substitution and payload access should be quick and simple to perform. The payload compartment should be capable of carrying a small package containing the equipment and instruments required for collecting data from the sea. The payload compartment should have the reference dimensions 320 mm x 220 mm x 120 mm and should provide access to the water below when the aircraft is sitting on station. The fuselage should be water proof.

2.6. Tail

The tail must be small and effective. It should use in their structure the same materials selected for the wings.

2.7. Landing Gear

The choice of using a landing gear will depend on the concept of operation proposed. If it exists, it must be rugged, yet simple, and should in no way interfere with water operations.

2.8. Payload

The payload (up to 3 kg) must be well secured in the fuselage to avoid any movement during flight. The payload can be considered as a box consisting of a device to analyse water properties, a probe to submerge in the water for that purpose, a GPS, a communications system for telemetry purposes and some processing and storage units. The power consumption of the payload when on station is 25 W.

2.9. Weight and Balance

The centre of gravity (CG) travel must be such that no negative impact on the stability or on the normal operation of the UAV is imposed for any payload weight transported onboard. It is important that the maximum take-off mass of the UAV does not exceed 25 kg but this is not mandatory.

2.10. Controls and Systems

The control system will include autopilot boards (or at least physical space for those) which are not required to be selected. Control surfaces, tilting surfaces and motor/engine's tilting mechanisms if applicable must be sized and must be actuated by servomotors. All electronic and electric components and mission equipment must be placed within the fuselage according to their function and in such a way as to allow its quick preparation or replacement. The electric system should be powered by batteries which can be charged by an alternator driven by the engine in the hybrid propulsion configuration.

2.11. Design Airworthiness Requirements

The design airworthiness requirements that should be used in the structural sizing are the EASA CS-VLA, CS-LSA or CS-23. The design manoeuvre limit load factors are, in principle, +3 and -3, but those should be checked with a V-n diagram. All work performed in the design should aim at achieving high levels of safety and performance.

3. TASKS

There are several tasks in the design project that must be carried out according to the time plan below. All tasks depend on each other so that there must be a close interaction and updating between them. The design process is also iterative in nature but perfection is not possible nor is necessary but an effort must be put forward to achieve a good optimization level in the outcome.

The necessary calculations may be performed with the help of spread sheets and also other analysis computer programs. All drawings should be, preferably, done in CATIA V5.

3.1. Concept of Operations

The exact mission profile and the way it is going to be operationally implemented must be defined and explained. The design of the vehicle will follow from the concept of operations (CONOPS) proposed to respond to the mission requirements.

3.2. Layout

The layout and functionalities of the vehicle must be selected so that the requirements are fully met. This task is very important because it integrates all needs of the other parts of the project into a viable configuration. A preliminary three dimensional (3D) study of all major components must be performed and these must be incorporated in the aircraft structure. 3D drawings must be produced in a CAD system for the complete UAV.

3.3. Aerodynamics and Stability

The aerodynamic study must cover the selection of the aerofoils, geometry and size of the lifting surfaces, nacelles and the computation of the aerodynamic characteristics of the whole vehicle (C_L, C_D e C_M). It must be assured that all choices made in the overall design do not impair the aerodynamic performance. A study of the stability and control of the UAV must also be performed.

The aerodynamic work must concentrate on the wings design and tail sizing. These must be optimized having in mind the necessary compromises for different flight conditions.

3.4. Propulsion and Performance

The propulsive system (motor, propeller, power source, fuel system) must be selected and sized according to the requirements. An estimate of the vehicle's performance (speeds, times, fuel usage, etc.) must be carried out.

3.5. Systems

A study of the landing gear system (if it exists), of the control system and of the electric system must be performed. These studies should include not only the selection of the main components and definition of its functionalities but also the positioning of components and routing of cables inside the aircraft. Commercially available components are preferred to speed up both design and building processes. A database containing such data as suppliers, working characteristics, weight, power consumption and price of all components selected must be produced.

3.6. Structure and Materials

The type of structure and materials for the different components of the vehicle must be selected and defined adequately keeping in mind their configuration and function. Preliminary sizing of the wing must be performed. A database containing such data as suppliers, physical characteristics, mechanical characteristics and price of all materials selected must be produced. A study on the manufacturing processes to be used must be carried out together with estimates of weight and balance and total cost of the UAV.

3.7. Time plan

The table below presents the time plan with the tasks required to complete de project.

Month	S	S	O	O	O	O	O	N	N	N	N	D	D	D	D	J	J	J	J	J	F	F
Task \ Week	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
Lectures																						
Layout																						
Aerodynamics/Stability																						
Propulsion/Performance																						
Systems																						
Structure/Materials																						
Test																						
Presentation																						
Report																						
Exams																						

Legend:
- Lectures
- Design work
- Weeks without lectures
- Assessment

3.8. Work Requirements

The design is carried out by groups of 5 students. In order for the project objectives to be fulfilled in time all students should work hard.

	Student's Name	Nº	Team	E-mail	Task
01	Luís Simões	32056	A	romeiro.silva.luis@gmail.com	layout
02	Daniel Rodrigues	32203	A	a32203@ubi.pt	aerodynamics/stability
03	Gonçalo Pacheco Rodolfo Lopes	32077 32187	A	sousappacheco@gmail.com	propulsion/performance
04	Gabriel Carrolo	32345	A		systems
05	Inês Ferrão	32217	A	ines_ferrao_abril_11@hotmail.com	structures/materials
06	Sara Alves	32165	B	sara.alves.95@hotmail.com	layout
07	André Franco	31934	B	andreromaofranco@gmail.com	aerodynamics/stability
08	Andreia Melo Francisco Figueira	33012 32646	B	a.sofia2@hotmail.com kiko_figueira_@hotmail.com	propulsion/performance
09	Nídia Ribau	32406	B	nidiribau@hotmail.com	systems
10	Cátia Miguel	32262	B	catiamiguel18@gmail.com	structures/materials
11	André Araújo	32848	C	andre_dias_araujo@hotmail.com	layout
12	Henrique Almeida	32229	C	henrique.mig.a@gmail.com	aerodynamics/stability
13	Miguel Leal	31814	C	miguel.viegas.leal@gmail.com	propulsion/performance
14	Adriano Brum	31982	C	adjrum@gmail.com	systems
15	Gustavo Garcia	31804	C	gusgarcia@sapo.pt	structures/materials
16	Hugo Lopes	32916	D	hsml1995@hotmail.com	layout
17	Pedro Barros	31902	D	pedroh.barros96@gmail.com	aerodynamics/stability
18	Fábio Romão	32051	D	fabioromao_95@hotmail.com	propulsion/performance
19	Gonçalo Gonçalves	32963	D	a32963@ubi.pt	systems
20	João Rocha	32824	D	joaoarturfr@hotmail.com	structures/materials
21	Daniel Ginja	32799	E		layout
22	Luís Oliveira		E		aerodynamics/stability
23	Bruna Araújo	32074	E		propulsion/performance
24	Luís Coelho	32194	E		systems
25	Nuno Sousa	32410	E		structures/materials
26	José Cruz	28897	F	jose__dsc@hotmail.com	layout
27	Rúben Ribeiro	31198	F	rubenribeiro222@hotmail.com	aerodynamics/stability
28	João Carmo	30762	F	joia_prestige@hotmail.com	propulsion/performance
29	Édi Monteiro	29379	F	edi.monteiro93@gmail.com	systems
30	André Branco	23912	F		structures/materials
31			G		layout
32			G		aerodynamics/stability
33			G		propulsion/performance
34			G		systems
35			G		structures/materials
36			H		layout
37			H		aerodynamics/stability
38			H		propulsion/performance
39			H		systems
40			H		structures/materials

4. ASSESSMENT

The grade of this subject is given based on one written test (T), one oral presentation (P) and one report (R).

4.1. Test

The test covers all the topics discussed during classes up to the date of the test (15 December 2016 – week 13). The test is divided into two parts: the first is closed book and the second is open book.

4.2. Presentation

Near the end of the semester there will be an oral presentation of the project (5 January 2017 – week 16). In the presentation, when the project is almost complete, each design team (all elements of the team must participate in the presentation) must show to the other teams that their design meets all requirements and explain the steps that led to the final concept. This presentation should take 20-30 minutes for each team, depending on the number of teams that exist.

4.3. Report

Each team must write up a design report that should contain all relevant steps taken in the UAV design process, including layout, decisions made, major calculations, results, etc.. Sketches necessary to fully understand the design and a three view drawing with all major dimensions and aircraft characteristics should also be included. The number of pages is limited to around 30, using letter size 12 and single line spacing. The report should be handed in *pdf* format at the last day of lectures together with the original CAD drawings (12 January 2017 – week 17).

4.4. Exam

There will be no written exam. If students fail the “Frequência” assessment or wish to improve their final grade, they must hand in an improved report of their design project at the dates of the exam, in weeks 19 or 21.

4.5. Grade

The mark of this subject is given by F = 0.3T + 0.2A + 0.5R and approval is obtained if F $\geq$ 10. The same is true for the exam final mark.

1.		Frequência (F = 0.3T + 0.2A + 0.5R)		100
	T	Test	15-12-2017 (09h30)	30
	A	Presentation	05-01-2018 (09h00)	20
	R	Report	12-01-2018 (24h00)	50
2.		Exam (E = 0.3T + 0.2A +0.5 R1)		100
	R1	Report (normal period)	??-01-2018 (??h30)	50
	R1	Report (recourse period)	??-02-2018 (??h30)	50
4.		Exam (E = 0.3T + 0.2A +0.5 R2)		100
	R2	Report (special period)	??-07-2018 (??h00)	50

5. REFERENCES

The books listed below can be used for the design. The design reports of previous years may also be useful as general guideline and source of ideas. However, one must bear in mind that the information contained in them may be incorrect. A lot of information can also be found in the internet using appropriate search criteria.

5.1. Text Book

01. Raymer, D. P., *Aircraft Design: A Conceptual Approach* - 4rd edition, AIAA Education Series, 2006

5.2. Aircraft Design Books

02. Gundlach, J., *Designing Unmanned Aircraft Systems: A Comprehensive Approach*, AIAA Education Series, 2012
03. Stinton, D., *The Design of the Aeroplane*, Blackwell Science, 1983
04. Jenkinson, Lloyd R., Marchman III, James F., *Aircraft Design Projects for Engineering Students*, Butterworth-Heinemann, 2003
05. Barros, C., *Introdução ao Projecto de Aeronaves* – Volumes 1 & 2, CEA/UFMG, 1979
06. Brandt, S. A., Stiles, R. J., Bertin, J. J., Whitford, R., *Introduction to Aeronautics: A Design Perspective*, AIAA Education Series, 1997
07. Corke, T. C., *Design of Aircraft*, Pearson Education, Inc., 2003
08. Howe, D., *Aircraft Conceptual Design Synthesis*, Professional Engineering Publishing, 2000
09. Jenkinson, L. R., Simpkin, P., Rhodes, D., *Civil Jet Aircraft Design*, Arnold, 1999
10. Pazmany, L., *Light Airplane Design*, Pazmany Aircraft Corporation, 1963
11. Roskam, J., *Airplane Design* – Volumes I to VIII, The University of Kansas, 1990
12. Torenbeek E., *Synthesis of Subsonic Airplane Design*, Delft University Press, 1982

5.3. Other Books

13. Abbot & Doenhoff, *Theory of Wing Sections*, Dover Publications Inc, 1959
14. Barnaby Wainfan, *Airfoil Selection – Understanding and Choosing Airfoils for Light Aircraft*, 1988
15. Barnes W. McCormick, *Aerodynamics, Aeronautics and Flight Mechanics* – 2nd edition, John Wiley & Sons Inc, 1995
16. Bernard Etkin, Lloyd Duff Reid, *Dynamics of Flight, Stability and Control* – 3rd edition, John Wiley & Sons Inc., 1996
17. Bill Clarke, *The Cessna 172* – 2nd edition, Tab Books, 1993
18. Darrol Stinton, *Flying Qualities and Flight Testing of the Airplane*, AIAA Education Series, 1996
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20. Euroavia, *Future Trainer Concept*, 1999
21. Geoff Jones, *Building and Flying Your Own Plane*, Patrick Stephens Limited, 1992
22. Ian Moir & Allan Seabridge, *Aircraft Systems*, Longman Scientific & Technical, 1992
23. *Jane's All the World Aircraft*, 1995
24. JAR-23, *Joint Aviation Requirements for Normal, Utility, Aerobatic and Commuter Category Aeroplanes*, JAA, 1994
25. JAR-27, *Joint Aviation Requirements for Small Rotorcraft*, JAA, 1993
26. JAR-VLA, *Joint Aviation Requirements for Very Light Aeroplanes*, JAA, 1990
27. Ladislao Pazmany, *Landing Gear Design for Light Aircraft* – Volumes I & II, Pazmany Aircraft Corporation, 1986
28. John Cutler, *Understanding Aircraft Structures*, Blackwell Science, 1999

29. Martín Cuesta Alvarez, *Vuelo con Motor Alternativo*, Paraninfo, 1981
30. Robert C. Nelson, *Flight Stability and Automatic Control*, McGraw-Hill, 1989
31. S. Hoerner, *Fluid-Dynamic Drag, Hoerner Fluid Dynamics*, 1965
32. S. Hoerner, *Fluid-Dynamic Lift, Hoerner Fluid Dynamics*, 2nd Edition, 1985
33. Stelio Frati, *L'Aliante*, Editore Ulrico Hoepli, Milano, 1946
34. Ted L. Lomax, *Structural Loads Analysis for Commercial Transport Aircraft – Theory and Practice*, AIAA Education Series, 1996
35. *The Metals Black Book – Volume 1 – Ferrous Metals*, Casti Publishing Inc, 1995
36. *The Metals Red Book – Volume 2 – Nonferrous Metals*, Casti Publishing Inc, 1995
37. T. H. G. Megson, *Aircraft Structures for Engineering Students* – 2nd edition, Edward Arnold, 1990
38. Tony Bingelis, *Firewall Forward – Engine Installation Methods*, EAA Aviation Foundation, 1992
39. Tony Bingelis, *Sportplane Construction Techniques – A Builder's Handbook*, EAA Aviation Foundation, 1992
40. Tony Bingelis, *The Sportplane Builder – Aircraft Construction Methods*, EAA Aviation Foundation, 1992