UNIVERSIDADE DA BEIRA INTERIOR
Covilhã | Portugal

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

PROJETO DE AERONAVES
AIRCRAFT DESIGN – 10403

2012/2013

Long Endurance Electric UAV

UAV-12

Project Description

ÍNDICE

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, since they are not manned vehicles, have dimensions smaller than manned aircraft, making their operation more flexible and more economical. The increasing automation and communication capabilities and the evolution of materials available 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 25 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 creation and maturation of appropriate legislation. Portugal needs to enter 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.

In the past few years electric propulsion for aircraft has seen a tremendous development and a widespread interest. Its application ranges from the model aircraft, UAVs, and already 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.

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 an new aircraft subject to specific requirements.

The optimization of the project is of extreme importance in the development of a new aircraft. Therefore, the development of a long endurance electric UAV is a good exercise to learn and apply this need. Thus, we intend to do the conceptual design of an electric UAV with long endurance taking into account some specific design requirements. The aircraft must have good flying qualities to allow easy and precise flying. The UAV will be fitted with an electric motor and photovoltaic cells. The vehicle must have low power requirements for which it will be necessary to optimize the structure and the aerodynamics for low power consumption. The simplicity and speed of construction and repair are essential to maintain high level of operability of the UAV.

This project description gives 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 accomplished 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 plane design.

2. REQUIREMENTS

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.

The following aspects should guide the design process:

Long endurance: achieved through the use of green technologies (electric propulsion system with solar energy), in particular by using highly efficient photovoltaic cells, batteries, large capacity/energy density, compact and efficient electric motors and aerodynamic configuration suitable for larger flight times.

High strength, low weight structure: achieved with the use of advanced materials (composites and others), with the fuselage and wing designed for good impact resistance and landing using simple construction techniques.

Multiple mission: achieved through the ability to use different payloads (volume and weight) with modular avionics that allow easy loading of software or exchange of components to meet different mission requirements.

2.1. Mission

The UAV must be designed for the following mission: it must be hand launched, then climb to the cruise altitude and stay aloft for 8 hours before it descends for the landing area.

2.2. Performance

The vehicle must show the following performance figures (on a typical summer day at Covilhã):

Takeoff	hand launched
Cruise speed	6 m/s to 10 m/s
Minimum flight endurance	8 hours
Range	200 km
Service ceiling	2000 m

2.3. Propulsion

The motor should have high efficiency yet being small and the electronic speed controller (ESC) should be compatible with the motor. Li Ion, LiPo or LiFe batteries can be used. The propeller must be selected according to the motor performance and UAV performance required.

2.4. Wings

The wings must be well designed, both aerodynamically and structurally, so that the overall efficiency of the vehicle is high and, thus, allow the required mission to be accomplished. The wings must be detachable from the fuselage for storage during transportation. The structure should use high specific strength and high specific stiffness materials to allow for an empty weight as low as possible. The use of photovoltaic cells on the wings must be considered to help maintain the batteries charged.

2.5. Fuselage

The fuselage should be slender and light, yet possessing the necessary internal space for systems and payload. Equipment substitution and payload access should be quick and simple to perform. The payload compartment must contain a cube of 100mm x 100mm x 100mm that represent specific mission equipment.

2.6. Tail

The horizontal tail and vertical tail, if they exist, must be small and effective. They should use in their structure the same materials selected for the wings. They probably need to be detachable for storage during transportation.

2.7. Landing Gear

The UAV-12 is hand launched and lands on its belly. If it is required that it takes off from a runway the landing gear system used must fall off after takeoff to allow high flight performance.

2.8. Payload

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 payload (1kg) must be well secured in the fuselage to avoid any movement during flight.

2.9. Weight and Balance

The centre of gravity (CG) travel must be such that for different payload weights no limits on the normal operation of the UAV are imposed.

2.10. Controls and Systems

All control systems must be electric and/or mechanical and actuated by servomotors. The aircraft should be remotely piloted or totally autonomous. The electric system should be powered by batteries and/or solar cells.

2.11. Transportation

The UAV must be capable of being disassembled into pieces smaller than 2m in length so that it can be easily transported.

2.12. Design Airworthiness Requirements

The design airworthiness requirements that should be used in the structural sizing are the EASA CS-VLA. The design limit load factors are, in principle, +3 e -3, but they should be checked with a n-V diagram. All work performed in the design should aim at achieving good level 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 spreadsheets and also other analysis computer programs. All drawings should be, preferably, done in CATIA V5.

3.1. Layout

The layout 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.

3.2. Aerodynamics and Stability

The aerodynamic study must cover the selection of the airfoil, 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), as well as assure 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. These must be optimized having in mind the necessary compromises for different flight conditions.

3.3. Propulsion and Performance

The propulsive system (motor, propeller, ESC, batteries and solar cells) must be selected and sized according to the requirements. An estimate of the vehicle’s performance (speeds, times, energy usage, etc.) must be carried out. The mission must be verified for typical summer days in Portugal.

3.4. 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 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 and price of all components selected must be produced.

3.5. Structure and Materials

The type of structure and materials for the different parts 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.

3.6. Time plan

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

Month	Set.		October					November				December				January					Feb.	
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

3.7. Work Requirements

The design is carried out by groups of 4 students. In order for the project objectives to be fulfilled in time all students should work hard.

	Student	Nº	Team	E-mail	Task
01	Jorge Oliveira	A24900	A	jorge_de_oliveira@hotmail.com	
02	António Marques	A29901	A	antoniomarques11@gmail.com	
03	Alícia Pais	A21314	A	alicia_belga@hotmail.com	
04	Dmytro Vasyanovych	A28163	B	dmytrovasyanovych@gmail.com	
05	Paulo Marchão	A24386	B	marchas@gmail.com	
06	Hugo Sousa	A25745	B	hugorochasousa@sapo.pt	
07	Tiago Gameiro	A28244	B	tiago.gameiro@gmail.com	
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4. ASSESSMENT

The grade of this subject is given based on one written test, one oral presentation and one report.

4.1. Test

The test covers all the theory topics discussed during classes up to the date of the test (9 January 2013 – week 17). The test is divided into two parts: the first is close book and the second is open book.

4.2. Presentation

At the end of the semester there will be an oral presentation of the project (16 January 2013 – week 18). 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 in pdf format at the last day of lectures together with the original CAD drawings (18 January 2013 – week 18).

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 20 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	09-01-2013	30
	A	Presentation	16-01-2013	20
	R	Report	18-01-2013	50
2.		Exame de Época Normal (E=0.3T+0.2A+0.5R1)		100
	R1	Report (1st call)	02-02-2013 – 14h30	50
	R1	Report (2nd call)	09-02-2013 – 14h30	50
4.		Exame de Época Especial (E=0.3T+0.2A+0.5R2)		100
	R2	Report	??-07-2013 – ??h?0	50

5. REFERENCES

The books listed below can be used for the design. The design reports of previous years may also be useful bearing in mind that the information in them may be incorrect. A lot of information can also be found in the internet using correct 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
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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
19. David A. Lombardo, *Aircraft Systems –Understanding Your Airplane*, Tab Books, 1988
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