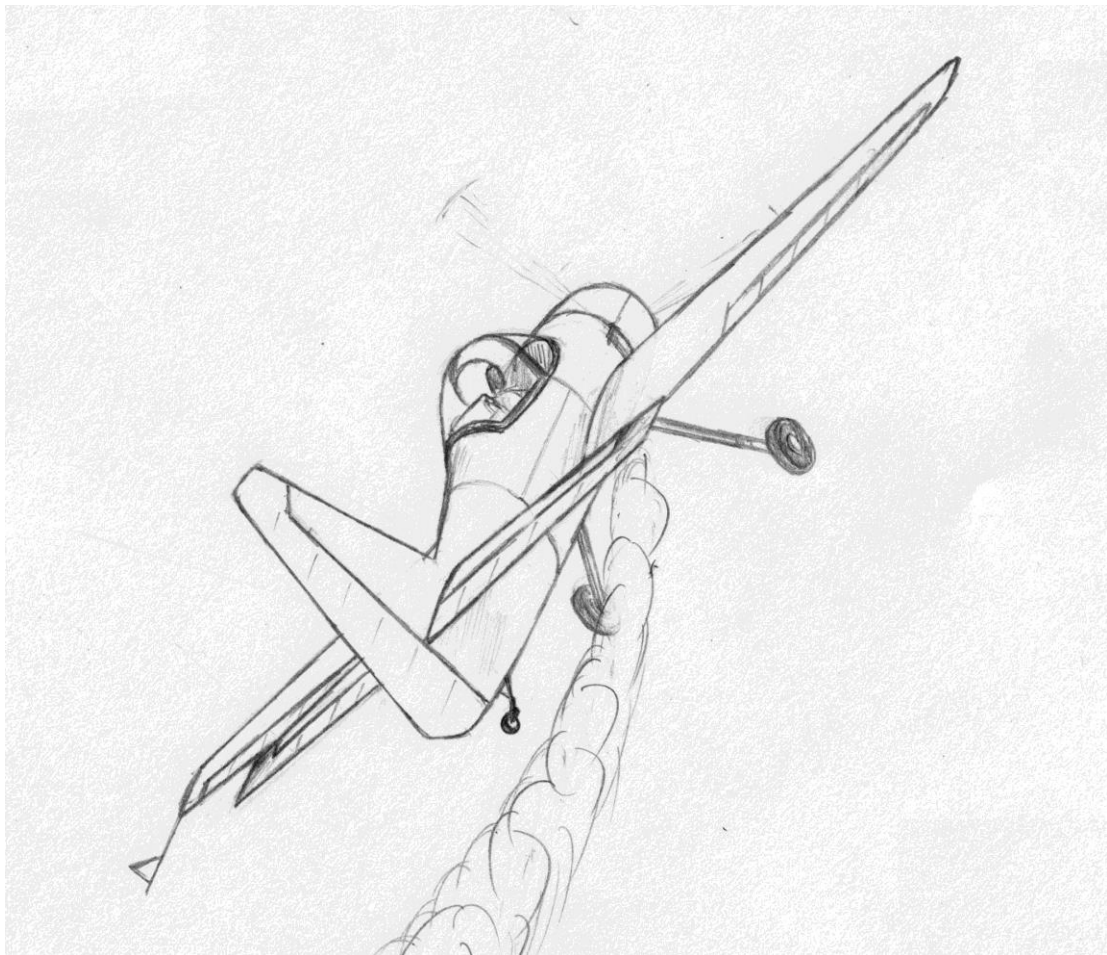


PROJETO DE AERONAVES  
AIRCRAFT DESIGN – 15096

2023/2024



Curricular Unit Description

and

Design Project Description



# **PART I**

## **THE CURRICULAR UNIT**

### **1. OBJECTIVES**

Students should acquire skills in the development of an aircraft subject to specific requirements and constraints, know how to apply aircraft design standards, develop integration, decision and compromise capabilities in a multidisciplinary team project and know how to communicate their results effectively.

With this UC students should be able to:

- describe the traditional aircraft design process and adapt it to specific cases;
- develop simple programs for the analysis and conceptual/preliminary design of an aircraft;
- integrate knowledge from various areas of science and engineering in the development of a multidisciplinary design project;
- carry out the conceptual and preliminary design of an aircraft to meet specific requirements;
- analyse design results and identify the most relevant parameters for the optimization of a given aircraft;
- effectively communicate project results;
- work in a team.

### **2. SYLLABUS**

#### **I. Introduction**

1. Introduction to the curricular unit. 2. The aircraft design process. 3. Airworthiness standards for aircraft design.

#### **II. Conceptual Design**

4. Sizing from a conceptual drawing. 5. Selection of the airfoil and geometry of the wings and tail. 6. Initial sizing. 7. Configuration and drawing. 8. Configuration considerations. 9. Cabin, passengers and payload. 10. Integration of the propulsive system and the power system. 11. Landing gear and other systems. 12. Case studies.

#### **III. Sizing, Analysis and Optimization**

13. Aerodynamics. 14. Propulsion. 15. Structures and loads. 16. Weight and balance. 17. Stability and control. 18. Performance. 19. Cost analysis. 20. Optimization.

#### **IV. Design of a New Aircraft**

21. Concept of operations. 22. Aircraft design. 23. Development of analysis and optimization tool. 24. Sizing and analysis. 25. Oral presentations. 26. Written report.

### **3. SYLLABUS/OBJECTIVES**

The contents of this curricular unit are structured in four blocks, the first three consisting of oral exposition and discussion of topics and the fourth consisting in practical and application of the knowledge. Those were designed with the main objective to develop teamwork skills in a complex multidisciplinary project in which theoretical and practical,

technical and scientific knowledge of various areas is necessary, in which the critical thought and compromise is essential and, at the same time, to foster the spirit of innovation through research of new scientific and technological information (outside the syllabus of the course) so that the requirements of a given project can be met.

In essence, the syllabus is designed so that students can deepen, develop and integrate knowledge from different areas (aerodynamics, propulsion, structures, materials, flight performance, flight stability and dynamics, systems, etc.) to produce a viable and optimized aircraft design.

## **4. TEACHING METHODOLOGIES**

This curricular unit is structured in two parts: one essentially theoretical and the other essentially practical. In the first part, the material is transmitted orally with multimedia slideshow support and additional information written on the blackboard. In the second part, methods for building a spreadsheet tool for analysis and optimization are taught and a new aircraft design is partially developed based on specific design requirements.

## **5. TEACHING METHODOLOGIES/OBJECTIVES**

The methodologies adopted for this curricular unit follow the trends of similar curricular units in other universities and the experience acquired by the University of Beira Interior in the development of several unmanned aircraft and in various research and development work. This curricular unit has four weekly hours of theoretical-practical lectures and is structured in two parts: one part (2 hours) essentially theoretical and the other (2 hours) essentially practical.

In the first part, the materials (blocks I, II and III) are orally transmitted using multimedia slides and supplementary information written on the board. The slides are made available online to students in pdf format for their individual study and for reference, as they are built in the form of notes. In this part, examples of application are also presented. The discussion of the topics presented is fostered during the contact hours for better understanding by the students and for the development of their critical thought.

In the second part (block IV), methodologies are taught for the construction of an analysis and optimization spreadsheet tool. With this basis and with the knowledge of the theoretical part, students develop in teams (typically 5 students) the conceptual design and preliminary design of a new aircraft to meet the requirements provided by the teacher. During these classes, the exchange of ideas among teams is also encouraged and short oral presentations concerning the design progress are made throughout the semester. A large volume of this work must be performed outside the class period due to the considerable amount of required work. This project allows the student to develop analytical and synthesis skills, also using knowledge acquired in other curricular units, and to acquire critical decision and teamwork skills in the development of a complex system. At the end of the curricular unit the design is orally presented, and a written design report is submitted.

Although the professor monitors the developed students' work during the contact hours, both in the theoretical and practical lectures, a considerable amount of individual work outside the class is necessary by the students, regarding the study of the syllabus of the curricular unit, the study of other related subjects contained in the bibliographic references and the realization of the design work. This individual work promotes the autonomy and critical capacity of the student.

To support the teaching of this curricular unit, different but essential teaching/learning resources are used, namely:

- Video projector
- Books, articles, and other bibliography
- Notes
- Computer
- Internet
- Spreadsheets
- Analysis software for: airfoils, wings, propellers, flight stability, etc.
- CAD/CAE software
- Aircraft models developed previously at UBI and others

## 6. CALENDAR

Lectures are divided into two main parts: one to present and discuss the fundamental topics; and another to discuss and develop the proposed design project. In the table below the syllabus chapters are assigned to the corresponding weekly lectures.

Week	Dates	Chapters
1	19/02/2024	1
1	22/02/2024	2, 3
2	26/02/2024	4
2	29/02/2024	21
3	04/03/2024	5
3	07/03/2024	5, 6
4	11/03/2024	25
4	14/03/2024	6, 7
5	18/03/2024	7
5	21/03/2024	8, 9
6	25/03/2024	Easter break
6	28/03/2024	Easter break
7	01/04/2024	Easter break
7	04/04/2024	22
8	08/04/2024	10
8	11/04/2024	11
9	15/04/2024	12
9	18/04/2024	25
10	22/04/2024	13
10	25/04/2024	holliday: 25 April
11	29/04/2024	13, 14
11	02/05/2024	14, 15
12	06/05/2024	23
12	09/05/2024	15, 16
13	13/05/2024	17
13	16/05/2024	23
14	20/05/2024	17, 18, 19
14	23/05/2024	20, 24

14	23/05/2024	test (18h00)
15	27/05/2024	24
15	30/05/2024	24
16	03/06/2024	25
16	06/06/2024	25

The available time for questions is Monday at 16h00-17h30.

## **PART II**

### **THE DESIGN PROJECT**

# **Electric Package Delivery UAV**

## **UAV-24**

### **7. INTRODUCTION**

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, ultralight, general aviation aircraft and even passenger 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 recharge these in flight. To avoid consumption of petrol-based fuels 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.

Also, the developments in electrical propulsion, with increasing safety levels has enabled the study and implementation of several designs for urban air mobility to transport people and cargo and small passenger aircraft.

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 during the course 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, layout, performance, systems, materials, and design standards. It also describes the necessary tasks to be carried out 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.

### **8. REQUIREMENTS**

The current requirements present a need for an electric autonomous UAV (also capable of being remotely piloted) with the capability to fly efficiently over a relatively long distance to deliver high priority packages over a regional area. 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.

### 8.1. Mission

The UAV must be designed for the following mission: it must take-off from an airfield of no more than 100 m long (or be launched by external means), then climb to a cruise altitude of no less than 500 m, cruise for at least 75 km to the destination, drop the payload and return to base. The objective of the operation is to deliver high priority packages to isolated areas (small villages, farms, or groups of people) within a regional area of 75 km in radius in a timely and efficient manner. The payload covered in this need comprises medicines or food with a mass up to 2 kg. The turnaround time should be as low as possible yet less than 10 minutes to allow for urgent package dispatching.

It is desirable, though not mandatory, to have a vehicle that can complete the journey through as many destinations as possible in the area given above during the daylight period in a Winter day (around 8 hours). There may be a centrally placed base from which the vehicle operates and to which it returns at the end of the journey.

The vehicle should be able to be disassembled into parts of no more than 0.8 m in length, so that it can easily fit in a typical car boot.

### 8.2. Performance

The vehicle must show the following performance figures (ISA – *International Standard Atmosphere* conditions):

Take-off	from an airfield (less than 100 m) or external launcher
Cruise speed	above 75 km/h
Flight operational radius	at least 75 km
Data link range	at least 75 km (or satellite)
Operational ceiling	at least 1000 m
Landing	on an airfield (less than 120 m) or other means

### 8.3. Propulsion

The aircraft shall utilise an electric powertrain using only batteries for energy storage. Up to four motors and up to four propellers may be used. In selecting the motor(s), careful attention must be given to its durability and reliability. Proper cooling of the motor(s) must be provided. Propellers must be fixed pitch. The propellers must be selected according to the motor performance and UAV performance required. The aircraft can either have tractor or pusher propellers. No thrust vectoring is permitted. The design shall be fault tolerant: able to continue to fly safely and land having suffered a failure of a single motor, battery, or propeller.

The batteries must be sized to provide both the required maximum power and range/endurance. Batteries may only be used between 100% and 20% energy levels, to allow a reserve. It may be assumed that a 100% discharge rate is available throughout this range. Proper cooling of the batteries must be provided. Teams must clearly state and justify their choice of battery parameters (e.g. specific power, discharge rate) based on battery cells currently available – not cells that are simply at the research stage.



Electric motors (including controllers) shall have a power density of no greater than 7 kW/kg continuous (for cruise and descent) and 10 kW/kg peak (for a maximum of 5 minutes). Batteries shall have a specific energy of not more than 250 Wh/kg at the cell level and a value of not more than 200 Wh/kg for the cells integrated into packs, including monitoring, control, and cooling.

#### **8.4. Wings**

The aircraft shall have a fixed wing configuration, with a maximum wingspan of 4 m. 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 can 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.

#### **8.5. Fuselage**

The fuselage should be slender and light yet possess the necessary internal space for systems, batteries, and payload. It should have high tolerance on payload weight (see 7.8) and position. Equipment substitution and payload access should be quick and simple to perform. A separate pod for the payload may be considered. The payload compartment should be capable of carrying a container which holds the cargo in a proper manner. The payload compartment should have at least the reference dimensions 230 mm × 115 mm × 115 mm (length × width × height) and should be accessed very quickly to load and unload the package container.

#### **8.6. Tail**

The tail, when present, must be small and effective. It should use in their structure the same materials selected for the wings. Proper stability and control should be guaranteed by the tail design.

#### **8.7. Landing Gear**

The choice of using a landing gear will depend on the concept of operations proposed. If it exists, it must be rugged, yet simple.

#### **8.8. Payload**

The payload (up to 2 kg) must be well secured in the fuselage to avoid any movement during flight. The payload can be considered as a container holding the high priority cargo. For some types of packages, such as medicines or food, the container must be well insulated in terms of temperature.

#### **8.9. Weight and Balance**

A Maximum Total Mass Authorised (MTMA) of 25 kg is allowed. The centre of gravity (CG) travel must be such that no negative impact on the stability or on the normal operation of the aircraft is imposed for any payload weight transported on board (see 7.10). It is

important that the maximum take-off mass of the aircraft is kept as low as possible. The vehicle should be capable of flying with partial load payloads (see 7.8).

### **8.10. 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 must be sized and must be actuated by servo mechanisms. The aircraft must be aerodynamically stable in all axes. Artificial stability systems may not be used to enhance an otherwise aerodynamically unstable aircraft.

All electronic and electric components and mission equipment must be placed within the fuselage or wing 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.

### **8.11. Design Airworthiness Requirements**

The design airworthiness requirements that should be used in the structural sizing are the EASA CS-LSA, CS-VLA or CS-23. The design manoeuvre limit load factors are, in principle, +2 and -2, 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.

## **9. 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 other analysis computer programs. All drawings should be developed in CATIA V5 or similar.

### **9.1. 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. Topics such as

### **9.2. 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.

### **9.3. Aerodynamics and Stability**

The aerodynamic study must cover the selection of the aerofoils, geometry and size of the lifting surfaces, controls, 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 aerodynamics work must concentrate on the wings design and tail sizing. These must be optimized having in mind the necessary compromises for different flight conditions.

#### **9.4. Propulsion and Performance**

The propulsive system (motor, propeller, power source) must be selected and sized according to the requirements. An estimate of the vehicle's main performance figures (range, endurance, rate of climb, ceiling, speeds) and mission performance (speeds, times, battery energy usage, etc.) must be carried out.

#### **9.5. Structure and Materials**

The type of structure and materials for the different components of the vehicle must be selected and thoroughly defined keeping in mind their configuration and function. Connections among components and assembling/disassembling requirements must be devised. Preliminary sizing of the wing should be addressed. A database containing such data as suppliers, physical characteristics, mechanical characteristics, and price of all materials selected must be produced. Estimates of weight and balance must also be performed.

#### **9.6. 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 cables routing 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, mass, power consumption and price of all selected components must be produced.

#### **9.7. Manufacturing and Costs**

A study on the manufacturing processes to be used in the main structural components needs to be carried out. An estimate of the total cost of the UAV, based on the number of units to be produced should be obtained.

#### **9.8. Operations and Costs**

Based on the proposed CONOPS, one or more operational scenarios for an operator to use the designed UAV or a fleet of several UAVs should be devised together with estimates of the costs and gains associated with those operational scenarios.

#### **9.9. Structural Sizing**

Preliminary sizing of the main components (wings, tails, fuselage and landing gear) are to be performed based on the structural concepts proposed in the Structure and Materials task.

### 9.10. Time plan

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

Month	F	F	M	M	M	M	A	A	A	A	M	M	M	M	M	J	J	J	J	J
Task \ Week	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Lectures																				
Concept of operations																				
Layout																				
Aerodynamics/Stability																				
Propulsion/Performance																				
Structure/Materials																				
Systems																				
Manufacturing/Costs																				
Operations/Costs																				
Structural Sizing																				
Test																				
Presentations																				
Report																				
Exams																				

Legend:

- Lectures
- Design work
- Weeks without lectures
- Assessment

### 9.11. Design Teams

The design is carried out by groups of 5 students who need to perform mandatory tasks 1 to 6. If, for any well justified reason, groups have 6 students one additional task from tasks 7 to 9 must be selected. All students should work hard for the project objectives to be fulfilled in time.

	Student's Name	Nº	Team	E-mail	Task
01	Pedro Moreira	48317	A		layout
02	Bernardo Guerreiro	48428	A		aerodynamics/stability
03	Alexandre Teixeira	47710	A		propulsion/performance
04	Miguel Albino	47808	A		structures/materials
05	Maria Fernandes	47978	A		systems
06	André Sousa	48185	A		operations/costs
07	Mafalda Assis		B		layout
08	Diogo Garcia		B		aerodynamics/stability
09	Mariana Peixoto		B		propulsion/performance
10	Pedro Rafeiro		B		structures/materials
11	Martim Vitório		B		systems
12	Leonor Almeida		B		
13	Afonso Gamboa		C		layout
14	Diogo Pinho		C		aerodynamics/stability
15	Anton Mamus		C		propulsion/performance
16	Beatriz Gonçalves		C		structures/materials
17	Miguel Ruivo		C		systems
18	Pedro Leite		C		manufacturing/costs
19	Breno Cabral	48334	D		layout

20	Alexandre Pereira	48502	D		aerodynamics/stability
21	Sebastião Ventura	47768	D		propulsion/performance
22	Fernando Afonso	48175	D		structures/materials
23	Francisco Albuquerque	48220	D		systems
24	Guilherme Martins	48007	D		operations/costs
25	Raúl Santos	48558	E		layout
26	Fernando Faria	48082	E		aerodynamics/stability
27	Francisco Ribeiro	48089	E		propulsion/performance
28	Henrique Vieira	47797	E		structures/materials
29	Gonçalo Dias	48008	E		systems
30	João Ramalhosa	47946	E		manufacturing/costs
31	Luís Almada	48808	F		layout
32	Daniel Câmara	47795	F		aerodynamics/stability
33	Octávio Lopes	48508	F		propulsion/performance
34	Gonçalo Moreira	48327	F		structures/materials
35	Isabel Gomes	47822	F		systems
36	Diogo Santos	53236	F		manufacturing/costs
37	Guilherme Rebelo	48107	G		layout
38	André Tomaz	48108	G		aerodynamics/stability
39	Cristina Martins	48392	G		propulsion/performance
40	Lara Sampaio	47835	G		structures/materials
41	Tomás Carneiro	47964	G		systems
42	Rodrigo Silva	48599	G		operations/costs

## 10. ASSESSMENT

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

### 10.1. Test

The test covers all the topics discussed during classes up to the date of the test (23 May 2024, 18:00 – week 14). The test is divided into two parts: the first is closed book and the second is open book.

### 10.2. Presentations

There will be 3 oral presentations: one for the concept of operations (14 March 2024 – week 4); one for the conceptual design (18 April 2024 – week 9); and one for the complete design (3 & 6 June 2024 – week 16). In the presentations, each design team (all elements of the team must participate in the presentations) must describe its concepts, design philosophy, analyses, and results. The first and second presentations should take only 10 to 12 minutes each while the last presentation should take 20 to 24 minutes, depending on the number of teams. The presentation files in *pdf* format should be forwarded to the professor (pgamboa@ubi.pt) at the end of each presentation session.

All presentations will be assessed based on:

- Oral expression and quality of the information on the slides.
- Relevance and scope of the presented information.
- Objectivity and coherence of the discussed topics.
- Adequate understanding of the discussed matters and knowledge of the design.
- Technical content.

- Replies to audience questions.
- Usage of the available time.

### 10.3. Report

Each team must write up a design report that should contain all relevant steps taken in the aircraft design process. A typical structure of the report would include the following:

- Introduction: presentation of the requirements, objectives of the design, and the team members' tasks.
- Concept of operations: presentation of the concept of operations devised to perform the mission.
- Conceptual Design: short description of the state-of-the-art relevant to the design, initial sizing based on the state-of-the-art, description and justification of the main features and innovations in the design – layout, aerodynamics, propulsion, structure and systems concepts (drawings should be used to illustrate these concepts).
- Preliminary Design: presentation of analyses and sizing – aerodynamics and stability properties; propulsion and performance estimates, weight and balance calculations (mass breakdown of the aircraft, including reasonable estimates for each major component), cost analysis, optimization studies, manufacturing, operations – and three-view general arrangement drawing of the design with all major dimensions and aircraft characteristics.
- Conclusions: summary of design outcomes based on the objectives.
- References: list of literature sources used in the report.
- Appendices: presentation of complementary data, drawings, and analyses.

The number of pages is limited to around 30, using letter size 10-12, depending on letter type, single line spacing and 20 mm left and right margins. The report in *pdf* format should be forwarded to the professor (pgamboa@ubi.pt) at the last day of lectures (07 June 2024 – week 16).

### 10.4. 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 18 and/or 20.

### 10.5. Grade

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

1.	Frequência ( $F = 0.3T + 0.2P + 0.5R$ )			100
T	Test	23-05-2024 (18h00)	30	
P	Presentations	11-03-2024 ; 18-04-2024 ; 03 & 06-06-2024	20	
R	Report	07-06-2024 (24h00)	50	
2.	Exam ( $E = 0.3T + 0.2P + 0.5 R1$ )			100
R1	Report ( <i>época normal</i> )	??-06-2024 (??h30)	50	
R1	Report ( <i>época recurso</i> )	??-07-2024 (??h30)	50	

3.	Exam ( $E = 0.3T + 0.2P + 0.5 R2$ )	100
R2	Report ( <i>época especial</i> )	50

## 11. BIBLIOGRAPHY

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.

### 11.1. Notes

00. Gamboa. P.V., Apontamentos de Projeto de Aeronaves, ~600 acetatos, UBI, 2024

### 11.2. Textbook

01. Raymer, D. P., *Aircraft Design: A Conceptual Approach* – 5th edition, AIAA Education Series, 2012

### 11.3. Aircraft Design Books

02. Gudmundsson, S., *General Aviation Aircraft Design: Applied Methods and Procedures*, Elsevier, 2014.  
 03. Torenbeek, E., *Advanced Aircraft Design: Conceptual Design, Analysis and Optimization of Subsonic Civil Airplanes*, Hoboken, New Jersey: John Wiley & Sons, 2013.  
 04. Gundlach, J., *Designing Unmanned Aircraft Systems: A Comprehensive Approach*, AIAA Education Series, 2012  
 05. Jenkinson, Lloyd R., Marchman III, James F., *Aircraft Design Projects for Engineering Students*, Butterworth-Heinemann, 2003  
 06. Corke, T. C., *Design of Aircraft*, Pearson Education, Inc., 2003  
 07. Howe, D., *Aircraft Conceptual Design Synthesis*, Professional Engineering Publishing, 2000  
 08. Jenkinson, L. R., Simpkin, P., Rhodes, D., *Civil Jet Aircraft Design*, Arnold, 1999  
 09. Brandt, S. A., Stiles, R. J., Bertin, J. J., Whitford, R., *Introduction to Aeronautics: A Design Perspective*, AIAA Education Series, 1997  
 10. Roskam, J., *Airplane Design* – Volumes I to VIII, The University of Kansas, 1990  
 11. Stinton, D., *The Design of the Aeroplane*, Blackwell Science, 1983  
 12. Torenbeek E., *Synthesis of Subsonic Airplane Design*, Delft University Press, 1982  
 13. Barros, C., *Introdução ao Projecto de Aeronaves* – Volumes 1 & 2, CEA/UFMG, 1979  
 14. Pazmany, L., *Light Airplane Design*, Pazmany Aircraft Corporation, 1963

### 11.4. Other Books

15. Abbot & Doenhoff, *Theory of Wing Sections*, Dover Publications Inc, 1959  
 16. Barnaby Wainfan, *Airfoil Selection – Understanding and Choosing Airfoils for Light Aircraft*, 1988  
 17. Barnes W. McCormick, *Aerodynamics, Aeronautics and Flight Mechanics* – 2nd edition, John Wiley & Sons Inc, 1995

18. Bernard Etkin, Lloyd Duff Reid, *Dynamics of Flight, Stability and Control* – 3rd edition, John Wiley & Sons Inc., 1996
19. Bill Clarke, *The Cessna 172* – 2nd edition, Tab Books, 1993
20. Darrol Stinton, *Flying Qualities and Flight Testing of the Airplane*, AIAA Education Series, 1996
21. David A. Lombardo, *Aircraft Systems – Understanding Your Airplane*, Tab Books, 1988
22. Euroavia, *Future Trainer Concept*, 1999
23. Geoff Jones, *Building and Flying Your Own Plane*, Patrick Stephens Limited, 1992
24. Ian Moir & Allan Seabridge, *Aircraft Systems*, Longman Scientific & Technical, 1992
25. *Jane's All the World Aircraft*, 1995
26. Certification Specifications for Light Sport Aeroplanes (CS-LSA), Initial Airworthiness, EASA, 2011, and Amendment 1 (2013)
27. Certification Specifications for Very Light Aeroplanes (CS-VLA), Initial Airworthiness, EASA, 2003, and Amendments 1 to 5 (2009 to 2017)
28. Certification Specifications for Normal, Utility, Aerobatic and Commuter Aeroplanes (CS-23), Initial Airworthiness, EASA, 2003, and Amendments 1 to 5 (2009 to 2020)
29. Ladislao Pazmany, *Landing Gear Design for Light Aircraft* – Volumes I & II, Pazmany Aircraft Corporation, 1986
30. John Cutler, *Understanding Aircraft Structures*, Blackwell Science, 1999
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