PROJETO DE AERONAVES
AIRCRAFT DESIGN – 10403

2021/2022

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 transmitted orally 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 about the design progress are made throughout the semester. A large volume of this work has to be performed outside the class period due to the considerable amount of work required. This project allows the student to develop analytical and synthesis skills, also using knowledge acquired in other curricular units, and to acquire critical decision skills and teamwork 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

PART II
THE DESIGN PROJECT

Autonomous Air Vehicle for Urban Air Mobility

AAV-21

6. INTRODUCTION

The international aerospace sector has been increasingly using 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 advancement 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 much more attractive cost-benefit ratio. 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 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 the past 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, ultralight and general aviation 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.

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.

7. REQUIREMENTS

The current requirements present a need for an autonomous air vehicle (AAV) with the capability to perform vertical landing, take-off and hover and to fly efficiently within urban areas to transport a passenger or cargo over a maximum distance of 50 km. The requirements for this aircraft are listed below and during the development of the project they must be respected. Possible changes in the requirements will be discussed and agreed upon by the professor and all teams involved in the project.

It is required to perform the conceptual and preliminary design of the AAV considering 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, reliability, and ease of repair are essential to maintain high levels of operational readiness of the AAV.

7.1. Mission

The AAV must be designed for the following mission: it must take-off vertically from a small yard or roof top by its own means, transition to horizontal flight, then climb to a cruise altitude of no more than 250 m, fly for up to 50 km, land vertically at the destination, drop the passenger or the transported cargo, and finally return back to base. The objective of the operation is to transport people within or deliver cargo within an urban area to avoid surface traffic. The payload is a combination of one person and cargo with a mass of up to 100 kg. The turnaround time should be as low as possible yet less than 15 minutes to allow for urgent cargo dispatching.

7.2. Performance

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

Take-off	vertical
Cruise speed	above 80 km/h
Maximum speed	at least 120 km/h
Flight operational radius	50 km
Data link range	at least 50 km
Service ceiling	500 m
Landing	vertical

7.3. Propulsion

Electric motors and/or piston engines may be selected for this AAV. The possibility of using a hybrid propulsion system should be considered for improved flexibility and increased range. The propellers must be selected according to the motor/engine performance and AAV performance required both in vertical and horizontal flight. 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 specific operational needs. The batteries must be sized to provide both the required maximum power and endurance and can be complemented with photovoltaic cells.

7.4. 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 transition and high-speed flight and have 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.

7.5. Fuselage

The fuselage should be slender and light yet possess the necessary internal space for systems, passenger, and payload. It should have high tolerance on payload weight. Equipment substitution and payload access should be quick and simple to perform. A separate pod for the passenger and payload may be considered. The passenger and payload compartment should be capable of carrying those in a proper arrangement with minimum impact on the centre of gravity (CG) position.

7.6. Tail

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

7.7. Landing Gear

The UAV-16 must have a rugged but simple landing gear. The use of a retractable gear may be used but it should only be selected if the overall performance of the UAV is improved over a fixed one.

7.8. Payload

The payload (up to 100 kg) is made of a combination of one passenger and cargo. I must be well secured in the fuselage or pod to avoid any movement during flight. It must be guaranteed that all systems work well in a wide range of temperatures from negative to positive. Heating and cooling may be required for the passenger. Adequate power and entertaining devices can be provided for the full duration of the flight.

7.9. Weight and Balance

The CG travel must be such that no negative impact on the stability or on the normal operation of the AAV is imposed for any payload weight transported on board. It is important that the maximum take-off mass of the AAV is kept as low as possible. The vehicle should be capable of flying with partial load payloads.

7.10. 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 actuated by reliable servo mechanisms. 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 which can be charged by fuel-fed generator.

7.11. 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, reliability, and performance.

8. 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.

8.1. 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.

8.2. 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.

8.3. 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.

8.4. 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 performance (speeds, times, battery, and solar energy usage, etc.) must be carried out.

8.5. 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 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 components selected must be produced.

8.6. 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.

8.7. Time plan

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

Month	S	S	O	O	O	O	N	N	N	N	N	D	D	D	D	J	J	J	J	F	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	20	27	04	11	18	25	01	08	15	22	29	06	13				03	10				
Concept of operations																						
Layout																						
Aerodynamics/Stability																						
Propulsion/Performance																						
Systems																						
Structure/Materials																						
Test																						
Presentations																						
Report																						
Exams																						

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

8.8. Design Teams

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

	Student's Name	Nº	Team	E-mail	Task
01	Miguel Vasconcelos		A		layout
02	André Lopes		A		aerodynamics/stability
03	Guilherme Almeida	39429	A	guilherme.almeida@ubi.pt	propulsion/performance
04	José Medeiros		A		systems
05	Guilherme Guerreiro	40007	A	guilherme.guerreiro@ubi.pt	structures/materials
05	Alba Fernandéz		A	alba.gomezf@alumnos.upm.es	all
06	João Santos	39544	B		layout
07	Rodrigo Correia	39925	B		aerodynamics/stability
08	André Mendes	39455	B	andre.mendes@ubi.pt	propulsion/performance
09	Carlota Morais	39456	B		systems
10	Pedro Belizário	40454	B		structures/materials
11	Gilberto Correia	40156	C		layout
12	Isidro Pereira	39391	C		aerodynamics/stability
13	João Amaral	37122	C		propulsion/performance
14	Luís Andrade	39377	C	gabriel.andrade@ubi.pt	systems
15	Joana Silva	39833	C		structures/materials
16	Nuno Neto	39438	D		layout
17	Ricardo Abreu	39836	D		aerodynamics/stability
18	Inês Varandas	40471	D	henrique.alves@ubi.pt	propulsion/performance
19	Maria Leite	39994	D		systems

20	Henrique Alves	39412	D		structures/materials
21	Samuel Prata	37001	E		layout
22	Edmar Lopes	40077	E		aerodynamics/stability
23	Danilo Garcia	40286	E	danilo.semedo.garcia@ubi.pt	propulsion/performance
24	Marcos Lopes	36280	E		systems
25	Gerson Fernandes	42754	E		structures/materials
26	Luís Ferreira	39049	F	luis.manuel.ferreira@ubi.pt	layout
27	Francisco Monteiro	39264	F	francisco.monteiro@ubi.pt	aerodynamics/stability
28	Inês Pereirinha	39874	F	ines.pereirinha@ubi.pt	propulsion/performance
29	Diana Martins	39704	F	diana.isabel.martins@ubi.pt	systems
30	João Vale	39277	F	joao.pedro.vale@ubi.pt	structures/materials
31	Vítor Silva	39098	G	vapsilva0@gmail.com	layout
32	João Pinho	39680	G	joao.pinho@ubi.pt	aerodynamics/stability
33	Bernardo Girão	41785	G	bennygiro99@gmail.com	propulsion/performance
34	Samuel Goulart	39598	G	samuel.goulart@ubi.pt	systems
35	Alexandre Reis	39301	G	alexandre.reis@ubi.pt	structures/materials
36			H		layout
37	Inês Carriço	39026	H		aerodynamics/stability
38	João Fonseca	38982	H		propulsion/performance
39	José Carrito	26801	H		systems
40	Luís Costa	38985	H		structures/materials
41	Jeremy Silva	39359	I		layout
42	Júlio Santos	39900	I		aerodynamics/stability
43	Ana Belas		I		propulsion/performance
44	Miguel Silveira		I		systems
45	Lara Cardoso		I		structures/materials

9. ASSESSMENT

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

9.1. Test

The test covers all the topics discussed during classes up to the date of the test (13 December 2021 – week 13). The test is divided into two parts: the first is closed book and the second is open book.

9.2. Presentations

There will be 3 oral presentations: one for the concept of operations (11 October 2021 – week 4); one for the conceptual design (15 November 2021 – week 9); and one for the complete design (10 January 2022 – week 16). In the presentations, each design team (all elements of the team must participate in the presentation) must describe to the other teams its concepts, design philosophy, analyses, and results. The first and second presentations should take only 5 minutes each while the last presentation should take 20-30 minutes, depending on the number of teams. The presentation files should be handed in 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 developed design; usage of the available time; and technical content.

9.3. Report

Each team must write up a design report that should contain all relevant steps taken in the UAV design process, including concept of operations, layout, decisions made, major calculations, results, etc. Sketches necessary to fully understand the design and a three-view technical 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 (21 January 2022 – week 17).

9.4. 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 and/or 21.

9.5. 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	13-12-2021 (14h30)	30
P	Presentations	11-10-2021 ; 15-11-2021 ; 10-01-2022 (14h30)	20
R	Report	21-01-2022 (24h00)	50
2.	Exam (E = 0.3T + 0.2P +0.5 R1)		100
R1	Report (normal period)	??-02-2022 (??h30)	50
R1	Report (recourse period)	??-02-2022 (??h30)	50
3.	Exam (E = 0.3T + 0.2P +0.5 R2)		100
R2	Report (special period)	??-07-2022 (??h30)	50

10. 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.

10.1. Notes

00. Gamboa. P.V., Apontamentos de Projeto de Aeronaves, ~600 acetatos, UBI, 2020

10.2. Text Book

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

Series, 2012

10.3. 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

10.4. 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

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