Systems integration in a UAS design

An example of undergraduate students' tasks

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Abstract— **Systems integration is the origin of most major difficulties found in the engineering design of aeronautical vehicles. The whole design team must assure that each subsystem accomplishes its particular goals and that, together with the rest of the systems, they all meet the general aircraft requirements. Design and building of UAS is a field of actuation to which leading Universities, research Centers and Aeronautical designers have dedicated a lot of effort. In recent years, a team of students, lecturers and professors at the Escuela Universitaria de Ingeniería Técnica Aeronáutica (EUITA) have been working on the design and building of a UAS for civil observation. The design of multi-mission Unmanned Aerial Vehicles (UAVs) has seen a rapid progress in the last years. A wide variety of designs and applications, some of them really ingenious, have been proposed. The project, which has been going on as a teamwork experience for the last ten years, consists of the design and building of a UAV, and its peculiarity is that it has been carried out entirely by undergraduate students, as part of their Final Research Project. The students face a challenge that includes all the features and stages of an authentic engineering project. We present the current moment of evolution in the process, together with a description of the main difficulties the project has undergone, as a global experience in engineering design and development.**

Keywords-component; UAS design; systems integration; undergraduate students; experience; design

I. SUMMARY

UAVs are inducing quite significant changes in software for design optimization of some subsystems, such as: reconnaissance sensors [8], communication of data and images [5], [10], [16], [31] terrain segmentation [5], etc. Consequently an investigation is needed on the way to merge, the shape [1], [7], the mission [24], the payload [23] and certain aerodynamic parameters [28], [7] in order to meet the present-day demands for airworthiness requirements [39], [41].

The experience of the authors is in the area of design and construction of UAVs for civil applications, for both fixed and rotary wings. In the UAV design and manufacturing areas, they have directed a group of students to design and build a real UAV; in that sense, the following articles can be consulted [11], [29].

Other universities present similar activities carried by undergraduate students [4], [6], [18], [19].

The concept "rapid prototyping" (quick prototype generation) is widespread in conceptual design processes and prototype design applied to engineering and other branches of applied sciences. There are whole books oriented to this concept; in some cases with an entire chapter dedicated to aerospace engineering [2]. It has also been used, as in the case of the authors, to generate airfoils to be tested in aerodynamic tunnel [12].

International research centers have been also sensible to this kind of tools; the reports [9], [13], [14], [20], [33], [34], [36] show interesting aspect of this technique.

In the design and building process of a UAV (or any aircraft) the concept of system integration in the cell is of the utmost importance. In that sense, we recommend to look through [1], [27].

Development of real time acquisition and management of on board data plays an important role [20]. Interesting applications of real time data acquisition systems are addressed in [16], [17]. Other applications, such as those presented in [26] refer to micro-UAVs. The solutions presented in [16] show the method of integrating several sensors in small rotorcrafts.

This paper presents the whole evolution of the project, from the design stage to the collection of data after the first flight. Quite an important part of the paper deals with the aerospace engineering aspect involved in the design and building of the UAV. The rest of the paper is dedicated to the role of the students in the development of the project, and to the objectives we intent to reach with their participation.

II. INTRODUCTION

It is not infrequent for Academic Research Centres, especially Engineering Schools, to offer students the opportunity to collaborate in developing projects for the design and building of prototypes. In this respect, our proposal does not differ much from the rule. We have not set out to establish a new mark or conquer a pre-established level, either. We consider that the challenge of placing the responsibility for the whole project in the hands of the students, who were carrying out their End of Degree Project would be valuable in its own right, because it would imply nothing less than their being responsible for the conceptual and preliminary design, the manufacturing, the assembly and finishing of an Unmanned Aerial Vehicle (UAV). Eight years have gone by since the starting point and we are now in a position to state that it has been a truly rewarding experience and that we can now see the flight of the UAV on the horizon.

The project – on the small scale- has swept through all the different stages of an aerospace project: state of the art analysis, definition of the requirements, preliminary design, technical feasibility study, design-building-assembly of the different structural components and systems, fitting and first flights

Particular attention deserves the use of rapid prototyping for the building of skin surfaces and inlets whose manufacturing without this procedure would have required the kind of processes students would be unable to develop.

The development of the project also implied focusing on some others fields related to some particular students' competences and skills, such as manual skill for manufacturing and assembly, leadership and coordination, schematics and drawings interpretation, oral communication, subject knowledge in other areas (electricity and electronics among others) materials selection according to the requirements, determining the technical specifications of a system.

III. STAGES OF THE PROJECT

A. General Considerations and UAV's Mission

Nowadays UAVs present a very wide variety of types and characteristics. The differences are not only in their geometry or configuration but also in performance. There are UAVs of over 14 tons of weight and able to carry more than 1,300kgs payload while there are others which can be carried in one's hand and manually launched. There is even a wide range of small dimensions micro- UAVs which can fly indoors.

Firstly, because of this variety in the designs and applications of present UAVs, it is quite complex to establish a unique classification. Of all possible classifications we have chosen the one shown in table which is included in [41].

TABLE I.   UAS CLASSIFICATION

UAS	Range (Km)	Flight altitude (m)	Endurance (h)	Maximum take-off weight (Kg)
Stratospheric	> 2.000	20.000 - 30.000	48	< 3.000
High altitude and long endurance (HALE)	> 2.000	20.000	48	15.000
Medium altitude and long endurance (MALE)	> 500	14.000	24 - 48	1.500
Low altitude and long endurance (LALE)	> 500	3.000	Approx 24	Approx 30
Low altitude and deep penetration (LADP)	> 250	50 - 9.000	0,25 - 1	350
Medium range	70 to > 500	8.000	6 - 18	1.250
Short range	10 – 70	3.000	3 – 6	200
Mini	< 10	< 300	< 2	< 30
Micro	< 10	< 250	1	< 1

The range of configurations available for UAVs/UAS' cells is as wide as that for their designs o even wider. It should be taken into account that UAVs' cells are generally much smaller than manned aircraft and that potential operators are more willing to accept unconventional solutions.

Runway actuations (take off/landing procedures) is a very convenient criteria for UAS classification [22].

The configurations are the following:

a) Horizontal Take-off and Landing, (HTOL).

b) Vertical Take-off and Landing, (VTOL).

c) Hybrid configurations.

B. Initial Layout

The aim of the project is to design a UAV for civil aerial observation, namely, the surveillance of mountain areas in order to detect potential fire risks.

Once its mission has been defined, a wide research analysis of similar airplanes is carried out since, in the initial stage of any project, it is quite common to resort to similar airplanes, in order to calculate key data for the design. Next, the preliminary sizing is undertaken, taking as a basis weight and wing loading calculations, the latter parameter being essential because it will

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allow us to study one of the most important elements of the plane: the wing.

The objective of the first work team was to establish an initial airplane layout, taking into account that many modifications would be incorporated during the development of the project.

Prior to the preliminary sizing, another group of students were engaged in the study of similar airplanes. In this way, we were able to compare common features shared by different aircraft and to calculate, at this first stage, numerical values which were needed for the pre-design.

This wide study of similar aircraft has been developed considering the minimum evaluable variables [15] in the UAVs of reference. In this way we could compare common features of the aircraft and to estimate the numerical values which are necessary for the pre-design stage.

With these requirements, the first group of students defines a baseline for the aircraft as the one shown in the figure.
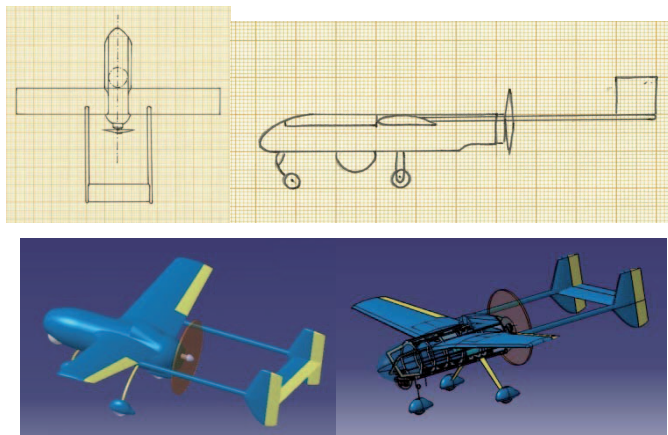
Figure 1. Initial configuration

After defining the configuration, the preliminary sizing study [25], [28], [30], [37] based on similar aircraft is undertaken. The values defining the configuration and the conceptual design of the aircraft are, among others, the following

By comparing and studying similar aircraft, the basic geometry as well as the values for maximum takeoff weight, empty weight and payload are defined.

The main values for similar aircraft are the following

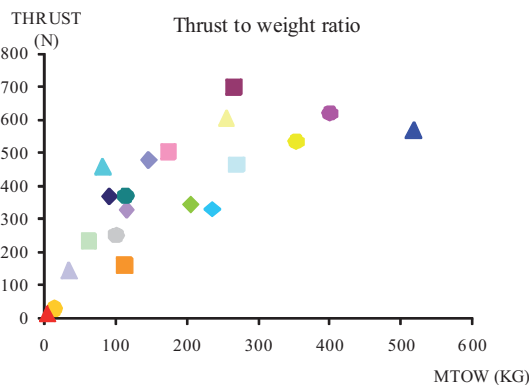- PL (payload) vs MTOW.
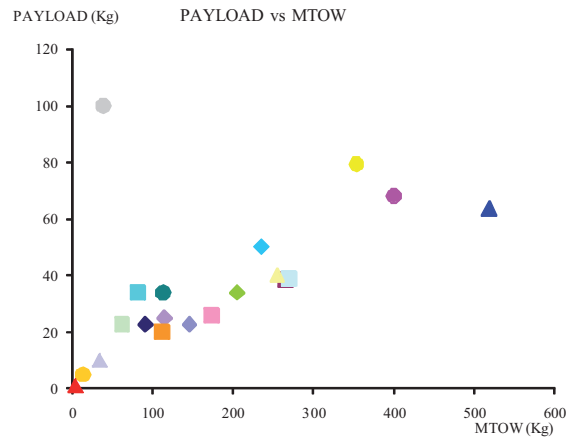- (Tto/MTOW) vs MTOW.

Figure 2. Weight to thrust ratio vs MTOW

Figure 3. Payload vs MTOW

From similar values, and taking into account the predetermined requirements, we get the following values:

1) Weight definition:

   a) MTOW = 30 Kg

   b) WE (empty weight)= 13Kg

   c) WF (fuel weight)= 9 Kg

   d) WPL(payload weight) = 8 Kg

2) Payload consisting of a webcam, batterie and trasmitter to ground. Maximum weight 8Kg, approximately.

3) Estimated range of 425 to 450 Km with máximum payload and with a fuel reserve of 10%.

4) Cruising speed, around 30 to 34 m/s.

5) Flight profile:

1. Engine start and warm-up
2. Taxi
3. Take off
4. Climb
5. Cruise
6. Descent
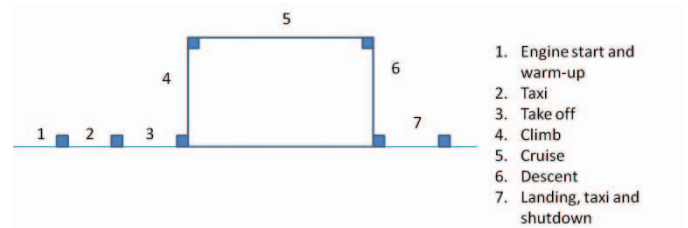7. Landing, taxi and shutdown

Figure 4. Flight profile

C. *Preliminary Structural and Aerodynamic Analysis*

The next stage in the project, after determining the preliminary configuration, was to calculate all the aerodynamic features and the aircraft's performance, so that they could later be checked and recalculated.

To complete all these steps, a sound analysis of the most important elements of the aircraft had to be performed, from the geometric and the aerodynamic points of view.

We concentrated on testing aerodynamic forces using the wind tunnel. The next figure presents the model used in wind tunnel testing of the whole aircraft.

After studying the performance, we proceeded to check dynamic and static stability, together with the aircraft control characteristics.

Once the study of the airplane from the aerodynamic point of view was completed, we had to carry out a basic structural study.

Before constructing the final prototype, and as an essential part of the whole project, we carried out a series of tests in our workshop; the didactic effect of these tests was considered essential for the entire project. We also checked the most critical structural elements by means of static load tests.

The following photos show one step in the static loading test. At this stage, the primary longeron of the wing is loaded until its collapses.

Figure 5. Loading tests until crash

D. Building the Airplane

Another key part of the static tests was the first run of the engine and the propeller-engine coupling.
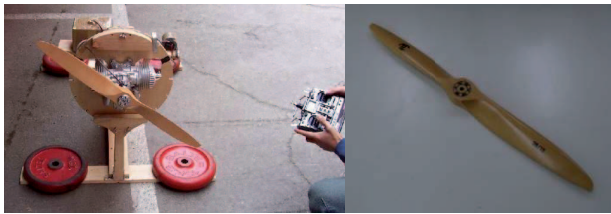

Figure 6. Propeller-engine first run

After we concluded the preliminary essential calculations, we moved forward to the detailed design and manufacturing stages. A global design was developed and we had to define materials, joining elements and fasteners.

We also include some comparisons between the initial design of the most important elements of the aircraft and the final manufactured ones.
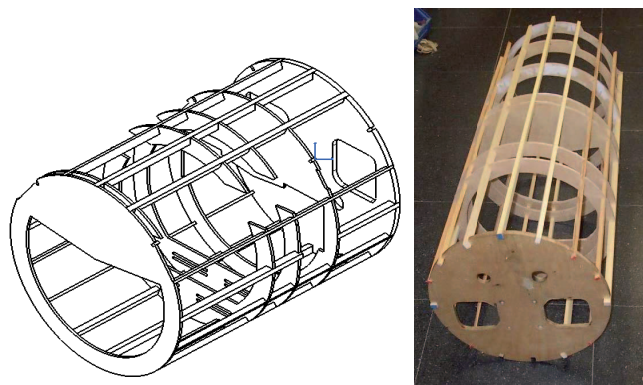

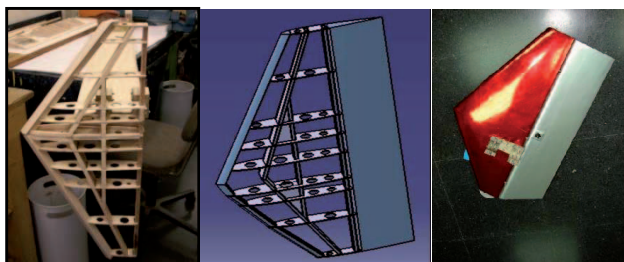Figure 7. Structural design of the fuselage

Figure 8. Comparison between design and final mounting. Fin

1) Using Rapid Prototiping (RP&M)

Rapid prototyping has been oriented, quite frequently, to the design of mechanical elements; prototyping has allow to evaluate design accuracy, complexity of the assembly process, dimensional compatibility, ergonomy based design optimization, and even structural tests, starting from previous calculus in CAD/CAM software. In addition, advanced engineering courses at the world's leading universities have oriented their classes in that sense.

Within the framework of the UAV design project, described in the previous chapter, it was addressed the design of a rapid prototype generation process for design and building some important elements of the UAV.

Some covers and aircraft fairings are designed –based on this method- like surfaces whose geometry is quite difficult to build by other methods, besides the obvious advantage of speed and versatility of assembly.

As an example of this, one of the elements manufactured using this technique is shown below: the UAV's tail-boom fairing.

Figure shows the area resulting of joining the forward and aft parts of the fairing.
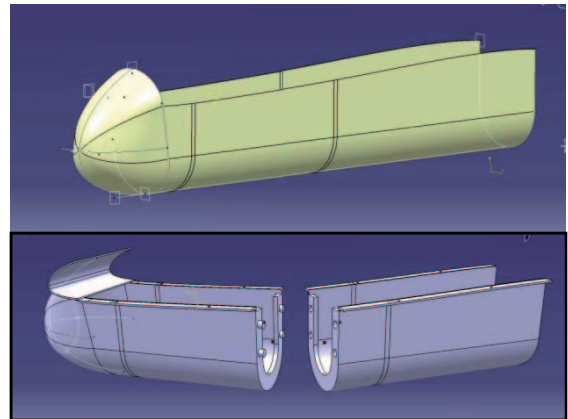

Figure 9. Preliminary design and two parts final assembly

Figure 10. Final prototype manufacturirang process

Figure 11. Fairing, placed and fixed onto the wing

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Figure 12. Final result

E. Guidance and Control

1) Introduction

In this case the objective is for the aircraft to perform a stable and controlled surveillance flight, involving take off, moving over to the surveillance area, a regular (generally, circular) flight over that area for a specific period of time, or consecutive movements overflying different areas, flying back to and landing at the starting point.

The purpose of the first stage of the Project is to be able to carry out several test flights in order to check that all major systems and components meet the requirements they were initially assigned.

In order to confirm the checks carried out, we must employ guidance and control system which meets the objectives previously defined and which, at the same time, is simple, reliable and economic.

The system selected is a radio controlled device similar to that of any remote radio-controlled model airplane but with some differences. So as to guarantee a better protection, should any aircraft component fail, we will use professional equipment with enough channels to handle more aircraft components (4 being the minimum required for any model) or to have a twin-drive guidance system (by means of duplicating the boosting mechanisms –servomechanisms, "servos").

At later stages of the project we intend to provide the vehicle with an upgraded and autonomous guidance system with a much longer range. The guidance system envisaged for the final stage of the project is an automatic control system (autopilot).

The radio controlled guidance system consists of the following components: a radio transmitter of the guidance signal, the receiver that receives and processes the signal, the servomechanisms (commonly called RC servos), the transmitter and receiver power source and the wiring or interconnection of the components. Since the antennae are supplied together with the receiver and the radio, it is unnecessary to analyze these components separately.

For proper guidance and control of a model aircraft at least 4 channels are necessary: rudder, elevator, ailerons and engine.

This configuration allows for the independent control of all the critical aircraft components, so that in the event of the failure of any of them its functions / performance could be compensated by the control of another element.

In a typical connection, both the left and the right ailerons are controlled by a single servo. This option would completely block roll control if both the channel and servo failed with the selected channel should the aileron on one wing fail, the one on the other side would maintain control of the aircraft.

Similarly, both the horizontal and the vertical stabilizers could have been controlled by means of a servo for each stabilizer.

Figure 13 shows the initial UAV model of the project, with the indication of the selected elements which a will be acted by each servo.
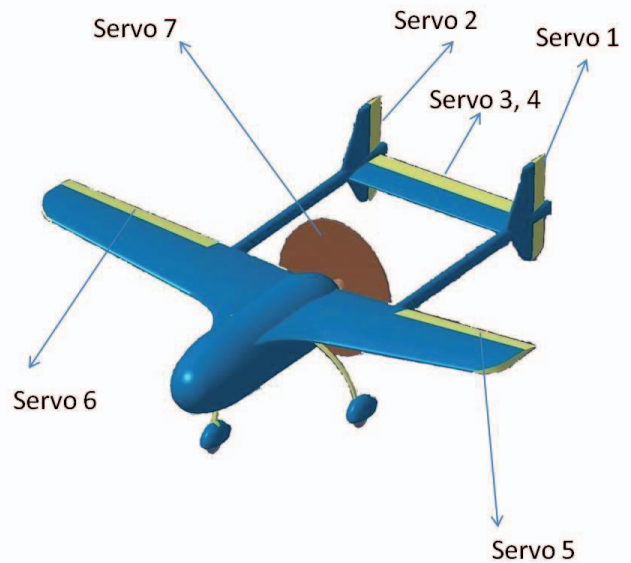

Figure 13. Virtual model showing the 7 servos configuration

F. Integration of Air Data Capture Systems

In this part of the project our aim was to develop a system capable of controlling our aircraft autonomously. For this purpose we need to measure exterior data and air-data.

We will be able to obtain static and dynamic pressure values, as well static temperatures, both from the engines and the chassis CompactRIO® (or cRIO®, realtime industrial controller made by National Instruments®)

CompactRIO® is a robust embedded system for control and and capture of data, which is used in applications requiring high performance and reliability in data sending. Furthermore, since this platform **operates in real time, it is suitable for an unmanned aircraft.**

1) CompactRIO® Technical Features

It features a real time autonomous processor, consisting of … a controller and an FPGA chassis with 4 slots for I/O modules. A photograph of the CompactRIO® fitted with all these components can be seen in Fig 14.

Figure 14. CompactRIO® 9004, with 4 modules

The chassis' slots house the modules, its assembly being fairly easy. Their working characteristics are very suitable for

use aboard a plane since they can withstand a very wide temperature and impact range.

The CompacRIO® version which we have used to carry out this project corresponds to the group of "Reconfigurable Embedded Systems", using a technology known as RIO.

The following modules are available: 1 Module 9205 with analogical input, and 3 Modules 9401 with digital input/output.

2) Fundamentals of Air Data Systems

Air data system supplies information about the variables corresponding to altitude based on pressure, rate of climb, calibrated air speed, true air speed, mach number, static air temperature, and density ratio.

All the calculations -with the air data system information- are made with microprocessors and the corresponding software; in our case, using LabView© (National Instruments®).

3) Sensors for use for data acquisition

As we have explained above, for flight data acquisition, we will have at our disposal some types of sensors. These sensors will be connected with the corresponding unit in the CompactRIO chassis.

4) Final result

In the following figure we show the entire Block Diagram carried out to display altitude, speed, temperature, mach number, engine temperature.
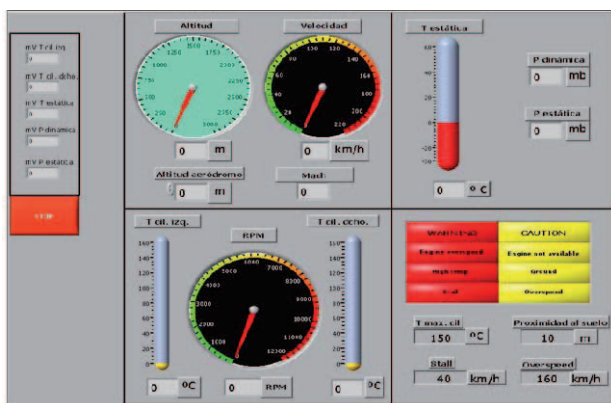

Figure 15. Final Front Panel

IV. ACQUISITION OF THE GENERIC COMPETENCES

When we first thought of designing and building a UAV at the EUIT Aeronáutica, in the last years of the previous century, our aim was basically the achievement of various engineering objectives, such as: to acquire the technological knowledge in this field, to propose some modest innovations for processes and procedures, to apply our knowledge to a wholly aeronautical project, to develop our own design of the cell and to create the software for managing its flight.

We conceived the Project to be developed entirely by final year students [32], [35], [40] so that each of their End of Degree Projectworks would constitute a part of the general Project. From this it logically followed that, once the initial stages had started, it was clear that the project offered another research perspective in addition to the one originally proposed. This was related to the development of the skills and competences that the students needed to acquire if they were to carry out the Project successfully.

The first question to be answered with respect to the acquisition of the generic competences was precisely which were the competences to be acquired.

The answer was contained in two reference documents of absolute relevance for the teaching of aeronautical engineering at the present moment in Spain, the Tuning Project (Tuning Educational Structures in Europe, [38]) and the Libro Blanco de la Ingeniería Aeronáutica en España [21] (White paper on Aeronautical Engineering in Spain).

The second of these two documents establishes the definition framework for future aeronautical engineering courses in Spain. When dealing with the competences an aeronautical engineer has to acquire, the Libro Blanco echoes some of the words on which the Bologna Process has been built:

" ...professional competences are characterized by constituting a full network of knowledge, procedures, skills and attitudes complementing each other so that the graduate has to "know to do" "to learn to know" "to learn to be" if he wants to act efficiently when facing professional challenges"

This document also establishes those competences which are considered the most valuable for the professional career of an engineer. Some of them are, in fact, related to those a student of engineering has to develop in the process of carrying out his/her End of Degree Projectwork: planning and time management, problem-solving, capacity for analysis and synthesis, knowledge of a second language, teamwork, ability to work in an interdisciplinary team, concern for quality, oral and written communication in his/her mother tongue, decision-making, critical and self-critical abilities, interpersonal skills and environmental concern. Of all these, the last is the only one not mentioned in the Tuning Project's list of generic competences.

V. CONCLUSIONS

It has already been stated that the initial aim of our Project was the design and building of a UAV, as a purely engineering task. However, the evolution of the students' involvement in the project along these years has led us to a point where, while being still important, the initial aim is not more important than the development of the learning environment, which is essential for the acquisition of generic competences.

The End of Degree Projectwork has traditionally been considered as a very valuable teaching instrument. It facilitates the development of an integrative process where students have to apply all the knowledge they have acquired along their course. The development of our project has shown that it can also be used for the acquisition and assessment of generic competences, which otherwise would be difficult to acquire and evaluate in an engineering course.

The students, who will be starting their professional career three or four months after completing their End of Degree Projectwork, will bring to their first job not only a high level of engineering knowledge but also some experience in the application of general competences.

The students, being fully aware of how important these competences are for the development of their careers, value very positively the opportunity they have been given to develop them.

Nothing would have been done without the enthusiasm and the dedication of all the students who have taken part in the project.

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VI. References

[1] Austin, R. Unmanned *Aircraft Systems. UAVS Design, Development and Deployement.*Chichester, Reino Unido, John Wiley & Sons Ltd. 2010.

[2] Blake, P., & Baumgardner, O. "Texas Instruments: An aerospace case study" in *Rapid prototyping & manufacturing: fundamentals of stereolithography*, P. F. Jacbs, 2003, pp. 434.

[3] Bloom, B.S. *Taxonomy of Educational Objectives Handbook 1: Cognitive domain*. Longman, Green & Company, New York, 1956.

[4] Brown, D., Collins, C., McClure, D., Meriden, A.A., Profitt, P., Smith, M., Yadack, V. "University of Kentucky Aerial Robotics Team: 2006 AUVSI Student UAV Competition Design". University of Kentucky, Lexington.

[5] Cárdenas, E. M., Boschetti, P. J., Amerio, A., and Velásquez, C. D., "Design of an Unmanned Aerial Vehicle for Ecological Conservation," AIAA Paper 2005-7056, Sep. 2005.

[6] B. Chartier, B. Gibson."Project-Based Learning: A Search and Rescue UAV - Perceptions of an Undergraduate Engineering Design Team: A Preliminary Study" in Proc. in *18th Annual Conference of the Australasian Association for Engineering Education*, 2007.

[7] Cuerno-Rejado, C., Alonso-Albir, L., G. "Conceptual design of a medium-sized joined-wing aircraft". Proc. Inst. Mech. Engs. Part G, Journal of Aerospace Engineering 2010, pp. in press.

[8] Davis WR, Kosicki BB, Boroson DM, Kostishack DF. "Micro air vehicles for optical surveillance". The Lincoln Laboratory J 1996;9:197-214.

[9] deWeck O.L., Kim I. Y., Graff C., Nadir W., Bell A.. "Engineering design and rapid prototyping: A rewarding CAD/CAE/CAM and CDIO experience for undergraduates". *1st Annual CDIO Conference*. Queen's University. Kingston, Ontario, Canada. June 7 to 8, 2005.

[10] Ettinger, S. M., Nechyba, M. C., Ifju, P. G., & Waszak, M.. "Vision-guided flight stability and control for micro air vehicles". Advanced Robotics , vol. 17, nº 7, 617-640, 2003.

[11] Gandía-Agüera, F., Rodríguez-Sevillano, A. A., Barcala-Montejano, M. A., & Pérez-Álvarez, J. (2008). "The design and building of an UAV: an actual engineering project for student cooperative work". *International Technology, Education and Development Conference (INTED)*. Valencia, 3-5 March.

[12] Gómez-Pérez, J. P., Rodríguez-Sevillano, A. A., Gómez-Pérez, I., Gandía-Agüera, F., & Barcala-Montejano, M. A. "Airfoil Rapid Prototyping for UAV Aerodynamics Modelling, Wind Tunnel, Simulation and Flight Test". *EUCASS*. Versalles, 2009.

[13] Heyes, A. L., & Smith, D. A. " Rapid Technique for Wind-Tunnel Model Manufacture". Journal of Aircraft , 41 (2), 413-415, 2004.

[14] Jacobs, P. F., & Reid, D. T. "Rapid prototyping & manufacturing: fundamentals of stereolithography". Computer and Automated Systems Association of SME, 1992.

[15] *JAR 22. Sailplanes and powered sailplanes*. Cheltenham, UK: Civil Aviation Authority, 1987.

[16] Kim, H. J., & Shim, D. H. "A flight control system for aerial robots:algorithms and experiments". Control Engineering Practice , 11, 1389-1400, 2003.

[17] Kitts, C., Quinn, N., Ota, J., Stang, P., and Palmintier, B. "Development and Teleoperation of Robotic Vehicles". Proceedings of the *2nd AIAA "Unmanned Unlimited" Systems, Technologies and Operations Conference*, 2003.

[18] Kitts, C., and Quinn, N., "An Interdisciplinary Field Robotics Program for Undergraduate Computer Science and Engineering Education", *ACM Journal on Educational Resources in Computing*, June 2004, 4, 2, pp 1-22.

[19] LaBerteaux, J., Moesta, J., Bernard, B. "Advanced Picosatellite Experiment". IEEE Aerospace and Electronic Systems Magazine. Volume: 24. Issue: 9. Pages: 4-9. Published: SEP 2009.

[20] Landrum, B., Beardt, R. M., LaSar, P. A., & von Sprecken, N. "Evaluation of stereolithography rapid prototyping". *Aerospace Sciences Meeting and Exhibit, 35th*, Jan 6-9. Reno, NV: American Institute of Aeronautics and Astronautics, 1997.

[21] *Libro Blanco de la Ingeniería Aeronáutica en España*. Agencia Nacional de Evaluación de la Calidad y Acreditación. (spanish)

[22] Lin, C.-F. *Series in Advanced Navigation, Guidance and Control and Their Applications. Modern Navigation, Guidance, and Control Processing*. Englewood Cliffs, New Jersey: Prentice Hall, 1991.

[23] Marchant, A. and Marchant, W. "An undergraduate experimental UAV payload project to teach problem solving and project lifecycle skills". ACM SIGITE Newsletter, 4 (2). 5-9.

[24] Martínez-Val R, Hernández C. "Preliminary design of a low speed, long endurance RPV for civil applications". Paper No. 3, *Proceedings of the 13th Bristol International Conference on RPVs/UAVs*, Bristol, UK, 1998.

[25] Nicolai L. *Fundamentals of aircraft design*. Dayton: Conmilit, 1984.

[26] Morgan Quigley, Michael A. Goodrich, Steve Griffiths, Andrew Eldredge, and Randal W. Beard. "Target acquisition, localization, and surveillance using a fixed-wing mini-uav and gimbaled camera". *Proceedings of the IEEE International Conference on Robotics and Automation*, 2005.

[27] Ollero, A. and Maza, I. *Multiple Heterogeneous Unmanned Aerial Vehicles*. Springer STAR, 2007

[28] Raymer, D. P. *Aircraft Design: A Conceptual Approach*. Washington, DC: American Institute of Aeronautics and Astronautics, Inc, 1992.

[29] Rodríguez-Sevillano, A. A., Gandía-Agüera, F., Barcala-Montejano, M. A., & Pérez-Álvarez, J. "The design of an aircraft: using the final research projectwork to develop multidisciplinary skills and general competences in engineering studies". *International Conference on Engineering and Mathematics (ENMA)*. Bilbao, 3-5 July, 2008.

[30] Roskam J. *Airplane design. Part I: preliminary sizing of airplanes*. Ottawa (KA): Roskam Aviation Engineering, 1985.

[31] Saripalli, S., Montgomery, J. F., & Sukhatme, G. S. "Vision-based Autonomous Landing of an Unmanned Aerial Vehicle". *Proceedings of the 2002 IEEE. International Conference on Robotics & Automation*. Washington DC, may 2002.

[32] Seymour, E., Hunter, A-B., Laureson, S.L., and DeAntoni, D., "Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study", Science Education, 2004, 88, pp 493-594.

[33] Springer, M. A. "Application of Rapid Prototyping Methods to High-Speed Wind Tunnel Testing". NASA / TP-1998-208396. NASA. Marshall Space Flight Center, 1998.

[34] Stamper, R. E., & Decker, D. L. "Utilizing rapid prototyping to enhance undergraduate engineering education". *Frontiers in Education Conference, FIE 2000. 30th Annual*. Kansas City, MO, USA,2000.

[35] Stiver, W. "Sustainable Design in a Second Year Engineering Design Course". International Journal of Engineering Education. Volume: 26 Issue: 2. Pages: 378-383. Published: 2010.

[36] Thomas, C. L., Gaffney, T. M., Kaza, S., & Lee, C. H. "Rapid prototyping of large scale aerospace structures". *Aerospace Applications Conference* (págs. 219-230). IEEE, 1996.

[37] Torenbeek E. *Synthesis of subsonic airplane design*. Delft: Delft University Press, 1982.

[38] *Tuning Educational Structures in Europe. Education and Culture*. Socrates-Tempus.

[39] *Unmanned Systems Roadmap 2007-2032*. Integrated Office of the Secretary of Defense. Department of Defense

[40] M. Usrey. "A case for engineering edutainment in the 21st century" in *Proc. 30th Annual Frontiers in Education Conference*, vol. 2, 2000, pp. S1A/20-S1A/24.

[41] *Visión Estratégica Española. Sistemas Aéreos no Tripulados (UAS)*. Plataforma Aeroespacial Española. (spanish).

[42] Valavanis, K. *Advances in Unmanned Aerial Vehicles: State of the art and the road to autonomy*. Springer, 2007.

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