AEROSPACE ENGINEERING EDUCATION AT THE FEDERAL UNIVERSITY OF ABC: A NOVEL APPROACH TO INTRODUCE AND MOTIVATE BEGINNER STUDENTS

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Abstract. *This work describes the introductory courses in the UFABC Aerospace Engineering curriculum. These courses are conceived to introduce new students to the aeronautics and astronautics branches of Aerospace Engineering, and to motivate them to carry on the career choice or to move to another option at an early stage of their university education. The university concept and the flexibility of its pedagogical project encourage other engineering specialties students and other non-engineering students to benefit from them, because aerospace sector workforce has a multi and interdisciplinary nature. The last two years of experience on teaching these courses is described and the trend for the near future is addressed.*

Keywords: *Aerospace Engineering, astronautics, aeronautics, courses.*

1. INTRODUCTION

Until the end of the last century, university degrees in aerospace specialty were granted by ITA (Technological Institute of Aeronautics), UFMG, EESC-USP (São Carlos School of Engineering – The University of São Paulo) and INPE (National Institute for Space Research). ITA had undergraduate degree in Aeronautical Engineering, UFMG and EESC-USP had undergraduate degrees in Mechanical Engineering, with specialization in Aeronautics. INPE, on the other hand, has only graduate degree in Space Engineering and Technology. These four institutions were responsible for supplying workforce for aeronautics and space sectors.

At the turn of this century, Embraer grew due to the great success of ERJ 145 family of regional jets, and due to the beginning of Embraer 170 development, the fly-by-wire regional jets family. At the same time, aerospace research institutes as INPE and DCTA (Department of Aerospace Science and Technology) faced a workforce shortage, which still persists. These events have caused bottlenecks in the aerospace workforce in Brazil. To overcome this lack of specialized engineers, Embraer used as short-term solution the temporary hiring of foreign engineers, and as a medium-term solution the implementation of a corporate university in which engineers with no aeronautical background were trained to acquire the desired aeronautical formation to meet Embraer needs. Thus, interests in aerospace engineering started to flourish as well as initiatives to the creation of aeronautical engineering programs.

Pioneer institutions such as EESC-USP and UFMG converted their specialization in Aeronautics into full Aeronautical Engineering programs. More precisely, in 1999 EESC-USP canceled the Aircraft specialization offered in Mechanical Engineering program and created Aeronautical Engineering (EESC, 2011). In 2009, after 40 years of creation of CEA (Center of Aeronautical Studies), the specialization in Aeronautics was also canceled and UFMG created the Aerospace Engineering program with specialization in Aeronautical Engineering. UFMG plans in the future to offer the specialization in Astronautical Engineering (UFMG, 2011). In 2010 ITA added the Aerospace Engineering option into the set of its engineering programs (ITA, 2010). In its spectrum of programs in the field of aerospace-related engineering, ITA has Aeronautical Engineering, Aerospace Engineering, Mechanical-Aeronautical Engineering and Civil-Aeronautical Engineering (formerly called Air Infrastructure Engineering).

There are other outstanding initiatives found in public tuition-free universities. UFU (Federal University of Uberlândia) created Aeronautical Engineering in 2009 (UFU, 2009). UFSC (Federal University of Santa Catarina) created a novel engineering modality called Mobility Engineering. Among the options set, this engineering program offers Aeronautical and Space Engineering (UFSC, 2011). UNICAMP (State University of Campinas) added the specialization in Aeronautics as an option for its Mechanical Engineering program (UNICAMP, 2011). UNIFEI (Federal University of Itajubá) created Mechanical-Aeronautical Engineering. This new engineering offered by UNIFEI will be of further help to its region because the helicopter manufacturer Helibras plant is located there for more than 30 years.

Aerospace Engineering is one out of eight engineering options offered at UFABC (Federal University of ABC), the new public tuition-free university in Brazil. The purpose of this paper is to present UFABC approach to introduce students to Aerospace Engineering and the way to motivate them to carry on an Aerospace career. In Section 2 the UFABC structure and its pedagogical project are presented. In Section 3 the introductory courses, which steer the students towards the aeronautical and astronautical sciences, and the different flying vehicles technologies are

presented. Finally, Section 4 presents an overview about what students will face after graduation if they choose to follow an Aerospace career.

2. UFABC: A NEW UNIVERSITY AND ITS PEDAGOGICAL PROJECT

The Federal University of ABC was created by the Federal Law number 11145 on July 26, 2005 (DOU, 2005). A public and tuition-free university, it is located in the ABC region, in the metropolitan area of São Paulo, congregating the following counties: Santo André, São Bernardo do Campo, São Caetano do Sul, Diadema, Mauá, Ribeirão Pires and Rio Grande da Serra.

UFABC is a multi campi university. Currently there are two campi, one in Santo André and the other in São Bernado do Campo. Its pedagogical project was developed based on a document of the Brazilian Academy of Sciences (ABC, 2004) and on the joint declaration of the European Ministers of Education (The Bologna Declaration, 1999).

The pedagogical project adopted by UFABC has many distinct features compared with those of other universities in Brazil and in other countries (UFABC, 2006). Instead of classical departmental structure, UFABC has a structure composed of centers, in order to break the barriers that separate the areas of knowledge one from another. The academic organization is based on three centers, namely, Center of Natural and Human Sciences; Center of Mathematics, Computation and Cognition; and Center of Engineering, Modeling, and Applied Social Sciences. This structure promotes an environment of interdisciplinary and multidisciplinary cooperation to develop the three main activities of the university, that is, teaching, research and extension.

UFABC adopted the trimester calendar system. One calendar year comprises three trimesters of 12 weeks each.

All newcomer students enroll in a unique and common program, an interdisciplinary curriculum called Bachelor of Science and Technology (BCT). This program is composed of 15 trimesters to be accomplished in 3 years. The BCT curriculum is organized in obligatory and free-choice courses. Around half part of the curriculum is composed of free-choice courses, a set of courses elected by the student accordingly to his/her desire. There is a strategy to choose the free-choice courses that is more suited to each individual objective, leading to a post BCT graduation to be completed in minimum time.

Once completed the BCT, the students are urged to further carry on their studies in one of the post BCT fields listed in Tab. 1. Nevertheless, other alternatives are possible.

Table 1. Post BCT fields offered by UFABC.

Engineering	Aerospace
	Bioengineering
	Energy
	Environment and Urban
	Information
	Instrumentation, Automation and Robotics
	Management
	Materials
Bachelor of Science	Biology
	Chemistry
	Computer Sciences
	Mathematics
	Physics
Teaching Bachelor	Biology
	Chemistry
	Mathematics
	Physics

In 2010 another interdisciplinary program was created, the Bachelor of Sciences and Humanities (BCH). The BCH follow the same model of BCT, offering the post BCH programs listed in Tab. 2. The BCH is available in São Bernardo do Campo only.

Table 2. Post BCH programs offered by UFABC.

Bachelor of Science	Philosophy
	Public Policies
	Economy
Teaching Bachelor	Philosophy

3. INTRODUCTORY AND MOTIVATIONAL COURSES

To earn the Aerospace Engineering degree, UFABC students should complete the Bachelor of Science and Technology program, to complete a core of courses mandatory for all engineering specialties, and courses specific for the aerospace field (CECS, 2009). Romero *et al.* (to appear) discuss the experience of CECS (Center of Engineering, Modeling, and Applied Social Sciences) faculty regarding engineering curricula and the introduction to engineering studies at UFABC. This paper focuses exclusively on Aerospace Engineering curriculum and the introduction to Aerospace Engineering studies at UFABC, and its interrelation to other engineering specialties, and, why not, its connection to other non-engineering programs of UFABC. More specifically, details the introductory and motivational courses introduced in Aerospace Engineering curriculum, which are at Aerospace Engineering students disposal, other engineering specialties students, all other non-engineering students, and, at last, to anyone external to the UFABC who meets the requisites stated in ConsEP (2010).

3.1. Aeronautical engineering versus astronautical engineering

Aerospace Engineering is the engineering of flying vehicles. Roughly speaking, flight could be defined as a tridimensional motion, not constrained to a surface. In this simplistic definition we may list the motion of all kind of atmospheric flying vehicles and spacecraft, including animal flights and underwater vehicles. Conversely, the motion of ships, trains and land vehicles does not match this definition once their motion is essentially restrained to a surface.

Flight could be divided into two categories: Atmospheric flight and space flight. At the dawn of the first atmospheric powered flights, the great challenge was to overcome the gravity in a controllable fashion, using engines to produce thrust and wings to produce lift (Tewari, 2007). Thus a new engineering branch was born, called aeronautical engineering. As long as the flight takes place into the atmosphere, *i.e.*, a material medium, the atmospheric flight is intrinsically aerodynamic in nature. On the other hand, space flight takes place under the influence of gravity and, in some cases, under the influence of a thrust. No lift is produced because the flight takes place in vacuum. Thus another new engineering branch was born, called astronautical engineering, which uses the theories of astronomy and ballistics, and developed its terminology inspired by Kepler, Galileo and Newton (Tewari, 2007). These two engineering branches were established separately just over a century ago. In this fashion they were developed over the decades, distinct and apart. Just prior the space flight has become a reality, the debuting astronautical activity started to overlap with the mature aeronautical activity, and they eventually merged to each other. In this way the terminologies “aeronautical” and “astronautical” used to denote the corresponding engineering activities become unsuited to the new reality. Thus, for the engineering activity which deals with flying vehicles, be it atmospheric vehicles (aircraft) or space vehicles (spacecraft), the terminology *aerospace engineering* is much more suited and representative.

Aerospace Engineering may be organized into the following areas: structures, aerodynamics, propulsion and flight dynamics. These are strictly aerospace courses. However, they are not enough. The workforce for aerospace industry needs much more. A lot of courses and specialties are needed to drive the aerospace industry gear to run. As an illustrative example, Table 3 lists the aerospace courses which have reached an expressive progress in research and development last year (AIAA, 2010). Note that most of the topics exhibited in Tab. 3 either do not belong to one of the strictly aerospace areas listed above or constitute a blend of aerospace and non-aerospace courses. It means that aerospace industry welcomes not only aerospace engineers but also other engineering specialties and other non-engineering professionals. For this reason, students not interested in Aerospace Engineering but interested in a probable future career in aerospace sector can take advantage of choosing some of these introductory courses from Aerospace Engineering curriculum as free-choice courses.

Table 3. The year in review 2010 of Aerospace America magazine (AIAA, 2010).

AEROSPACE DESIGN AND STRUCTURES	Adaptive structures Design engineering Materials Meshing visualization and computational environments Multidisciplinary design optimization Nondeterministic approach Structural dynamics Structures Survivability	INFORMATION SYSTEMS	Communications systems Computer systems Digital avionics Intelligent systems Sensor systems Software systems
AEROSPACE SCIENCES	Aeroacustics Aerodynamic measurement technology Applied aerodynamics Astrodynamics Atmospheric and space environments Atmospheric flight mechanics Fluid dynamics Ground testing Guidance, navigation and control Modeling and simulation Plasmadynamics and lasers	PROPULSION AND ENERGY	Aerospace power systems Air-breathing propulsion systems integration Electric propulsion Energetic components and systems Gas turbine engines High-speed air-breathing propulsion Hybrid rockets Liquid propulsion Nuclear and future flight propulsion Propellants and combustion Solid rockets Terrestrial energy systems
AIRCRAFT AND ATMOSPHERIC SYSTEMS	Aerodynamic decelerators Aircraft design Aircraft operations Balloon systems Flight testing General aviation Lighter-than-air systems V/STOL	SPACE AND MISSILES	Life sciences and systems Missile systems Space colonization Space logistics Space operations and support Space resources Space systems Space theaters Space transportation Weapon system effectiveness
ENGINEERING AND TECHNOLOGY MANAGEMENT	Computer-aided enterprise solutions Economics Management Society and aerospace technology Systems engineering		

3.2. Aeronautical branch

In a first approach to introduce the beginner to aerospace engineering, a set of courses with the label “Aeronautics” were proposed and included into the Aerospace Engineering curriculum. The main objectives of these courses are to introduce the students to aeronautics and aviation knowledge, to familiarize them with the terminology, and to present the philosophy behind all aeronautical practice and activity.

To create the introductory courses, we used as guidelines the theoretical knowledge expected by an applicant for a private pilot certificate (ANAC, 2006). This knowledge can be roughly grouped into the following aeronautical knowledge areas:

- Technical knowledge and engines
- Theory of flight
- Meteorology
- Flight rules and air traffic services
- Navigation

Thus, grouping these aeronautical knowledge areas into courses, we can provide to our students the theoretical knowledge equivalent to a private pilot. Of course, flight proficiency is not covered in such an attempt. Once acquiring such knowledge, the students may be able to pass the required aeronautical knowledge test of the National Civil Aviation Agency. A pilot certificate is not mandatory for the aerospace engineer formation. However, it would be a plus

in students' formation, improving their skills and abilities in aerospace engineering practices. Hence, one immediate consequence of the introductory courses is to insert the aerospace engineering students to aeronautical knowledge by equivalencing their aeronautical knowledge to the private pilot theoretical knowledge.

Among these five knowledge areas, two of them are dependent on the aircraft category. Technical knowledge and theory of flight of airplane differ from technical knowledge and theory of flight of helicopter. Here it is important to stress that the objective of the aerospace engineering formation at UFABC is not only to qualify students to master the airplane technology, but also helicopter as well. Usually, aerospace engineering programs give little importance to such category of flying vehicles or even ignore them at all. Moreover, UFABC is merged into the metropolitan region of Sao Paulo which has one of the busiest helicopter traffic in the world. Sao Paulo was the first in the world to implement an air traffic control service exclusively for helicopters (Bento and Camargo, 2009 and DECEA, 2010). Not to mention that having a helicopter background would benefit the graduate to enter into the regional workforce. Due to future exploration of the pre salt layer, a huge increase in the use of helicopter is expected, hence, the need of helicopter experts. Therefore, the technical knowledge and theory of flight, which depend on the aircraft category, were grouped together to form the courses "Aeronautics I". So, there is "Aeronautics I-A" (Anderson Jr, 2005, FAA, 2003, Menezes Jr, 2004, Talay, 1975 and Welch, 1995), which deals with technical knowledge (Homa, 2009b, Schiavo, 1982 and Schiavo, 1993) and theory of flight for airplanes (Homa, 2009a, Saintive, 1999, Saintive, 2001 and Torenbeek and Wittenberg, 2009), and "Aeronautics I-B", which deals with the same areas for helicopters (Seddon and Newman, 2001, Silva, 2000 and Wagtendonk, 2006). On the other hand, the remainder three knowledge areas, namely, meteorology (Bancy, 2009, CHM, 2009, DECEA, 2009a, Grimm, 2009 and REDEMET, 2009), flight rules and air traffic services (DECEA, 2009b), and navigation (Bianchini, 2008, DECEA, 2008, Miguens, 1996 and Roos, 2007) do not depend on the aircraft category, so that they were grouped together to form the course "Aeronautics II". As a matter of fact, flight rules and air traffic services have a slight dependence on the aircraft category (DECEA, 2007). However, that does not invalidate the assumption of aircraft category independence. We can summarize the foregoing explanation as:

- Aeronautics I-A (Airplanes)
  - Technical knowledge of airplanes.
  - Airplanes theory of flight.
- Aeronautics I-B (Helicopters)
  - Technical knowledge of helicopter.
  - Helicopter theory of flight.
- Aeronautics II
  - Meteorology
  - Flight rules and air traffic services
  - Navigation

The courses "Aeronautics I" have their syllabus dependent on the aircraft category, and "Aeronautics II" has its syllabus not dependent on the aircraft category.

3.3. Astronautical branch

The beginners are introduced to the astronautical branch of Aerospace Engineering through the "Introduction to Astronautics". In this course, the main concepts related to the science and technology of the space flight are presented in an introductory way. The course also discusses new concepts, fundamentals, applications and trends in space engineering and technology in the world and especially in Brazil. In order to meet these objectives, the course was structured into the following subjects:

- Why space? Here, the student gets in contact with the presence and importance of space applications and activities in the contemporary world. A glimpse of the future is also addressed in this part of the course.
- Elements and architecture of a space mission.
- History of space navigation and exploration. The ancient astronomy, the modern astronomy, the dawn of the rocket era, space race, 1970s, 1980s, 1990s, the future of space exploration.
- The space environment: The cosmic perspective, the space environment and the spacecraft, space flight physiology.
- Space vehicles: past, present and future.
- Spacecraft orbit and attitude: Basic concepts and systems used to determine and control attitude and orbit of spacecraft.
- Commercial frontiers, policy and laws for space.
- National Program of Space Activities.

This course is of capital importance for the introduction of the students into Aerospace Engineering, giving them a broad perspective of the activities in the space sector, and preparing them to the specific courses in the astronautical branch. Furthermore, this course exerts a strong appeal on students in general. For instance, Physics students interested in areas as astrophysics, cosmology and cosmic rays, and Biology students interested in astrobiology surely will choose "Introduction to Astronautics" to compose the set of free-choice courses. The main line of thought that drives this course follows the one suggested in the reference Sellers *et al.* (2005). The astronautics historical review is conducted also according to Spitzmiller (2007). Many insertions and complements related to the space activities as carried out in Brazil are done. Special attention is paid to the Brazilian activities and needs, in terms of what is established in the ten-year National Plan of Space Activities (AEB, 2005).

3.4. Trends for the near future

The set of introductory aerospace courses covers the basic aspects and fundamentals of aeronautics and astronautics. These courses, however, focus on airplane and helicopter. Our proposal is to expand the range to include other categories of flying vehicles, such as airships, missiles and rockets.

Airships had their golden age and decline. After an interregnum of over half a century, airship reborn is expected. This category of flying vehicle will play a specific role in cases where it performs better than other transportation systems. For example, airships are potential reliable alternative to surface transportation of loads (Machry, 2005). Airships may be used as a platform for unmanned aerial vehicles (Paiva *et al.*, 2006). They differ from other flying vehicles due to outstanding features such as long endurance, long range and heavy-lift capability, lower environmental impact (emissions and noise), lower operational costs, etc. As far as we know, this topic has not been explicitly covered in Aerospace Engineering curricula. On the other hand, it attracts the interest of our students (Garcia, 2010 and Kume, 2010). The creation of an introductory course covering airships (Khoury and Gillett, 1999) would motivate students to engage in the revival of this category of aircraft. So that, in the near future, Aerospace Engineers with background in Airships will be available. It would eventually become a start point to the creation of higher level courses in airship engineering and technology. Besides, from the point of view of our university, it is mandatory to offer to our students a certain number of research choices and professional possibilities. The airship cargo potentialities can lead to new careers in a few years from now.

Rockets and missiles form another class of flying vehicles which deserves the interest of the aerospace industry, especially space and defense industries. These vehicles are capable of accessing the upper layer of the atmosphere and space. Scientific and technological mission to space, whether in suborbital, orbital or interplanetary flight, depends on these categories of vehicles. AEB (2005) is a document issued by Brazilian Space Agency which summarizes the strategic importance of mastering space technology. Therefore, the creation of this introductory course covering rockets and missiles (Bate *et al.*, 1971, Taylor, 2009 and Turner, 2006) is undoubtedly of paramount importance to motivate and prepare students to attend higher level courses in this subject. A first introduction to the rockets' history, their crucial role in accessing space, and the future launch vehicles, are the subjects of the course "Introduction to Astronautics".

Thus, the next courses to be created in the near future are:

- Aeronautics I-C (Rocket and Missiles)
  - Technical knowledge and propulsion systems of rockets and missiles.
  - Rocket vehicles theory of flight, trajectory and mission planning.
- Aeronautics I-D (Airships)
  - Technical knowledge of airships.
  - Airships theory of flight.

Today, the set of introductory courses of Aerospace Engineering course of UFABC covers the traditional aspects of Aeronautics and Astronautics. In the near future it will cover a wide range of the spectrum of flying vehicles, *i.e.*, airplanes, helicopters, rocket vehicles and airships.

4. CAREER IN AEROSPACE: PERSPECTIVE TO THE FUTURE

As mentioned before, aerospace industry workforce needs not only aerospace engineers, but a wide range of professionals. In order to address what the future reserves to students regarding employment opportunities, let´s have a close look at the different industry sectors and the types of jobs available to aerospace professionals.

Table 4 shows the different aerospace industry sectors. However, the job opportunities for Aerospace Engineers are not restricted to the industry sectors listed in the Tab. 4. They may work in any other activity sector which utilizes Aerospace Engineering knowledge.

Table 4. Aerospace industry sectors.

AEROSPACE VEHICLE MANUFACTURING	Airplanes Airships Helicopters Rocket and Missiles Spacecraft Unmanned Aerial Vehicles	GOVERNMENT	Air Force Army Navy ANAC Public Security Secretariats DCTA INPE
AEROSPACE SYSTEM MANUFACTURING	Avionic/Electronic Components and Subsystems Electro/Mechanical Systems Flight Controls and Instrumentation Hydraulic/Pneumatic Systems Power and Propulsion Systems Other Parts/Components and Subsystems	SERVICES	Consulting Research and Development Education Science
AIR TRANSPORTATTION	Airlines Air Cargo Executive and General Aviation Offshore Helicopter Operation Specialized Air Service	SUPPLIERS	Computer Engineering/Manufacturing Equipment Materials Software

AIAA (2002) describes the types of jobs available for two categories of aerospace professionals: Engineers and Scientists. According to this publication, within the aerospace industry, engineers may play one or more of the following roles: Analytical, design, field service, manufacturing, materials and process, software, systems, and test engineer. Scientists deal with new products and processes, work for commercial business, research companies, government institutes and universities.

5. CONCLUSION

In this paper we presented the approach used at UFABC to introduce students to Aerospace Engineering. It is important to stress that UFABC is still a university in implantation, *i.e.*, campi structures, facilities and laboratories are still under construction and are not fully operational yet. Its faculty, technical and administrative staff are not still complete, and the courses are still being shaped.

These courses introduce the students to aeronautics and astronautics science and technology, and to a wide variety of flying vehicles. UFABC Aerospace Engineering students will have a suitable fundamental formation in both aeronautical and astronautical branches of Aerospace Engineering.

The particularities of the UFABC concept permit students not to choose their post BCT courses at once. In such a fashion, students may choose the courses in each trimester according to their career wish which may change along their stay at university. These introductory courses may help them to decide to carry on in Aerospace Engineering, or to change their mind to another career option. The flexibility of UFABC pedagogical project permits students not interested in Aerospace Engineering but interested in an aerospace career to acquire a suitable aerospace familiarization and background which would be valuable in the future, thus improving their insertion into aerospace sector.

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