THE EXPERIENCE WITH THE EDUCATION ON FUNDAMENTALS WITHIN THE CONTEXT OF THE AERONAUTICAL ENGINEERING

Donizeti de Andrade – donizeti@aer.ita.br
Instituto Tecnológico de Aeronáutica – ITA, Divisão de Engenharia Aeronáutica
Praça Mal.-do-Ar Eduardo Gomes, no. 50, Vila das Acácias
12228-900 São José dos Campos, SP

Abstract: *Taught to more than 300 students with the Professional Master Program in Aeronautical and Mechanical Engineering as part of an ITA-EMBRAER alliance and also as part of specialization courses to more than 700 EMBRAER's engineers and executives since June 1999, the course of Fundamentals of Aeronautical Engineering transformed itself into a strategic tool for the successful start-up of new professionals in the aerospace industry. This article analyzes the key-factors involved in this process, in special: (1) the smooth coupling of the concepts involving Fluid Mechanics, Strength of Materials and other engineering basics with their Aerodynamics, Structures, Propulsion, Performance, Stability, Control and Aeronautical Conceptual Design fundamentals' counterparts; (2) the dynamics involved within the course, where concepts are passed to the student following the historical context of the technological innovation which are cornerstones for the current state-of-the-art in the sector. This is accomplished through documentaries, movies, analyses of technical articles, complemented by tips on the international aeronautical market and its major players challenges.*

Key-words: *Fundamentals, Aeronautical Engineering, Aerodynamics, Conceptual Design*

1. INTRODUCTION

If one goes back in time and look over six to seven years overlapping the privatization period, prior to and after it, the scenario was not so good for EMBRAER AIRCRAFT CORPORATION (EMBRAER). Sales were well below the forecasts, and, as a direct consequence, the company had to get rid of a lot of its important engineers, a scenario that created a real experience gap within the company. Things started to change by June 1999, when the ERJ-145 brand-new regional jet toured through North America and Europe, becoming a real marketing success: that aerodynamically smoother and much less noisy aircraft could be purchased by the airlines for around USD 1.5 million less than its major competitor. With the high international demand for providing the ERJ-145 to the airlines worldwide, a big effort to face the new challenges was just starting. A large number of firm-options came, and, with them, the need of having well-prepared engineers behind the scenes, for delivering the aircraft, was there. In the following six months the company ended up hiring around 700 engineers and a lot of job shoppers. Strategically speaking, the former were supposed to fill up a gap destined for junior engineers; the latter, most of them experienced engineers from all over the world working on a individual or a partner-company basis, were supposed to keep pushing the company's technological envelope. The company's

Engineering Technical Directory (DTE) through its prospective development managerial arm, the Technological Development Group (GDT), decided to offer a series of courses to the newcomers in order to avoid the then fast growing of the so-called "knowledge gap," felt by then already over most of the company's ranks. In fact, with the terrible financial situation which had been hovering the company for around six or more years, a lion's share of its best engineers had gone out, and most of the ones who stayed had to pursue managerial functions leaving behind a chasm in terms of the aeronautical engineering knowledge. The matter-of-the-fact is that the just-privatized company had one program (the ERJ-145) hanging on to literally "take-off," the long awaited demand was finally there and a big effort to face the new challenges was just starting.

Within this scenario, EMBRAER's DTE decided to offer a course tailored to present the basic conceptual knowledge in Aeronautical Engineering, for most of the newcomers have other engineering majors but aeronautical. The proposal involved two basic premises for a 36-class-hours course named "Fundamentals of Aeronautical Engineering": (1) the course should involve Aeronautical Engineering concepts, in a way to smooth out the connection between engineering basic courses, like Physics, Fluid Dynamics and Strength of Materials, and the essential concepts behind the aircraft's aerodynamics, structures, propulsion, performance, stability and control; and (2) offer the student the basic notion of the aeronautical conceptual design, reinforcing the formal vocabulary and daily jargon employed in the industry. It was supposed to be tailored in such a way to opening the aeronautical scene for a brand-new, non-aeronautical engineer professional.

It was clear that both Aircraft Aerodynamics---which makes a real difference between Mechanical and Aeronautical Engineering---along with the Conceptual Aircraft Design, were identified as the key-points to be presented in the course. Also, equally important, a macro but precise view of the aeronautical engineering fundamentals and its industry should be delivered, while other courses to be simultaneously offered by the company would be responsible for a deep incursion in the multiple disciplines surrounding an aircraft design.

With this in mind, key-questions were there to be addressed beforehand to maximize the expected results: (1) what would be the most effective contents for a course like this, and what would be the sequential order to better set the context of the aeronautical knowledge to someone who probably had never get formal technical information about an airplane up to that point in life? (2) what would be the threshold of formality, in other words, to what level should the analytical formulation be exposed in the course? (3) which references should the course be based upon to assure the best results? (4) what would be the best class dynamics for motivation purposes?

Before going through the logistics of preparing such a course, a personal introspection to carry out the task ahead was carried out, for a great deal of puzzling but important driving challenges were standing by. For so long the author was waiting for an opportunity to prepare a course such as this. One important point at hand was the "correct" order of contents to be offered, a order that, in his experience, would naturally work as a real motivation factor for any engineer to work with the aeronautical sector. And, by the way, in fact, most of us certainly know how have we learned things in our areas of knowledge: almost never in a helping sequence. Also, any proactive professional working in an area such as this understands that the knowledge of the fundamentals in education these days is paramount: a high tech area like the aerospace engineering, with all its associated new design and processes tools, boarded avionics, and inherent dynamic economics shall be first understood by means of its basic concepts, which are in fact its DNA, its touchable cornerstone. At the same time, a taste of the aeronautical culture shall be transmitted in a correct dosage, bringing

about the dormant dreams, at the same time that it keeps the flame for the ones which are already active, present and placed in people's daily lives.

In terms of previous experience, a course with such macro goals had not been offered yet, except for a version involving only part of its contents, prepared for the Technological Institute of Aeronautics (ITA) students during their ROTC program in the first year of the five-year engineering course and for junior students starting their professional studies (last three years), for a short period in the past.

2. COURSE PREPARATION STRATEGY

Keeping in mind the premises, all the mentioned boundaries and that the course's target public involved someone who had already completed his/her basic engineering courses, the preparation started. And it had to go along the first classes taught, because there was no time in advance: EMBRAER's final decision to starting the course came just five days prior to the first day of classes.

2.1 Zeroing in on the right contents

The chosen selection for the subjects followed a natural order, distributed in 12 chapters within a 257-page course's notes: (1) a brief history of flight and an introduction to the aeronautical (aerospace) engineering; (2) aeronautics nomenclature, dimensions and units, and coordinate systems; (3) the atmosphere, winds, turbulence, and humidity; (4) presentation of the aircraft and its major parts; (5) the aeronautical flow (lift, drag, and pitch moment); (6) effects of the subsonic flow: the airfoil (nomenclature and properties), high-lift devices, and the total drag of the aircraft; (7) notions of the transonic, supersonic, hypersonic flights; (8) introduction to the subsonic aircraft layout: wing, engines, tail surfaces, and landing gear placement; notions on non-conventional aircraft; (9) performance, stability, control (aircraft handling qualities); (10) notions on aircraft propulsion systems; (11) notions on structural analysis and loads; and (12) phases involved in the configuration development within the aeronautical maker (including thoughts on certification and airworthiness interfaces).

Though each chapter contained (and still contains) a detailed particular reference, the bulky part of the contents is within the basic references: for general view of the aeronautical engineering: TALAY (1975), ANDERSON, JR (1985), and MCCORMICK (1994); for Aerodynamics: ANDERSON (1984); and for Aircraft Conceptual Design: TORENBEEK (1986) and RAYMER (1989). The references used are well-known to today's faculty in the aeronautical knowledge: they combine the appropriate concepts with an easy way to motivate the students, while offering a natural way of reasoning over and questioning the subjects involved. The course's notes prepared by this author is, in fact, a mixed work of suitable and detailed editing, translation and authorship, in this order. The core of the text is presented in Portuguese, but all the major concepts are expressed in English as well.

2.2 Selecting the appropriate class dynamics

Along the way, from the beginning, the course contents were very welcome by the students, and an incipient associated dynamics was chosen: complementing each major topic with movies, documentaries, scientific and market related articles. Some NASA videos and special movies were presented in class. In 1999 only, 5 complete courses were offered both for newcomers and engineers with up one or two years within the company.

This first experience showed that the best student participation in class should involve a class dynamics somehow. How to present this new technical concepts blending contents preciseness, students' motivation to learn, without standing too much on a mathematical formulation? We all know that, truly, the simpler the subject the harder the task of explaining it…

3. EVOLUTION PROCESS WITHIN THE COMPANY AND CURRENT STATUS

In 2000, EMBRAER decided to hire a software development company to create a Computer Based Training (CBT) course, named "Concepts of Aeronautical Engineering," aiming substituting the Fundamentals in-company course for a kind of e-course simplified version of it. This move didn't really work out, and, after six months of trial, an in-company course complementation, with the instructor present, was in place.

With the start of EMBRAER's Engineering Specialization Program (PEE), from 2001 on---also known as its Corporate University---, the Fundamentals of Aeronautical Engineering course was the first to be offered. It also turned itself as part of EMBRAER's engineering training programs (for which, independently of the engineer's field of occupation within the company, a minimum knowledge of the aeronautical technical terms and a systemic view of the aircraft in the context of the company's market scenario) and was the first to be taught to the specialization class of 165 students, when PEE started its activities.

Right now, the Fundamentals of Aeronautical Engineering course has been taught in the familiarization phase of EMBRAER-ITA Professional Master in Aeronautical Engineering program, and in the brand-new Program of Software Engineering Specialization (PES), an EMBRAER-UNICAMP partnership.

Along the years, an enhancement of the course classes' dynamics came naturally. Now as a 40-class-hour course, a good selection of video, DVD and CD presentations are there to make the course contents even more attractive. Because of their importance, it is worthwhile to mention a set including the latest versions of the course:

- "Personalidades, Alberto Santos Dumont". Instituto Cultural ITAÚ, a 12-minute video describing the Brazilian pioneer's life, focused in his major aeronautical contributions to mankind;
- NATIONAL GEOGRAPHIC'S "**For all mankind**," and Jack Kennedy's speech announcing that the Americans decided to go to the moon still in that decade; posting what is known as one of the most important speeches of historic accomplished promises; May 1961; class presentations involve approximately 2 minutes of the original video;
- AMERICAN HELICOPTER SOCIETY'S "**A most useful invention: the Helicopter**," a TRT 29min08 video, showing the history, technological evolution, military and civil operations, current state-of-the-art designs and future investments;
- **NASA America's Wings,** a 30-minute video, including:
    - The Wright Brothers, Kitty Hawk, NC, December 17, 1903;
    - E. Jacobs, wind tunnel work, the NASA series, 1930s and early 1940s;
    - Richard Whitcomb and the supercritical-wing, 1965;
    - Professor Boussmaq and the idea of the swept-wing, 1935 – 1940s;
    - James Osborn and the vortex generators, B-47 program, 1946;
    - Richard Whitcomb and the area rule, 1965;
    - "Kelly" Johnson, and the SR-71, the Black Bird, mid-1960s;
    - Richard Whitcomb and the winglets, mid-1960s;
    - Igor Sikorsky and the importance of team work, 1967.

- WARNER BROS' "**The Right Stuff**", on the breaking of the sound barrier and the campaign to choosing NASA's seven Mercury astronauts, 1947 up to 1959; in class, presentations include around 1h30 minutes of a total of 3h37 minutes from the original video;
- MCA-UNIVERSAL'S "**Apollo 13 – to the Edge and Back**," a1h27minute video showing the historical deeds involving Jim Lowell and his mates, in one of the most fascinating and risk-taking adventures of the humankind;
- ABC's "**The Challenger explosion and the rebirth of America's space shuttle program**," video documentary, lasting approximately 55 minutes, presenting the complete process of selection, training, liftoff and explosion of the shuttle on January 28, 1986, and the post-accident investigation that followed (this was the first space trip to officially have a civil citizen aboard, Christa McAuliffe, a New Hampshire elementary and high school teacher);
- CBS 60 MINUTES, "Delayed, delayed, delayed, …" video on the current aeronautical gridlock in the USA, a country where around 700 million air tickets are sold annually; reported by Steve Kroft, September 11, 2000;
- HBO special edition, "**In Memoriam, New York City – September 11, 2001**", on the terrorist attacks to New York City's World Trade Center twin-towers; the speaker is Rudy Giuliani, the then NYC mayor; a 60 minute video;
- TIME LIFE & AW&ST's Air Power collection, "**Flight Deck**;" on how is life within the USS Constellation, one of the most important aircraft carrier of the US Navy; a fascinating 43 minute-video;
- DASSAULT FALCON**, JET HAZARDS OF HIGH MACH** (24 minutes); showing the outstanding stability and handling qualities characteristics of this company's very successful corporate jets operating within local Mach numbers within the transonic flow; and
- **EADS** (European Aeronautic and Defense Systems), **THE STEP BEYOND**, a high-tech marketing and technical CD showing all the civil and military products within the portfolio of that transnational conglomerate which is currently competing neck-to-neck with Boeing**.**

In the first day of classes, along with the instructor's welcome message covering the holistic approach to be applied, a detailed commentary is done on the course's notes, the list of videos, CDs and DVDs to be present. A very powerful pedagogic tool employed from the start-up of this course is a class dynamics questionnaire, which is handed-in to the students and worked out in small groups all over the course's timeframe. This questionnaire opens the stage for real hands-on knowledge: it helps the instructor regarding previous vocabulary, jargon and general concepts brought along with students to the course, pointing out the choices regarding the depth in which the subjects can be covered in an effective form. It's a set of tens of questions bridging all the main points of the course. It works as a welcome guideline for the student, helping him along the way, even for test preparation studies. Furthermore, the dynamics are a fundamental tool for observing the team work characteristics of the students, how they post their viewpoints during their own small groups activities, setting the stage for the instructor's detailed analysis of each topic that follows.

Another important point to mention, a key motivational factor for a lot the students, is the information passed regarding the current status of the aeronautical market, which involves the major players in EMBRAER core business, for both the military and civil sectors. EMBRAER's competitors ongoing technical and decision-making moves, available somehow

in the specialized press and of real interest to the aeronautical industry expert, are key-factors affecting the strategic way to positioning the Brazilian maker products and are discussed in class as well. Some basic business-related aspects are commented very briefly, like how to commit the company's competences under the current matrix-interaction format, which is by the way evolving to a business-units like modus operandi, in order to guaranteeing an ever-growing brand image for the company as a whole, thanks to the units which will survive, after all. Internationally, for the last four years or so, it's known that EMBRAER has one of the best results involving all the aeronautical industry makers, regarding the return on equity (ROE) and shareholder return on investment (YIELD). A culture of being well-informed, an intrinsic ingredient, specially for someone who wants to succeed in this business, is passed to the students: readings of magazines like AEROSPACE AMERICA (a monthly publication of the AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, AIAA), AVIATION WEEK AND SPACE TECHNOLOGY (a weekly basis magazine of the Philips International Inc.) among other, the access of their associated Internet e-sites are part of the main goals related to this course as-it-is.

From 2002 on, the Fundamentals of Aeronautical Engineering's course has been taught to the Institute of Fostering and Industry Coordination (IFI), one of CTA four institutes, the authority meant to certify and be responsible for overall airworthiness processes involved with all the aircraft made or flying in our country. Also, the Mechanical-Aeronautical Engineering in ITA decided to offer its new engineer students this course as well. The Aeronautical Engineering Division will probably follow suit starting next year. One step beyond today's involvements is an EMBRAER upgrading of this course to be taught from a distance within the company, as an e-learning educational asset. In this regard, Rio de Janeiro based Catholic Pontifical University (PUC-Rio) is in charge of starting the media support service for the company.

In terms of evaluation, the Fundamentals' course has the best results compared to any other course offered to EMBRAER since its start in 1999. Obviously, this is the result of a close and focused work done by everyone involved in the process. Somehow it proves that the education on concepts is invaluable, mainly within a field where the leading edge of knowledge and techniques, going hands-to-hands with an ever-increasing international competition. And it indeed demands a multi-national collaboration and financial risk-sharing in order to assure the best regional aircraft to be offered globally.

4. CONCLUDING REMARKS

The experience in preparing and ministering the Fundamentals of Aeronautical Engineering course, an educational task specially tailored for a hands-on professional coming to the aerospace industry, fostered from the beginning by EMBRAER, has been one of the most rewarding in the author's career. Other experiences teaching this course to ITA and IFI students also show the success of this professional aeronautical enterprise. There is no doubt that the overall scenario, involving the notes, class dynamics, merging technical concepts with company's strategic thoughts with market snapshots and forecast insights are key-factors for the success reached so far. In the author's view, this experience can come to contribute in the continuous effort of tailoring a strategic mosaic for the aeronautical engineering knowledge in our country, within and beyond the academic nest.

REFERENCES

ANDERSON, JR., J.D. **Introduction of Flight.** McGraw-Hill Book Co., 1985.

ANDERSON, JR., J.D. **Fundamentals of Aerodynamics.** McGraw-Hill Book Co., 1984.

MCCORMICK, B.W. **Aerodynamics, Aeronautics, and Flight Dynamics.** John Wiley & Sons, Inc., 1994.

RAYMER, D.P. **Aircraft Design: a Conceptual Approach.** AIAA Education Series, 1989.

TALAY, T.A. Introduction to the Aerodynamics of Flight. Washington, **NASA SP-367**, 1975.

TORENBEEK, E. **Synthesis of Airplane Design.** Delft University Press, 1986.