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# The Scientific and Technological Projects Developed Between University of Sao Paulo and Embraer and its Impact on Engineering Education*

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This work will describe the programs of science and technology development between Brazilian aircraft industry and the academy particularly those programs developed in aeronautical engineering. It will focus on the Brazilian Silent Aircraft Program which is an initiative of six Brazilian Universities and Institutes with Embraer to develop studies, methodologies and solutions for the aircraft external noise problem. The impact of this initiative in both Industry and academy will also be discussed. As expected both institutions has beneficial spin-offs from this kind of R&D project. For the academy, besides of the incremental of the research laboratories, publication increase and others, the behavior in face of the industry need and time scale is among the most important impact in the whole academic community from under-graduation and graduation students, to faculty researchers and professors. This will better prepare the graduates to cope with the market needs.

**Keywords:** academy-industry funding; R&D programs; aeronautical engineering education

## 1. Introduction

The Financier of Studies and Projects (FINEP), is a Brazilian public company to promote science, technology and innovation in companies, universities, technology institutes and other public or private institutions. Headquartered in Rio de Janeiro FINEP is under the Ministry of Science, Technology and Innovation. You can set the 50 as the starting point of policy CT & I in Brazil, from the creation of the National Council for Scientific and Technological Development—CNPq and Coordination of Improvement of Higher Education—CAPES in 1951. However, measures of greatest impact would occur only at the end of the 60s, with the institution of the Financier of Studies and Projects (FINEP), in 1967, and especially with the creation of the National Fund for Scientific and Technological Development (FNDCT), by means of Decree-Law No. 719, dated July 31, 1969, which Finep become the Executive Secretary, in 1971. In turn, the PADCT (Program for Support and Development of Science and Technology), officially established in 1984, aimed to provide a complementary tool to the policy of promoting C&T expanding through foreign loans, the funds available for investment in research programs. Among its main features were to introduce new criteria and mechanisms for resource allocation and induction support in areas defined as priorities. Coordinated by the Ministry of Science, Technology and Innovation, and with the executing agencies CNPq, FINEP and CAPES, the PADCT was divided into three stages, since the funds released by the World Bank divided into three agreements, dated July 9, 1985, 15 February 1991 and 17 March 1998 [7].

The first activities of PADCT focused on trying to recover the infrastructure of universities and research institutes, which were in the stage of impoverishment through adverse conditions to which they were subjected. Among the new criteria established by the program was the great concern of the state in promoting the transformation of knowledge generated in universities and research institutes in innovations that elevate the Brazilian competitiveness. However, a more significant participation of private sector for funding R&D was understood as a necessary condition to boost national competitiveness. In developed countries most of investments come from the private sector. Brazil should found its way to diminish the gap between the private and govern investments on R&D and innovation, which not means in any ways that government investments should decrease or be congealed. Establish mechanisms to encourage greater participation of industrial investment in R & D, though necessary attribute, does not exhaust the possibility of involvement of companies with the national innovation system. It is also necessary to encourage industry participation in the enterprise of research,



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development and innovation. There is a need to encourage the integration of the productive sector in the national innovation system, stimulating the formation of synergies between this, universities and research institutes in order to enable companies to contribute to the financing and execution of research, development and innovation. At present, attempts to provide alternatives to these needs by establishing Sectorial Funds for Scientific and Technological Development (CTs). The Sectorial Funds, created since 1999, are instruments for financing research projects, development and innovation in the country. There are 16 Sectorial Funds, of which 14 related to specific sectors and two transversal. Of these, one is focused on university-industry interactions (FVA—Green-Yellow Fund), while the other is intended to support the improvement of the institutions of science and technology Infrastructure. Revenue Funds are derived from contributions on the result of the exploitation of natural resources belonging to the Union, portions of the Excise Tax of certain sectors and Contribution for Intervention in the Economic Domain (CIDE) incident on the values that the use or remunerate acquisition of technological knowledge/technology transfer from abroad [8].

The position that the Empresa Brasileira de Aeronautica S/A (EMBRAER) won in the international market for commercial aircraft demonstrates the technical capacity of Brazilians in this area. This motivated the creation of the CTAero, the Sectorial Fund in Aeronautics. With the Fund is intended to encourage investment in R & D in the sector to ensure competitiveness in domestic and foreign markets. Scientific and technological capability are seeking in the field of aeronautical engineering, electronics and mechanics to diffuse new technologies, upgrading Brazilian technology industry and improve attraction of international investment into the sector.

São Paulo Research Foundation—FAPESP is an independent public foundation with the mission to foster research and the scientific and technological development of the State of São Paulo. In 2011 FAPESP invested more than 0.5bilion US$ in research. FAPESP has a special program called PICTA (program of science and technological development in aerospace) which purpose is to create a network between Sao Paulo state universities and an aerospace industry to develop a subject which is strategic for both academia and industry. In this program FAPESP supports the academy for improving and capacitating their laboratories to cope with the project tasks. In the other hand, the Industry will provide 50% of the total amount of the project investment, which includes under-grad, MSc and PhD scholarships and payment of the University professors involved in the project. Also, the industry supply their human resources to collaborate with the developments and most important to interact with the academy professors and students [9].

The aeronautical Engineering department of the Sao Carlos School of Engineering of the University of Sao Paulo has been involved with two PICTA program with EMBRAER in the last 10 years. This paper will describe two RDI program developed under both research funding the FAPESP Picta and the CTAero and the effects in the engineering education at University of São Paulo.

## 2. Motivation and historical review

The University of Sao Paulo (USP) is the largest higher education and research institution in Brazil. It has outstanding projection around the world, especially in Latin America, and develops a large number of Brazilian masters and doctors who work in higher education and research institutes. It is a public and free university, with open access for students selected by the 'vestibular' (Brazilian entrance exam for universities). Many of these students, after graduation, hold strategic and leading functions in different segments of public and private industries. Near to complete 80 years it has not always been easy collaboration between industry and academia at the USP. In fact, there is a need of creation of a more balanced participation of these actors in the national research, development and innovation (RDI). The main task of universities and public institutes is still the development of basic science and training of human resources with a high level of excellence that can be absorbed by industry. It should also be noted that while only 11% of Brazilian scientists are working on the industry environment in developed or rapidly developing countries this value is always above 50%, emphasizing the United States (79%), Britain (64%), Korea (55%) and Canada (52%).

Stereotypes created between both sides in some way hindered the development of contracts over the years. The most common stereotypes are:

From the academy:

1. Industry has its own time that is different from the academy.
2. The contracts between industry and academia will disturb the freedom of researchers.
3. Technological developments not always produce papers and so the paper count is impaired.

And from the industry:

1. The University does not always keep to the schedule.

2. The timing is too long at the University.
3. Most of the people at university do not know what are the problems in the industry.

Fortunately, although some people on both sides still think that the stereotypes are true; in every area of knowledge contracts with the industry are very welcome. The opportunity for the academics to work in a problem which involves solutions that can be adopted by the industry in a near future has attracted many professors, researchers and students. The development of pre-competitive technologies between universities and industry contracts has enormously collaborated to the country development.

In recent years the aerospace community introduced the term TRL Technology Readiness Level as shown in Fig. 1. In this way everyone involved in a thematic research subject has the opportunity to know when and where the work starts and finish. Also, both sides have the opportunity to learn more and "make the difference".

As pointed before, due to the historical low interactions between academy and industry a considered amount of research developed at academy never reaches TRL 3. In the past 10 years with the efforts of both state and federal governments a change in this retrograde behavior started with the already described programs. Words like applied research, technology development and innovation appears in all application for research grant. Brazil has experienced a long period of economic health in a unique situation with the rest of the world in recession and crises. This situation has brought foreign investments and competitive multinational industries with a terrible side effect in the national industries. This scenario has worsened over the period with a valued Brazilian currency against the American dollar which caused a favoring imports and decreasing the competitiveness of Brazilian products. The Brazilian aeronautics industry is the one that most needs to maintain its competitiveness in the international market and these research projects and technological development became the key to survival especially in areas of knowledge not yet fully mastered both by academia and by industry.

The objectives of such programs of RDI are not only to fill the technological gap of the aeronautical industry but also to change the behavior of academy researchers, graduation students and mainly the under-graduation students. Aerospace engineering students should understand the changings and needs of the industry that they will work in a near future and, even if they decide to stay at academy for a PhD for instance, they will be much better prepared to develop a project which will deliver a proposal up to TRL 3. This will only be possible if the academy is involved with such RDI programs which affect the students from under grads to PhD.

The traditional Engineering education must take advantage from these contracts with the industry and promote a change in the lectures and disciplines syllabus. This will create an incremental culture of research, technological development an innovation. The graduation MSc and PhD students can directly be involved in the solutions of the problems in both academy and industry timing.

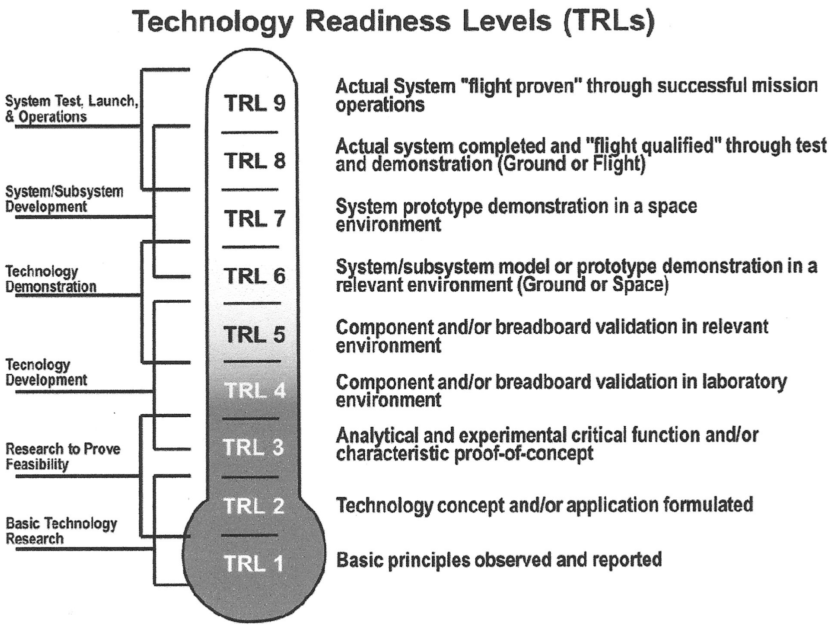


**Fig. 1** The TRL "thermometer".

In the following sections will be describe two projects at the same subject, one under the FAPESP-PICTA-EMBRAER contract and other under the FINEP-CTAero-EMBRAER and how they have helped to developed the way the University faces the challenges of coping its necessities with the industry' needs.

## 3. Brazilian silent aircraft program

The production of civil aircraft has become an important strategic industry for the continuous sustainable development of Brazilian nation. Looking for self-sufficiency in conception, design and certification of civil aircraft Brazilian Aeronautic Industry, leading by Embraer, has sought for technological advances in several important areas. Aircraft external noise is one of these areas. The environmental issues have emerged as an important and difficult technological challenge for the growth of aeronautic industry in the world. Among the various environmental concerns, the aircraft noise has been constantly growing in importance over the past years. It is one of the most important challenges to be overcome in order to permit the aircraft operation continues to increase in the world. Communities and people living in the vicinity of airports around the world concerned with improvement of life quality have put pressure on government authorities to decrease the noise generated by aircraft traffic. This pressure is translated in increasingly restrictive in noise certification limits which is a constraint for new designed aircrafts and its operation in airports. This is also a constraint for any aircraft in current operation. Although the aircraft and specially the engines have continuously decreased generated noise levels due to technological progress, the community noise annoyance has increased since the air traffic has been growing in impressive rates.

Recently, a more restrictive aircraft noise certification requirement took effect in January of 2006, it has resulting in a 10 EPNdB decrease in the certification cumulative noise levels and discussions for other new requirement have already started for another 8 to 10 EPNdB reduction. The certification noise reduction historic along years is presented in Fig. 2.

From Fig. 2, it is important to note the asymptotic trend of the curve which reflect the increasingly difficult to find feasible ways to decrease aircraft noise levels along years. In this scenery, both EU and US have often launched research projects in all areas related with the community noise issues. Among these projects, it could be highlighted X-Noise network projects supported by EU, which involves about 32 partners from 20 countries. X-Noise main goal is to support EU objectives of reducing aircraft external noise by 4–5 dB and by 10 dB per operation in the short and long-term respectively.

To consolidate the development and research of this area in Brazil, Brazilian Silent Aircraft Program was organized.

The objective of the Program has been to integrate and consolidate aerodynamic and acoustic research efforts focused on external noise to become possible a stable, continuous and deep development of all related topics. And one of the main goals is to become this area strong enough in the universities for continuous development even after the end of the program. The Silent Aircraft project which was an initiative of EMBRAER and six Brazilian Universities and Institutes: University of Sao Paulo—Sao Carlos Engineering School and

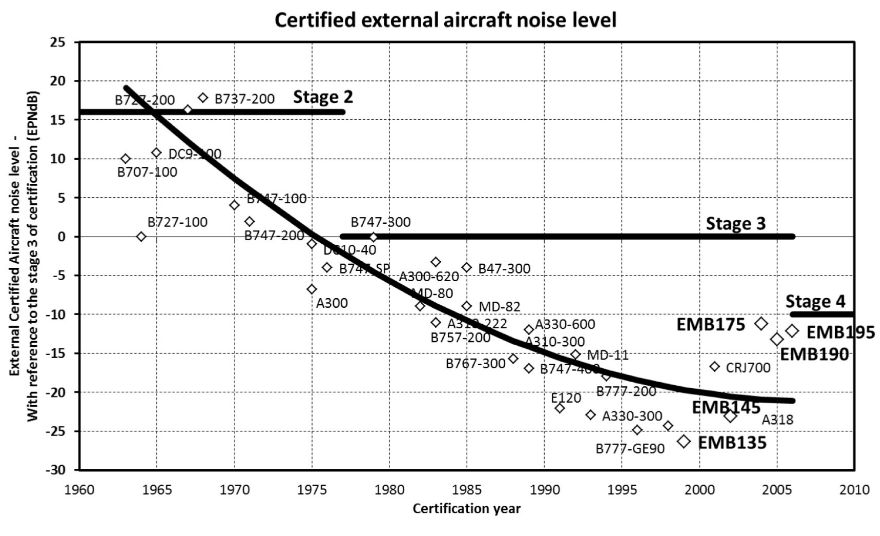


**Fig. 2.** Certification noise levels.

Polytechnic School, Federal University of Santa Catarina—UFSC, Federal University of Uberlandia—UFU, University of Brasilia UnB, and IAE—Brazilian Institute of Aeronautics and Space. Embraer and these universities are working together to develop methodologies and solutions for the aircraft external noise problem. The main goal was to study and develop methodologies that will permit to estimate the aircraft noise generation and propagation through three main approaches: numerical simulation (CAA), analytical and semi-empirical models, and wind tunnel and flight tests. It is important to highlight here that the integration of these three approaches focused in Aeroacoustic is completely new in Brazil. The localization of the Universities is shown in Fig. 3.

This program has started in 2005 and it is sponsored by Embraer, FAPESP and Finep CTAero. Since the beginning, up to total of 90 Brazilian researchers, undergraduate, post-graduate students and engineers have been involved in the program and a lot of important results have been produced. The role of Universities in the project is very important to really make effective a new technological level of this subject in Brazil and continuously deepen the research in all areas related with community noise.

### *3.1 Expected results for the project:*

- Development of experimental methodologies for acoustical treatments of engines.
- Numerical models and semi-empirical prediction of acoustic treatment of engines. validated.
- Development of experimental methodologies of nozzles for jet noise suppression.
- Numerical models and semi-empirical prediction of nozzles noise validated.
- Development of experimental methodologies for fan noise improvements.
- Numerical models and semi-Empirical prediction of fan noise validated.
- Advanced codes for noise sources identification validated.
- Validation of microphone antenna for source Identification.
- Consolidation of an environment for testing aircraft external noise.
- Master the technological knowledge in aerocaoustics testing.

### *3.2 Expected impacts by the Project*

Scientific Impact:

- Development of approximately 14 dissertations and 12 Ph.D. theses throughout the project, in addition to continuing to work after the project.
- Training of academic and technical staffs who have been involved over time with aerodynamic problems and recently in acoustics, focusing on knowledge in the field of aeroacoustics.
- Future research work in the field of aeroacoustics and external noise aircraft.
- Generation of scientific publications in refereed journals, conferences and media.
- Development of research and studies with renowned research centers abroad.

Technological Impact:

- Development of infrastructure for the ongoing studies and research related to aircraft aeroacoustics.

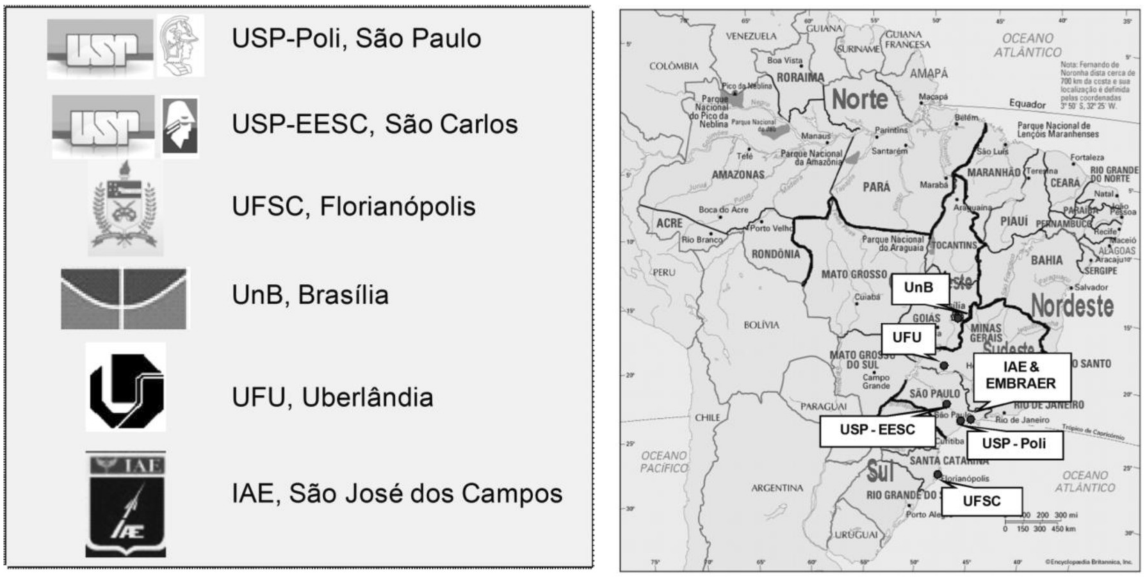


**Fig. 3.** Universities involved in the program.

- National innovative technology development in the area of aerocoustics testing.
- Technology development and improvements in pre-competitive novel aircraft external noise suppression.
- Autonomy and agility on aeroacoustics testing.
- Independence and technological readiness in the development of aircraft with improved external noise.
- Training of technicians, undergrads, engineers and researchers in the areas related to aeroacoustics.
- Potential generation of patents and registrations.

Economic Impact:

- Increased competitiveness of Embraer aircraft in the world market, allowing increased exports.
- Reduced dependence on services and aeroacustics tests from outside.
- Reduction of cycles and costs of product development by increasing productivity and reducing the number of modifications in the design of aircraft, through the use of predictions and design practices of low external noise in the preliminary stages of defining products.
- Reducing the number of flight test, with the consequent reduction in associated costs, such as design modifications and preparation of experimental aircraft and instrumentation for testing.
- Increased autonomy and agility to meet the demands of customers and guarantees.
- Reduction of taxes and fees paid by airlines due to noise generated in the operation of aircraft.
- Potential generation of patents and registrations.
- Ensure ownership by Embraer and Universities economic value represented by the provision of aeroacoustics testing services.

Environmental Impact:

- External Noise Reduction of aircraft, which is currently the largest environmental comfort items around in airports.
- Development of multidisciplinary aircraft more efficient and optimized.

Social Impact:

- Formation of highly specialized human resources.
- Employment generation as a result of increased production of Embraer.
- Reduction of noise exposure of households and residents in the vicinity of airports.
- Increase in high tech activities in Brazilian universities.
- Viability of airports near urban areas.

## 4. The effect on engineering education

We will focus in the impacts of the academy-industry program on the aeronautical engineering course offered by the São Carlos School of Engineering of the University of Sao Paulo (EESC-USP) by its natural relationship with aircrafts world. Although, the subjects to be studied to fulfill the objectives of the program are multidisciplinary is more likely that the impact of such activity will be more continuous and permanent on aeronautical engineers. It will also be discussed the impact of the graduation students from master to PhD level.

### *4.1 The case of undergraduation*

The educational project of the EESC-USP course in aeronautical engineering follows a set of activities based on requirements outlined below, in order to the graduate possesses the desired profile. These requirements are [4]:

- Background of classical science and general education.
- Learn to learn.
- Teamwork.
- Addressing open problems.
- Multidisciplinary.
- Environmental and social information.

The Aeronautical Engineering course at EESC-USP is a 5 year course divided in three phases: 1-basic, 2-general professional engineering and 3-specific engineering. Each phase has a main stream of disciplines although some preparatory/introductory disciplines in aeronautics are distributed through the first two years. It is exactly at these first two years that was decided to introduce some modifications in the traditional engineering disciplines in order to better prepare the students for the specific engineering disciplines. We realize that, despite the immaturity of the students at these initial years, they are in need of orientation and, most of all, motivation to keep studding after these very demanding years. A two years survey was carried-out by the academic commission to evaluate the disciplines of the aeronautical engineering course. Results showed that the excess of theory without applications to practical problems is among of the most demotivating issues. Fig. 4 shows some main concerns of the students related in this survey:

Of course Fig. 4 shows only part of a broad results but it presented a good opportunity of introducing modifications in the disciplines syllabus in order to use the industry-academy Silent Aircraft program environment. As the subject of the program is on aircraft noise and this is a world demand for todays and future generation of aircraft is our duty as educators to introduce knowledge and low noise

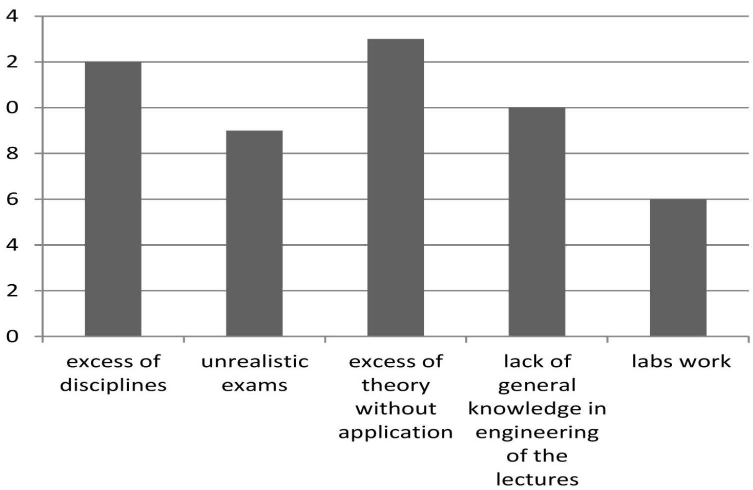


**Fig. 4** Results of the survey.

thinking. However, it must be avoided creating only traditional disciplines in the field of aeroacoustics but others where the learning would occur in a manner that the students could be involved and motivated. The way it was found to carry-out those requirements was to introduce a set of new disciplines or modification of the regular ones, where the presence of the industry staff would be important. These changing were carried out as following:

1. *Seminars and presentations in aeronautics*: This is a 1st academic year/second semester discipline where the students attend seminars on aeronautical engineering. The change here is that there is an emphasis on future aircraft issues such emissions; fuel burn, aerodynamic efficiency and noise reduction presented by both industry and faculty researchers. Of course the presentations are more informative but the students will be in contact with the future problems of aircraft industry and aviation they will face in the future. The second part of this discipline is the presentation by group of students in topics related to aeronautics. This is the first time they will face team work and public presentation which is very important in their career.
2. *Seminars and presentations in undergrads research*: This is a 2nd academic year/first semester discipline where the students attend seminars on research topics of the faculty member of the aeronautical engineering department. The change is that now industry researchers involved in RDI programs will also give a talk and try to convince students to join the program. The candidates will have another semester to prepare their research project with his supervisor and apply for a scholarship. There are many sources of governmental and institutional funding available supporting undergrads research including private funding. With the presence of the academy-industry RDI program another source of funding is available. The scholarship from industry has an advantage of a very short period of implementation whereas all the others, there is a period of application and two to three months of implementation. These scholarships are very valuable for the egress curriculum especially for positions for MSc or PhD program. The most valuable are the FAPESP scholarship due to its referee evaluation and because the student must be of high standard. With the industry scholarship the student will participate of the meetings with faculty and industry researchers including visiting the site, experiments etc.
3. *Aeroacoustics*: This is a 4th academic year/first semester elective discipline where aeroacoustic theory is introduced to the students especially those involved with the RTI project. The change in this discipline is incremental in every semester with the development of the deliverables of the project. Also with improvement of the laboratories the results of testing can be presented in the lectures as well as fundamental aeroacoustic experiments can be carry-out by the students. As more information and results are delivered, more involvement of the academy and industry researchers is achieved. The students with undergrad research supported by the industry have the opportunity to show their projects and results.
4. *Aircraft Design I and II*: The Aircraft Design course is split in two consecutive semester of the 5th academic year. The first semester is dedicated to conceptual design and the second semester to preliminary aircraft design. Normally composed of 40 students, classes are

divided into five groups of 8 students each. The work is undertaken in a dedicated classroom called "aircraft design atelier", specially designed and assembled to simulate the actual industry design environment. The atelier is composed of five round tables, each one with two computer stations providing access to CFD, finite element and CAD. At the beginning of the first semester an aircraft specification is supplied to the design teams, providing details on the mission, range, speed, and take-off and landing performances etc. for the aircraft they should design. All specs are kept under the vision of actual certification requirements. The students' groups work then through a process of conceptual design, using most of the acquired knowledge during the past 4 years of the engineering course they attended to. Although, at this stage the students are free to develop their own design solution and proposals, they must always keep their minds on requirements such as certification, market needs, environmental constraints etc. as it is in the actual industry environment. This phase of work is very important because the students must deal with open problems in almost every part of their proposal. The concept of team work is now decisive for each team member to be emotionally involved in the proposal. After conceptual design is mature enough, a final configuration is frozen and results presented to a board of reviewers. The preliminary design, undertaken on the second semester, advanced engineering tools are used by students for aerodynamic, structural, flight dynamics and control systems calculations. In this discipline the presence of industry is very important in every stage of the design process. Not only by introducing the constraint in noise reduction in the design process but to present real world problems and how the process of product design is developed at the industry. It is not surprising that the best students are straight employed.

### *4.2 The case of the graduation*

The EESC-USP has many graduation courses in various areas of engineering research. Each area has their own commission which decides the new applications, disciplines, scholarships and administration. Through the Coordination of Improvement of Higher Education—CAPES every three years each area course pass through an evaluation that gives a mark from 1 to 7, Regular courses are not less than 3 and these marks are very dependent on the paper count and their impact, number of masters and PhD theses by registered student and, recently the number of patents. High marks receive more funds and scholarships. By university rules master and PhD degree students must complete disciplines credits and the dissertation/theses book in 30 and 54 months respectively. To obtain the title of MSc in engineering the candidate must present his/her dissertation to a board of three members including the supervisor. For the PhD title the theses must be presented to a board of five members. Graduate courses at University of São Paulo, were created and implemented in 1969, answering, since then, mainly by training human resources in science and technology, and currently 28% of Brazilian scientific production. As pointed out in the introduction section, the majority of this research and scientific production were results from federal or state funding. Also, it was shown that both govern and the productive sector are promoting more industry-supported research understanding that the concept of university-industry collaboration is an important social experiment in the nation's innovation system. It is clear that industry-supported research elevates the importance of commercially-valuable outputs: products and processes, licenses, patents, invention disclosures, hardware and the like. More-industry-supported research involves students to the same extent, and in the same roles, as less-industry-supported research, and generally offers the same skill-development and educational benefits as less-industry-supported research, although some trade-offs are inevitable [3]. In the past decade, Brazil is facing a need for innovation and R&D with deep academy-industry collaboration. As pointed out before there are many opportunities for RDI programs supported by both govern and industry which differs from others countries because the govern funding still the same as a regular grant for research but you cannot get it without the collaboration with the industry. Also these programs are of long duration instead of the only industry funded ones are normally of short duration. This creates opportunity for both master and PhD students in the long term program. For the short term industry only funding is possible the involvement only of the faculty researcher, or maybe master students.

This brink to the question of the effect of such programs on the traditional graduation course: it is possible to have an equilibrium between the basic research and the now days highly demanding for applied research and innovation which brinks the funds from both govern and industry? The answer is yes of course without some transitional conflicts. The presence at EESC-USP along the years of such contracts has changing the profile of the graduation students; they are much more interested in short stay research to be quickly employed at the industry and quite a few stay for a doctorate and apply for faculty position. In the other hand, because the presence of the industry in the graduation courses brought its modus operandi and real life problems, the one who stay for a doctorate will have a chance to be a better engineering educator and a faculty member more pro-active too long and short term academy-industry contracts. Some authors [3] among others argue that "more engineers with today's research-oriented training are not the country's primary need. Instead, it will be more practice-oriented engineers. These affirmations could be also suitable to Brazil but in fact, there is a need of a large number of engineers with all kind of formation. There are no worries that the basic research will vanish from the engineering graduation courses but an indication to equilibrium between the basic and applied research.

## 5. Conclusions

This paper described a research, development and innovation academy-industry program supported by both govern and industry funding. The partners of this program are Brazilian state and federal Universities and EMBRAER working together to develop research and development in the field of aeroacoustics. The presence of industry not only promoted researchers benefits by faculty members to complementing their own academic research by securing funds for graduate students and lab equipment, but also promoted an opportunity to the faculty researchers the deal with "real life problems" and more applied research. The academy-industry R&D program is an important social experiment in the nation's innovation system, especially for Brazil where a massive incentive on this kind of collaboration is been carried out in the past ten years. The undergrads course on Aeronautical Engineering is adapting its curriculum syllabus to take advantage of such programs in order to transfer industry thinking and timing in the egress mind. They will better prepare to cope with industry needs. As far graduation students are concerned, the main conclusion is that the engagement of master and doctorate students on such programs is very beneficial for both sides although, some trade-offs must be made. For instance the faculty members should find the proper mix of academic engineering research activity, and industry R&D activity, for optimal economic growth and university research excellence. The development of more of ten years of collaboration between industry and the EESC-USP has brought a lot of investments for Labs enhancements, changing the way the faculty see such programs and contributing for the country development.

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