

# The PERSEUS Project to Promote Excellence in Aerospace Education

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**Abstract**—The paper presents the main achievements of the EC H2020 financed project “Promoting Excellence & Recognition Seal of European Aerospace Universities (PERSEUS)”, that has identified a possible roadmap for the definition of a European quality label for aerospace related higher education degrees. The tools and processes proposed are sufficiently simple to be manageable by Universities in addition to national accreditation processes or as stand-alone assessment. 8 field tests with volunteering universities throughout Europe have been performed. They experienced the method as very practical and to the point.

**Keywords** — *aerospace engineering, quality assurance, learning outcomes*

## I. INTRODUCTION

The AeroSpace and Defence Industries Association of Europe (ASD), which represents the Aeronautics, Space, Security and Defence industries in Europe, publishes yearly statistics for the European Aerospace Industries showing the general good health of the sector, the level of employment, turnover and their breakdown with reference to some specific parameters. This turnover is increasing over the years, except a small decrease in 2013, but without affecting aeronautics and space. More than 70% of the almost 800 thousand employees are in aerospace and about 40% are university graduates. Their trend from the year 2009 is a continued increase, both in aeronautics and space. These numbers should give an indicative idea of the importance of the aerospace sector in Europe and moreover how much this sector relies on higher education and therefore the importance of having a clear overview of it, and eventually finding out gaps to be reduced and ideas for improvements.

The necessity of providing the European aviation sector access to a greater, highly-skilled, excellently educated, experienced and motivated workforce has been commonly recognized by all Aeronautics and Air Transport stakeholders as well as, most importantly, by the European Union. In this context, the European Commission has strongly supported the formation of numerous groups and networks in an effort to structure and obtain access to the European Academia as a whole. The PEGASUS network (i.e. Partnership of a European Group of Aeronautics and Space Universities) is one distinguished and renowned example of such groups,

predominantly aimed at improving the education of the future engineering workforce and structuring the European Academia.

Moreover, in addition to the EC, the Advisory Council for Aviation Research and innovation in Europe has, already since 2004, correspondingly recognized the problem of the declining magnitude and deftness of the European aviation engineering and scientific workforce, and accordingly supported the publication of two relevant studies: an “Education Study” [1], and an “Accreditation Study” [2]. Amongst the foremost conclusions of these studies was the acknowledgement of the need to take a concrete action towards the establishment of a platform where university representatives or networks (e.g. PEGASUS) and the demand side (e.g. Industry, Research Establishments) could meet at regular intervals to exchange views on the requested developments of the curricula at universities. In addition, issues such as the importance of identifying and implementing appropriate mechanisms to measure the quality of education through accreditation and student qualification, as well as, of improving the image of a potential career in the Air Transport sector, were also underlined.

Equivalent conclusions and suggestions have been outlined, yet again, by ACARE Working Group 5, which had the responsibility to provide input to the Strategic Research and Innovation Agenda, related to the educational needs of Europe towards the ambitious strategic goals of Flightpath 2050. In particular, ACARE WG5 has intensely and very keenly stressed [3] the prominent need to establish a common European aviation education system capable to deliver the required high-quality workforce (for example curricula harmonization in terms of structure, quality and accreditation, as well as curricula adaptation to the sector’s evolving needs), as well as, concurrently, to ensure excellent relations and cooperation of academia, industry and research establishments. This issue has been pointed out by ACARE in its Strategic Research and Innovation Agenda (SRIA) with a deliverable concerning the implementation of a European accreditation system for Aerospace set for 2035.

Another important consideration is that, currently, there is no commonly accepted accreditation system applied in the European Academia. Understandably, it may still take a long time to reach a European education accreditation system that would have a legal status. ACARE has therefore recommended

to implement a voluntary accreditation system for aeronautical education recognizing the diversity of the national education systems. The application of such an accreditation system would significantly increase the students' confidence and skills, enhance their mobility across Europe, as well as allow for better exploiting the potential of European Aeronautical engineers.

The above mentioned gaps and drawbacks, are, evidently, long-debated and commonly acknowledged by all major aerospace stakeholders. Taking advantage from the fact that engineering education in the single domain of aerospace may be easier to overlook, the PEGASUS network [4] was established almost simultaneous to the first set of Bologna scheme implementations: a network of qualified aerospace engineering European programs aiming to build up a comprehensive understanding of what "aerospace engineering education" means in Europe, and then to bring that knowledge to our integrated industry, in an interactive process of self-improvement. The members of PEGASUS have collaborated for years on a voluntary basis by comparing their curricula, enhancing their reciprocal ERASMUS-funded student exchanges, launching experimental assessments of their aerospace education with the endorsement of the industry.

All this, however, is not sufficient to generate that profile of "European Aerospace Engineer" which, in spite of the richness of its diversities, may be easily and univocally recognized by its stakeholders, namely the European aerospace industries and services.

The PERSEUS project [5], promoted and lead by the PEGASUS network, was proposed in order to thoroughly address the above mentioned issues in a systematic manner and with a strong involvement of the relevant stakeholders in order to come up with a set of coherent mechanisms and actions.

PERSEUS has defined and implemented in pilot form a specific quality system for aerospace related higher education degrees, as a tool for improvement and harmonization of the EU education in the sector. Harmonization is intended on the basis of quality of the processes and sharing of the learning objectives.

## II. THE CONCEPT

Taking into account the current situation of external quality assurance in the European Higher Education Area, in setting up the subject-specific quality label for aerospace engineering the following features should be considered to make it fit the EU education system as a whole and maintain compatibility with national Quality Assurance or Accreditation systems:

- Standards developed should be strictly learning outcome based. Input criteria such as provisions for a certain number of credits allocated to specific subject areas should be avoided as much as possible.
- Learning outcomes and competence profiles should be compatible with the EUR-ACE Framework Standards learning outcomes.
- The aerospace specific criteria to be developed should be limited to learning outcome statements as all generic aspects

of program design, implementation and review are typically stipulated by the national criteria.

- The procedure should be as light as possible. The evaluation process should, whenever possible, be performed as a piggy-back of an existing national accreditation process, including in this also the EUR-ACE process. Piggy-backing is considered as a means of avoiding the duplication of efforts as well as economizing costs. In a piggy-backing procedure, only those subject-specific elements are added which have not yet been assessed in the basic procedure. These will be in most cases limited to learning outcome statements as all generic aspects of program design, implementation and review are typically stipulated by the national criteria.

- Expectations of all stakeholders (in particular those external to HEIs such as industry requirements) should be taken into account.

- Considering the wide variety of employment options for the aerospace graduate, it is not recommended to formulate any standard requirement in terms of one or more specific profiles linked to one particular job orientation, yet in the aerospace sector, but rather provide some general guidelines on what is expected from high-standard aerospace curricula at master level.

The above mentioned characteristics have been the main drivers to define what will be hereafter called PERSEUS process for the analysis of the quality of aerospace engineering curricula. The process consists of 3 main pillars:

- 1) identification of the learning outcomes of a high quality aerospace curriculum;
- 2) preparation of some formal documentation for the presentation of the curriculum and for its evaluation;
- 3) peer review from a group of experts on the basis of the documentation provided and a site visit to the evaluated institution.

## III. IDENTIFICATION OF LEARNING OUTCOMES

The curriculum requirements identified specify subject areas appropriate to aerospace engineering degrees but do not prescribe specific courses. The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program. The requirements have been identified after an iterative consultation of all the relevant stakeholders (academia, industry, research establishments).

The main curriculum in aeronautical / aerospace engineering should include a mix of fundamental sciences, general engineering sciences, specific aerospace engineering sciences and general courses. Indicatively, considering the average teaching and learning capacity, the following division among the 4 groups can be identified as a preliminary indication in terms of input.

- Fundamental Sciences (recommended minimum 15%), that corresponds approximately to one year of a combination of University level mathematics and basic sciences, eventually with experimental experience. Basic

sciences are defined as chemical, and physical sciences, as well as computer science.

- Engineering Sciences (recommended minimum 40%), having their roots in mathematics and basic sciences but carrying knowledge further toward creative application.

- At least 50% of the Engineering Sciences should be Aerospace Engineering Sciences (that is, minimum 20% of the overall program or 60 ECTS for a 5-year curriculum).

- General Courses, which complement the technical content of the curriculum, eventually including foreign languages if not adequately provided by the previous high school education.

The specific Aero-Engineering Sciences should provide the graduates with learning outcomes in the following knowledge areas

1. A/C Design, avionics and subsystems design / integration
2. Flight dynamics, performances, flight operations and flight testing
3. Fluid Dynamics, Aerodynamics
4. Structures, materials
5. Propulsion systems design
6. Aerospace telecoms / CNS / ATM systems engineering
7. Airworthiness/Aviation safety, A/C Ops & Product Life Cycle
8. Aeronautical production and A/C maintenance
9. Non-conventional / Rotary wing aircraft design
10. Space technology
11. Space applications
12. Economic / Financial aspects of aerospace projects, Air Transport Economics
13. Environmental aspects / Sustainable development of aerospace projects
14. Configuration Management in Design and production
15. Integrated and complex technical environment

Knowledge areas are further expanded into two broad learning outcomes as detailed in the following section.

#### A. The Curriculum Description Table

A global and synthetic description of the aerospace curriculum offered can be provided by assessing the level of achievement of the learning outcomes, through the so called Curriculum Description Table (CDT), composed of technical and non-technical skills. The technical skills refer to the set of 15 knowledge areas characterizing the aerospace sector.

It is expected that the learning outcomes will in most part cover the areas listed from 1 to 12, which represent core aerospace knowledge areas, while knowledge areas 13, 14 and 15 are complementary aerospace knowledge areas.

Furthermore, it is expected that learning outcomes of a high quality Master will cover at least 3 or 4 of the above listed core knowledge areas.

Students must be prepared for engineering practice through a curriculum culminating in a major individual work (design project, internship and/or thesis) based on the knowledge and

skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints. The individual work should also incorporate the latest knowledge and eventually prepare the graduates for further studies and research.

Aerospace graduates should possess also skills and abilities suited for a typical international technical employment in a multicultural and multidisciplinary team. This is detailed by a set of technical, methodological and interpersonal core skills and abilities. A set of complementary skills and abilities, such as language proficiency and management skills, is also identified, in addition to the core skills and abilities.

The use of the Curriculum Description Table is twofold. On one side, the Universities can provide a picture of what the curriculum is providing to the graduates, while on the other side the expected profiles needed by the employers will be collected adopting the same table and by asking an appropriate set of relevant employers of aerospace engineering graduates to identify the skills needed by indicating the relative importance of the learning outcomes as seen from the employer side.

The curriculum learning outcomes will be then compared to the information provided by the employers, to understand how the curriculum fits the employers' needs. A successful curriculum can in general:

- Fit the needs of one employer
- Fit the average needs of a group of employers
- Fit the average needs of the employers

#### IV. THE PERSEUS PROCEDURE

Taking into consideration the qualifications and skills needed by the aerospace sector, the criteria and methodology for the evaluation of aerospace-related higher education programs is defined at Master level. The methodology is based on the classical pillars of accreditation systems: self-evaluation of the program, site visit and final report of the audit team.

About the aerospace curricula, not only the technical content and the percentage in fundamental sciences, general engineering, general courses and aerospace Engineering will be analyzed, but also the internationalization, teaching language, facilities, the research and academic quality level of the teachers and the skills and abilities acquired by the students in the different courses.

The composition of the evaluating team might include representatives of aerospace industry, research establishments and education institutions from a variety of EU countries. The duties of the audit team, who will be in charge of visiting the evaluated University, are defined in order to establish the level of fulfilment of the criteria and standards. The template, structure and content of the report to be produced by the evaluation team is also defined and provided in advance. This document provides a judgement on the fitness-for-purpose of the program contents as seen by the aerospace stakeholders, expressing, if appropriate, a criticism on the information provided in the self-evaluation, presenting an objective analysis of the strengths and weaknesses of the aerospace program(s) offered by the evaluated academic Institution. As result of the

evaluation, the audit team will provide suggestions for improving the evaluated aerospace program.

If the University under evaluation is being currently tested with national accreditation or quality assurance, then the PERSEUS curriculum description table should be added to the documentation for the national accreditation.

The PERSEUS audit team will visit the University and the documents will be prepared before, during and after the visit in order to provide the final visiting team report.

The PERSEUS evaluation process can also be adapted and complemented to consider the cases of an add-on to a national quality assurance or accreditation process or as a stand-alone process.

#### A. The Curriculum Description Table

The Curriculum Description Table has been prepared for a self-evaluation of the aerospace disciplines addressed in the master courses. When compiled by the University, it represents the level of achievement of each learning outcome. Each learning outcome can be graded according to four ranking levels (None, Basic, Intermediate, Advanced). This should have a close correlation with the entry requirements to the program and to the number of credits assigned to each learning objectives. A non-mandatory suggestion is to mark the cell:

- o None if no credits are addressed to that topic,
- o Basic if at least 3 credits are attributed to that topic
- o Intermediate if at least 6 credits are attributed to that topic
- o Advanced if at least 9 credits are attributed to that topic

One additional column “list of courses / optional remarks” should report some comments on how the learning objectives are achieved, or the name of the courses where those learning objectives are included.

#### B. The Visiting Team Report

The Visiting Team is composed by 3 members. The composition of the evaluating team should include at least 1 representative from the academic sector and at least 1 representative from non-academic sector (industry, research establishments, accreditation agencies, education institutions from a variety of EU countries).

The Visiting Team should receive in advance the PERSEUS curriculum description table duly completed and a preliminary version of the Visiting Team Report (or self-evaluation report for combined National / EUR-ACE process), completed in some sections to provide the necessary information to the Visiting Team.

Considering the European perspective of the PERSEUS label, whenever possible the documentation provided should be written in English.

The VTR should:

- a) Provide a judgement on the fitness-for-purpose of the program contents

- b) Express, if appropriate, a criticism on the information provided by the PERSEUS Curriculum description table

- c) Present an objective analysis of the strengths and weaknesses of the aerospace program(s) offered by the evaluated academic Institution.

- d) Include and discuss relevant additional information gathered by the visiting team

- e) Provide an evaluation of the program together with recommendations.

#### C. The site visit

Main purpose of the Team Visit is to supplement the information provided by the PERSEUS Curriculum description table, to ascertain the correctness of information presented and to check it against the needs of the relevant industry, also by inspecting materials compiled by the institution, such as educational program framework, course outlines, lecture contents. Furthermore, the involvement of industry and position in international university networks will be considered. Infrastructures, management, administrative processes, human and material resources, etc are not object of evaluation. The PERSEUS audit focuses on the educational programs, on their objectives and their outcomes.

### V. THE VALIDATION OF THE PROCESS

The procedure identified has been implemented and tested on a group of 8 Universities across the EU. Out of these, 5 participate in the PEGASUS network while 3 are non-PEGASUS Universities. The education institutions have been selected on a voluntary basis, in order to evaluate the level of fulfilment of the required standards for aero-engineering curricula and the aerospace specific quality criteria defined. PEGASUS is a University network which has established a set of criteria for their members, based on two fundamental keywords: quality and international cooperation. This ensures that all PEGASUS University graduates meet a minimum threshold of quality criteria, reason why this group of Universities has been included in the test.

#### A. The 8 tests

The 8 Universities have been selected on a voluntary basis but trying to compose a diverse group of curricula to analyze, in order to test the applicability of the PERSEUS procedure across the EU. Diversity of Universities has been interpreted as geographical diversity, different size of the aerospace unit and number of students in each University, different tradition of the University in the aerospace sector, different focus of the aerospace curriculum offered. This search for a good mix of Universities led to the application of the PERSEUS procedure to:

- France – ENAC Toulouse.
- Spain – UPV Valencia.
- Italy – “Sapienza” Università di Roma.
- Netherlands – TU Delft.
- Portugal – IST Lisbon.
- Greece – University of Patras.

- Slovakia – University of Zilina.
- United Kingdom – University of Liverpool.

A total of 21 experts have been involved in the visiting teams, out of which 12 from the academic sector and 9 from the non-academic sector.

#### *B. Feedback from the 8 tests*

Following the site visits, the 8 visiting teams provided some comments on the PERSEUS procedure and on the ease of evaluation of the quality of the curricula on the basis of the documentation requested (CDT and VTR) and on the structure of the visit. The feedback on the PERSEUS process provided by the teams is relevant and important to allow improving the process and methodology. Overall, the PERSEUS procedure has been appreciated for its simplicity and appropriateness.

The overall conclusion on this important step in the project is that the PERSEUS process appears well balanced in terms of effort and in terms of effectiveness in assessing the quality of the aerospace curriculum offered.

Following the site visits and the completion of the Visiting Team Report by the visiting team, the Universities under test have been asked to provide a feedback in order to assess the usefulness of the PERSEUS process as perceived by the provider of the aerospace degree. The opinion on the following points has been asked in particular:

- Validity of the process (“do you think that the PERSEUS process is a valid tool to assess the quality of the education in the aerospace engineering curriculum?”)
- Effort required (“is the effort put in preparing the documents and the visit worth the result?”)
- Synergy with national accreditation (“how does the PERSEUS process fit within your national processes on accreditation?”)
- Major benefits of PERSEUS (“what is, if any, the major benefit you obtain from the PERSEUS process?”)

6 Universities provided their impressions. According to the opinions of the University staff involved in the peer evaluation, some strong points clearly emerge as added value, compared to other types of evaluation of the curriculum. It is here recalled that the visiting team is composed by a mix of academic and non-academic experts in the aerospace domain.

The first point that can be highlighted is the appreciation that the evaluation is made by peers. Furthermore, since the visiting team is typically international, the combination of visit and discussion with the host University is seen as an excellent opportunity to test the University against colleagues that do not necessarily share you're the same national views in the field of higher education. Similarly, from the visit it is possible to obtain an independent opinion of external experts on the quality of education.

A second group of positive comments relate to the fact that the experts in the visiting team must also critically analyze the curriculum offered by the University under evaluation, proposing improvements and highlighting eventual weak

points. This is appreciated due to the constructive approach adopted and the fact that the focus is on the curriculum rather than on other aspects of the education, allowing to detect some aspects that are not enough covered by standard accreditation systems. PERSEUS process is clearly more focused on contents and less time consuming on subsidiary issues.

A third consideration relates to the formation of the visiting teams, where experts often have also participated in the evaluation of their own University with a different role. In this case, the dual function is beneficial since it gives the opportunity to participate in the evaluation process of other universities and allows to benchmark the institutions visited with those that employ the visiting team members. Similarly, it gives an opportunity to be a part of team of top professionals, exchanging views on different subjects and establishing links for further co-operation.

Another consideration relates to the involvement of the Faculty in the process. In the preparation of the documentation and during the visit, the participation of Faculty and students is required to some extent, variable from case to case. This is extremely useful for internal communication, since preparing the documents allows to involve most of the teaching staff and a broad cross section of students, making them aware of the internal processes leading to evolving curricula.

Some of the Universities even stated that they would not mind if PERSEUS would be the only accreditation process in place, replacing even the national accreditation. All the Universities agree on the fact that the effort in preparing the documentation and managing the site visit is worth the final result.

#### *C. Achievements of the PERSEUS project*

The PERSEUS project has achieved a series of results that can be the basis of a sustainable European system of QA in aerospace studies. For this, in line with general QA systems, one generally needs to have at least the following elements in place:

- sound set of broadly accepted criteria/learning outcomes
- sound procedural principles
- group of trained peers
- international recognition
- legal registration

For the first three elements, the results of PERSEUS are a really solid basis on which to leverage. The PERSEUS project has accomplished a lot in the definition of accepted criteria/learning outcomes, in as much as this is one of the few existing fields, where below the umbrella of the general engineering criteria more refined qualification profiles for sub disciplines were formulated/elaborated. The procedures elaborated within the PERSEUS project have been accepted and appreciated by the Universities, that consider them as valid as their national accreditation processes. Should the ideas proposed within PERSEUS find a future development, a careful check of consistency with the European Standards and Guidelines (ESG), which are a binding link for all European quality assurance systems in their various forms, should be done. Furthermore, the PERSEUS project, with the execution

of all together 8 pilot evaluations, has created a first group of PERSEUS experts, which constitutes the nucleus of a future of qualified peers in the field of aerospace engineering.

The issues of international recognition and legal registration still need to be worked out and represent the challenge for the future, as described in the following section.

## VI. THE WAY FORWARD

The most appropriate application of the criteria and methodology developed during the PERSEUS project seem to be for internal quality assurance and for the evaluation aspect of the external quality assurance. In order to establish a EU-wide system of external quality assurance in aerospace, it is mandatory to find an external well-established organization to continue the work with the use of the procedures developed within the PERSEUS project. This organization should also be the one that formally issues the labels. The most obvious organization for this would be the Council of European Aerospace Societies (CEAS). CEAS is well established and has a complete overview of what is happening in the European aerospace sector. Furthermore, the Royal Aeronautical Society, which is a CEAS member, already has the authority to accredit British aerospace degree programs.

In principle, CEAS would be in charge of the quality assessment, eventually involving the already established pool of experts created during the PERSEUS project, and whenever required an established accreditation agency, like the German agency ASIIN, could be partner in the process if the University asks for accreditation.

A further option could be the establishment of an organization, under the patronage of CEAS, to open a databank in which all interested European Aerospace schools can deposit their Curriculum Description Table according to the final format presented by PERSEUS. The new organization would have a pool of experts that is available to answer a request of the school for advice on the possible improvement of the curriculum. Only at a later moment such a school may request to enter the quality label award procedure, for which the process might be as described above. This alternative would help the lesser advanced schools/countries to improve their aerospace education.

There are still some open issues that the PERSEUS project has been discussing, for which it has been felt that the solution should be identified once the proposed EU system is becoming operational. The major open issues regard the eventual establishment of a differentiated system with more than one quality label, the time validity of the quality label, the frequency of update of the Curriculum Description Table, the systematic comparison of standards and procedures with the exigencies of the European Standards and Guidelines and with the ENAEE standards.

## VII. CONCLUSIONS

Including all activities, the PERSEUS project has involved 15 EU Countries, 21 Universities, 4 research establishments,

25 EU companies (Large and SME), 2 accreditation agencies. The 8 visits to Universities have involved degree courses counting for approximately 6500 students potentially involved. The outreach activities have reached all the EU Universities where higher education in the domain of aerospace engineering is offered. It can be truly stated that the PERSEUS project has stimulated discussions within the global EU aerospace community, finding good consensus on the ideas and methodologies proposed.

The recommendation to implement a voluntary labelling system for aerospace education has been on the table for several years, but no structured action at the EU level has been planned so far. Discussions have been arisen on the subject of the validity of an accreditation system mainly to separate the scientific content from the administrative, organizational and infrastructural aspects. The PERSEUS project has mainly focused on the scientific and teaching aspects which appeared to be more interesting for both students and industries.

The main result of this labelling system appears to be the definition and application of a Knowledge and Abilities identification system which could significantly increase the students' confidence and skills and enhance their mobility across Europe.

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