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# A Semester Abroad Scheme for Stage 4 Aeronautical Engineering MEng Students\*

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The continuing globalisation of the aerospace industry requires that graduate engineers are equipped for working in a multicultural environment. This paper describes a *semester abroad* SOCRATES-ERASMUS scheme that is designed to add an international dimension to the MEng degree course in Aeronautical Engineering at Queen's University (QUB), Belfast, Northern Ireland, UK. The scheme has benefits for both the individual students and the degree programme as a whole. One benefit in particular has been an expanded collaboration into other aspects of the education of the students in the European context.

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## INTRODUCTION

In recent times, the aircraft industry has changed out of all recognition. Not so many years ago, companies like Avro in Manchester, England, UK, designed and built their own aircraft and Shorts did the same in Belfast, Northern Ireland, UK. No one company now designs and builds its own aircraft on one site. Fokker in the Netherlands was probably the last major company to do so with the Fokker 100 and the Fokker 50.

Aircraft are now designed and built on the international stage. Airbus may be an Airbus Industrie aircraft but it is partly designed and built in France, Germany, Netherlands, Spain and the UK. Moreover the breadth of skills and disciplines used in industry is difficult to match in an undergraduate programme in a single institution, and many undergraduate programmes focus on core disciplines.

This international aspect requires aeronautical engineers with a much more international outlook and training. With this in mind, the School of Aeronautical Engineering at Queen's University (QUB), Belfast, Northern Ireland, UK, introduced an ERASMUS

*semester abroad* exchange scheme into the fourth year of the MEng degree programme; this has added a very useful international dimension to the QUB course.

There is also a move amongst European universities to encourage their engineering students to spend some of their study time in another European university. At a recent conference in Paris, one of the French universities explained how their engineering graduates were expected to be competent in, not only their own language, but also in English and one other European language at graduation [1].

The Top Industrial Managers for Europe (TIME) scheme could well point the way ahead in this area. Basically, the TIME scheme requires a one-year extension to the current degree programme in each country to allow the student to spend two years in the host university. Upon graduation, the young engineer will graduate with two degrees, namely that from the home university and the second from the host university. This *one-year extension* is an interesting concept that can allow UK universities' 4-year MEng programme to mesh into the 5-year European model as proposed in the Bologna Declaration without too much conflict.

This article also presents a detailed discussion about how this is being made to work between the QUB

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system and that of École Centrale in Paris, France. In this arrangement participating students will graduate simultaneously with MEng and Diplome d'Ingenieur.

There is current dissatisfaction with the narrowness of the UK A-level system and talk of replacing it with a multi-subject Baccalaureate. Since this would probably reduce the pre-university standard of mathematics still further, a possible scenario would be a Bachelors phase consisting of a foundation year plus the current Stage 1 and Stage 2 for a BEng and followed by a Masters phase consisting of the current Stage 3 and Stage 4. This would then align the UK with many countries in Europe and be in agreement with the stated objective of the Bologna Declaration to which the UK is a signatory. Moreover, it would also satisfy the SARTOR requirements for an accredited engineering Masters degree as the normal route to CEng.

## BENEFITS

The benefits of providing students with the opportunity of spending a *semester abroad* during their MEng undergraduate programme are many:

- Aeronautical engineering is seen as a more attractive study option in the grammar schools and increased student numbers means more FTE's and more staff; in other words, a thriving and expanding School.
- The School's profile in Europe is enhanced.
- The attraction of better quality undergraduates to an MEng degree programme in a forward thinking School.
- The potential for European students to return to QUB to study for a PhD.
- The personal advantages to students going abroad include cultural, language and developing the soft skills that make them more attractive to future employers.
- Teaching Quality Assessment, such an exchange scheme, is viewed as adding value to the degree course.
- The links established with exchange schemes can lead to joint research and other collaboration through personal contacts with academics at the collaborating university. Research collaboration within Europe is very much a plus point in the Research Assessment Exercise.
- At accreditation, the Royal Aeronautical Society looks very favourably on such international exchange schemes.
- Specialist options at the host university can be made available.

## THE SEMESTER ABROAD SCHEME

To date, Queen's has ERASMUS contracts with six European universities in Delft, Göteborg, Poitiers, Munich, Aachen and Toulouse and QUB students must take the equivalent of three modules abroad. Equivalence is calculated on the basis of the European Credit Transfer System (ECTS) (1 QUB module = 10 ECTS credits). In a typical QUB 4-year MEng degree, students take 24 modules, equating to six per year of study.

The *semester abroad* scheme is only open to MEng students in the first semester of their final undergraduate year (fourth year). The reasons for this are:

- These are the best students who are very unlikely to let QUB down academically at one of QUB's partner European universities. This is of the utmost importance to ensure continuity. QUB students act as ambassadors and it is important that the very best image of QUB students is projected abroad.
- Such students have already established a very good to excellent track record and it is highly unlikely that the scores coming back from abroad will adversely affect their final MEng degree classification. This is a factor that does concern QUB students and they often ask for reassurance. QUB experience to-date is that good students can hold their own with their counterparts in Europe.
- The first semester was chosen because getting results back to QUB for examiners' meeting deadlines can be difficult. Many European universities have a more leisurely and flexible approach to examining and they often do not appreciate the very rigid system that is common in the UK. The results from the first semester have always been back in time for the June examiners' meetings. QUB would be fearful that if the second semester was used problems would be experienced and this would also militate against a full *year abroad* scheme. However, this is not ruled out and could be achieved with very careful planning and good communication between the partners involved.
- Stage 4 students have already covered all the basic subjects in aeronautical engineering and this gives them much more freedom of choice when abroad. For example, their three modules abroad can be made up of any combination of project and lecture courses. In Germany, this usually means a 3-module project because of the language difficulties, while in Delft or Göteborg, where lectures are available in English, a

2-module project plus one module of lecture courses is common. However, no restriction is placed on the combination as long as it adds up to three QUB modules.

A very interesting comment from a student returning from Delft was that, because of the vast range of optional lecture courses available at that University, it would make more sense to take three modules of lectures in Delft and leave the project work to the second semester back at QUB. In principle the School would have no objection to such a choice.

Incidentally, the Technical University of Delft has some 1,300 aeronautical engineering students and approximately 70 academics, while QUB has 160 students and 10 academics, so they are about eight times QUB's size and the range of modules on offer is most impressive. Even allowing for the fact that only a small selection of options is made available, this still adds a significant *virtual menu* of options to QUB's Stage 4 course. Also, as a general point, it has been observed that every institution has both strong and weak points. Most universities have at least one research area where they are recognised as being excellent. This network effectively allows QUB students access to that excellence in almost any given subject area.

### **PROMOTION OF THE SEMESTER ABROAD SCHEME**

Promotion of the scheme is of the utmost importance, so on the first Monday of the second semester, those students who have just returned from their first semester European ERASMUS placement give a presentation to all other MEng students (Stages 1, 2, 3 and 4) and QUB staff. Representatives from the International Office, NSLT, Careers, QUB Publicity and members of the Faculty International Committee, which includes the Dean of the Faculty, are also invited to that presentation. The inevitable enthusiasm that the returning students generate is intended to inspire next year's students to choose a *semester abroad* the following year.

This is a very important meeting because early enrolment for the *semester abroad* is absolutely essential since accommodation at many European universities is at a premium and getting into the system early is a must. This year, Friday of week 2 in the second semester has been set as the deadline for application for a placement in the following year. A very important invited group among the spectators is the European exchange students who are in the School on ERASMUS placement. In the case of those

arriving for the second semester this is actually their first day in the School and it serves as an excellent opportunity to introduce them to local students.

In addition to the presentation, returning students also write a short report, preferably containing photographs, about their experience abroad. They are encouraged to include cultural, social and technical experience. These reports are then bound, together with an introduction, into an ERASMUS report for the year and this serves as a reference manual for students in subsequent years, which helps them to make a reasoned choice of location for their *semester abroad* placement. The final report is also circulated to interested parties within QUB and was used last year as the basis for an article in *Queen's Now* by QUB's Publicity Office.

This year, for the first time, visiting European ERASMUS students on placement in the School are being asked to write a similar report in their own language. This will then be bound and sent back to their home university with a view to encouraging their fellow students to choose Queen's Aeronautical for their placement next year. Since six Dutch students are joining QUB this year, the plan is to combine both the English and the Dutch ERASMUS reports into one document and send multiple copies of this back to Delft to publicise QUB Aeronautical for next year.

### **MANAGEMENT OF THE SCHEME**

Person to person contact with the six European universities is absolutely essential and this is beyond the capabilities of any one person. This task up has been divided among the Aeronautical School's academics so that each can concentrate on one or two universities. Fortunately, there are staff members from both France and Germany and this has been of great advantage in liaising with their respective countries, in particular in having an awareness of administrative systems and timescales, as well as how to work with contacts.

The involvement of the QUB International Office throughout is indispensable and ensures that the scheme is running along official ERASMUS lines and that all the paperwork is in order. The latter is a sizeable task in view of the volume of paper required for the European Commission.

A very important feature of the scheme is, of course, the examinations abroad and getting the results back to QUB on time and in a form that suits QUB's system. This has proved to be less of a problem than originally envisaged. QUB students are enrolled for three modules under a single module code. So only one percentage mark is needed to put into

that column on the official examination sheet and this is obtained by calculating a weighted average of the marks from abroad. Some difficulty was experienced with project marks when Göteborg, for example, gave a letter grade where the A was in the band 70-100% and no further detail was available in their system. To address this, all projects are now double marked, ie that they are re-marked by QUB to ensure that the mark awarded fits into QUB's range. This has two benefits in that it eases the mapping problem (of letter grade to percentage) and also helps to ensure parity of standards between the two systems. This seems to have solved the problem. However, it does illustrate the point that unforeseen difficulties will arise, but that these can be overcome.

Learning about each other's examining procedures and marking schemes is part and parcel of making the ERASMUS exchange work successfully. To this end, some Swedish academics were invited on one occasion, and Dutch academics on another, to attend QUB's examiners' boards. This was a very productive and enlightening experience for all concerned because the rigidity of the UK university examining system is not well understood in Europe. The visit of these counterparts also provided the opportunity for next year's student group going to (say) Delft to speak to the Dutch academics about the courses they could take there. In view of the developing collaboration with France, an academic from École Centrale has been invited to sit-in on QUB's examiners' boards in June of this year.

Within the UK Higher Education system, a review process is carried out at subject level by both the institution and the national body, HEFCE. At QUB, the internal system involves each module being reviewed each time it is run. This assessment takes account of the views of students, staff, external examiners and professional accreditation bodies. The *semester abroad* scheme is monitored within this system to ensure that it is both running smoothly and still meeting the course objectives.

The *semester abroad* is a significant portion of the final year and hence the degree classification of this last aspect is of the utmost importance. The objectives of the course relating to international dimensions and the European context cannot overshadow the objectives relating to the development of technical engineering skills.

The *semester abroad* scheme is therefore regularly discussed and reviewed at School Board meetings to ensure that all School staff are aware of what is going on, and the technical aspects of any options assessed. This satisfies requirements from the point of view of Teaching Quality Assurance (TQA)

and keeping staff involved in the month to month working of the scheme.

## STUDENT SUPPORT WHILE ABROAD

QUB students do need support when they go abroad into a European environment that is quite different from that in the UK, and there are various ways this is provided:

- Regular e-mail contact is a must. This is the responsibility of the academic allocated to the particular European university since they have the personal contacts to smooth out any problems that may arise.
- Videoconferencing links are used for face-to-face contact.
- One visit to the European university by one of the School's staff during the semester is usual and desirable.
- On return, a private meeting with the student(s) is necessary to learn of any particular difficulties experienced with a view to avoiding these in future placements.

## LANGUAGE TRAINING

Few students of the School have a competence in a foreign language and this is not really surprising, since English is a major world language spoken by some 450 million people as a first language. In addition, English is also widely used by non-native speakers in the international scientific and engineering community. Compare this with Dutch, spoken by some 25 million people, or Swedish, spoken by some 9 million, and it becomes obvious why the Dutch and the Swedes all have competence in English and often in German and French as well. This has the unfortunate side effect that QUB students also lack the basic cultural awareness that often comes with speaking another language. Therefore, competence in a second European language by QUB students would be highly desirable and would equip them much better to compete in the European scene, as well as feel comfortable working and studying there.

The development of foreign language skills is encouraged in three ways:

- By encouraging attendance at Non Specialist Language Tuition (NSLT) classes during their undergraduate years at QUB.
- In appropriate cases, by taking formal lecturing options, such as the Stage 3 *French for Engineers* module.

- By encouraging attendance at long (or short) language courses in the country of their *semester abroad* placement. Such courses are available during the summer months prior to their ERASMUS placement starting in September. The EC will fund such courses in minority European languages such as Dutch and Swedish, but not in major European languages like French, German or Spanish.

In spite of the School's efforts, there has been limited success in encouraging foreign language skills due to the pressure of the study workload competing with NSLT in the earlier undergraduate years or a preference for an IAESTE placement instead of a language course prior to starting at their European university.

However, there have had some notable successes. Jeannette Lavery took the long summer language course in Göteborg and was able to give her project presentation at Christmas in Swedish. This was partly due to the fact that she already had competence in German and, since Swedish is a Germanic language, she was off to a flying start. It is interesting to note that Jeannette is now employed by DASA in Hamburg and is no doubt fluent in German. Peter Pratt took a similar route and developed sufficient knowledge of Swedish to take part in a simple conversation or read a Swedish newspaper by the end of his semester. Both the NSLT and the EC-supported language courses abroad are promoted at the presentational meeting on the first Monday of the second semester referred to above.

One interesting hurdle often encountered by students is that, while they are trying to practice their newly acquired foreign language skills, the students and staff of the host institution are keen to practice English. The result is normally that everyone benefits from the exchange.

## SPIN OFF

### Joint Aircraft Design Exercise with TU Delft

The *semester abroad* scheme can lead to other forms of cooperation once communication is established. One very good example of this is a joint aircraft design project at Stage 3 that started in January 2002 with the Delft University of Technology (DUT), Delft, the Netherlands [2]. This consisted of two teams of six students, one team based at QUB and the other at DUT. The subject of the design was an *extremely long-range reconnaissance aircraft* and the students utilised modern methods of communication and data

transmission to collaborate and progress the design. This replicated the current design techniques used by the aircraft industry on a global scale and provided excellent training for both sets of students, as well as promoting knowledge exchange between the academics running the project. The project started with a 2-day visit by the DUT students to Belfast in January and finished in May 2002 with a return visit by QUB students to Delft for a final joint project presentation.

This project added a dimension to the School's multicultural experiences that is not provided for in the *semester abroad* scheme – namely distance (or remote) working. Since the two teams spend most of the time apart, communicating (mainly via e-mail and videoconferencing) plus additional factors came into play, such as the clarity of requests and statements (no idioms or colloquial expressions could be used since they are often misinterpreted) and agreeing to work around each other's timetables and holidays (eg DUT students take exams in week 6 of the project, QUB students take exams in weeks 13-15). These seemingly minor issues required considerable understanding and empathy, especially when there was pressure to produce results.

Martin Jacobs, who is a psychologist employed by the DUT to assess in-house learning and teaching techniques, evaluated this project in a report entitled *Cooperation and learning at a distance in an aerospace design and synthesis exercise* [3]. Martin interviewed all of the students and staff concerned, both in Delft and Belfast, and commented very favourably on the effectiveness of the exercise, which is quite unique among European engineering faculties. A follow-on project has started in January 2003 and the teaching and learning process will be further refined as experience is built up in this European cooperation.

### TIME Double Degree programme with ECP

The School's involvement with the ERASMUS programme brought it into contact with the École Centrale (ECP) in Paris, which encouraged QUB to join them in a TIME exchange scheme [4]. The objective of the Top Industrial Managers for Europe (TIME) scheme is to promote high-level degree programmes for student engineers to prepare them to function across national borders in the European Community.

Participating students in the QUB-ECP scheme spend their first two years at QUB followed by two years at ECP and finish with their final (Stage 4) year at QUB. On satisfactory completion, students obtain simultaneously two degrees, namely MEng (QUB) and

Diplome d'Ingenieur (ECP). At the end of 2001, approximately one thousand engineering students had graduated with double degrees from European universities.

ECP is one of the most prestigious technical universities in France; its graduates fill some of the top posts in industry and government in France, and to date QUB is the only UK university participating in the TIME scheme.

At the moment, there is one QUB student on this course (Ciaran O'Rourke, an Aeronautical Engineer). Ciaran completed Stages 1 and 2 at QUB and is now in his first year of a 2-year placement at ECP. He will then return to QUB for Stage 4 and finish with a double degree making for a five-year programme in total.

This is a Faculty of Engineering programme and is open to students in all Schools within the Faculty. Students must have shown a high level of academic achievement, it is likely that they will already be on the MEng course and they must also have a competence and fluency in French, probably holding an A-Level in that subject. Additional language tuition will be provided in Paris during the long vacation preceding their start at ECP.

This is, of course, an exchange programme and the Faculty has agreed to accept ECP students on a reciprocal basis. These students will spend four years in the French system and come to QUB for our Stage 3 and Stage 4. They will then graduate simultaneously Diplome d'Ingenieur and MEng, making for a 6-year programme in total.

At the present time, the School is conducting a search for suitable applicants to follow-on in Ciaran's footsteps and, with that in view, a *presentation* will be arranged in the second semester of the current academic year in order to explain the scheme to interested and suitably qualified students. It is planned that Ciaran will be in Queen's on that occasion to provide first hand up-to-date information to potential applicants.

## FINANCIAL ASPECTS

Prior to the arrival of the *low cost* airlines, airfares were much more expensive and the School subsidised each student with £300 to get the *semester abroad* scheme off the ground. This was roughly the cost of a return airfare from Belfast to Amsterdam and, at that time, there were five or six MEng students wanting placement in Europe. This situation has dramatically changed and this year (2002-2003), out of a final year group of 22 MEng students, 12 have been placed in European universities. At the same time, since the

return airfare from Belfast to Amsterdam is now approximately £44, the School's subsidy has been reduced to £100 per student. In addition, QUB students are also encouraged to apply for university travel scholarships and these are publicised at the ERASMUS presentational meeting.

The EC ERASMUS scheme makes a contribution to each student accepted for placement. This contribution is intended to make up the difference in the cost of living between the UK and the host country and varies slightly from country to country. A typical amount for the Netherlands is about £900 per semester and that is just about enough to cover the cost of renting a room. The amount last year for Göteborg was £1,000 per semester. However, these sums are paid in two instalments; the first in August (just prior to departure) and the second in March/April after the student has returned to QUB. So students should be aware that some funding arrives after the *semester abroad* is completed.

The Swedish language course in Göteborg lasts 7 to 8 weeks and starts in July. The ERASMUS programme provides two additional months of funding to cover this period and Chalmers University of Technology, Göteborg, has paid for the fees for this course. The short Swedish language course lasts just two weeks and is obviously less intense. There are similar excellent courses in Dutch offered in Delft.

Feedback from QUB students who have been on placement indicates that the ERASMUS funding plus the contribution from the School gives reasonable financial support. A travel scholarship does ease the burden further, if they are successful in obtaining such an award, but the real gain is in the experience acquired in Europe.

## SOME CASE STUDIES

In 2000-2001, Peter Pratt went to Chalmers University of Technology in Sweden. He took part in an intensive Swedish course in Göteborg during the summer months immediately preceding his placement. This ran for seven weeks with classes for four hours each day. The class sizes were small and everything was done in Swedish. A related social programme of cultural visits was organised for each weekend that complemented the total immersion in the language.

Peter undertook a 3-module project in experimental fluid dynamics at Chalmers. He worked closely with two of their PhD students to study transition on a swept wing due to a point source disturbance on the upper surface. A paper, based on his work, was accepted

for the EUROMECH conference in Frankfurt in April 2001 [5]. Chalmers was keen to have Peter stay on and register for a PhD in Göteborg but he opted for a return to Belfast where he is now in his second year as a researcher and registered for a PhD.

In the same academic year, Simon Hall went to the Technical University of Munich in Germany. Again it was a 3-module project entitled *Grid Generation and Evaluation for a Delta Wing* using computational fluid dynamics (CFD) techniques and applied to the Eurofighter. Simon commented that *It is surprising how quickly you can pick up a language when you are using it every day*. Simon has returned to Queen's and is now registered for a PhD.

In 2002-2003, Ciara Bonner went to the Technical University of Delft in the Netherlands. One advantage with Delft is that many lectures are offered in English and Ciara constructed a three-module package that consisted of two modules of lecture courses and a one-module project. Her chosen lecture courses/practicals were:

- Low and high speed wind tunnel practicals;
- Flight test in the DUT Cessna citation aircraft;
- Air traffic management;
- Sheet metal forming;
- Avionics;
- Rotorcraft mechanics.

Her project title was *The use of KBE (Knowledge-Based Engineering) in cost-effective aircraft modifications*. Ciara also took part in a Dutch language course in Delft prior to starting her semester at DUT.

## CONCLUSIONS

Several conclusions can be drawn from the information provided above:

- The *semester abroad* scheme makes a major contribution to the personal development and future career prospects of QUB MEng graduates by giving them an appreciation of cultural differences in Europe and encouraging the development of language skills.
- To date, all QUB MEng students who have taken the *semester abroad* have succeeded academically, linguistically and socially.
- The School aims to achieve a balance between outgoing and incoming students. Obviously, there will be years when this is not achievable, but the School strives to achieve balance over the longer term.

- Internationalisation in the aircraft industry is a fact of life and aeronautical engineering schools must embrace it. Internationalisation in the aeronautical engineering curriculum is increasingly being regarded as an indication of *quality* in its broadest sense.
- Many technical universities in Europe are already very alert to international developments and promote study abroad opportunities for a large percentage of their students; in this regard the QUB's Aeronautical School is still catching up.
- The *semester abroad* should be viewed as an enhancement of, and an addition to, the QUB's traditional MEng degree course in aeronautical engineering.
- Specialist options or topics with recognised international expertise become available, adding a *virtual menu* of options to the Stage 4 course.
- Pastoral care arrangements are essential.
- To further develop language skills, QUB's French and German members of staff will give a few seminars in their own language to appropriate students with an emphasis on technical language.
- The School of Aeronautical Engineering at QUB recognises the considerable benefits of such international programmes to itself and to its students.
- At a Faculty level, the Faculty International Committee has proved to be an excellent forum for exchanging views and expertise on such exchange schemes.

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## BIOGRAPHIES



Sam Sterling is a graduate of London University and the College of Aeronautics (Cranfield University). He was a student apprentice and subsequently a test engineer with Short Brothers in Belfast. He worked as a stress engineer with Fokker NV in Amsterdam and later with ICI Plastics Division at

Welwyn Garden City in England, developing engineering applications of thermoplastics. He has been a lecturer and senior lecturer in the School of Aeronautical Engineering at the Queen's University of Belfast (QUB) for some 30 years.

He is now retired and was appointed an Honorary Senior Lecturer by QUB where he still lectures part-time and coordinates international affairs for the Faculty of Engineering. He is a Chartered Engineer and a Fellow of the Royal Aeronautical Society.



Dr Mark Price is a lecturer in Aeronautical Engineering. He graduated with a BEng in aeronautical engineering from QUB in 1987 and followed with a Master's degree in engineering computation in 1988. After a period as a stress engineer, he returned to QUB to undertake a PhD in Hexahedral Mesh Generation, graduating in 1993. After this, he worked in the CAE software field until taking up his current post

lecturing in aircraft structures in 1998. His research activity includes CAD-FE integration focusing on the automatic generation of idealised models for analysis, and the modelling, analysis and testing of the buckling behaviour of aircraft fuselage panels.



Dr Alan Gibson is a lecturer in aeronautical engineering. He began his career as an apprentice fitter in the aircraft manufacturing industry. After several years in the industry, including a period in South Africa, he returned to full-time education as a mature student in 1989, studying for a BTEC

Diploma in engineering. He subsequently graduated with a BEng in aeronautical engineering from Queen's University of Belfast (QUB) in 1994, followed with a Master's degree in aerospace vehicle design from Cranfield University in 1995. He returned to QUB in 1995 to study, initially full-time, for a PhD in the field of welded aircraft structures, graduating in 2000. In 1998, he was appointed as Research Assistant, working on the non-linear buckling analysis and testing of aircraft fuselage panels. He was appointed as Teaching Fellow in 2000 and as Lecturer in 2001, lecturing in aircraft design and structural analysis.

His research activity includes the analysis and testing of welded, extruded, bonded and integrally machined fuselage structures.



Dr Emmanuel Benard obtained a degree in Mechanical Science from the University of Lille (France) and a PhD from the University of Poitiers (France). After a post-doctoral year in Trinity College Dublin (Ireland), he joined Queen's University Belfast in 1998 as a lecturer

in aerodynamics, specialising in the field of experimental fluid mechanics. He is also in charge of ERASMUS exchanges with Poitiers and Chalmers University of Technology (Sweden).