NEW COOPERATION METHODS BETWEEN INDUSTRY AND ACADEMIA: THE RESEARCH TRAINING GROUP (GRADUIERTENKOLLEG) – "ASPECTS OF FUTURE SATELLITE RECONNAISSANCE MISSIONS"

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OVERVIEW

A strong cooperation between academia and industry is necessary in order to transfer new technologies and concepts as well as to attract young, high-qualified scientists and engineers. This is important for nearly every branch of industry and in particular for the aerospace industry. Astrium GmbH and the TU Dresden founded in October 2006 a Research Training Group (Graduiertenkolleg) to foster and demonstrate a promising new way of cooperation between industry and academia.

The main objectives of the Research Training Group "Aspects of Future Satellite Reconnaissance Missions" are to investigate new technologies and concepts but also space utilisation aspects needed for future earth observation and interplanetary science missions. Up to 8 doctoral students shall be financed by both partners for this purpose in the next years. An accompanying study programme shall provide to the young scientists an advanced methodical knowledge, participation in activities of the scientific community and a monitoring of their research progress.

This article presents the motivation, the structure and the first research projects of this initiative.

1. INTRODUCTION

"Why should I continue at the university, achieving maybe a higher degree by performing a scientific work, but, on the other hand, loosing some years for my career opportunity in industry and this, by the way, also for a very much lower income?" is very often a question posed by young graduated engineers, and especially by the very best of them. Indeed, the doctorate is not necessarily a requirement for a career in industry, but it is still a prerequisite for an academic career. Thus, many highly talented students in engineering leave the university immediately after achieving their first degree, in Germany the diploma. In consequence, many research projects and ideas cannot be started because of the lack of adequately qualified doctorate candidates. This development has also additional impacts and side-effects, e.g. that the transfer of available technological and scientific knowledge from the university to industry is handicapped as it is usually not completely included in the curriculum for a first academic degree. Also a continuous research activity is aggravated.

"Please, could you support us to find an excellent, young engineer with some special knowledge in a certain area X or Y beyond the general studies, but also having still an overview of a complete field Z?" is on the other hand a question, which is frequently and increasingly posed by responsible industry representatives, especially in the aerospace sector. Indeed, this seems to become a more and more increasing problem in Germany, i.e. not only to find young engineers, but additionally with a certain additional qualification of high value for a company. There is not much clairvoyance necessary to forecast that the situation will become even worse in the very near future. Based on the decreasing number of children, also the number of graduates in engineering will decrease – according to some studies by an amount of up to 50% in the next 5-10 years. For a long-term strategic planning of a company, it is therefore very important to find methods for securing the future demand of "human resources" with an adequate qualification. Thus, there is obviously a common interest between industry and academia concerning the rising generation of engineers.

The upcoming deficiency of scientists and engineers with higher academic qualification was already an argument in 1990, when the German government (Bund) and the federal states (Länder) agreed to increase the supporting structure for doctoral students by the creation of a research training group programme. A Research Training Group (in German: Graduiertenkolleg), supported by the German Research Foundation (DFG), is a university graduate training programme. The primary goal is to improve the quality of doctoral training connected to scientific excellence in a specific field. In 2003 the DFG spent more than 76.5 million Euros for 274 Research Training Groups, 12 % of which were dedicated to engineering and computer sciences, 30 % to natural sciences and mathematics. Nevertheless, in 2000 only 3 % of all the doctoral students in engineering received their doctorate within a Graduiertenkolleg in Germany [1]. The vast majority are funded by other resources, many of them connected to research and development projects with industry.

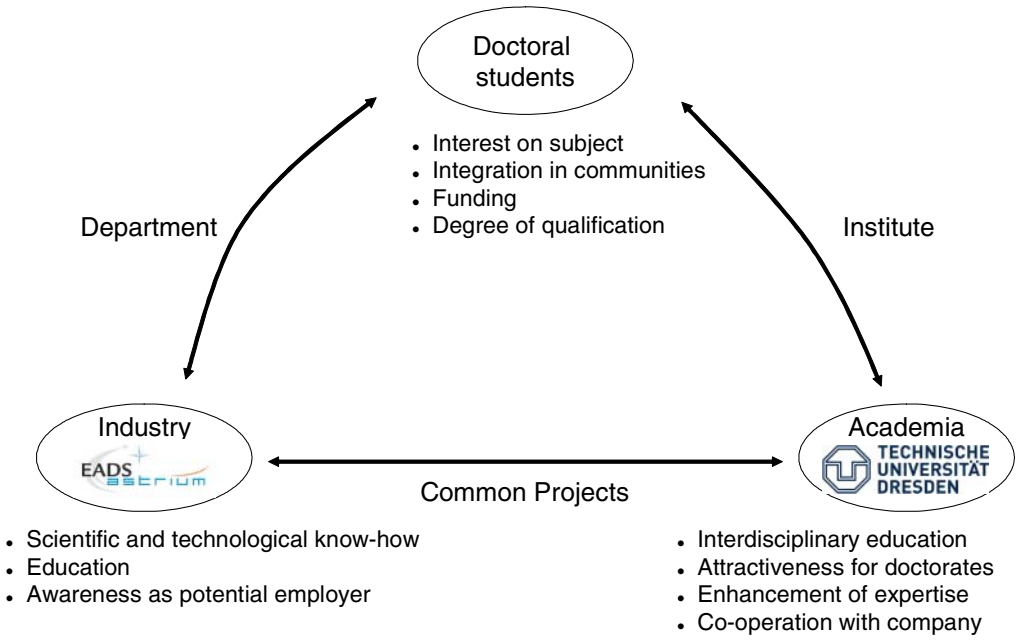

Figure 1. Identified benefits for all involved partners for foundation and participation in the Graduiertenkolleg.

However, several surveys indicate the advantages of a Graduiertenkolleg [1]. There are no noticeable differences in the motivation for pursuing a doctorate between the students who are funded by a Graduiertenkolleg and those who finance their doctorates through other sources. On the other hand, due to the inspiration by the progress of the other students, they are better motivated in their work and thus they finish their theses half a year earlier. Usually, they are also better integrated in the scientific community, and because of being part of a team, obtain additional knowledge in surrounding areas.

Now, with this background information, having already some common research projects running, and identifying additionally a variety of fields of common interest, Astrium GmbH and the TU Dresden looked for a platform to improve and extend their cooperation. Thus, it was decided to adopt the idea of a Graduiertenkolleg from the DFG, however now financially supported by industry. In contrast to usual industrial projects, where the research and development results are the main focus, also the qualification of the young engineers and scientists to a higher academic degree is now of equivalent importance.

An overview about the specific motivation of the partners and the expected benefits for all parties is given in the following. Then, the scientific environment, the objectives, and some important organisation details of the Graduiertenkolleg are described followed by a short overview about the research projects. Finally, some first experiences of the initiative are given.

2. MOTIVATION

About 20% of the total revenue in the aerospace sector is invested in research and development, one of the highest values in German industry [2]. A broad link between industry and academia is therefore necessary to transfer new technologies and concepts as well as to attract young, high-qualified scientists and engineers. This becomes more and more important with regards to the steadily increasing lack of qualified personnel in engineering sciences.

Knowing this lack of qualified personnel and the demands in cooperation between industry and academia, the German aerospace industry stated in 2001, as one of four key areas for the future, the assurance of the qualification of young professionals [2]. One mentioned method is the direct financing of doctorates. Also, the efforts made by the DFG and the universities for improving the graduate training and the efforts made by industry should be combined. In parallel, the German Science Council (Wissenschaftsrat) and the German Rector's Conference (HRK) pointed out that a considerable amount of reform is necessary to support structures for doctoral students [3,4]. Otherwise there is the risk of loosing high potential young scientists to foreign countries or to a non-scientific career.

Beside these more or less general reasons, there are additionally many specific arguments based on the expected benefits which lead Astrium and the TU Dresden to the foundation of an interdisciplinary Graduiertenkolleg inspired by the DFG model (see Fig. 1). The expected benefits for Astrium are in summary:

- Access to external scientific and technological know-how,
- Interdisciplinary approach,
- Integration in the education, very close contact to the rising generation of engineers and scientists,
- Multiplicand for additional accompanying study and diploma theses,
- Increase of awareness and attractiveness as a potential employer.

The expected benefits for the TU Dresden are in summary:

- Advancement in interdisciplinary education,
- Increase of attractiveness for doctorate students,
- Enhancement of expertise in a scientific ambitious and attractive field, transfer of knowledge to industry and vice versa,
- Close co-operation with the leading industrial space company in Germany,
- Demonstration of new, alternative ways in high-level education,
- Building of a frame for the anyway already existing co-operation in single research projects.

Finally, also many benefits for the key element of the initiative, the doctorate students, were identified, the most important of which are:

- Immediate and simultaneous integration in scientific and industrial community,
- Part of an interdisciplinary team giving the basis for a future career network,
- Performing research work of high interest also for industry, not just for achieving a higher academic degree,
- Secured funding of research activity for three years.

Summarising, through the partnership the scientific knowledge is improved by the experience of an industrial company and vice versa. At the same time the concept provides a way for a better structural support and integration of doctoral students.

3. SCIENTIFIC ENVIRONMENT AND OBJECTIVES

The scientific objectives of the Graduiertenkolleg are to investigate new technologies and concepts but also space utilisation aspects needed for future earth observation and interplanetary science missions. An impression about the various required technologies for the realisation of future space missions gives for example the European Space Agency (ESA) in the European Space Technology Requirements Document [5]:

- Propulsion technologies, e.g. advanced thrusters and tanks, new propellants,
- Components & materials technologies, e.g. digital radiation-hardened microelectronic components,
- Engineering tools, facilities & services technologies, e.g. automated development systems based on distributed processing and concurrent engineering,
- Mechanisms technologies,
- Structure technologies, e.g. high-efficiency, high-stability, high-precision spacecraft structures,
- Thermal control technologies, e.g. two-phase heat transport systems, deployable radiators,
- Power technologies, e.g. high-efficiency solar cells and integrated cell structures,
- Telemetry, tracking and command technologies,
- Attitude and orbit control technologies, and many others more.

This excerpt is supposed to indicate that there is probably no technology domain from which the space industry could not benefit. Of course, each smaller, lighter, more reliable, more miniaturized and cheaper technological development is also of interest for the space sector. Vice-versa, a technological problem in the space sector often initiates other points of view to single technologies, which thus can profit by the developed solutions and products.

Additionally to the new technologies also the various utilisation domains are important. This is a very broad area in industry and science, for example in astronomy, geodesy, communication, navigation, traffic and tourism. The variety of space utilisation needs certainly also a profound knowledge about the possibilities and limitations of space technology. Thus, the title of the Graduiertenkolleg was consciously chosen very broadly to “Aspects of Future Satellite Reconnaissance Missions”. The Graduiertenkolleg is therefore intended as an integrated approach in form of an interdisciplinary research group within a broad field of research projects (see Fig. 2). This broad field of projects in space engineering and space utilisation provides the way that the doctoral students are familiarised with the complex, scientific problems and at the same time get extensive knowledge in other domains.

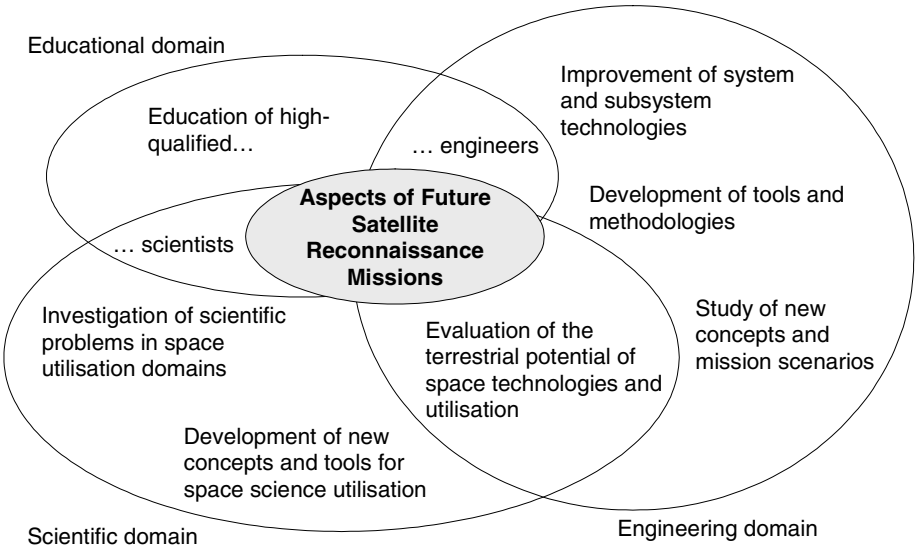

Figure 2. Overview of aspects of the Graduiertenkolleg “Aspects of Future Satellite Reconnaissance Missions”.

The TU Dresden can provide an interdisciplinary environment for the scientific support of the Graduiertenkolleg with the "TU Dresden Centre of Aeronautics and Astronautics" (Universitäres Zentrum für Luft- und Raumfahrt der TU Dresden, UZLR). The UZLR was founded in December 2003 as an alliance of professors of the TU Dresden. It aims to link together different specialized disciplines with relation to aeronautics and astronautics. Foundation members have been 21 professors from 16 institutes of the faculties of Mechanical Engineering, Electrical Engineering and Information Technology, Transportation Sciences, Forestry- Geo- and Hydro Sciences, as well as Medical Science and Law. Some selected examples of the activities related to space sciences are:

- Satellite based surveillance, high-precision navigation,
- Influence of mechanical stress on the function and structure of cells,
- Development of miniaturised scientific equipment
- New materials, production methods and construction principles,
- Investigation of thermodynamic data on chemical media for green propellants,
- Simulation of processes and systems for thermal and thermoelectric energy conversion,
- Simulation of combustion processes,
- Mapping and map-making by means of SAR-interferometry, applied earth observation,
- Analysis / concepts of interplanetary missions and coupled subsystems,
- Remote sensing (altimetry, interferometric SAR) for the determination of sea / ice topography and ice movement,
- Precise gravitational field determinations from satellite measurements,
- Precise positioning by means of GPS, also on multi-sensory platforms.

More details about the ULZR are given in [6].

On the other hand, Astrium, the European leader in satellite development, is a multinational, interdisciplinary company with 11,000 employees and facilities in France, Germany, the United Kingdom, Spain and the Netherlands. Apart from the design and manufacture of launchers, payloads, ground infrastructure and space equipment, Astrium has a broad knowledge in satellite design as prime contractor for over 70 communications satellites, Earth observation and meteorological systems and ESA's space exploration programmes. Some examples are Envisat, Metop, Mars Express, Rosetta, Cryosat 2, and Swarm.

The topic of the Graduiertenkolleg is chosen in a broad field in order to provide an optimal balance between the thematic context and high quality standards, while having the possibility to integrate the various mentioned aspects. The scientific programme is centred on a rather general topic of future technologies and concepts of space mission to connect the different domains and still allow attractive and demanding research projects. This variety allows the selection of the students (and projects) according to their excellence rather of topical consistence.

4. ORGANISATION

The Graduiertenkolleg is administrated by an advisory board of four members, to which each partner designates two members. Currently, the advisory board consists of:

- Dr. G. Willich, Astrium GmbH, Head of System Technologies, Future Missions & Instruments,
- K. Schönherr, Astrium GmbH, Head of Electrical Engineering,
- Prof. Dr. K. Janschek, TU Dresden, Institute for Automation, Faculty Electrical Engineering and Information Technology,
- Prof. Dr. S. Fasoulas (speaker), TU Dresden, Institute for Aerospace Engineering, Faculty Mechanical Engineering.

The complete structure is depicted in Fig. 3. New research projects can be initiated by both partners and are reviewed and selected by the advisory board. Also, the doctorate candidates are chosen by both partners, but employed by the TU Dresden. Their research work is funded for three years with an additional possible

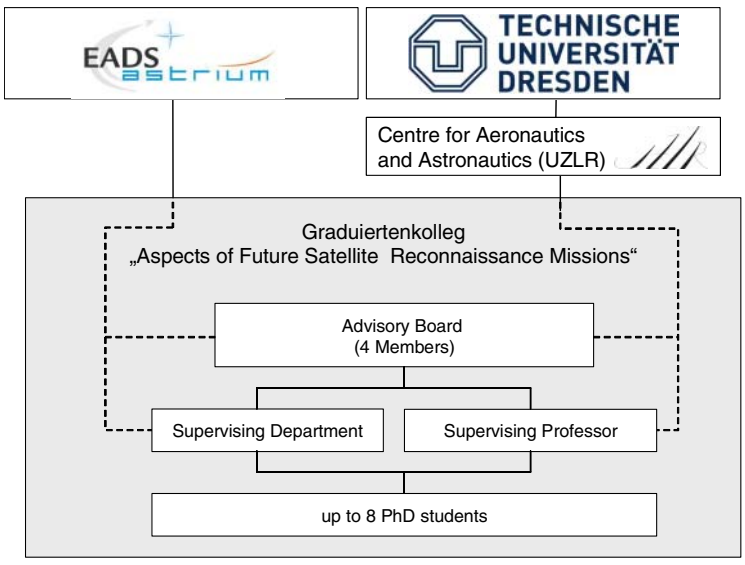

Figure 3. Structure of the Research Training Group (Graduiertenkolleg).

extension of half a year. Up to eight high qualified young scientists shall be supported in the first phase of five years. Depending on the success of the initiative, an extension of four years is planned subsequently. With the foundation of the Graduiertenkolleg two research topics have been launched. The start of the other projects is planned for 2007 and 2008.

An accompanying study programme is designed to provide the Ph.D. students with advanced methodical knowledge, support participation in activities of the scientific community and monitor the progress of their research. Each of them is supervised at least by one senior scientist from the TU Dresden and one senior engineer from Astrium GmbH to assure the project quality and necessary support. At the beginning of each project the familiarization with the complex theoretical and experimental background plays the major role. Senior scientists from the different domains support the doctoral students in this phase. In the following steps, the scientific communication and the own contributions are intensified. The participation and involvement in cooperated scientific presentations and workshops foster the flexibility of junior scientists and engineers. Apart from the publication of scientific results, this is a possibility to keep up to date with the recent scientific developments and to find direct contact to other senior scientists. The participation of an industrial partner additionally provides an access to senior engineers who can help in the first familiarization process with the complex topics as well as can contribute with their know-how to the scientific discussions in the later phases. The accompanying study programme is mainly composed of 6 basic elements:

- Individual additional lectures,
- Lecture series of involved senior scientists, senior engineers and guests,
- Summer school at Astrium in Friedrichshafen,
- Self organized seminar days,
- Colloquium (presentation of the results and intensive scientific discussion),
- Participation on international conferences.

This study programme concept fulfils the recommendations of the DFG [7] and the German Science Council [3] for a Graduiertenkolleg.

Finally, a very important issue has been also the topic of intellectual property rights. Here, the solution has been found to guarantee by contract of all involved parties that the industrial partner obtains privilege priority rights concerning licensing for all potential intellectual property rights which might evolve in the frame of the Graduiertenkolleg.

5. RESEARCH PROJECTS

The Graduiertenkolleg combines scientific and engineering research topics. The first two research topics are situated in the engineering domain:

- GEO Satellite State Estimation with Multispectral Image Information.

  The development of earth observation satellite missions trends towards high-resolution and detailed optical measurements. This results in high requirements on pointing and stability of the platform and the instruments and an exact geo-referencing of the images. To meet the requirements improved sensors and actuators as well as “Image Recognition” and “Image Processing” can be implemented. Within the scope of this dissertation the usability of multispectral image information for navigation purposes of geostationary satellites will be analyzed.

  Earth observation satellites acquire multispectral images during operational mode. Based on these images the motion of the satellite will be estimated by evaluating the image shift between two consecutive images (Image Motion Analysis). In conclusion, improved information about the state vector of the satellite is obtained. It will be analyzed which elements of the state vector can be derived and which AOCS configuration gives an optimal result.

- Application of Evolutionary Algorithms in the Design of Future Asteroid Missions.

  The design approach for space missions usually starts with the definition of scientific objectives. Based on these objectives the requirements for the measurements and the instruments are derived and it is decided on the architecture. Usually two or three design points are selected and further developed. The design points are improved by experienced system engineers based on intuition. This concept is well suited for traditional missions with fixed science objectives. However, in the recent years the cost efficiency becomes more and more important. Thus, nowadays a monetary budget is fixed and the question is vice-versa: “Which amount of science can be obtained to which costs?” Subsequently, a method for the exploration of design variants is necessary. The intention of the dissertation is to study the employment of evolutionary algorithms to the design of asteroid missions as one possible method. Asteroid missions are chosen as reference due to the increased recent interest and due to the amount of potential mission targets. A mission study will be performed to identify potential optimization criteria. Evolutionary algorithms are a well known multi-objective, “black-box” optimisation method. The Institute for Aerospace Engineering has developed a genetic tool for structural optimisation. It is intended to modify this tool to the needs of conceptual design optimisation.

Further topics are for example intended in:

- Possibilities for the Update of High and Medium Scale, Topographic Information Systems with TerraSAR-X Data in Flat, Hill and Mountain Areas.

  The main objective of this dissertation is the evaluation of the resolution of anthropogenic objects with the German radar satellite TerraSAR-X, who was launched successfully in June 2007. It is intended to investigate the influence of the relief and possibilities of reduction interferences. Additional investigations are intended to evaluate the aptitude for topographic information systems.

- Virtual Assembly Room for Satellite Development

  The virtual development including product simulation and process management with its potential for cost reduction and increasing reliability is an essential part of the future satellite development. The status quo of

available methods and technology is not able to cope with the future problems. For example, due to the increasing percentage of electrical components (e.g. harness) the geometric model (mCAD) is not able to answer the classical mechanical problems like moments of inertia. Therefore, the dissertation is supposed to evaluate and develop concepts of a virtual reality environment in which all actual developments can be included and accessed by all members of a development team.

Additional projects concerning the application of regenerative fuel cells for space applications and in the field of microwave and antenna design are under discussion.

6. FIRST EXPERIENCES

At the time being, some months after the launch of the Graduiertenkolleg, a final experience report certainly cannot be given. However, already now, some of the envisaged strategic objectives of the initiative can be confirmed. For example, the number of graduated students (interestingly the best of each year) expressing interest to be part of the Graduiertenkolleg in this constellation is very high. It turned out that pursuing a doctorate's degree especially in close co-operation with industry is a highly attractive factor.

Additionally, the amount of undergraduate students seeking for topics for their diploma or study theses in close relation to the topic of the Graduiertenkolleg received an appreciable increase – and not only from aerospace engineering students, but also from many other disciplines.

Another positive development is the enlarged number of students from the TU Dresden, who are applying to Astrium for internships, diploma or study theses in the last months. Most probably, this is a direct impact of the establishment of the Graduiertenkolleg.

Finally, the Graduiertenkolleg is seen within the TU Dresden as a successful model for a very close co-operation with industry without neglecting one of the core tasks of a university, the higher education of scientists and engineers.

7. CONCLUSION

The Graduiertenkolleg between Astrium and TU Dresden was successfully launched. Two projects are already running, 2-3 more positions shall be filled in 2007. The first experiences with this initiative are very promising and encouraging concerning the achievement of the envisaged benefits. It turns out that the constellation is highly motivating for young graduates as it gives them the possibility to perform scientific work but not disregarding a close relation to industry.

Based on the first experiences, it is the hope of the initiators and the authors of this article that this model of co-operation between industry and academia will be copied not only in the aerospace sector but also in other, especially engineering disciplines.

8. ACKNOWLEDGMENT

We would like to gratefully thank Prof. R. Benz (Astrium GmbH), who together with one of us (S. Fasoulas) had the idea in 2006 to found this industry supported activity. However, without his extraordinary engagement, the project would have never become reality.

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