Academic and Industrial Cooperation in Innovative Space Research

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The European Space Agency's interest in the broad area of academic research stems from the objective of building up capacity in universities in order to stimulate technological innovation, synergy and harmonisation throughout the ESA Member States. This article gives an overview of several initiatives and activities within the Directorate of Industrial Matters and Technology Programmes pertaining to academic research and cooperation, namely the Academic Research Programme (TRP), the Academic Research Pilot Initiative for the Mapping and Harmonisation of Space R & D Activities in European Universities, studies on University-Industry Relations in the Space Domain, and the Conference on Academic and Industrial Research Cooperation in Space (Vienna, 4-6 Nov 1998). Conclusions and recommendations resulting from the studies and the conference are also provided.

Introduction

ESA recognises that the interaction with the university and research centre community is of a different nature to that of industry in that it emphasises both scientific and technological cross- and multi-disciplinary innovative research, as well as the advancement of knowledge and education. The challenges of the 21st century demand creative and breakthrough solutions to space science and engineering problems. The funding of activities in institutes of higher education to encourage new ideas and stimulate subsequent innovative research and development is a necessary step in this direction.

Basic research in the space field is to a great extent carried out in universities; such efforts, however, may not always be taken full advantage of by the space industry or by agencies responsible for space activities. Although networks facilitating cooperation and exchanges between universities and industry do exist at European level, these are not necessarily in the space domain.

Since a university has two other interrelated missions besides research, namely education and a role in society, the research it undertakes could also be used as a basis for curriculum development (particularly in science, technology and engineering), enhancement of student research potential and contribution to the space workers pool, and for student and regional community outreach programmes in space topics.

A framework thus needs to be developed which would improve and reinforce the contacts and relations between academic research institutions and industry, particularly SMEs, in the space field and which would also encourage university groups not usually involved in space activities to create partnerships with industry (and vice-versa), and to enhance innovation and competitiveness in the space domain. Such a framework should be designed to assist regions within Member States to develop an academic research enterprise in conjunction with local industry which is directed towards longer-term, self-sustaining competitive capabilities, contributing not only to the improvement of the European space industry in general, but also to the region's overall economic viability in the future.

It is against this background that ESA's Directorate of Industrial Matters and Technology Programmes has initiated a number of activities with the ultimate aim of supporting the academic community in break-through research leading to innovative applications in the marketplace (Panel 1). The purpose, then, is to contribute to a more coordinated and innovative European technology research and knowledge base by harmonising the type and extent of space technological work carried out at universities, and showing how universities and industry could be mutually beneficial to each other in encouraging entrepreneurship and in sharing long-term objectives.

Academic Research Programme

Universities and research centres have always been involved in ESA's Technology Research Programme (TRP) either by providing ideas or input, by obtaining direct contracts or by acting

Objectives of D/IMT Academic-Industry Cooperation Activities ***Panel 1***

The main objectives of the various academic-industry cooperation activities can be summarised as follows:

- exploring and improving conditions for synergy and exploitation of research results between universities and industry in order to stimulate innovation and excellence in basic research, thus ensuring European competitiveness in the longer term and enabling new space programmes
- enhancing regional cooperative programmes among universities and local entities by encouraging scientific and technical R&D groups in both academia and SMEs, not usually involved in space activities, to create partnerships and exchange knowledge to the benefit of the space effort and the local community.
- provide the basis for any necessary technical and institutional framework for an expanded role for ESA in fostering links between academia and industrial sectors.

as sub-contractors. Whilst the research resulting from this method of working has been worthwhile, it was felt that an additional impetus was required. Hence the establishment of Academic Research as one of the Technology Domains under the Technology Axes of the current Basic Technology Research R&D Programme (1997-1999), in order to complement and enhance earlier arrangements by emphasising industry(SME)-backed research in universities which would eventually become a capability-building effort.

The Academic Research Programme (ARP) should ideally concentrate on institutes of higher education which have a demonstrated competence and are able to offer a high rate of return – though this is not to say that universities which currently have little or no involvement in European space programmes would be precluded. Universities would be expected to conduct frontier research into space-related developments, which could be transferred into applications and exploited by local industry (SMEs) to the benefit of the European space programme, thus contributing to a stronger science and technology research and knowledge base. Such developments have the effect of raising the profile of research, transferring knowledge from the academic to the public or market domain, and fostering regional development.

Funding options

Various options under which the funds available from the Academic Research Programme could be allocated for unsolicited proposals from academic institutions in order to complement the existing participation of universities in the TRP have been explored. These included the following methods:

– Joint Academic/Industry Research Programme:
  Part of the funds could be used to establish a Joint Academic/Industry Research Programme whereby awards of e.g. 10 000 € would be given to a university researcher to collaborate with a local industrial partner. This seed funding would be matched by the university and/or industry. The aim would be to bring university researchers together with industrial researchers and technologists in highly innovative space R&D projects with significant economic (return on investment) development potential. It would have the effect of introducing top university scientists and engineers to real industry problems, and would give the region's smaller industries access to the high-tech, high-cost facilities at universities.

– Direct funding:
  Another way could be to provide funds directly to institutes of higher education in order to stimulate R&D in non-defined areas (i.e. in topics not initially suggested or defined by ESA). There could be two approaches – proposals from universities can be either unsolicited or solicited. In both cases, there would be some form of Announcement of Opportunity. This could be made in a number of ways:
  - via an Academic Research Activities home page on the Internet (linked via ESA pages such as the Industry home page or EMITS); this is likely to generate many responses (replies from non-European countries could be controlled) some of which, however, may be frivolous
  - via an announcement in the ESA Bulletin; this would go to a much smaller space oriented community and thus be more manageable. On the other hand, such an approach is likely to miss non-space oriented universities which are considered vital to the success of the activity
  - via TRP Technology Gatekeepers who could be asked to recommend

universities able to do research in given areas based on their experience; the university could then be approached to do solicited research or could be requested to make unsolicited proposals
- via university vice-chancellors; any general announcement is likely to generate several requests from different departments within a university. Since funds are limited, it might be useful to put the onus on the university itself to select proposals initially. The university vice chancellor (or equivalent) could be asked to solicit proposals on ESA's behalf, evaluate them and forward a maximum number to ESA.

Allocation of funds
Following discussion on the preceding options, the following approach was adopted as the initial scheme. Funds available under the Academic Research Programme are allocated in collaboration with the TRP Technology Gatekeepers. A selected number of these twenty or so staff members are issued with an Announcement of Opportunity (for contracts up to 50 k€) under which they are asked to find and recommend universities able to do innovative and breakthrough research in given areas based on their experience. The universities then make an unsolicited proposal involving, or endorsed by, a local SME. Such involvement can take the form of matching funds, provision of staff, making available research or marketing facilities, and so on. Funding is given for only one year's activity and the Technology Gatekeeper monitors the work.

Grants are given to universities (or research centres) as seed money for upstream research that ESA should not or cannot do itself, and a local industrial company (as user or applicator) is ideally identified and involved from the start. Equally, it should be research that the SME also cannot do by itself. Further, under the ARP, the proposals cannot be submitted by an SME even though it may want to work with a given university.

Although the SMEs do not receive direct funding from ESA at this stage, they can benefit by being able to avail themselves of the university's facilities, obtain visibility during the research phase by contributing to joint published papers, and being able to exploit and apply the research into marketable products and thus reap later rewards.

Based on their experience and contacts, the Technological Gatekeepers require prospective universities to submit a short proposal which principally includes: the background and introduction to the proposal; a statement of why the research is innovative and interesting or necessary for broad space use, and how it might be later applied and in what time scale; a concise description of the actual research to be undertaken, its estimated duration and cost, and details on the precise output to be achieved; and an indication of the interest, type and extent of involvement of the SME.

The Technological Gatekeepers make an initial assessment of the proposals and pass them, together with a recommendation on whether to accept or not, to the Academic Research Programme Coordinator who arranges for them to be further evaluated. Criteria for the acceptance of proposals include: novelty (breakthrough potential) and general usefulness of the research; the planned exploitation or application of the research at a later stage, the interest, suitability and relevance of the research for space; the priorities and balance indicated by ESA's Dossier 0; and the relationship proposed between the university and its SME partner. The development of a simplified small contract procedure means that, following acceptance, work can start almost immediately.

Within the constraints of the TRP budget, some 30 proposals for funding under the envelope for Academic Research have so far been received of which about 20 have been accepted. The funds requested varied from as little as 5 k€ in one case to 70 k€ in another, although the average amount given was 38 k€. Nearly all Member States have one or more universities receiving funds under the Academic Research Programme.

Other initiatives under the TRP
Academic Research Cooperation Programme
The Academic Research Cooperation Programme (ARCoP) is a follow-on initiative to the ARP. However, unlike the present ARP, where SMEs are not expected to receive direct funding from ESA, in the ARCoP programme only SMEs would be given the possibility to submit proposals, though preferably in cooperation with a university or research centre. An Announcement of Opportunity is expected to be issued in the first half of 1999 and it is anticipated that the proposals selected will be funded to a maximum of 30 k€ per proposal. Funding is not given to both a university or research centre and an SME for the same research project, and the same simplified procurement procedures developed for the ARP would be implemented.

Announcement of Opportunities for Technology
The Announcement of Opportunities for

Technology (AOT) within the current TRP has the objective of soliciting proposals from non-primes (including SMEs as well as universities and research centres) for the development of near-to-market products in the space domain in order to gain better positioning of new technologies in the commercial market. The AOT is essentially a partnership scheme involving ESA, industry and other European partners dedicated to improving the worldwide competitiveness of European industry, and leading to a significant and demonstrable improvement of space products close to market. The Announcement of Opportunity for Technology Innovation for 1998 resulted in some 21 proposals being selected for co-funding. It is expected that a new AOT will be available in the first half of this year. Although not aimed specifically at universities and research centres, such institutions are not discouraged from replying to the AOT.

Academic Research Pilot Initiative

Through its Directorate of Industrial Matters and Technology Programmes, ESA is undertaking a technology mapping exercise to be used as input to the European Space Technology Master Plan (ESTMP), which is being established in cooperation with the major players of the European space sector, namely space industry companies and national space agencies. One area that has to be addressed in this cooperation is that of universities and research establishments, as regards their research and development activities relevant to medium- and long-term space needs.

Through its Technology Research Programme, as well as other programmes such as the ARP, ESA does provide some funding for universities working in areas deemed to be of interest. However, the Agency would like to obtain a more complete picture of the space-related research and development actually being carried out in universities. An exercise is thus underway to map the European known technological priority requirements and future needs (as given in Dossier 0) with the current research in universities and research centres. The major objective of this ongoing Academic Pilot Research Initiative is to push for innovative R&D in order to prepare for the long-term competitiveness and capability of the European space industry. The results should prove useful to space agencies, industry and research sectors, serving to harmonise the type and extent of space technological research carried out in universities. Furthermore, they would clarify current academic research priorities, where redirection of effort or additional funding might be desirable, and reveal areas of technological research and development that could lead to innovations applicable to the space sector (Panel 2).

Given the enormity of what is essentially an in-house effort, rather than targeting all institutes of higher education and research establishments in the Member States, during December 1998 some 640 questionnaires were initially sent out to all the university departments given in the ESA Bidders List. To date 179 (28%) completed questionnaires have been returned from a total of 96 different university departments/institutes. Replies were received from all Member States except Denmark, though the number of returns was rather low from some other countries (particularly France and Sweden). Both Italy and the UK provided almost 50% response.

The results from an analysis of the questionnaires show the extent of cooperation between universities and other bodies: some 80% of respondents carry out their research activities with other partners – usually either another university, a research institute, or large industry. Most respondents had multiple partners and many of these partners were in different countries. Regarding funding of space technological R&D, many activities were co-funded or funded by the universities themselves. Roughly half of all the research activities were being undertaken without ESA funding. In fact, although ESA was a co-funder for 40% of the activities, only 14% were fully funded by ESA. The biggest source of funding was government departments or programmes – mainly in Italy, the UK and Germany. Other important sources of funding were large industrial companies and the EC. Although many of the topics where European requirements for prioritised technology R&D, as exemplified by Dossier 0, were being well-covered by academic research, others were not. Furthermore, research was ongoing in several areas where there were no apparent Dossier 0 requirements.

University-industry relations in the space domain

Background

In line with the overall activities for academic-industry cooperation, two parallel General Study contracts (50 k€ each) were run during 1998: one with the Technical University of Dresden (TUD) (D) working in conjunction with HTS GmbH (D) and JRA Aerospace and Technology Ltd. (UK), and the other with the Turku School of Economics and Business Administration (SF) also working in conjunction with JRA for coordination, monitoring and support. The overall goal of the studies was to eventually be able to contribute to a stronger

Mapping Technological Priority Requirements ***Panel 2***

The following tasks are to be undertaken within the framework of the three-step approach currently foreseen for the European Space Technology Master Plan (ESTMP):

Task 1 - Inventory
- map ESA's known technological priority requirements and future needs with current and planned research in European universities and research centres in the space technology field
- map existing cooperative relations and links between and among European universities and research centres, and the European space industry and SMEs
- identify the most effective methods and mechanisms for transferring the results of university space-related R&D and knowledge to the market place.

Task 2 - Prioritisation
- establish a priority list (with justifications) of technologies relevant to the European space effort and that are currently being, or could in future be, researched and developed in universities or research centres either alone or in conjunction with an SME or larger industry
- access these space-related technologies, as well as the university research and education process, against the four axes of European strategy as defined by ESA's Director General with the aim of building up university research activities in the space technologies
- compare space technology R&D, collaboration with industry and transfer to the market place at European universities with those of universities in the USA, Japan and elsewhere.

Task 3 - Synthesis
- determine whether current funding and cooperative mechanisms for academic research are adequate and what new approaches might be required (e.g. from ESA, industry, the EU, governments)
- review whether university curricula meet the needs of tomorrow's space technologists
- establish coordinated and harmonised planning of space-related technology R&D within European universities and research centres in line with the ESTMP.

University-Industry Relations Study Tasks ***Panel 3***

The following tasks constituted the major activities of the studies:
- conduct a review of the existing cooperative relations between universities on the one hand and industry (particularly SMEs) and research centres on the other, in space-related areas in ESA Member States
- examine and compare the methods and mechanisms (and their effectiveness) currently employed in Member States for transferring the results of university R&D in both scientific and technology domains to the marketplace - particular attention being paid to the transfer of space-related know-how, research and technologies
- identify current and on-going space-related research and developments in universities and ascertain whether such research is likely to be of benefit to ESA and European space industry in the short-, medium- and long-term
- identify and propose activities and promising areas of long-term research into topics from which future space missions could benefit, and which could then be conducted at universities, later proving beneficial to promote cooperation and information exchange between the universities and SMEs
- formulate requirements aimed at improving and facilitating the relations and interfaces between academic institutions on the one hand and industry (particularly SMEs) and research centres in space-related areas, as well as space agencies (including ESA) on the other
- ascertain what funding (e.g. grants, matching funds, seed money) might be required for university scientific and technical research activities needed by the European space industry; determine which universities could undertake the research, with whom and what (additional or proved) mechanisms are required to bring university space R&D efforts to the market place via local SMEs as rapidly as possible
- identify a number of initiatives, either on-going, planned, or newly proposed, being carried out either in universities that could be made into cooperative ventures (i.e. by teams from both a university and an SME in the same region) and that would be suitable to act as pilot projects in this context.

science and technology research and knowledge base by encouraging greater cooperation between universities and industry in the same region. The actual activities undertaken by the contractors are given in Panel 3.

The two study teams took different approaches to the tasks and concentrated on a different set of countries in order to avoid duplication and overlap. The TUD study, which covered the German-speaking ESA Member States (Germany, Switzerland and Austria), Russia and Eastern Europe, tended to be more 'horizontal' and quantitative, looking at relations between research groups according to the technology classification of Dossier 0. The research found that academic-industry relations were broadly aligned with requirements of the space industry and also identified university groups without much contact with SMEs.

To complement the Technical University of Dresden study, the geographical focus of the parallel Turku study was on the Western European countries and Scandinavia. The European Union and nine European countries (Belgium, Denmark, Finland, France, The Netherlands, Norway, Spain, Sweden, United Kingdom) and the technical universities within them were reviewed to identify the types of collaborative practices employed and encouraged. In addition, seven Asian countries (Hong Kong, India, Japan, Korea, Malaysia, Singapore, Taiwan) and the US were reviewed to determine what sort of support and mechanisms are being utilised in university-industry collaboration outside of Europe. The Turku study was a logical extension of the TUD study and was more 'vertical' and qualitative, addressing more practical issues associated with the establishment of university-SME partnerships.

Summary of study conclusions

The transfer and commercialisation of space technology presents opportunities to European industry to enhance its competitive standing in the global applications marketplace. The role of universities and SMEs in this process is becoming increasingly important, particularly with the widespread recognition of the abilities of SMEs to mobilise the outputs of university research and to provide the impetus for innovation. It was found that there was a disparity across Europe among both universities and SMEs in the activities currently practised which promote collaboration, and that the space-specific collaborative activities are limited in focus. Furthermore, SME-specific support is limited in both the university and space industry settings. What is required is new mechanisms to create opportunities to bring more space R&D innovative efforts in both science and technology at universities to the marketplace via industry as rapidly as possible.

A literature review of some 40 print sources and interviews with two dozen SMEs in Finland and the UK highlighted a number of key issues for these companies in participating in technology transfer and collaborative research activities. In particular, it was found that SMEs often lack the resources for space technology transfer, including financing, managerial and other human resource support. Possibly as a result of this, they typically tend to seek short-term (i.e. less than one year) business solutions. In addition, SMEs have different communication needs than larger enterprises, and rely more on personal contacts and print materials than their larger counterparts. They also prefer informal contracts, and mechanisms that are simple and familiar to them.

There is a clear need in Europe for a single information disseminator, especially for technology requirements, and an objective assessment of the support that can be provided to space and non-space companies by university-based space research groups. This clearly points to a requirement for mechanisms to promote long-term collaborative activities.

In the Turku study, nine such primary mechanisms were identified. An assessment of each mechanism was made to determine the long-term effectiveness in promoting continued university-industry collaborative relationships (based on criteria such as frequency, duration and scope of contact) and the level of contribution/inputs of the participants. Among the most effective mechanisms were collaborative research and exchange of personnel.

Whilst European countries and universities offered a similar breadth of programmes and support mechanisms as their counterparts in the US and Asia, there were some notable differences, for instance: the concept of an Industrial Liaison Office and the use of intermediaries is not standard practice in much of Europe. Furthermore, collaborative mechanisms that support long-term relationships and support services, which focus on business planning and strategy as well as technology development, are lacking in many European countries. Indeed, many support services in the US are provided on a fee-for-service basis, which could be adopted in Europe and work to minimise the need for government funds. Some areas of technology development in Asia are specifically reserved

for SMEs, whereas support for SMEs in general is inconsistent across Europe. Industrial PhD programmes are gaining popularity in Europe, however, they have yet to prove their achievements and success in promoting collaboration.

A review of space agency support for university-industry collaboration was also completed utilising print and WWW information, as well as personal contacts. This review included agencies in the US, Japan, European Union, Belgium, Denmark, France, Spain, and the UK. Key findings for Europe were that gaps exist in SME support programmes and that there is a lack of focus on long-term programmatic support, such as access to facilities and technical/business expertise. In addition, awareness of space support programmes is irregular and nationalistic, and assessment of university space research capabilities is virtually non-existent. A strong 'big picture' provider and a road map for long-term research are also lacking.

Because it was determined that the existing mechanisms were insufficient for promoting the development of long-term university-industry collaborations in the space sector, two alternative collaboration mechanisms were developed and analysed. The first was a cluster model in which SMEs could be matched to individual university research groups to form a series of clusters, potentially fulfilling some future space technology requirement. Clustering among university research groups and businesses can provide not only informal links and collaborations that promote information sharing and long-term relationships across borders and sectors, but also a low initial investment collaboration option which is SME-friendly. A rationale and methodology for forming the clusters was developed, and a proposal was made for the formation of nine distinct clusters in seven different European countries. An association model was also developed which proposes that universities or intermediary organisations seek to establish a forum with businesses, in particular with SMEs, with the express purpose of investigating technology development and commercialisation opportunities within the space sector.

Resulting recommendations to ESA are discussed in the section 'Summary and Recommendations'.

Conference on Academic and Industrial Cooperation in Space Research

Background

The forgoing ESA assessment studies on university-industry relations provided useful input on issues requiring assimilation and discussion, and it was to this end that ESA organised a conference in Vienna, Austria from 4-6 November 1998. The main objectives of the conference were, firstly, to provide a stimulating forum for bringing together staff from universities, research centres and industry, particularly SMEs, with a view to presenting their collaborative leading-edge research activities, exchanging ideas, and discussing ways of enhancing medium- and long-term research cooperation, synergy and transfer in specific fields of interest to the space sector. Secondly, to explore what expanded role ESA should play in providing a framework for stimulating and fostering more collaboration leading to innovative and commercially-viable space applications. It was anticipated that the conference would provide recommendations for the formulation of policies and procedures for the transfer and use of research, knowledge and personnel in the space domain between universities, industry and ESA.

The conference was attended by some 100 delegates from virtually all ESA Member States as well as the US. Papers presented (contained in ESA SP-432) covered cooperative ventures between universities and industry, particularly SMEs, in a wide variety of initiatives including: joint development of, and flight opportunities for, scientific payloads; joint development of advanced technologies; transfer of technology and knowledge to industry; and building up of industrial capabilities.

Two hypotheses were advanced and addressed during the ensuing discussions. The first noted that the degree of interaction and cooperation between academia and industry has a profound influence on the competitive ability of the space community in all fields, i.e. from basic science to commercial applications. The second stated that we are far from the optimum in this respect in European space activities. The question then becomes: What can ESA, academia and industry do to improve the situation? A good deal of discussion took place on the topic of industrial and academic cooperation in space research (summarised below), and a number of recommendations were made (see section 'Summary and Recommendations').

The changing space industry

The space environment is changing, strongly affecting all players, i.e. the space industry, space agencies, SMEs, research establishments and universities. Space activities are also forcing transformation in the roles and interaction amongst the partners.

With the growing importance of space applications as essential contributors to the knowledge-based information society of the next century, the economic dimension of space is changing dramatically. Already today, the commercially-oriented space applications business counts on private investments, which exceed public space budgets – in fact, 1998 saw the production of more private than government-financed satellites. Space applications businesses are growing and have all the ingredients of becoming even bigger in the years to come. This can be attributed to industrial competitivity on a global scale, which has become the key driver for survival.

As a consequence, the roles played by space agencies will make the transition from exclusive leadership to genuine partnerships, and in the applications fields to one of supporting industry. Public-private partnerships will become the rule for many new ventures and will not remain mere exotic exceptions. Industry, in turn, will have to develop a more long-term strategic orientation, take more independent user and market-oriented initiatives, and invest while assuming the principle risks of business success or failure.

This era also opens new opportunities to SMEs with entrepreneurial spirit. Their flexibility, short response times, and cost effectiveness can put them in a strong position to corner a myriad of newly emerging market niches. Small satellite systems or ground equipment, for example, are becoming more powerful and less expensive, and today they can be afforded by many new customers and/or replace more complex solutions of the past.

Universities must respond to this new future and become proactive by adjusting their space curricula and research agendas. Research establishments must seek to open up to industry more than in the past and work in joint ventures with multiple partners. As knowledge update cycles continue to accelerate, more efficient interaction mechanisms between industry and academia could become survival issues for a number of players also in the space field.

Two paradigm shifts of fundamental importance to the conference were noted. One was that the fundamental changes in space activities and the space business are enormous – this has an effect on industry, society, the role of space agencies, public/private bodies, partnerships with industry and so on. The second was the shift from an industrial to a knowledge-based society with the need for closer cooperation in the development of new knowledge, coupled with a need for more rapid knowledge transfer and likely shorter knowledge update cycles. For example, telecommunications, navigation, remote sensing are all upgrading the knowledge base and enhancing society life, e.g. in agriculture, cartography, communications, etc. The challenge is to recognise, accept and respond adequately to these two paradigm shifts.

The university environment

Although the modern university is fundamentally an institution which conducts research and trains researchers, it does have other roles such as educating the population, providing education and training for industry and government, providing specialist consulting services, and acting as a think-tank. It has been noted, however, that the role of universities in research and high technology is decreasing in general and is often poor. There is a clearly a need to do something about this – mainly by universities becoming more involved with industry possessing fast market response times.

While most universities are undoubtedly excellent in specialist technical domains, they are also perceived to be unfamiliar with business cultures, shying away from real-world problems, good in information gathering but weak in knowledge transfer, and emphasising newness rather than efficiency. Universities are also often believed to exhibit poor evidence of cooperation on innovative, long-term frontier research partly because they advocate taking a

step-by-step approach leading to incremental improvement rather than breakthroughs. In particular, and in so far as space research is concerned, more industrial integration is needed with university faculties.

In Europe, there has traditionally been a strong demarcation between the academic and industry worlds because of different cultures, motivations, mechanisms for getting things done, knowledge domains, etc. In the university community there are highly qualified professors, motivated graduates, flexible working arrangements and a concentration on mid- to long-term fundamental (and increasingly applied) research. In industry, the emphasis is more often on near-term research, strong financial and time constraints and rigid working rules. Often, industry lacks the ability to independently carry out highly specialised applied research.

Happily, the situation is gradually changing with collaboration in all areas of the space field and a new trend in small spin-off companies. There are three main areas of cross-fertilisation between industry and universities in so far as space programmes are concerned: space research, teaching and training. University staff could provide seminars and specialised courses in industry, e.g. continuous teaching in basic knowledge and specific, project-oriented training in state-of-the-art knowledge. Conversely, industry could bring its expertise and operations to universities by providing engineers to lecture to students and by having industry representation on the university board of advisors. Longer-term student immersion in industry (with e.g. a thesis as output) would be more beneficial than shorter-term (few weeks) to both students and industry.

These ideas imply new methods of education, which, in some institutions, are already taking place. For example, The University of Surrey is practising 'learning by doing'. TU Dresden is giving entrepreneurship courses to train undergraduates with, among others, skills in creating business plans. The International Space University takes post-graduate students and young professionals who are already well-educated in their own particular discipline and gives them a good foundation in all the other disciplines encountered during a space programme.

British Aerospace has invested in its own Virtual University under a Managing Director/Vice-Chancellor to meet the industrial challenges in an ever-changing environment. It is part of BAe's commitment to expand the knowledge base and build in a self-sustaining culture of learning and continuous improvement right across the company through education, training and research. In conjunction with partner universities, BAe is offering to staff an array of education and training programmes (many degree courses) containing a balance between academic content and the unique requirements of the company.

A rather more ambitious initiative is being undertaken by the Michigan Virtual Automotive College, which is a consortium linking the State of Michigan, Michigan's universities and the automobile industry. The idea is that MVAC will integrate the automotive education and training offerings of Michigan's higher education providers with the support services needed by local car manufacturers and suppliers to provide convenient, cost-effective, and high-quality automotive education and training. MVAC provides surveys and assessments of the automotive industry needs, and creates education and training programmes to ensure that the car industry is kept supplied with the correctly trained personnel.

Another instance is found in Sweden where a strategic research education programme on advanced instrumentation and measurements based at Uppsala University has been proposed to ensure that Swedish industry has access to highly qualified PhDs. There is also the European Consortium for Advanced Training in Aerospace, comprised of universities and major industrial companies, with the aim of educating and training aerospace engineers and scientists in areas of multi-cultural and international cooperation in an effort to improve European competitiveness in this field.

As part of the objectives to strengthen Europe's competitiveness and to have a more active role in the future of Europe, ESA is faced with challenges of reinforcing, in a pan-European manner, its contribution to promoting excellence in education in the space field and, in particular, in favouring the creation of a talented workforce needed for the 21st century. Additionally, it is charged with setting up strong and lasting partnerships amongst ESA, industrial and educational communities, and enhancing scientific and technological literacy in Europe. Meeting these objectives required the creation of a dedicated Office for Educational Project Outreach Activities. The Office will endeavour to promote the inclusion of space-related topics in the curricula of students at all levels, and to foster the creation of possibilities for students to actively work on space projects before graduating, thereby promoting space activities and preparing them for a career in the space field. In addition,

students will be offered the opportunity to work on real projects together with professionals from ESA, national space agencies and European industry and will be made aware of technology available on the market or in its development stage, as well as how to evaluate it.

The industry environment

Several barriers and perceptions were identified that hinder the university-collaborative process in the space industry. Specifically, there is a common belief that space technology is too high-tech, over-engineered and complicated for 'real-life' application. Furthermore, the space sector is widely perceived by SMEs as a club which is difficult for them to penetrate, particularly with its reliance on consortia and prime contractor networks. The European space industry has, however, demonstrated a capability to reach businesses including SMEs through a variety of mechanisms including personal networks within the SPACELINK group, the distribution of the TEST catalogue of transferable technologies and the ESA web site. Although technology licensing tends to be the preferred method of transfer in the space community, it does not tend to promote long-term relationships. Additionally, communication gaps still exist between universities and SMEs – indeed, it is said that most SMEs are unaware of European university space research capabilities.

SMEs are considered as being excellent in their technical domain, though unfamiliar with academic research culture, unscientific in their approach and often as having only a vague perception of real-world problems. They are highly dependent on the acquisitional and administrative infrastructures of larger industrial partners. Their activities are often single-task based rather than having a strategic intent. SMEs could be an interface or catalyst between academia, large industry and space agencies in so far as R&D is concerned because they have simple organisational structures; offer motivated personal undertaking, inventiveness and intellectual capital; have a fast adaptive response to new market requirements and new technological concepts; and are flexible.

SME expectations from cooperation with universities could be seen as leading to new applications, providing a synergy effect in non-space related industry, as a prelude to establishing innovative teams (possibly at student level), as a way of attracting knowledge, and keeping qualified people. Currently there are too few PhDs attracted to industry and, thus, there is a need to guide academic research towards industry. Since industry felt it was not sufficiently represented on academic boards, then this is possibly one aspect to consider.

The relationship between industry and academia is changing. For instance, US industry is now attracted to NASA's Space Grant consortia not only because of the collaborative nature of the consortium and the positive political influence, but also because of the possibility to carry out high risk R&D for minimal cost. It also affords a single source of resident expertise, as well as employees with problem-solving experience. On the other hand, university attraction for US industry is the ability to tap industry for political, economic, human and infrastructure resources, and gain real-world expertise for faculty and students by enabling them to attend summer or academic internships in industry. In addition, universities are able to tap industry for mentors and use industry as a vehicle for technology transfer to reap the benefits of subsequent royalties.

Universities benefit from international partnerships and exchange opportunities because they are exposed to different ways of working. Besides benefiting from (space) industry's experience, students are provided with an opportunity to learn on the job and gain working experience before actually entering the workforce. In fact, industry wants more multi-disciplinary people to work in its ranks to provide a cross-fertilisation of research. Many industry applications benefit from leading-edge research, which in turn stimulates new applications.

Improving academic-industrial cooperation

Academic-industry relations are essential, not necessarily for the business case of today, but for that of tomorrow. A number of mutual benefits of academic-industry cooperation have been advanced:

- by expanding knowledge, industry can become more competitive
- industry fosters research by funding universities and research centres
- industry may be regarded as a link between the market and the scientific community and, thus, is able to transfer research results to operational products and universities get real-world testing of scientific models
- university labs can orient research as a function of the market
- industry encounters reduced R&D costs for innovation and new technology that can be translated into a significant competitive advantage in terms of quality and efficiency
- a richer industrial fabric would result from new spin-off SMEs.

Thus, there are advantages to both universities and industry to be gained with closer cooperation.

Of course, there are a number of potential pitfalls that need to be overcome. These include communication and cultural barriers, and the very different reasons for being in existence. Attention must be paid to ensuring respect for intellectual property rights and that industry secrets are not leaked to competitors. Equally, industry must not think that students and faculty can be used as a source of cheap labour. Instead, industry should contribute to motivate advanced research with, for example, appropriate award schemes.

Cooperation in some areas between universities and industry is happening naturally and no special measures are needed in these cases to facilitate or improve cooperation. In the biotechnology field, for instance, nothing happens without good cooperation between universities and industry – it is a natural process and more formal cooperation is probably unnecessary. On the other hand, in the space field, it would be very desirable to have a greater degree of cooperation particularly where SMEs are concerned.

Suggestions for successful cooperation between academia and industry include: establishing effective communication, finding areas of common interests and defining common problems, initiating solutions that benefit both partners – particularly public/private partnerships, more ESA funding for academia (e.g. for funding PhDs in innovative research fields) to induce other kinds of cooperation. Closer physical locations are also seen as an advantage – science parks have not generated close symbiotic relations. Integrated university/industry sites may also foster further exchange in staffing, e.g. academics working in industry. This could sharpen academic research with real applications, provide independent funding, enthuse and train a young generation of engineers in technology, as well as management and finance.

The European Universities Space Research Association: a proposal

ESA clearly has a role to play in fostering such cooperation. In light of its desire to reposition itself and enhance its role within the space community, it might be advantageous for ESA to initiate the creation of a European Universities Space Research Association (EUSRA). The proposed association would provide a mechanism through which universities and other institutes of higher education could cooperate more effectively, not only with one another, but also with ESA, national space agencies and the space industry at large.

A similar body, the Universities Space Research Association (USRA), set up as an independent consortium of universities and specifically oriented toward the problems of NASA, has been successfully functioning in the US for almost thirty years. Standing panels of scientific experts provide programme guidance in specific areas of research. Most of USRA's activities are funded by grants and contracts from NASA.

The Association of Aerospace Universities is a network of UK universities involved in aerospace teaching and research. It was formed in 1997 to enable universities to collaborate and promote courses, consultancy and research expertise, to strengthen links with the aerospace industry and commerce, and to develop relevant higher education provision.

Obviously, it will be necessary to gauge the interest of universities in the ESA Member States, but an initial survey has shown that no such European-level academic body specifically oriented to space activities exists at present, and that universities would welcome some form of organised cooperation.

The precise composition, management, activities and funding of the EUSRA would have to be discussed and formulated. There should be some form of a Board of Directors responsible for setting corporate policy, with one Board member being selected from each Member State and possibly including a representative from ESA, the EU and national space agencies. Each university or institute of higher education in the Member States wishing to join EUSRA would appoint a representative to serve on the EUSRA Council of Institutions which would oversee and sponsor collaborative programmes of research activities, conducted jointly by universities (possibly with local SMEs) and relating to the needs of the various space projects at European and national level, as well as the space industry itself.

ESA already funds research conducted at universities through a variety of programmes and means. This funding could be possibly be consolidated and channelled to/through the EUSRA. Additional funding could come from the EU, national space agencies, industry and, possibly, the universities themselves.

Summary and recommendations

General conclusions

There are many institutes of higher education and research with currently little or no

involvement in European space programmes and which could develop useful synergy with them. Thus, a mechanism or framework which would bring such institutions into the space fold with the assistance of local small- and medium-sized enterprises (SMEs), while at the same time improving and reinforcing the overall contacts and relations between academic institutions and industry, would be a useful development. Furthermore, the support of industry in strengthening, expanding and enriching science/engineering curricula and improving educational capabilities, training opportunities and skills in space and related fields, is also a vital aspect. This would constitute a capability-building effort in line with the decision of the ESA Council at Ministerial Level to stimulate innovative capacity of European industry, paying special attention to SMEs. Universities could conduct research into space-related developments – particularly those at the cutting edge of technology (e.g. micro/nano technologies, superconductivity, interferometry, materials, energy sources, biogenetic applications, etc.) – which could be exploited by local space industry.

The motivation for the Vienna conference was to identify and discuss which mechanisms could be used for improving and harmonising innovation in space research especially between universities and industry. Universities have changed dramatically over the past twenty years – they support the industrial base more and still have a leading role to play in creating ideas and knowledge. While there are various degrees of cooperation between academia and industry with many examples of success stories, there are still too many scattered initiatives that could benefit from a wider harmonisation at European level.

ESA should foster new ways of thinking and collaboration. There needs to be a change in universities to some extent – a new kind of reward system, for example – and this requires also a cultural change to break through existing barriers. Communication, strategic and marketing channels are all needed as facilitators and graduates coming out of universities should not just have scientific/ technical knowledge, but also business, marketing, and entrepreneurial skills and understanding.

SMEs and universities do not have the resources to keep up with space programme needs and, therefore, ESA should promote these more and make its knowledge more readily available. Good communications are required, especially since universities have to promote themselves (through publications, research, etc.) and also need industry support. Successful cooperation should result in new applications and space developments with synergy effects in the non-space sector.

Recommendations

The two studies on university-industry relations in the space domain referred to earlier made a number of recommendations to ESA for improving the state of academic and industry cooperation (Panel 4). In addition, at the Vienna conference several other well-received general and specific recommendations were also made. Some of the more pertinent ones are detailed below.

It is abundantly clear that a role for the

Recommendations for General University-Industry Cooperation ***Panel 4***

- make the specific research capabilities and competencies of university departments better known
- encourage dual university-industry teams through specific budget lines (national/European levels)
- increase the number of national and European thesis grants earmarked for joint university-industry research
- industry should reserve a share of its R&D budget for joint university-industry research
- have internships in industry for PhDs/Masters with a focus on projects with universities
- reduce the intellectual barriers between universities and SMEs – this could be facilitated by entrepreneurship programmes at student (undergraduate) level between universities and SMEs
- improve communication links and generate resource support (human, financial, business)
- facilitate the matching process by having audits of university research departments with results available to SMEs and cluster complementary SMEs that could be partnered with university developments
- make more funding available for encouraging innovative university-industry commercialisation projects.

European Space Agency exists not only to raise the awareness of future space technology requirements amongst universities and SMEs, but also to provide market knowledge and reduce barriers to space industry entry, as well as to build an infrastructure in support of university-SME collaboration. Provision of such collaboration support would allow universities and businesses to focus on their core competencies and maximise resource utilisation.

In this context, one of the most immediate recommendations was that ESA should create some kind of Office for Academic Research Activities, within the Directorate of Industrial Matters and Technology Programmes, whose tasks are to promote and coordinate the Agency's academic-industry collaboration on R&D activities (such as the establishment of the EUSRA outlined above), map and monitor the innovative technological research conducted in universities, and ensure that such technological research is harmonised throughout the Member States in accordance with the ESTMP. Such an office would obviously work in close cooperation with those responsible for ESA's SME Initiative, as well as the Office for Educational Project Outreach Activities and PRODEX.

Other recommendations to ESA were that:

– mechanisms between ESA and the EU should be revisited and reinforced. Since the EU already has action plans involving universities-industry links in non-space areas (e.g. COMETT), then possibly ESA could use these mechanisms for training, research, teaching, etc., in the space field, and integrated into a unified policy and action plan. In addition, further harmonisation with other EU programmes (e.g. CRAFT) might reduce ESA budget needs, may reveal new SMEs not yet involved in space, and may improve access/relations to commercial markets. In this respect, ESA could run a funding scheme similar to, or perhaps even in concerted action with, the EU CRAFT programme, whereby groups of space oriented SMEs could be awarded funding to develop near-market technologies and products.

– ESA should make more information available and make it easier for universities to find out what industry does and needs. Examples could be the setting up of EUSRA, funding PhDs, workshops where universities can present their research and industry can say what their requirements are, technology fairs where short 'product/service presentations' could be given, and having a dedicated Academic Research Web page.

– ESA could establish a kind of supply chain review (i.e. identify all SMEs and university institutes that provide technologies or services to ESA contractors) to 'capture' the companies and institutes currently involved in space activities. ESA could provide funding on a competitive basis to supply the 'chain members' (SMEs and institutes) looking for development and expansion of their range of products and services, particularly through university-based contract research.

– ESA could co-fund regular technology audits within space SMEs in order to establish and consolidate its long-term technology needs. Using the outputs of these activities, ESA could then direct the SMEs to university research groups in their country that could help to promote, and permanently upgrade, their technological base, either through technology transfers or contracted research.

The ESA Department of Industrial Matters and Technology Programmes is giving active consideration to these recommendations and will shortly ascertain whether the European space sector should elaborate priorities and strategies on long-term innovative and harmonised technological research in universities and research centres. If so, it will determine the criteria to be adopted in distributing the work plans of a coordinated/ cooperative European space research programme. esa