TECHNICAL UNIVERSITY OF DRESDEN	University-Industry Relations in the Space Domain ESA Contract No: 12685/97/NL/MV	HTS GmbH JRA Aerospace & Technology Ltd

Executive Summary

University-Industry Relations in the Space Domain

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EXECUTIVE SUMMARY

1 Study Background

Basic research in the space domain is often carried out by universities; such efforts, however, may not always be taken full advantage of by the space industry nor space agencies. Although networks facilitating co-operation and exchanges between universities and industry do exist at European level, these are not necessarily in the space domain.

There are also many institutes of higher education which currently have no or little involvement in European space programmes. Thus a mechanism which would bring such institutions into the space fold with the assistance of local industry would be a useful development. This would constitute a capability-building effort and be in line with the decision of the ESA Council at Ministerial level to stimulate innovative capacity of European industry, paying special attention to small- and medium-sized businesses. Such universities could conduct research into space-related developments – particularly those at the cutting edge of technology (e.g. micro/nano technologies, superconductivity, interferometry, materials, etc.) – which could be exploited by local industry to the benefit of the European space programme.

Since a university has two other interrelated missions besides research, namely education and a role in society, the research could also be used as a basis for curriculum development (particularly in science 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. Universities thus would merge the knowledge-based activities of their research and training activities and make them available to SMEs within the regional community.

A framework thus needs to be developed which would improve and reinforce the contacts and relations between academic institutions and industry, particularly SMEs, in the space field and which would also entice or encourage university groups not usually involved in space activities to create partnerships with industry (and vice-versa) to the benefit of the space effort, and to enhance competitiveness.

Such a framework should be designed to assist regions within the Member States to develop an academic research enterprise in conjunction with local industry which is directed towards longer-term, self-sustaining competitive capablities which will contribute not only to the betterment of the European space industry in general, but also to the region's overall economic viability in the future.

1.1 General Goals and Objectives

The main goals of this study can be summarised as:

- Support to the development of mechanisms which would bring academic institutions (universities and other institutions of higher education) into the space field with the assistance of local industry

- Support to the transfer of academic research results - particularly those at the cutting edge of technology (e.g. micro/nano technologies, superconductivity, interferometry, materials etc.) to the benefit of the European space programmes

- Support to the stimulation of innovative capacity of European industry, paying special attention to small- and medium-sized businesses (SMEs)

In the course of the study following objectives are envisaged to be met:

× analysing the efficiency of links and relations between universities and companies (particularly SMEs) in the same region working in the space industry.

× assessing the potential benefits for SMEs in working together with local universities to promote post-graduate research in space-related areas

× defining requirements for a framework which will
  - improve and reinforce the contacts and relations between academic institutions and industry, particularly SMEs, in the space field
  - entice or encourage university groups not usually involved in space activities to create partnerships with industry (and vice-versa)

These results shall put ESA into the position to define some necessary technical and institutional framework which will enhance the role of ESA in fostering greater links between academia and industrial sectors.

1.2 Study Team

The study team provides "insider" knowledge on each of the main groups involved in the technology transfer process:

Group (A) "Universities"
is represented by Dresden University of Technology (TUD), whose representatives are being involved both in current space and non-space academic research activities.

Group (B) "SMEs"
is represented by HTS enterprise, whose representatives are being involved in space and non-space related commercial business

Group (C) "Technology Transfer Institutions"
is represented by JRA, whose representatives are being involved in particular with space related transfer programs.

1.3 Authors

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1.4 Study Outline

⊆ **Work Package 1: Co-operative Relations Modelling**

The result of this task is a formal "Co-operative Relations Model". The model shows and maps representatively the structure of university-industry relations in space-related topics. To use this model as a working tool it has been implemented in a commercial data base system (Microsoft Access™).

⊆ **Work Package 2: Know-how and Results Transfer Modelling**

The results of this WP is a "Know-how and Results Transfer Model" which shows how successful universities are in rapidly exploiting the results of their scientific and technical R&D activities and to what extent they use local SMEs and the Internet to assist in this process.

⊆ **Work Package 3: Space Activities Modelling**

The result of this task is a "Space Activities Model" which correlates space-related scientific and technical R&D in universities to the actual needs and requirements of the space industry and forthcoming ESA programs. This model is also implemented in the data base tool and complements the Co-operative Relations Model.

⊆ **Work Package 4: Institutional Framework Requirements**

The results of this WP is an institutional framework and implementation plan and a suggestion of a "best practice" set of guidelines based on the findings from WP1-3.

⊆ **Work Package 5: Pilot Projects**

The result of this task is an outline programme of selected space-oriented co-operative Pilot Projects suitable for follow-up investigation by ESA.

2 Co-operative Relations Modelling

In this study chapter, a review of existing co-operative relations which exist between universities on the one hand and industry (in particular SMEs) and research centres on the other hand in space-related areas is carried out.

Furthermore, university groups are identified which undertake research activities in space-related domains and their research is grouped into baseline technology classes as well as in types of relations. This information is stored in a data base and statistical data of this database is presented. The same activity identifies SMEs which are active mostly in the same region as the university research groups they work together with. The basis for this analysis is a short survey, carried out among 108 university institutes and research establishments working in the space domain.

The result of this review is a model which characterises the overall actual and potential European university-industry relationships in the space domain.

2.1 Research Transfer

University-industry relation exploitation of university research results can be increased by using *research-*, *knowledge-* and *technology transfer* which are regarded as applicable transfer mechanisms. **Research transfer** is defined as the application of results (inventions) of scientific research in non-scientific fields. **Knowledge transfer** has been defined as „the process by which knowledge concerning the making or doing of useful things contained within one organised setting is brought into use within another organisation context". **Technology transfer** is commonly regarded „...as the movement of technological and technology-related organisational know-how among partners (individuals, institutions and enterprises) in order to enhance at least one partner's competitive position.

There is no clear and common definition of the term *know-how*. Know-how can be presumed to be *applied knowledge*, e.g. knowledge that is collected, learnt and understood by the individual and applied to some specific purpose. Hence the focus is on the applicability of knowledge. A *know-how owner* (KHO) is defined as a person, academic or non-academic institution or company possessing specific technical and technological know-how; *clients* are companies, academic or non-academic institutions or persons as possible parties involved in research-, knowledge- and technology transfer, see Figure 1). Hence universities are not know-how-owners by definition. Moreover they can be in the position of *clients* as well. However, the usual transfer process will be determined by academic institutions (e.g. universities) being know-how owner (this is largely due to the original task of universities of being active in basic research possessing a certain responsibility and capability for basic technological breakthroughs).

Regional/Generic Academic/Industry Relations

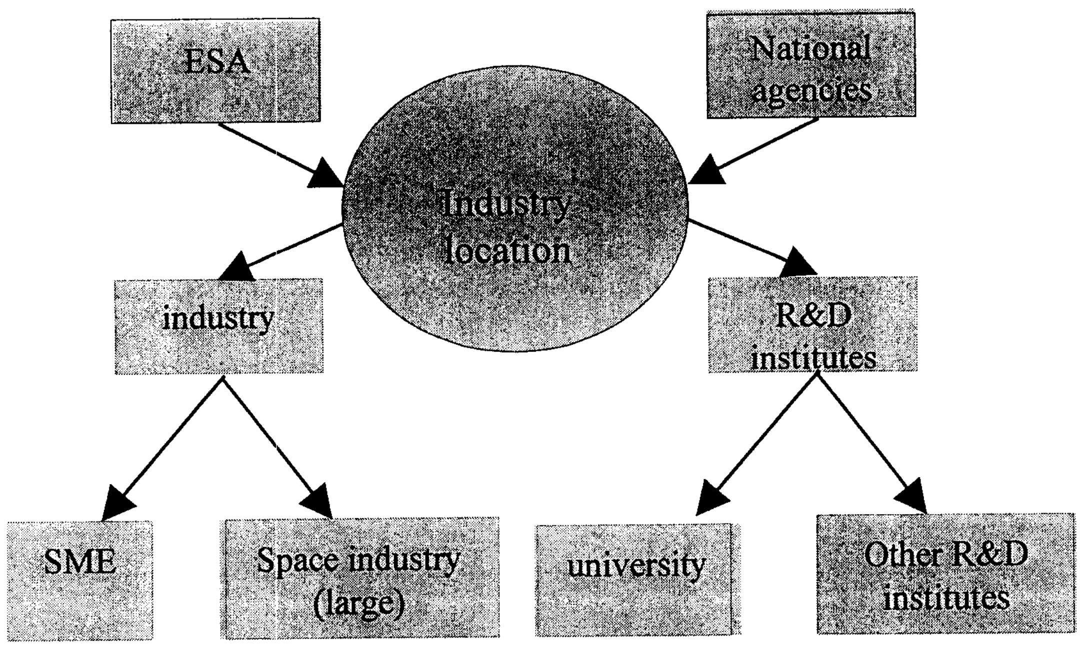


Figure 1: Generalised Relations Tree

2.2 Modelling Approach – A Generic Relations Model

Partner in transfer projects can be universities, R&D laboratories, SMEs and large industry, government institutions as well as national or international bodies. This is reflected in the generalised relations tree, Figure 1.

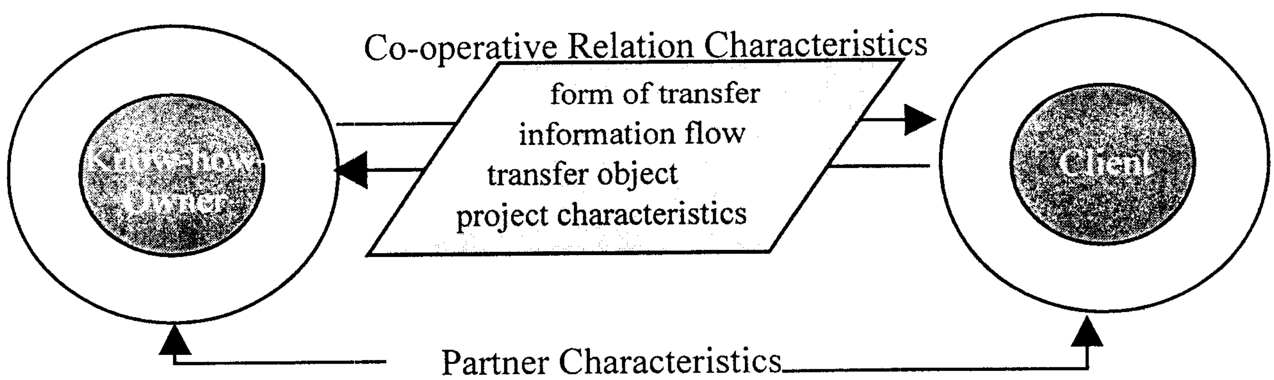


Figure 2: Generic Relations Model.

Partners can be classified by their total number of staff, turnover and regional activity. Technology transfer depends on the technical and technological position of the partners and therefore some basic partner characteristics can be derived, as shown in Figure 3:

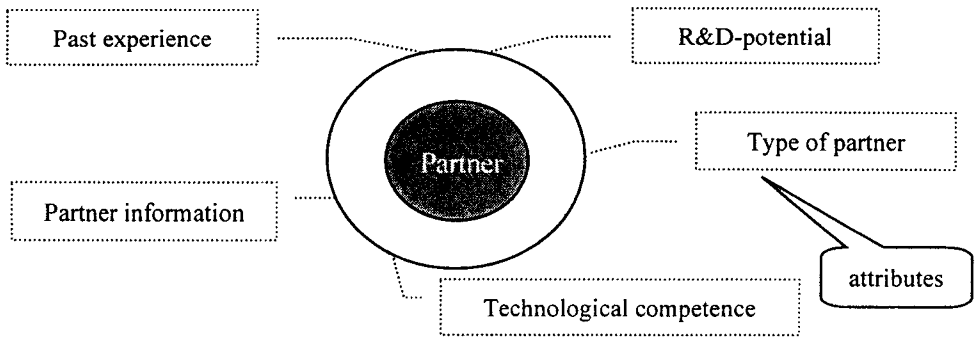


Figure 3: Partner Characteristics

The characteristics can briefly be described as:

- Technological competence: Depending on the transfer object, the fields of industry, science and technology have to match between partners. A classification of technologies will be given later.
- R&D potential is determined by R&D-staff and - budget. Both figures can vary depending on fields of industry (of technology and science, respectively).
- Type of partner: Partner in transfer projects can be universities, R&D laboratories, industrialists of both big and small and medium sized industry, governmental institutions as well as national or international bodies (see also generalised relations tree, Figure 2).
- Partner information: partner information can be given by name, country, reference source, total staff, turnover and regional activity.
- Past experience: Partners should both posses a certain level of knowledge and experience in related technology (science) fields.

2.2.1 Co-operative Relations Characteristics

Co-operative relation is determined by the transfer form, the transfer object, the information flow direction and project specific characteristics. These items shown in Figure 4 should describe the co-operative relations sufficiently.

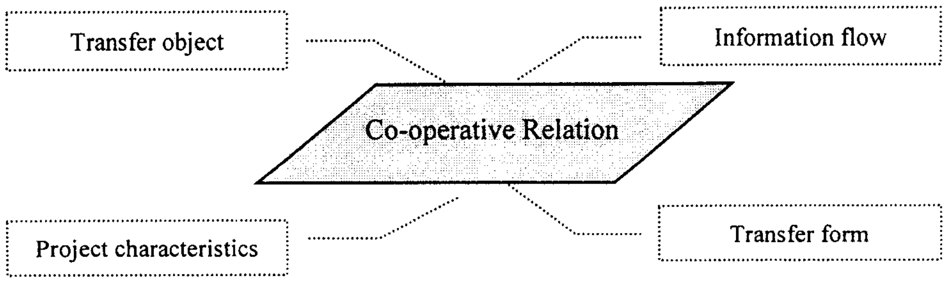


Figure 4: Cooperative Relations Characteristics

- Transfer form: The transfer form can be
  - knowledge driven
  - Know-how driven
  - Intellectual Property Rights (IPR) driven
  - Communication driven
  - Network driven
  - University service driven.

- Transfer object characteristics: Three levels of Technologies were identified, Table 1. A basic class, designating technologies as space-related, a subset dividing these into space specific, ground specific and general technologies and a further subset of technologies leading to baseline technologies, mainly taken from ESA's Dossier 0. The individual specific technologies identified through the survey are introduced as keyword attributes.

- Information flow: The direction of information flow largely depends on type of relation (transfer) as well as transfer object. It can be categorised into:
  - One-sided information flow (KHO towards Client or vice-versa)
  - Two-sided information flow

- Project characteristics: The character of a project can be described by
  - duration
  - past experience
  - reference
  - project name
  - funding / funding sources

Basic Class	Derived Class Level 0	Derived Class Level 1	Keywords
Space System	Space Specific	Components	individual
		Solar Cells	
		S/C Data Systems	
		S/C Instrument Technology	
		Control	
		Digital Communication Payloads	
		Systems/Technologies for Microwave Payloads	
		S/C Radar Technology	
		S/C Antennas	
		Thermal Analysis/Control	
		Electric Propulsion	
		Structures & Mechanisms	
		Pyrotechnics	
		Chem. Propulsion/Aero-thermodynamics	
		Materials	
		Micro/Nano Technologies	
		Manned Spaceflight	
		Space Biology	
		Power & Energy Conservation	
		Robotics	
		Precision Eng. / Optics	
	Ground Specific	Production / Test + Verification	
		Ground Facilities (Operations)	
	General	Software Engineering	
		Product Assurance	
		Space Systems Engineering	

Table 1: Baseline Technology Classes

2.3 Data Base Implementation

The database aims at

- implement the formalised generic relations model
- provide the data base as a tool for the verification and refinement of the generic relations model
- work with a first set of data gained through a small scale survey and obtain first results on university-SME co-operative relations in a limited area (Germany, Austria and Switzerland as well as Eastern Europe)

The contents of the data base also allows to identify university groups which undertake space-related research or which have the capabilities to do so. Also SMEs and their associated partners can be identified on the basis of the data sets contained in the data base. The relations to their partners and their characteristics represent a basis for the further analyses concerning the present university technology transfer. They also show which technologies are represented by which know-how owner, which technologies need to be supported by further research and in which countries they are present. The co-operative relations model shows and maps representatively the structure of university-industry relations in space-related topics.

A pilot survey was conducted in the geographic areas of Germany, Switzerland and Austria, which was later complemented by JRA by introducing information on Great Britain. Eastern European countries (Czech Republic, Kasachstan, Poland, Russia) were added on the basis of information available on the WWW due to time and budget constraints. Initial information was found by using the World-Wide-Web (WWW) which was later expanded by a mail survey using the survey sheet printed in the Annex of chapter 1. For budget reasons within this study, the survey is understood as a starting point and not as a comprehensive survey covering all relevant universities, research institutions and SME's. Therefore, it can only represent a "snapshot" of the situation regarding the relations between the relevant groups.

Besides research groups at universities, there are a number of independent research institutions which are not associated with universities. These institutions usually receive a large proportion of their funding from industry and public carriers. It is also apparent that these research institutes contribute enormously to the scientific research in the space domain. Also, many co-operative relations between these research institutes and university groups exist. In the data base, independent research institutions are treated like university research groups.

2.3.1 Data Base Structure

The data base offers four main data sets:

1. Know-how owner data set
2. Clients data set
3. Relations data set
4. Technology field data set

The structure of the data base is shown in Figure 5:

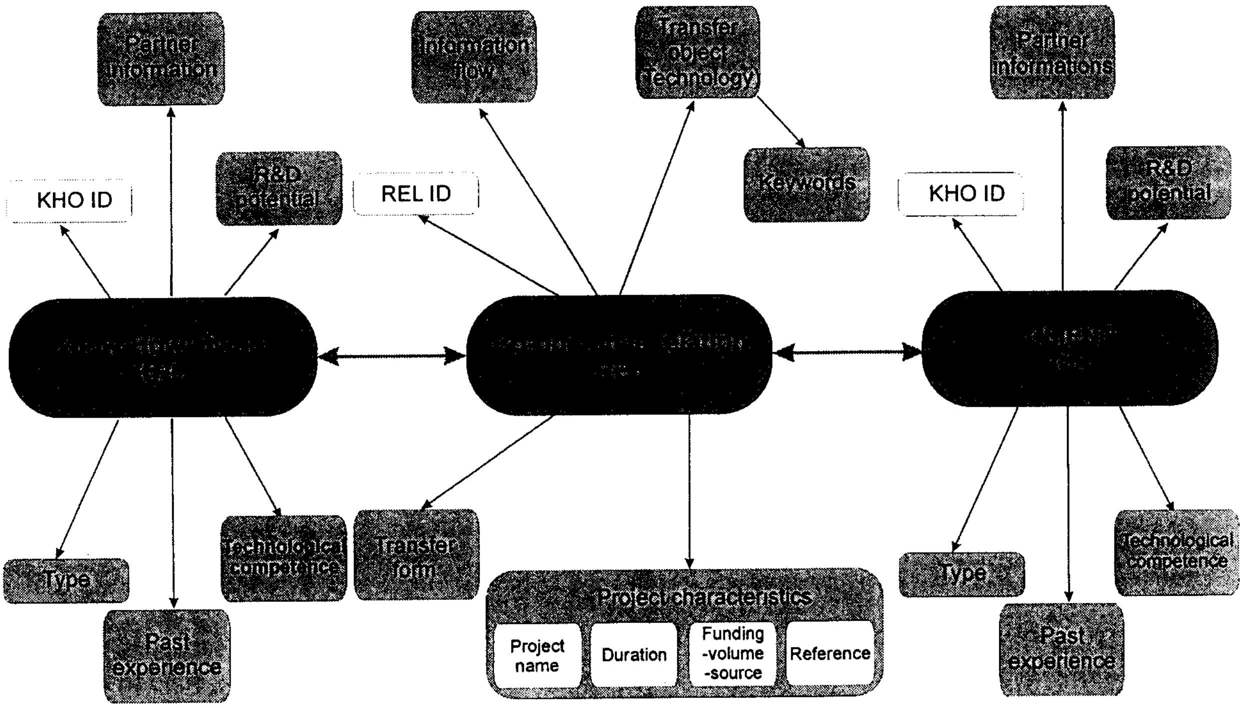


Figure 5: Implemented Data Base Structure

2.3.2 Data Base Results

The data base results can be summarised as valuable resources for information search concerning know-how owners, specific technologies, geographical distribution and partner types. Statistical diagrams of this data is presented in chapter 1.

The data base identifies 154 KHO's in Germany, Austria, Switzerland and Eastern Europe. 157 relations in form of projects in the space domain were identified . Most of the relations are between university groups and large industry followed by the relations between universities and small and medium enterprises. This situation is reflected by research institutes as well. Most of their relations are with large industry, followed by SME's.

The available data set shows that the participation of the small and medium enterprises at the space related projects with university groups is not satisfactory. First, the absolute number of projects with SME participation is small and second, this projects are concentrated in only very few technology fields.

A complete view of the actual situation can only be obtained through a more detailed investigation by introducing more data sets into the data base. This should result in a more representative description of the university-SME relations. Also, the geographical area could be extended beyond England and German-speaking countries, leading to the establishment of a European university-SME relations data base which also includes Eastern Europe and non-European countries. Owing to budget reasons of this study, this step has to be left for a possible follow-on study.

3 Know-how and Results Transfer Modelling

Tacit knowledge plays a key role in creating scientific and technological innovation. Industrial competitiveness depends to a large extent on spreading such knowledge. Building on chapter 1 of the study, methods and mechanisms currently employed by the member states to transfer the results of university R&D to the marketplace are compared and examined. The effectiveness of these mechanisms is evaluated.

The chapter follows the already mentioned forms of know-how and results transfer modelling (see Figure 4) and examines them in detail and evaluates them concerning their effectiveness. Characteristic properties of five case examples experienced by three space oriented SMEs in the region of Saxony (Germany), the HTS GmbH Coswig, FPM Space Sensor GmbH Freiberg and the IMA GmbH Dresden are presented and evaluated.

3.1 Example Projects

The five example project titles are:

- Development of specified CFRP-structures
- Extension of applications of standard S/W-products
- TUD Satellite (Feasibility Study)
- Development of a micro-optical sensor system for velocity and length measurement
- Personnel qualification and development by a special national subsidy programme

Summarising the results of these five case studies, the mentioned transfer forms and mechanisms of research transfer applied and pronounced in many different ways cannot be seen as separated from each other. Also it does not make sense if the research transfer is restricted to selected mechanisms. It is more important to develop the range of portfolios of transfer forms. The field of transfer scientific staff in particular has a considerable potential in the future. The universities profit by experiences made by enterprises, which support the practical applicability of the co-operation project. The fear of contact, especially small and medium-sized enterprises are afraid of, gets increasingly smaller by the link with the practice.

3.2 Promotion Methods of Know-how Transfer

In most cases policies and programmes are flanked with financial support measures to boost and/or initiate the utilisation of the different advantageous forms of know-how transfer between know-how owners and clients, between universities and industrial enterprises.

For the effective choice of appropriate promotion methods for managing and financing the realisation of a suitable know-how transfer form it is of great advantage to know about the differentiation and structure of programmes and projects.

There are on the one hand large programmes with more or less large to moderate budgets and medium to long term duration (more than 3 years) characterised in their realisation e.g. by

- mainly interdisciplinary character,
- with international multilateral project teams,
- centrally co-ordinated but decentralised organised work and consulting,
- consuming usually a lot of time and pre-financing as well as voluminous preparation activities for application.

On the other hand there are small programmes with smaller budgets and limited short or medium term duration (one half up to 3 years) which among others are mainly characterised by

- their limitation to special areas (regions, branches, subject matters etc.),
- require less partners (single applicants possible),
- require only limited co-ordination and
- need less time, financial and administrative loads for preparation of applications.

Due to limited resources in the SMEs the search for the right promotion method and the choice of an appropriate promotion programme or project is of particular importance for SMEs. Thereby the choice is done by means of certain evaluation criteria the enterprises individually determine according to their present economic and technological situation.

3.3 Choice of Appropriate Transfer Forms

There are priorities according to which the utilisation of know-how supporting programmes and along with special know-how transfer forms are chosen: As first resource for financing know-how transfer activities so far necessary for R&D full self-financing will be considered. In case the required volume would exceed the companies' own budgets for the measures time period secondly mixed or co-financing should be scrutinised, i.e. using partially own money but also outside funding. Only when there is an extremely desperate situation for money requirement in conjunction with an urgent know-how transfer necessity at a pressurising time the third way of generating exclusively outside financing from bank credits should be chosen.

In the following the most important evaluation criteria for the choice and utilisation of transfer forms are listed from an SME's point of view. The ranking on the criteria depends on the nature of the institution and the overall economic environment.

Essential evaluation criteria are:

- strategic business plans of the companies or strategic action plans of universities
- emergency of action and necessity of remedial measures, caused for instance by:
    * a new market and competitive situation which requires urgent and fast product/service improvements to further prevail or cope up with the market or even survive
    * human and capital capacity bottlenecks which hinder a smooth and continuous progress in product developments
    * time horizons and time pressure, etc.

- necessity and the willingness to handle an emerged situation of required sustainment or further extension of the company's business areas in order to combat the market hurdles
- pros and cons of the different transfer forms applicable to the actual situation

Once decided to utilise any form of know-how transfer to manage pressurising know-how problems within a demanding business environment additionally other factors for decision making come into play, as there are:

- availability of own financial resources and judgement of own capacities
- availability of a promotion programme and assisting financial support, granting to be expected
- character of the possibly assisting programme (level and area of applicability, access to the programme, conditions and modalities of co-funding)
- time between ITT release and submission of proposal
- extent of project proposal
- expenditure for proposal preparation (time and cost)
- partners required (kind and number)
- administrative workload (preparation and realisation phase)
- success probability of proposal acceptance
- certainty of payments
- availability and conditions of outside funding sources

Summing up, in general

the application/utilisation of any appropriate transfer form for the solution of a pressurising R&D task essentially depends on the question whether there will be a financing possibility at the very time the know-how transfer measure is necessary.

However, financing could mean pure private or self financing by the actors themselves or mixed financing or even fully outside public or private funding. The last two opportunities again depend on the access to technology transfer supporting programmes and actions on international, national or regional levels, their conditions and duration.

3.4 Discussion on Data Transfer Technologies

Today modern communication technologies like digital mobile phones, e-mailing and other multimedia and Internet services support the transfer of know-how immensely. New forms of co-operation between different institutions have work out like networking via Internet in a kind of virtual enterprises.

As already proved by example universities and SMEs can build up networks via Internet and thus can act as "Virtual Big Players" and doing it apparently they can open new resources to better compete with the Big Industry.

Main advantages of modern data transfer technologies for universities and enterprises are:

- increasing information flow and exchange (data volume)
- increase of time efficiency
- cost minimisation, e.g. due to time savings and reduction of travel expenses

4 Space Activities Modelling

Building on chapters 1 and 2, this part of the study identifies on-going space-related research and development at universities. It allows to

- map the technologies between universities and future ESA programme needs
- identify on-going space-related research at universities with promising benefits to ESA and the European space industry
- propose and identify on-going and future activities at universities of which ESA future space missions could benefit and could promote collaboration between universities and SME's.

The output of this chapter is a description of a space activities model. The modelling approach is to map requested technologies against baseline technology classes defined in Table 1. The baseline technology classes were found using the technology classes from Dossier 0. The technology baseline classes do not define technologies themselves, they contain certain *keywords* which represent the technologies. Those keywords define specific technologies and products which can be derived from available files specifying future space programmes.

The ESA technology needs are derived from official space programme-related files, specifically the "Dossier 0" which points out future prospects, technology requirements and industrial trends for the European space sector.

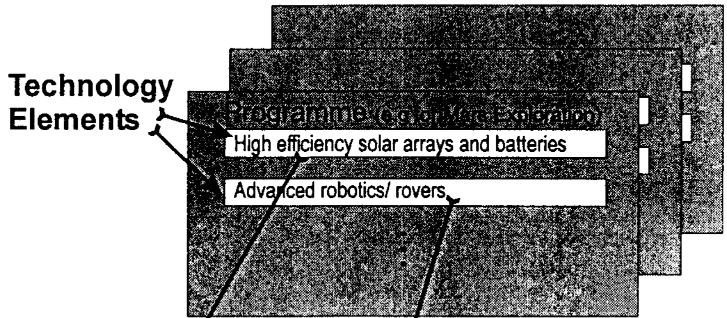
The technology needs are classified into following main classes:

1. Public Services
2. Commercial Services
3. Science and Exploration
4. Man in the Space Domain
5. Major Requirements for Commercial Applications

Technology mapping: The identified technology fields, as stated in Dossier 0, were published with the intention to contribute to preparing a research and development strategy. Converting this strategy into real projects requires an overview on where required technologies already exist and where technologies need to be developed.

To see a mapping between the technology classification and the ESA technology requirements, a matrix table was set up. The working principle of this matrix is shown in the example outline sketch given in Table 2. Here, a possible programme for mars exploration includes a lander with a rover. Among the technologies required are high-efficiency solar cell arrays for operating the lander on Mars' surface. Further, advanced robotics are required for the rover vehicle. These example technologies are derived from the technologies listed in

Dossier 0 (Section 3.3) and are, with their codes, the links between the baseline technologies used in TUD's data base (left) and the technology classes used in Dossier 0 (top).



Baseline Technologies	Technology Requirements: Commercial Services	Science & Exploration	. . .
Power & Energy Conservation	High efficiency solar arrays and batteries	Nuclear reactor power source	
Robotics		Advanced robotics rovers	
S/C Instrument Technologies	L-Band SAR	Doppler Wind LIDAR	
⋮			

Data Base

Table 2: Principal Technology Mapping

Technology mapping results: Figure 6 shows the *total number of ongoing relations* (black), taken from our database, and *technology requirements* (shaded), taken from Dossier 0. These numbers are drawn against the baseline technology classes as used in the data base. The technology requirements are not given in absolute number but were converted in relative numbers showing the relative frequency of their appearance, compared to the relative numbers of relation entries in the data base. The number of relations is an absolute number and the figure shows their distribution.

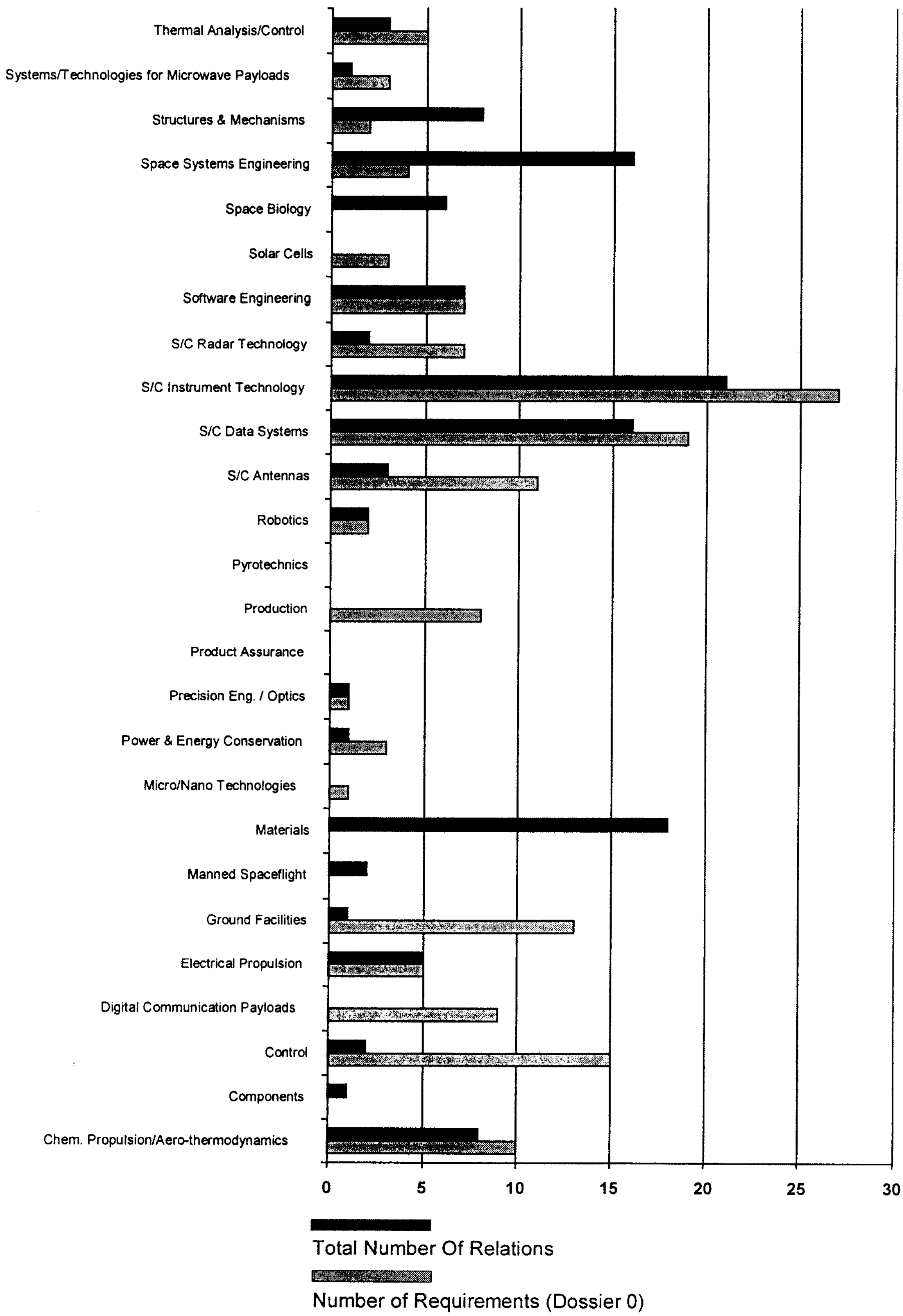


Figure 6: Example evaluation: Absolute number of technology requirements (taken from Dossier 0, shaded) and the total number of relations represented in the data base (black), grouped into baseline technology classes.

It is important to know that the conducted survey, which is represented in the data base, cannot present at this stage absolute and comprehensive numbers of technology developments. It reflects the situation in Germany, Austria and Switzerland and allows to identify which technology fields may need further development and which are already taken care of. In case of an urgent technology development, know-how owners can be identified quickly through the data base.

Some of the technology classes are not represented in the University-SME relations from the data base. This is partly owing to the relatively small number of data sets contained in the data base, which will be expanded during the course of this study, and partly because some technologies may not be present in the University-SME domain for cost and complexity reasons.

As an example, centres of expertise in the University-SME domain exist in structures & mechanisms, thermal analysis, materials, instrument technology as well as spacecraft data systems.

General remarks: The data contained in the data base is an example for a future tool, which should be used by ESA and all possible partners involved that are in need of information on technology fields, Know-how owners and clients.

- Determination of specific Know-how owners for specific technologies:

  The data base allows the selective extraction of all know-how owners, client and co-operative relation attributes. Also, a user can search for specific baseline technology classes (as given in Table 1) and their associated keywords listed in the keyword directory. Lists showing all these items can be assembled automatically after the specification of user-defined requirement attributes.

- Generation of statistics:

  The data base user can get an overview on university-SME relations and their attributes on the basis of the data base data sets. With an up-to-date and comprehensive set of data (not provided within the framework of this study) these statistics also allow the identification of regional activities in specific geographical areas. This feature would be useful to identify clusters of companies, working on specific space technologies, and their location. This could lead to the development of a space technology atlas.

- Further development of strategic and programmatic goals

  The data in the data base, together with the technology mapping activities, could help ESA and national space agencies to support and establish SME's as well as universities and research institutions in specific space technology fields. This could be beneficial if ESA or a specific member country has special technology demands and needs which are underrepresented or not available. ESA could also use this data to support the formation of alliances among companies on a national or international basis, if required.

From a statistical point of view, it would be valuable to complement the data base with survey data gained from other European countries. If a company or organisation is in need of a specific technology, it can find out about a suitable know-how owner. In this way, technology mapping by region or country can be done. Also, the data base could be made available to a number of users on the Internet, where they could extract data and update the data base with their information.

5 Institutional Framework Requirements

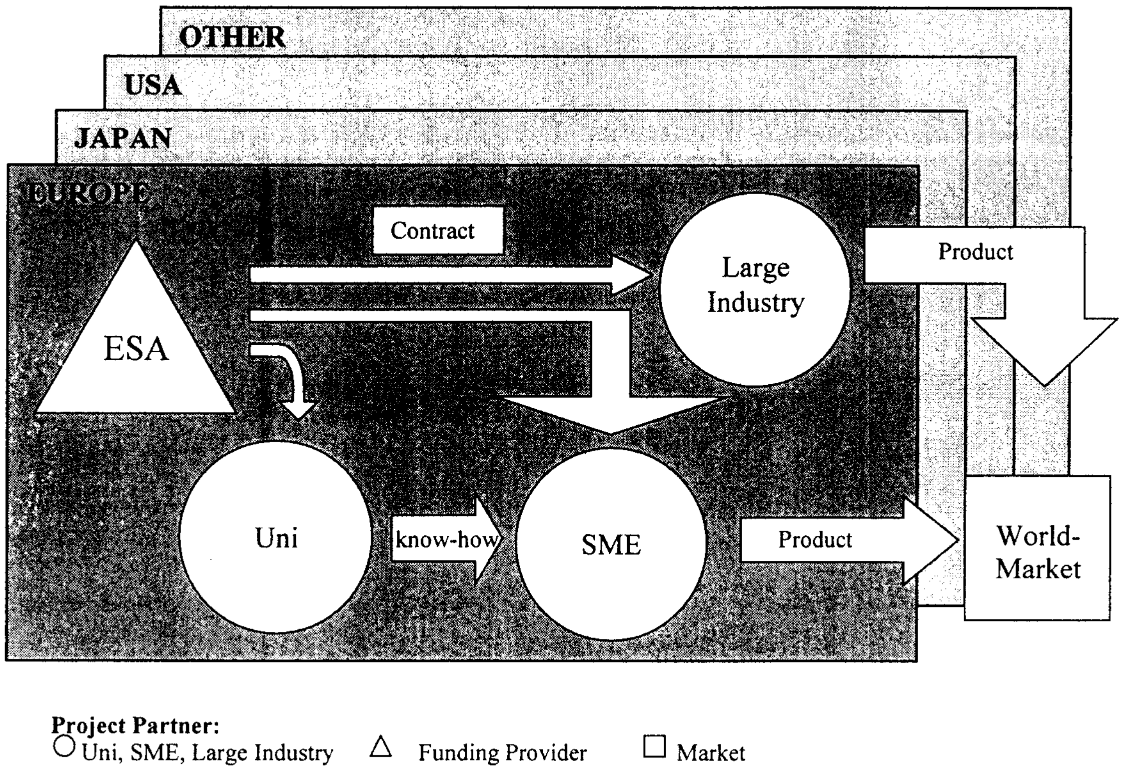


Figure 7: Overview of the relations between space agencies, academic institutions and industry.

On the basis of the established model, a set of requirements and recommendations is formulated in Chapter 4 of the study, aiming at improving and facilitating the relations and interfaces between academic institutions on the one hand and industry (particularly SMEs), research centres in space-related areas as well as space agencies, including ESA, on the other hand, see Figure 7.

As part of this efforts, funding sources are examined which are mostly required to carry out scientific and technical research activities at universities which could be needed by European industry. Chapter 4 of the study also gives an overview of which university could carry out

what research and which mechanisms are/would be in effect. The data presented here is contained in the data base and includes SME partners as well as large industry partners.

Also, a suggestion for an institutional framework to foster university/industry relations is presented which also defines a role for ESA. Furthermore, a look into other national space agencies (Germany, Austria, United States, Japan) was taken as to how they handle the issue of university/industry relations, which role they play and how this compares to ESA's current activities.

Several sections describe following issues:

1. Existing funding mechanisms for universities
2. Example for a know-how transfer mechanism via industry to market
3. Examples of centres of expertise
4. Examples for institutional frameworks support
5. Comparison of European institutional framework support to other parts of the world
6. Conclusion with recommendations to ESA

5.1 Types of Funding for Universities

The types of funding for universities can be divided into conventional, existing ideas and new unconventional ideas, which have partly been implemented but are mostly under consideration for the future. Conventional funding mechanisms include:

- PhD Student grants
- Foundations, trusts to support space-related research
- Industrial placements, thesis topics
- Contract work

Unconventional types of funding include:

- Funding of graduate PhD student groups
- Student competitions
- Prize Money
- Provision of ESA owned resources and products

Indirect sources of funding include:

- Matching funds
- Seed money

In summary, PhD student grant are a very modest contribution towards space-related research contributing to living expenses, books and travel cost add enormously to space-related research and enable young scientists to prepare themselves through their work for a later job in industry mostly in the areas of R&D. The universities or research establishments, however, have to pay for the infrastructure needed to conduct the research. Foundations correspond to a more traditional way of funding done by governments to support specific research areas.

Industrial placements and thesis topics are very effective ways of research funding as they usually attract motivated students for short-term research activities with the advantage of possibly recruiting these students after they finish their studies. Contract work also presents a classic form of funding.

Unconventional sources of funding present a very effective way of conducting research in universities as they cost relatively little money and take advantage from higly motivated students. This area should be paid more attention by industry and space agencies. Finally, matching funds and seed money are forms of funding often used by government bodies as well as the EU. However, in the space domain many potential startup businesses rather prefer pure contract work with full project funding to get into the business as it requires a high level of know-how as well as facilities and on the other hand, poses often a high risk potential in terms investments.

An analysis of ESA involvement is shown in Table 3 and shows some potential for ESA to expand its funding structure:

University Research Funding Type		ESA Involvement
Conventional Funding	Individual PhD Student Grants	
	- inside ESA	YES, 50% funding with host institution
	- outside ESA	NO
	Foundations, Trusts	NO
	Industrial Placements	
	- inside ESA (Stage)	YES
	- outside ESA	NO
Unconventional Funding	PhD Research Groups	NO
	Student Competition	NO
	Prize Money	NO
	Provision of ESA resources	NO
Indirect Funding	Matching Funds	NO
	Seed Money	NO

Table 3: ESA involvement in academic funding

5.2 Transfer Mechanisms from Universities via Industry to Market

An example for transfer forms between universities and SMEs is given by means of a case demonstration in the region of Saxony. This shown example runs under the category Network-driven transfer forms. A necessary precondition for executing this form is communication which is usually supported by short distances between the SME and the partner university. As a matter of fact the university-industry relationship examples found in this region reflect in its detailed forms of realisation all main categories of transfer forms as they were pointed out in chapter 2. A schematic overview of such a academic-industrial network aiming at serving a competitive market environment is given in Figure 8 below.

The example describes a selected case which shows how the utilisation of particularly one of the know-how driven transfer forms - *the exchange of staff between university and industry* –

that can help to promote near market developments at universities and the development of new business areas for industrial enterprises. This is not only resulting in benefits for the involved partners but also supports the regional development in form of improvements and extensions of the regional networking between industry and universities.

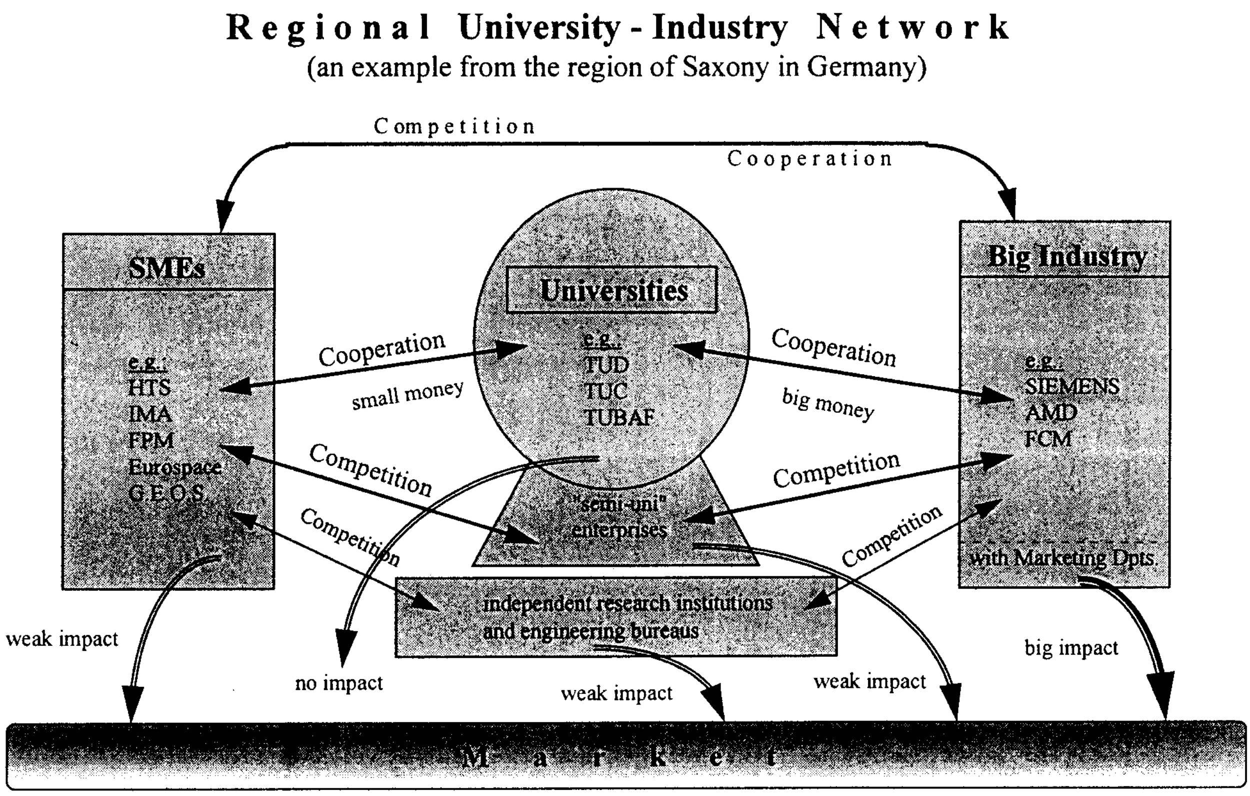


Figure 8: Schematic view of an academic-industrial network

Abbreviations:

AMD	Advanced Micro Devices Corp., Dresden
EUROSPACE	Eurospace GmbH, Flöha
FCM	Freiberger Compound Materials GmbH, Freiberg
FPM	FPM Space Sensor GmbH, Freiberg
G.E.O.S.	G.E.O.S. Freiberg Ingenieurgesellschaft mbH, Freiberg
HTS	HTS HochTechnologie Systeme GmbH, Coswig
IMA	IMA Materialforschungs- und Anwendungstechnik GmbH, Dresden
TUC	Technische Universtät Chemnitz
TUD	Technische Universtät Dresden
TUBAF	Technische Universtät Bergakademie Freiberg

5.2.1 Remarks on Most Practised Transfer Forms Experienced in Several Co-operative Projects between University and Industry

The study shows that the communication driven forms are practised to a large extent whereby particularly symposia, colloquia, workshops and conference publications reach priority followed by other diverse scientific presentations of joint R&D results and by research publications within the universities concerned. Also the joint presentations at fairs and exhibitions are effective kinds of closer university-industry relations. The review has shown that within this group of transfer forms the widest spread of utilisation appears. The advantages of these transfer forms lie mostly in their modest cost.

Knowledge driven forms like the utilisation of instruction materials and further training offered by universities as well as student internships and industrial placements are also essential in the development of effective university-industry relationships.

University driven forms are important and utilise the counselling competence of universities. Also services by the university's transfer centres and the processing of expert reports receive positive resonance.

The know-how driven forms were considered with some kind of reservation. This may be particularly due to their connection to necessary and often extensive and time-consuming organisation, administration and financing efforts. However, the examples have also proved a coverage of almost all of the sub-forms in this group of transfer forms. Very attractive seem to be staff exchange projects, joint and co-operative research as well as consultancy. Most problematic in these projects seems to be the time overhead required for applications procedures and reporting activities. These procedures are required for short-term projects and therefore limit their attractively.

Network driven forms should be the most effective because of their complex and exhaustive character. They require a great deal of time and effort to be set up and settled before efficiently working to the satisfaction of all partners involved. Forms like joint ventures and enterprise established by university staff commonly require capital and /or seed money which is difficult to attain particularly for SMEs with limited capital. Therefore, partnership network relations have been established who finally utilise other more simple, cost saving (but not automatically less effective) forms for their detailed joint activities. The network itself provides a sort of a pool for information and therefore simplifies the choice of the right partner for certain defined project.

5.3 Examples for Educational Centres of Expertise

Centres of expertise may be valuable for:

- SMEs that are looking for a competent partner concerning
  (A) Scientific Knowledge
  (B) Facilities
  for research of R&D efforts of product pre-developments

- Any kind of industrial partners looking for potential contract partners in the R&D domain for cost and experience reasons
- Space agencies that would like to concentrate their R&D efforts in specific geographic areas or technology fields with competent partners.

As the data base contains a limited initial set of data, a few selected entries are presented in the study. Optionally, if this feature of the data base is considered useful, it can be extended and maintained under further contract activities and be made available to a wide scale of users e.g. through a CD ROM or the INTERNET. It is important, however, to note that the data base content is a snapshot of activities and past experience by the academic institutions and may need further research efforts to represent a complete image of space research activities in Europe. In the following sections, research activities in Germany, Austria and Switzerland are presented. Further data sets were contributed by JRA and comprise other European countries like Italy, Hungary, The United Kingdom, The United States of America and Japan.

ESA may take advantage of centres of expertise if scientific or academic problems have to be resolved. Again, a data base containing this information may be useful. Examples contained in the data base are presented as of:

Germany:
- Justus-Liebig Universität Gießen
- Technical University of Braunschweig
- Technical University of Berlin

Austria:
- Technical Univertsity of Graz
- Technical University of Vienna

Switzerland:
- ETH Zürich (2 examples)

UK
- Leicester University
- Birmingham University
- University of Kent
- Glasgow University

Other parts of Europe
- Hungarian Academy of Sciences, Budapest
- University of Genoa, Italy

US
- Georgia Institute of Technology
- University of Florida

Japan
- University of Tokyo

5.4 Institutional Framework

Following ESA programmes are presented and commented by its policy towards universities and their industrial partners:

- PRODEX (Programme de Development d'Experiences Scientifiques)
- ARA (Academic Research Programme)
- ARCoP (Academic Research Co-operation Programme)

A summary of the contents and characteristics of these programmes is given in the report.

5.4.1 Review of Actual ESA Organisational Frameworks in Support of University-Industry Alliances

To today's knowledge there is no other framework apart from the above mentioned established programmes and policies in ESA. Along with them, organisational procedures have been developed and practised which are hardly or only by accident harmonised since all the separate programmes have their own co-ordinating approval guidelines and bodies.

The *PRODEX and SME Initiative* have their own offices but are as much as the other programme co-ordinators also amalgamated with the R&D discipline gatekeeper offices through which most of the official and unsolicited proposals are channelled.

For the Academic Research Activities the procedures and organisational flow is a bit more decentralised. There is not explicitly a special office named which co-ordinates the project handling beginning from the proposal submission up to final reporting on the project results. As main co-ordinator appears the gatekeeper of Research Activities under the TRP. The supervision of the individual projects is organised independently of the programme source and occurs mainly through the technical disciplines. However, projects can be submitted either through the technological gatekeepers of the individual field programmes of the TRP or through the gatekeeper of Academic Research. The procedure of passing through a project within the mentioned programmes is described in detail in the report.

5.4.2 Review of National European Space Activities Regarding University-Industry Projects

The study discusses activities concerning university-industry projects inside:

- Austria
- The British National Space Centre (BNSC)
- The German Centre for Aerospace Research (DLR)
- EU
- NASA
- NASDA

5.4.3 Comparative Summary

All reviewed Space Agencies have recognised the necessity to promote closer co-operative relationships between universities R&D and industry in order to boost beneficial technology transfer processes within the space domain and between space and non-space sectors.

It has been recognised that particularly publicly funded R&D does not automatically result in form of products and services on the market. Governments and even space agencies were therefore forced to design special promotion measures or programmes at several levels and to different extents to encourage awareness between research carriers and industry. And it has been grasped that such programmes and measures must also be backed by a funding policy.

Different approaches were chosen to realise, promote and fund programmes and policies to encourage the establishment of fruitful university R&D-industry alliances. The main objective is improving the efficiency in the space R&D and technology transfer of research results as well as in the development of competitive space products and services.

Resulting from the review only some space agencies like ESA, NASA and BNSC and the EC have dedicated specific programmes and policies to intensively support closer relationships between academic institutions and industry. Here, often special emphasis is given to involve especially SMEs into such alliances. Other agencies and nations realise measures to connect universities and industrial enterprises more closely by different and in most cases more decentralised local policies and smaller programmes subordinated to general technology transfer programmes and initiatives.

In general, technology transfer programmes along with special promoting measures aiming at tightening up academic-industry relations should be given more importance and priority. For better efficiency, monitoring and controlling purposes, it should contemplated to join and/or synchronise the EC programme CRAFT and ESA programmes with special respect to space application tasks and targets.

Finally the review has proved that all new measures serve the realisation of the main target to qualify space R&D towards the development of competitive highly-qualified space products and services for space and non-space applications in a shortest possible time and at an economical level.

Altogether it has been realised that the access to programmes issued by ESA or national agencies is difficult. This is because various programmes do exist and sometimes overlap in their target groups. Also, the existence of these programmes is not transparent from outside. The establishment of a more streamlined administration of these programmes and one contact partner for company-university alliances inside the individual national agencies and ESA seems to be required.

5.5 Suggestions on Improvements of the ESA framework

All improvements should be driven by the idea that the close relationship between universities and industry (particularly with SMEs) is of essential interest because both parties have one and the same characteristic which is at the same time also their prior objective:

Striving to and gaining utmost benefits by consuming only little money.

Suggestions on Improvements of the ESA's Organisational-Administrative Framework

In the sections below, a few suggestions are given on how ESA could improve its organisational framework for more efficient management and controlling of measures supporting a closer relationship between university R&D and industry. Figure 9 presents the current situation as it appears when Universities/SMEs approach ESA. Figure 10 shows a possible future scenario to improve the situation.

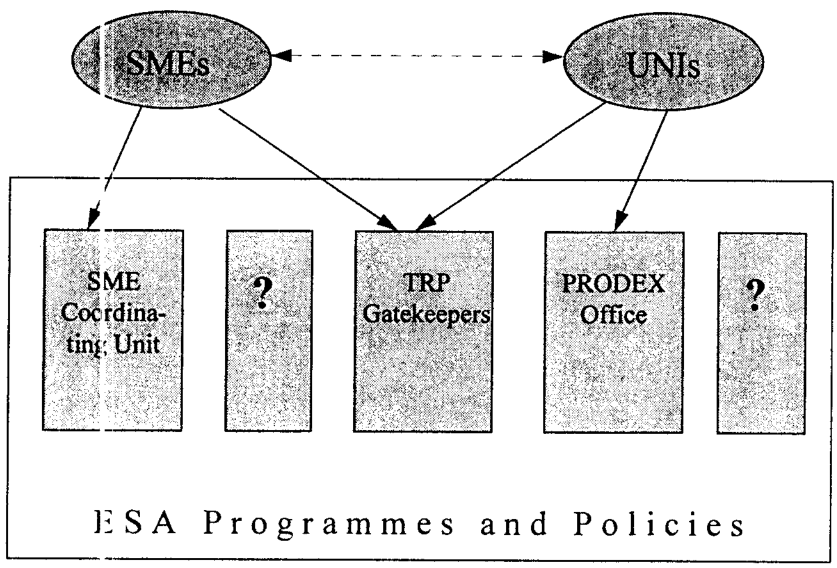


Figure 9: Today's situation when SMEs/Universities approach ESA

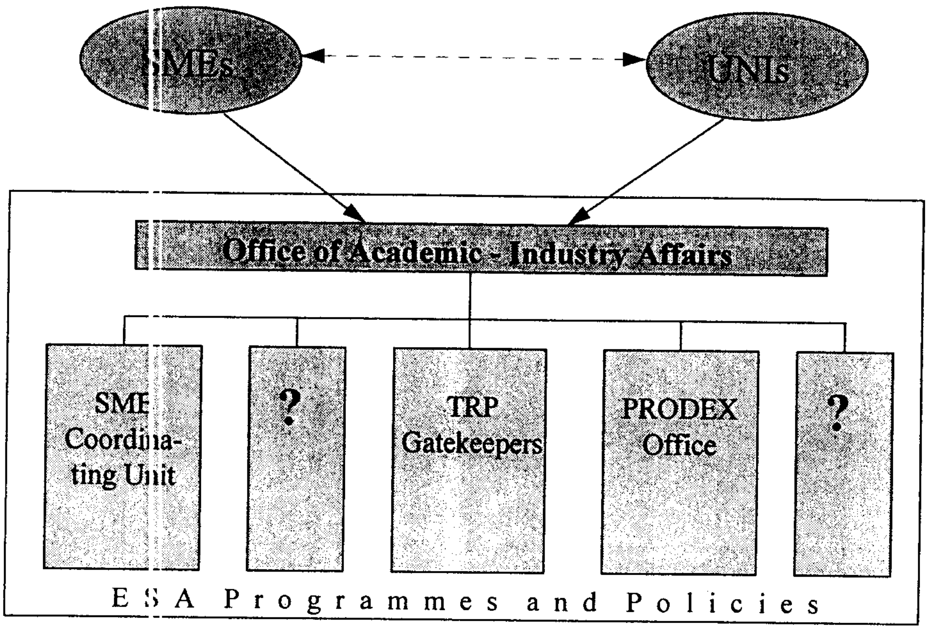


Figure 10: Possible future situation when SMEs/Universities approach ESA (a suggestion)

Taking together all present observation on ESA's activities towards strengthening university-industry relations it is suggested to concentrate these activities organisationally and programmatically.

Specifically,

- ESA may summarise her up to now existing programmes, policies and initiatives into one single programme on PROmotion of Academic-Industry Relationships for space (suggested name: PROAIR) where all the positive and useful experiences of already practised initiatives as well as the newly suggested measures should be considered in total.

- ESA should look for a solution to accommodate the co-ordination and controlling of the all university-industry relations and respective projects in *one appropriate administrative unit.* Different alternatives may be available for a possible implementation:

(A) to incorporate all the administrative responsibilities and procedures in the SME Co-ordination Unit which is installed with the SMI Initiative at ESA's Headquarters in Paris

(B) to extend the PRODEX office's competencies and responsibilities since the main tasks are almost identically with the other initiatives' requirements

(C) to increase the status of the TRP Academic Research gatekeeper and leave all responsibilities with his office (within the Department of General Studies where academic and SME studies mainly have been initiated and supervised up to now).

Another *favoured suggestion* for a solution is to create a kind of superseding *Office of Academic-Industry Affairs* maybe along with the establishment of a joint *Programme on Promotion of Academic - Industry Relationships for Space* the objectives and tasks of which are mainly:

- to register and record all incoming proposals involving partnerships between universities and industry
- to distribute the incoming project proposals for evaluation and later on when approved for supervision to the respective technological gatekeepers, departments and divisions
- to operate a data base with potential candidates of university relationships and networks
- to advise and co-ordinate networks between universities and industry
- to provide consulting services with respect to interfaces with other departments and divisions as well as other technological gatekeepers at ESA
- to co-ordinate its activities with the PRODEX office and with the SME Co-ordinating Unit (so far their existence will still be required)
- to manage and watch the exact realisation of ESA's legal and funding regulations

Further Suggestions for Medium to Long-term Initiatives of ESA to further Improve Linkages between Universities and SMEs

Apart from the above suggestion with respect to an organisational improvement of ESA's university-industry policy and programme realisation this chapter provides some further ideas which could be considered when revising ESA's instruments for a closer university-industry relationship.

- ESA could establish a kind of *supply chain review* (i.e. identify all SMEs and university institutes who provide technologies or services to ESA contractors) to "capture" these companies and institutes who are currently involved in space activities. On this basis ESA could provide *funding on a competitive basis* to supply those "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 also give *preferential treatment* to space primes and projects which use networks between SMEs and university research groups. For example: (1) ESA could possibly include a clause in the General Conditions of Tender requiring space primes to identify SME-university groupings they intend to involve during the contract. Whereby, ESA could be asked for assistance in identifying potential groups from their data base for not all prime contractors have a sufficient overview in all possible space related research areas. Some of the research areas to

be considered may be quite new to a potential prime contractor and may therefore require new partnerships.
(2) ESA could even indicate within her various field programmes but also particularly in the SME Initiative programme that they will give preference to tenders which include such groupings. This means e.g. that tenders submitted by consortia involving partnerships of SMEs and university research groups are given higher status than those which do not. Of course obviously this would not be relevant to all contracts - so it could be restricted to certain supply contracts, for example below a certain threshold value.

- ESA could *sponsor a space SME secondment programme for postgraduate researchers from universities.* These researchers would be placed within companies to work on real, definable problems in this unit. These researchers could be assigned a mentor from within ESA to help them develop an understanding of the functioning of the international space industry and its matching with national and local programmes and developments in the industrial sector.

- ESA could *run a funding scheme* similar to or better in concerted action with the *EU CRAFT programme.* Here groups of space-oriented SMEs should be awarded funding to develop near-market technologies and products whereby here the funding is mainly placed with a research establishment. In this connection it seems to be worthwhile to observe and compare with the ESA's PRODEX programme on possibilities for extensions or revisions in order to avoid a too wide diversification of programmes and activities.

- ESA could *co-fund regular technology audits within space SMEs* in order to establish and consolidate her long-term technology needs therein. Using the outputs of these activity, ESA could then direct these SMEs to university research groups in their country who could help to further and permanently upgrade their technological base either through technology transfers or contracted research. Again it is to check on whether this activities could also be additionally included in the PRODEX programme.)

- The *creation of "virtual" Centres of Excellence/Expertise* using the *internet* could be another valuable suggestion. Here ESA could identify university research groups undertaking common or similar research in different Member States, and encourage them to co-ordinate their research activities by making available through the Internet information on current research projects. SMEs seeking assistance could be directed to these Centres of Excellence/Expertise.

Finally it is recommended that ESA may summarise her up to now existing programmes, policies and initiatives into one single Programme on Promotion of Academic - Industry Relationships for Space (suggested name: PROAIR) where all the positive and useful experiences of already practised initiatives as well as the newly suggested measures should be considered in total.

6 Pilot Projects

Chapter 5 of the study identifies a number of example initiatives or *pilot projects*, which could be transformed into future co-operative ventures between university and SME partners on a local basis. The example projects presented in this chapter are taken form the relations data base, containing information both in terms of example technologies as well as transfer models. Furthermore, an assessment of the value of these pilot projects concerning scientific and technical criteria as well in terms of as institutional, organisational and collaborative aspects is done.

The following table presents an overview of the example projects:

Project	Name	Participating Universities	Participating SMEs	Topic
I	Traffic Monitoring Project A	TUD	IfeK Radebeul + TBD	Traffic Information Generation by Information Fusion – Demonstrator Non-Real Time Using Posteriori Data
II	Traffic Monitoring Project B	TUD	TBD	Traffic Information Generation by Information Fusion – Demonstrator Real Time Using Image & FCD Data
III	Traffic Monitoring Project C	TUD	TBD	Development of a Satellite Payload for Traffic Observation
IV	Traffic Monitoring Project D	TUD	TBD	TUD-Satellite Light – Test of Key Technology Elem. of Nano Sats
V	Traffic Monitoring Project E	TUD	FPM Space Sensor GmbH, Freiberg (D); HTS GmbH, Coswig (D); IMA GmbH, Dresden (D)	Development of a University Micro Satellite Aiming at the Observation of Mobile Objects
VI	Fuel Cell	University of Keele (UK)	JRA Aerospace & Technology Ltd. (UK)	Investigation of an Advanced Soil Oxide Fuel Cell Technology
VII	Space Tech Cluster	University of Warwick (UK)	JRA Aerospace & Technology Ltd. (UK)	New Space Technology Research and Commercialisation Centre

Table 4: Overview of the presented pilot projects

6.1 Lead Project "Traffic Monitoring of Mobile Objects"

The lead project is presented as an example for an educational effort with a strong scientific background. Established in 1997, the interdisciplinary TUD-Satellite project group aims at a variety of different science fields, all combined within the lead project. The main objective is the satellite-based observation of mobile objects, in particular vehicles. For a detailed project description, please refer to Annex A of Chapter 5.

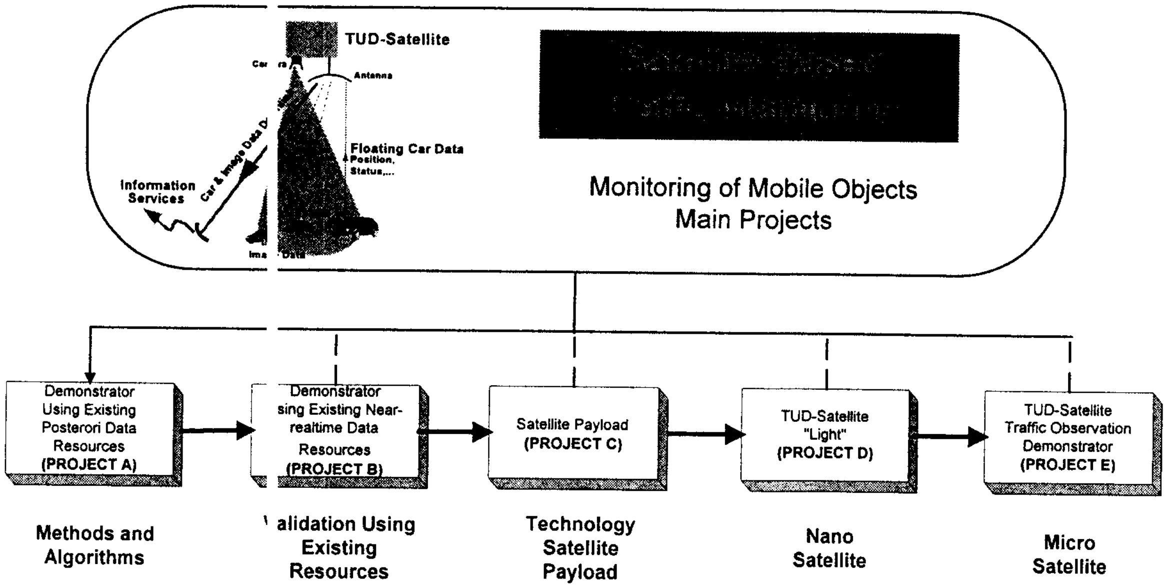


Figure 11: Stepwise concept of the overall project "Satellite-Based Monitoring of Mobile Objects".

The project follows a stepwise approach, focusing on the development of core technologies. For achieving this, the lead project "Satellite-Based Monitoring of Mobile Objects" consists of five individual projects, A to F. Those contain core technology developments which are important to the overall mission objective and have to be developed chronologically. Therefore, those technologies developed earlier in the overall project are the preconditions for other subsequent technology developments (Figure 11).

6.2 Description of Pilot Project I

Within the overall project "Satellite-based Traffic Monitoring", project A plays a key role:

The aim of this activity is to develop methods and algorithms for an automated generation of traffic data by merging satellite EO images and collected vehicle data samples.

In short, the project combines:

- A scientific background: Information fusion of image- and non-image data
- A service-driven project using available space resources: Existing time-correlated EO and Floating Car Data (FCD) systems will be used to generate reliable traffic information
- SME involvement and technology transfer: Once this concept has been proven to be economically viable and technically feasible in a field trial, it could be operated by a commercial enterprise, e.g. as a startup- or university spin-off company.

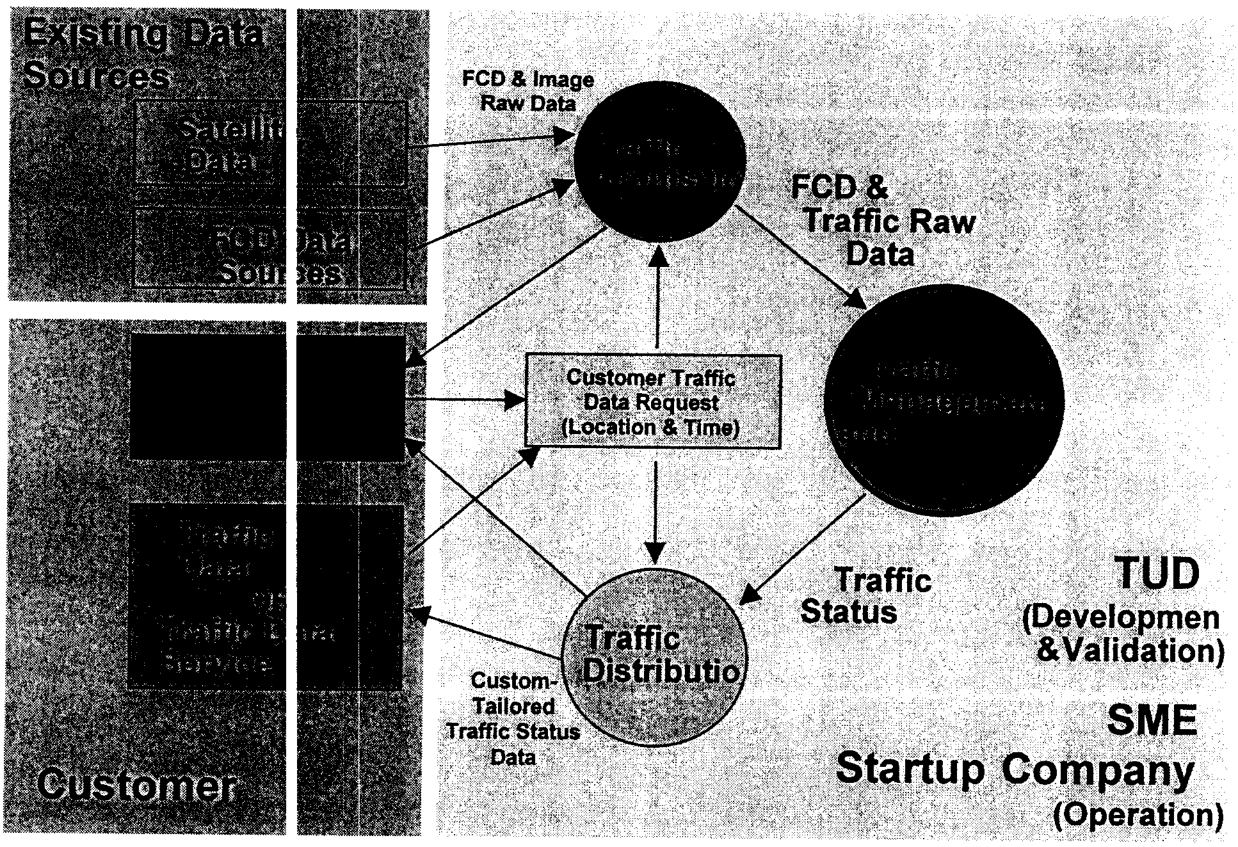


Figure 12: Traffic data generation, processing and distribution overview inside the TUD-project "Satellite-Based Monitoring of Mobile Objects". The key technologies for the *traffic data fusion* will be developed in project A and validated in project B with an option for the establishment of a *startup company* operating the system.

Figure 12 shows the structure of this business idea:

- Traffic data acquisition
- Data processing (existing SME or TUD enrepreneur startup company, Project II)
- Service provision

This group of businesses would handle the customer requests (e.g. by a traffic source data provider) for traffic information in an area which can be observed by a suitable satellite. The ability to positively respond to this request depends on:

- The time of the request owing the satellite orbit
- The cloud coverage and lighting conditions (uncritical for RADAR satellite image data)
- The availability of the EO instruments on-board the satellite
- The ability of the satellite operator to provide real-time image data.

It is planned to transfer the knowledge (equipment, people) to SMEs which can operate as "traffic raw data service providers" to close existing traffic data gaps in Europe (locally and timewise). Further to this, the system concept may be able to also respond to real-time EO image data requests from other customers.

The value of this project can be seen threefold: Firstly, it poses a very interesting research task in the area of automated pattern recognition of satellite EO image data. Secondly, it opens a new commercial application for existing space resources and thirdly, it helps establishing am SME in the space domain.

6.3 Short Description of Subsequent Pilot Projects II to V

Once the concept proves to be technically and economically feasible, it is planned to convert the described scientific method into an operational system where associated project partners of the user community (commercial traffic data service providers) can frequently calibrate and validate their traffic data collection and processing systems by using external traffic data, usually taken from traffic count stations. Also, it would fill in gaps in the existing infrastructure of traffic data sources in Europe adding traffic data where existing systems are not sufficient.

Real-time spaceborne traffic data has the advantage in a larger coverage area compared to all other terrestrial systems. Based on PROJECT I, the project activities extended in the areas of access to real-time spaceborne traffic raw data, which now includes an intelligent satellite access management and request handling. Also, a user interface will be created allowing an automated near real-time access to traffic data when required.

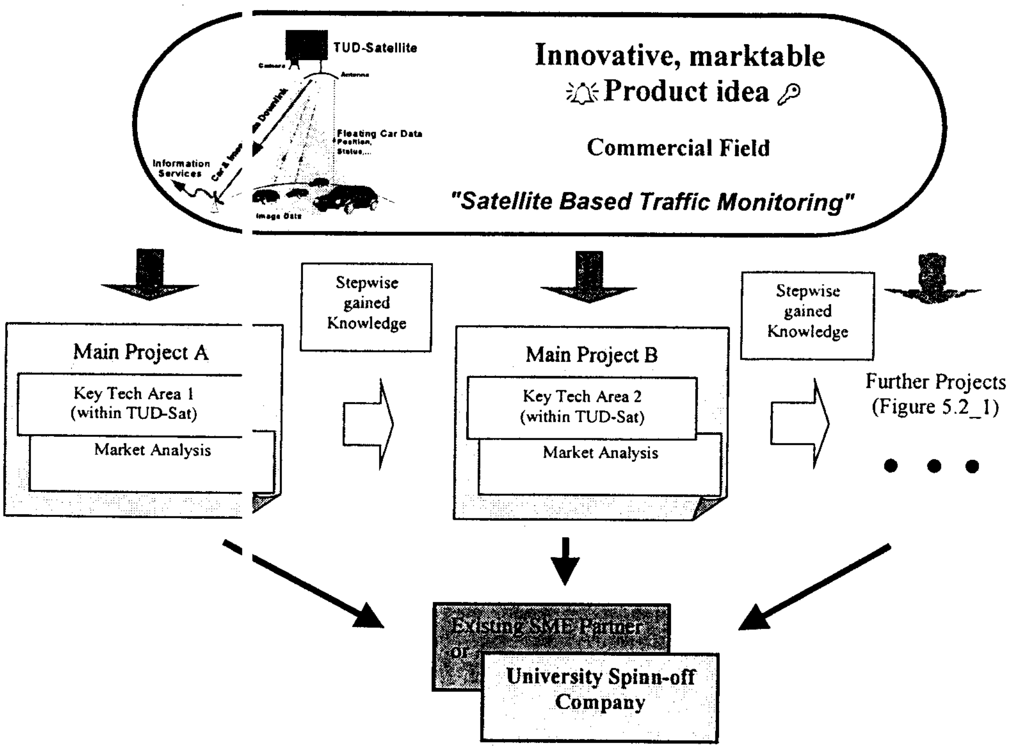


Figure 13: Spin-off company option originating from the TUD project "Satellite-based Monitoring of Mobile Objects".

The product of PROJECT II, a traffic data information fusion software allowing near-real time access to requested traffic data in a certain area, can also be seen as a transfer object from a university to an SME. The software could be transferred as a tool allowing to open a commercial service to traffic data providers as an additional traffic data source for the end-user service they sell. This SME can either be an existing company or a spin-off startup company, Figure 13.

PROJECT III will then concentrate on satellite hardware technology development. These developments can largely be conducted at the university and be transferred to an SME partner as mentioned earlier. Marketable developments could be high-resolution camera optics developments and space sensor developments, leading to a joint satellite development for the demonstrator (PROJECTS IV and V) and possibly a dedicated or shared system for traffic observation in a satellite constellation, which would be a purely commercial development following a successful demonstrator mission.

PROJECT IV: TUD is planning to launch a nano-satellite mainly for technology demonstration purposes towards the TUD-Satellite carrying the EO and FCD data collection payload. On this demonstration mission, a light-weight camera for landmark navigation and simple EO tasks may be integrated. Also, together with image processing software, an on-board GIS system may be established and tested. The satellite also poses a testbed for the software run on an automated ground station for small satellites based on PC's with remote operation and monitoring capabilities. On board the satellite could also be new nano technologies developed at TUD as well as a CAN bus originating from the automotive industry with rad-hard custom chipsets by TUD and an industrial partner (TBD). Owing to the small dimensions of the nano satellite and its low weight (probably below 20 kg), the satellite would not be able to carry a camera capable of identifying vehicles, but nevertheless, it will demonstrate and qualify key technology components and methods required for the TUD-Satellite, PROJECT V

PROJECT V: The initial stage of a project aiming at building a single satellite was funded by the Saxonian Ministry of Science and Arts of the State of Saxony (Germany). This Phase A study for the satellite shows the mission objectives as well as the technical and organisational feasibility to build a satellite in the framework of the Technical University of Dresden and participating SMEs.

With the results of the Phase A study the project team has shown the feasibility of satellite-based monitoring of mobile objects. The TUD-Satellite demonstration mission offers a new way of traffic information generation by combining multiple information sources, spaceborne high resolution image data and vehicle FCD data. The data fusion methods developed in this context are equally applicable for extended data sources like SAR image data. The satellite also can be used for common high resolution remote sensing and for store-and-forward communications as well as for packet data gathering.

Further to the Phase A study, a three stage plan was set up to further develop the project, resulting in the earlier described approach which can be grouped into three stages.

Three Stage Plan:

1. Further development of *key technologies* within the satellite project, e.g. methods and algorithms for image data and non-image data fusion; advanced navigation concepts; general technologies for small satellites in the areas of attitude control and on-board data processing.
2. Implementation of these key technologies in a *demonstrator mission*. This implementation can be done within the university-SME environment.
3. Implementation of an *operational mission*, which may consist of several satellites within a constellation. Clearly, a project of this scale would have to be implemented within a consortium of companies, using the technical expertise of the Technical University of Dresden and the participating SMEs.

6.4 Conclusion and Outlook

- TUD is currently implementing the software algorithms for *pilot projects I and II.* Furthermore, SME and large industry project partners expressed their interest in "satellite-based traffic monitoring" and would like to take part in trials and possibly in an operational scenario proving the usefulness and commercial relevance.
- TUD is also working together with DLR on a solution for the TUD-Sat on-board camera. This would lead to a satellite payload development corresponding to *pilot project III* with a possible SME participation at a later stage.
- Pilot *project IV* (nano satellite) is in a definition phase. This includes the choice of key technologies which are tested for the micro satellite, pilot project V.
- *Pilot project V* has a consolidated concept. A phase A study has been completed and has sucessfully passed two reviews. The review board consists of ESA, DASA, DLR and Mannesmann Autocom. Phase B is currently in progress with the participation of local SME's.

6.5 Projects Proposed by JRA

Pilot projects VI and VII are proposed by JRA as two pilot projects , one concerning advanced solid oxide fuel cell technology and another for the development of a new space technology research and commercialisation centre. For details, please refer to Chapter 5 of the study.

Technical Investigation of an Advanced Solid Oxide Fuel Cell Technology

The pilot project relates to the further investigation of a new solid oxide fuel cell technology for selected space-related applications developed by the Chemistry Department at the University of Keele in the United Kingdom.

The advantages of fuel cell technology over conventional power plants include increased efficiency, low pollution, low vibration, and the possibility of dispersed units reducing the need for extensive and costly transmission systems. This technology overcomes some of the problems associated with other fuel cell technologies, such as the tendency for ceramic-based cells to crack on rapid heating and cooling, and the problems of sealing the cells. The fuel cell can be used with a range of fuel types including hydrogen, methane and methanol.

The pilot project proposed involves conducting a detailed technical appraisal of the fuel cell technology for selected space applications. As part of this activity, the technology's suitability for use in space will be examined along with issues associated with its qualification. It is envisaged the technical appraisal could, if successful, lead on to the development of a bread board model for further testing and possibly a flight model (e.g. for evaluation on-board ISS).

The technology is currently being developed for various non-space applications in partnership with a number of commercial companies including several UK-based SMEs. It is proposed that these latter enterprises, where appropriate, be actively involved in the pilot project. If the pilot project indicated the technology could find application in the space industry, these companies could be actively involved in its development and manufacture.

Development of a New Space Technology Research and Commercialisation Cluster

The aim of this pilot project is to develop a new space technology research and commercialisation 'cluster' based around the University of Warwick in the United Kingdom. The intention will be to conduct a detailed technology and capabilities audit at key scientific and engineering departments within the University to establish which research groups are conducting research and developing technologies of potential long-term interest to the European space industry.

Upon completion of the technology/capabilities audit, high-tech companies based in the University of Warwick Science Park will be contacted to establish whether they would be interested in collaborating with selected university research groups to address identified space technology requirements. The aim will be to identify a nucleus of companies willing and capable of commercialising technology developed within the university for the space industry.

The University of Warwick's Space and Astrophysics Group will be actively involved in the project to assist with the formation and operation of the cluster. Personnel from the group have extensive experience in working with the space industry and will be on-hand to assist both researchers and companies interested in bidding for technology development and/or supply contracts. The group will in effect act as a mentor for the other participants in the project.