Using Basic Research as a Catalyst to Exploit New Technology Based Innovations - a Case Study

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ABSTRACT

The difficulties related to the commercialisation, or even to the introduction of new technologies and solutions to common problems are well documented. The paper presents a case on how to introduce new technology to a complex research environment, in order to catalyse its commercialisation. The central theme of the approach is on understanding all the possible applications and implications that the new technology shares when implemented to replace conventional solutions. The potential customer of the new technology with the related technological domains must be mapped systematically to establish technological trajectories which overlap with the possible applications. This mapping provides the framework for detailed application analysis with pointers to the right people responsible for the potential application area. The results produced indicate that three characteristic application classes for a new technology can be mapped. Special solutions pinpoint a non-standard application area where the new design is being implemented as a prototype. Research and development based applications require collaboration with the customer as the new technology may assist in achieving the goals set for the future. System applications emphasise the use of the new technology as a part of a complete and widely used conventional system. A thorough case study is documented to demonstrate the classification of alternative application areas of a new technology. Also the evolution of a new technology through different application classes is discussed. The case technology is related to high-speed electrical machines and the potential user is CERN, the European Laboratory for Particle Physics.

Keywords: technology transfer, new technology, technology diffusion, technological trajectories, innovation process, high-speed technology, mega-science

1 Preamble

Several innovation studies [e.g. SAPPHO, 1971; Freeman, 1981; Lindell, 1991; Autio, 1993; Hameri, 1993] have documented the difficulties related to the introduction and commercialisation of a novel technology. The incubation times for revenues from a new technological application stem from several years up to a decade, depending on the novelty of the solution. Incremental innovations may enter the market fluently, yet radical innovations with significant implications to conventional practices seem to take

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more time to receive full acknowledgement from the markets. Systematic approaches are needed to catalyse innovation processes that act as the fundamental driving forces of capitalist economies. Some methods and process descriptions do exist, yet they are almost solely related to financial and venture capital issues. The very core on how to establish collaboration based commercialisation process for an invention are scarce. Exciting stories on successes have been reported, but without any auxiliary methods to formalise the process.

Being well aware of the uniqueness of each and every innovation, and of the impossibility to define a method to materialise the future potential hidden in an invention, the paper provides in case format an approach to systematically scan and classify the prospects related to a novel technology. Especially, the small or medium sized high-tech companies with new technologies may make the first crucial steps towards further improvement and commercial exploitation by interacting with basic research. The paper uses the technology related to high-speed electrical machines and its introduction to CERN[1] as a test case. Mega-science centres, i.e. the laboratories with global intellectual participation to design, engineer and execute large-scale scientific experiments, provide high tech companies with a fertile soil to test the applicability of a new solution to a large variety of technological domains [Hameri, 1996]. This is often seen to be the privilege of large companies, while smaller ones tend to seek niche markets with limited growth potential.

Mega-science and its importance has been realised on several national levels and significant role for this awakening is played by the Organisation for Economic Co-operation and Development [OECD,1993] and the special Megascience Forum. This body of administrative experts aim to remove obstacles encountered by governments whose policy is to develop regional or global co-operation in big science. By cross-fertilising industrial, scientific and public incentives with the diverse technological trajectories related to scientific instrumentation the outcome should have a positive impact on the economic environment. European big science centres in the field of high energy physics and space research should give more attention to these issues, since they stand to gain from industry co-operation in the form of increased funding. The estimated expenditure in both fields of study in Europe for the coming decade is up to 30 Billion ECUs (based on annual expenditure to major mega-science centres). The industrial potential of this resource should be exploited both through spin-offs and through upgrading the competence bases of existing firms.

Next the paper presents a case on how potential application areas of a new technology are mapped with the technological trajectories existing in the target organisation. This is followed by a generalisation of the results obtained from the case study, emphasis being on the classification of alternative application potentialities of a new technology. Finally, conclusions are drawn and some prominent future research areas are discussed.

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[1] CERN, the European Laboratory for Particle Physics, has its headquarters in Geneva. At present, its Member States are Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom. Israel, the Russian Federation, Turkey, Yugoslavia (status suspended after the UN embargo, June 1992), the European Commission and Unesco have observer status.

2 Case: High-Speed Technology and CERN

The starting point of the applied case approach is to scan all the applications of the given technology, including the potential ones with no installations. This sounds trivial, yet in most cases the development work of a new invention is solely focused on to solve a specific problem. Usually the innovators are perplexed by the sophisticated techniques and see only few applications for their innovation. Discovering the true application potential of the breakthrough requires systematic research work, which comprise literature study and, perhaps, third party consultation together with the reflection of the results from the pilot projects. Each and every application area is documented by outlining the pros and cons of the given technology together with, whenever it is possible, economical benefit calculations. The more thorough the ground work the more fluent and successful the introduction process will be.

In the case at hand the new technology is that of high-speed technology (HST) [Vuola, 1996]. The optimum rotational speed for a turbocompressor, high pressure pump, vacuum turbopump, turbogenerator or machining spindle is usually far beyond the speed of a conventional electrical machine - even with a gear. High-speed electrical machines (HSEM) are developed to rotate directly at the speed the application requires. In high-speed technology the application device is integrated into the HSEM so that there is only one moving part rotating. No gearboxes, shaft couplings, separate lubrication systems or their cooling/heating are needed. Size and weight of system can be reduced by up to 95 % by increasing the rotational speed. Size reduction and simplified drive systems cut not only maintenance but also production and installation costs through material savings, simpler piping, absence of safety basins for oil leaks and cooling / heating lubricants. High rotational speed requires contactless bearings (the rotor of the machine is suspended without any mechanical contact), which is the very core of the innovation along with advanced rotor design and the use of latest power electronics. In use the technology yields better reliability through oil and vibration free operation, improved efficiency and minimum maintenance. Oil-free and hermetic design provides the possibility for operation in vacuum, extreme temperature or submerged environments.

Once the application areas are known the screening of the technologies related to the selected mega-science centre commences. The most prominent starting point is the purchasing office of the centre, where procurement procedures are divided according to some kind of technological breakdown. Purchased items at CERN comprise more than 50 major technologies with their more subtle division into specific application areas. In short, CERN, like other mega-science centres comprise practically most of the fields of human ingenuity related to the design, manufacturing and operation of complex system artefacts.

The application areas and technology domains are then mapped into a two-dimensional matrix [Vuola, 1996]. A rough analysis was carried out to drop out the obviously irrelevant technological domains. Examples of such technological categories were electronics, data processing and particle detectors under which HST clearly has no applications. With those left, the matrix was devised by applying the possible application areas of HST. Then a more detailed pre-screening was performed to find out the potential application areas. Each and every cell of the matrix was studied whether the new technology met the technology trajectories of CERN. Some HST application areas, such

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as centrifuge[2], were dropped out as they did not have any place at the science centre. The most prominent ones entered the feasibility study, during which the people responsible for the technology were contacted, interviewed and the new technology was discussed. Figure 1 summarises the approach in flow chart format.

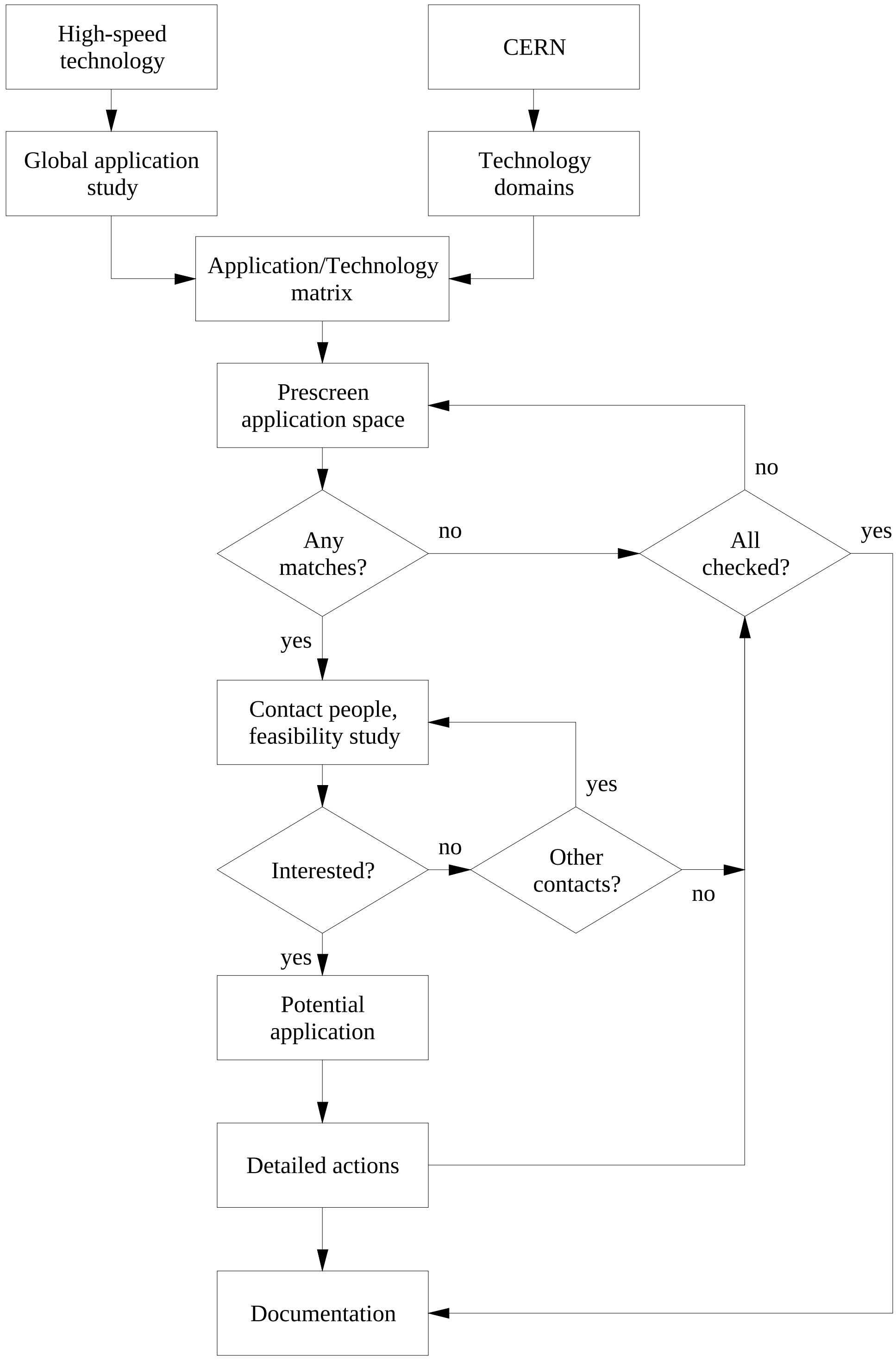

Figure 1. Flow chart describing the case approach to introduce high-speed technology to CERN.

[2] Actually, in last century the particle physics experiments did use centrifuges, yet in today's research they are obsolete.

During the feasibility study and interviews it became apparent that certain scepticism was always present when the new solution was presented. Yet, further discussions resulted in fruitful cross-fertilisation and an assessment of the applicability of the new technology. To ease the process of information diffusion a descriptive hand-out was produced to provide the contact persons with the technical details and performance information of the HST. After few sessions the potential applications were classified and plans for future actions were made. The results are displayed in Figure 2, where the resulting matrix is presented along with the potential applications and their classification.

Activity code	CERN TECHNOLOGY DOMAIN	HST APPLICATION	Turbocompressor	High pressure pump	Vacuum pump	High-speed machining	Flywheel energy storage
100	***Civil engineering***						
155	Air conditioning units		system				
171	Pumps			special			
173	Cooling plants		system	system			
181	Compressed air - compressors		special				
200	***Electrical engineering***						
281	Filters						R&D
282	Power capacitors						R&D
285	Accumulators						R&D
520	***Machine tools***						
522	Machining equipment			system		system	
525	Surface treatment equipment					system	
610	***Vacuum pumps***						
611	Mechanical				R&D		
615	Turbomolecular				special		
620	***Refrigeration equipment***						
621	Air separation plants		system				
622	Linde-cycle systems		system				
623	Claude-cycle systems		system				
624	Sterling-cycle systems		system				
630	***Gas-handling equipment***						
634	Recovery pumps and blowers		special				
635	Compressors		R&D				
640	***Storage and transport of cryogens***						
647	Pumps			special			

Figure 2. The matrix resulting from the feasibility study.

The nature of each potential application is further studied in terms of the scope of the application, i.e. whether it is a specific application related to the existing scientific instrumentation, or if R&D collaboration is required due to future application potential. System applications are found as part of a conventional system that is not directly related to the scientific instrumentation. In order to have better grip on the practical results from the field interviews one case from each class is discussed in more detail:

- *R&D application*: Cold helium compressor for the accelerator cryogenics. The use of cold compressor instead of warm compressor is a new way to cool down superconducting magnets. So far, there is experience only on small-scale cold compressors but the future, more than 20 kilometres long, superconducting magnet unit will require powerful and sophisticated compressors. Two small-scale prototypes has been already delivered and tested, but CERN is still looking for novel ideas in cold compressor design in order to fulfil the requirements of the future collider. HST was regarded as being a highly interesting alternative and a joint project is being set up.
- *Special application*: Turbomolecular pumps. These special pumps are already applied at CERN, as the technology is already well established in Europe. Yet, HST provides some special advantages over the conventional solutions. Being a niche application the market potential is limited, but CERN provides the innovation with an interesting test-bench for HST. Mode of future collaboration is being discussed.
- *System application*: Refrigeration equipment and machine tools. These applications are part of a larger system, like compressors or lathes capable for high-speed machining operations. The new technology provider is advised to contact the suppliers of these systems directly. There are also several other more or less conventional system applications, where the technology could be applied at CERN. Yet, this may not be of interest to the scientific research organisation as they do not have direct impact on their performance to achieve the scientific goals. System applications may provide significant markets for the innovators through interaction with the system manufacturer.

The case shows that the approach provided the researchers with a framework to enter such a diverse organisation like CERN. The systematic approach forced to study all the potential applications (pre-screening), of which the most potential ones were further studied (feasibility study). The practical results indicate that contacts were made with the right people and without retarding time delays. All of the interacting parties, i.e. academics, including both the physicists at CERN and the university researchers participating in the development work, together with industrial and public representatives, seemed to benefit from the case approach. Academics recreated further research topics to exploit and test the technology, while industrial partners learned from potential markets through collaboration with system manufacturers. Public instances, which have been funding the new technology development process were satisfied for seeing new applications both with economic and research potential. Finally, the megascience centre was provided with a novel solution to some of their instrumentation problems.

In this research, CERN is used as a test case, but, in general, the purchasing policies of public research organisations in Europe are similar to CERN. The European Space Agency (ESA) and European Synchrotron Radiation Facility (ESRF) select suppliers based on the lowest bidder and geographic quotas. The Joint European Torus (JET) and the European Community (EC) select their bidders in a similar fashion to CERN [Nordberg 1994]. Facing a multinational research centre may cause some problems for a business oriented company. Mega-science is characterised of being an academic institution where procedures related to management, schedules, budgets, etc. are significantly different from industrial ones. Yet, special technology liaison offices have been established to ease the interaction between research personnel and the technology providers. Taking care of the interests of certain member states these offices participate on the co-ordination of the major purchase operations. Working with the liaison offices provides the technology bidder with a quick start to enter the organisation. The division into detailed technology domains should be carried out in such a manner that the right and responsible persons are tracked and their contact information is documented. Too broad of an analysis misses the focus on finding the right applications and right people.

3 Generalising the results

Often new technologies and their applications incorporate several advances in other technological trajectories [for the concept see Dosi, 1982]. In figure 3 these are referred as auxiliary technologies, which in case of HST, are related to the development of contactless bearings, advances in rotor design and the major innovations related to power electronics. These technologies had to be available before HST could be materialised into first pilot machines. Actually each of these technologies have their own similar process, with their own auxiliary technologies and application divisions. Once the first models of the new artefact has been developed then the R&D based collaboration becomes critical to further exploit the innovation. Yet, it is precisely this step, from the in-house development to R&D based real world implementations, during which collaboration and mapping the application potentiality with a basic research centre becomes viable. This step is crucial in the process, as it usually is very slow and time consuming. Performing the technology mapping procedure with a megascience centre may significantly catalyse the whole innovation process.

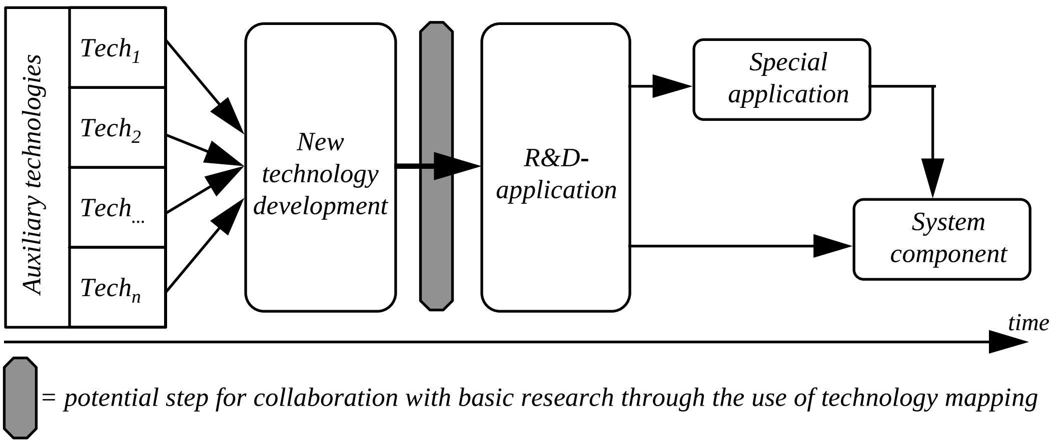

Figure 3. The timewise evolution of a new technology, together with the “grey area” where the megascience collaboration may take place.

The threefold classification of the potential applications provides also perspective to understand the evolutionary aspects of a new technology. As the case indicates that the classification of an application is a tentative one and subject to changes as the work proceeds between the partners. Essentially the procedure is an iterative one, meaning that each and every potential application needs to be studied very thoroughly before assigning the final classification, which may, in turn, affect the mode (strict business vs. R&D) and content (low vs. high management involvement) of future collaboration. Cases do exist where the mode of interaction has not been the right one, and therefore the anticipated results were not achieved. An example of such a case is related to teleoperation in hostile environments. The work was regarded as crucial for the company developing the technology and, thus, R&D collaboration was launched. Yet, at the basic research centre the work was merely understood as service work with no direct impact to the scientific results or to existing know-how, which, in the end, resulted in lack of enthusiasm to collaborate. The following more detailed characteristics of the different potential application classes may serve as a guideline for the work to come:

1. *R&D application* involves research and development collaboration with the science centre aiming to design and build something unique. These kind of projects are mostly related to the materialisation of future scientific instrumentation. Participation requires research oriented strategy with patience to adapt to the rhythm of mega-science projects. The innovation potential is significantly higher than in other applications, yet, so are the related risks. These kind of projects serve as a logical continuation to the development process that precedes any new technology before it reaches the application level. Science centre provides the innovators with an unique environment to improve the technology along with other fore front technology development activities.
2. *Special application*, i.e. the new technology at its present design and possible prototypes fulfils the requirements of the science centre concerning a specific and non-standard application. Typically, these applications may not have counter examples in industry, as they are bound to the scientific instrumentation or to a peculiar operational environment far from conventional ones (e.g. operation in very low temperatures or in space). From the science centre point of view the new technology provides them with a novel and, sometimes, with an economically and technologically attractive solution to an existing problem. For the technology provider the special application establishes image related benefits and increases experience. Yet, the application may require extra design and engineering work which may cut the direct profits.
3. *System application* acts as a part of a larger system where it could be used to replace conventional and standard solutions, because of its outperforming economic and operational properties. Science centre may not be interested on the application, as the system is purchased as a complete delivery and/or it is part of the infrastructure (ventilation, telephone network, heating, escalators, etc.) and not directly contributing to the scientific results. Therefore direct collaboration with system manufacturer or system supplier is required. With

the system manufacturer the collaboration means design co-operation together with acting as a component supplier. Prospects for voluminous implementations with reasonable profits are potentially present in system applications.

The actions to be taken on each potential application class are dictated by the very case at hand. Motivations to continue R&D may be scarce for a small innovating company, which is already exhausted by the in-house development effort. Yet, the players in new technology development are often many. Industrial participation is only one facet, as research institutes (neutral and research oriented) and public authorities (funding and macro economic motivations) may share differing incentives to proceed with their work. Thus, validating all potential applications is very important to realise the full prospects of the new technology to all partners participating the innovation process. The above presented classification of potential application areas serves as a tool to define right from the first contacts the nature of possible collaboration and actions to be taken.

The linear model of technological innovation process has been criticised severely [Kline and Rosenberg, 1986; Rosenberg and Nelson, 1994] to be oversimplifying, as the process clearly has several feedback loops and stages. Entering the markets takes place concurrently along several potential application trajectories. Some may enter directly from the R&D phase to a system component or it may take long time before a specific application turns into a state-of-the-art practice (see Figure 3). For example using the HST in air conditioning systems may provide the technology holders a direct access to significant and well established markets. On the other hand applying HST to gas turbine engines in aeroplanes is still at the laboratory level, yet one day the propulsion of a gas turbine may be turned partly into electricity through high speed generator [Ferreira et al., 1995], which can rotate at the same speed as the engine.

It is obvious that public funding has a diminishing role as the new technology penetrates towards market acceptance. The work focuses more on business making along well defined commercial applications, thus the innovation potentiality shrinks more towards on incremental refinements. On the other hand during the development and specific application phases the activity encloses multiple innovation potentials. Also partners tend to change as the process moves towards commercial environment. Interests for R&D and specific applications are often associated with small and publicly supported knowledge intensive firms working together with research institutes and universities, while already well established technology intensive companies may find collaboration with system manufacturers more attractive.

The results obtained from the case may be generalised to certain extent to depict the process of new technology entering the markets. Clearly, the applied approach is not bound to basic research centres as it could be used to map any multi-technology environment. The extraordinarily diverse technology base related to basic research serves as a very fruitful test ground both for the technology itself and for the people to realise the true application potentiality of their innovation. Especially, for small high tech companies the case approach presented is considered valuable when the company is:

- entering the markets with the advanced technology and the pilot, which outperforms conventional solutions in any specific field of activity or industry (market penetration);
- mapping the common or specific markets in order to find other potential applications for the design they master (market diversification);
- searching for unrealised technological trajectories to further develop the technology (product development);
- looking for other partners with knowledge or market intensity to establish synergy benefits (partnering dimension);
- aiming to broaden their financial sources to support the development work (financial dimension).

4 Conclusions

The paper has described a case to clamp new technology based applications with the technological domains embedded in a mega-science centre. The applied approach is based on detailed application study which is mapped with the existing technology domains at the target organisation. The case resulted in a general threefold classification on the potential application areas of a new technology. The special application areas show a unique technological opportunity to exploit the new technology. Research and development based applications provide the new technology with a potential to further develop the technology and to enlarge its potential market cover. System applications, i.e. the new technology is sold as part of a larger and conventional system, establishes a channel to enter existing and voluminous markets by directly partnering with the system manufacturers.

The technology mapping presented may be applied for other purposes than mega-science centres. For a small or medium sized high tech firm the approach provides a framework for pre-screening the market potential of their innovative product. The initial perspective of the potential application space of a new innovation is often limited to the very first prototype installations. The used approach provides the innovators with a tool forcing them to explore a wide spectrum of potential application areas, assess their nature and to devise action plans on how to proceed. When carefully done, this kind of an application evaluation process increases the self-esteem of the development team, improves the reliability of the project in the eyes of the funding representatives and strengthens the focus of future business planning.

Some normative, or hypotheses like, implications from the technology mapping and the case represented can be drawn (see also Figure 4.), yet these should be studied in more detail in the future:

- During the evolution of an innovation from R&D, through specific to the system application the role of research institutes diminishes, while the role of industrial interaction increases. This may sound trivial, yet depending on the nature of the innovation this argument can be further questioned.
- Innovative and small scale companies may catalyse their market entrance through active exploitation of system applications. The form of collaboration with the system manufacturer can materialise in different ways, e.g. by

licensing, merging or subcontracting. But, depending on the case at hand, which of these mechanisms are most benefiting the innovation.

- Mega-science collaboration seems to provide the new technology providers with a fertile ground to explore, exploit and introduce their novel application. However, this process should be documented in more detail to establish formalised means for the interaction, e.g., studies on mega-science spillovers are scarce. The industrial and economic potentials embedded into basic research must be translated into routine procedures as part of the general innovation processes in the economy.
- Venture capital and its integration to industrial and mega-science R&D collaboration is an ignored topic. Significant amount, especially of the low volume high-tech components, of scientific instrumentation is delivered by small companies and research institutes. These, truly one-of-a-kind deliveries comprise always novel ideas, which when properly studied may share significant commercial application potential.

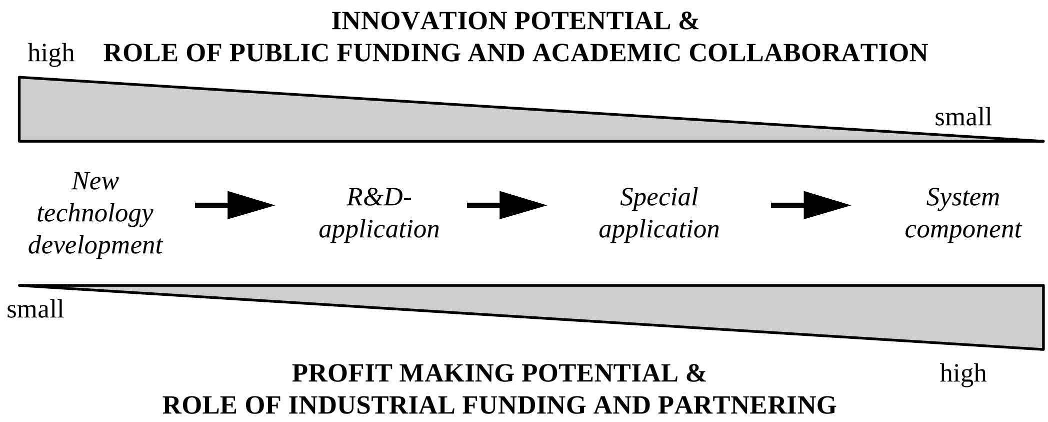

Figure 4. The evolution of a knowledge intensive new technology based innovation with respect to potential partners and funding sources during the commercialisation process.

Objective and experimental exploration of the cosmos around us is among the sincerest missions that mankind can practice. The efforts needed to further increase our scientific understanding is of such a scale that it would not be possible without harmonious and global collaboration cross the political, social and religious barriers. Reinforcing the industrial dimension in this unique errand is more than justified as the expenditures for fundamental research tend to increase and the political pressures to generate more practical gains from it are piling up.

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