Role of Ceramics in a
Self-sustaining Environment
R. Pampuch and K. Haberko (Editors)

LINKS BETWEEN SCIENCE AND INDUSTRY

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„The future prospects of modern societies are dependent more than ever on the efficiency of science. We are living in a world that relies on the creation of more knowledge for its survival, and that has an organised work distribution and is globally networked. Investing therefore in the science and research of today's scientific growth assures the quality of life in the competition orientated world society of tomorrow." With these words a group of high-ranking representatives from industry, trade, commerce, agriculture, banks and research organisations (Fig. 1) recently appealed to the economy under the title of „Science is Indispensable" in order to strengthen the economy's commitment to science. This appeal makes clear the common responsibility that science and industry carry for common welfare as essential protagonists for the research in universities and other state run research institutions on one side, and for the implementation of innovative ideas to new products and technologies in industry on the other.

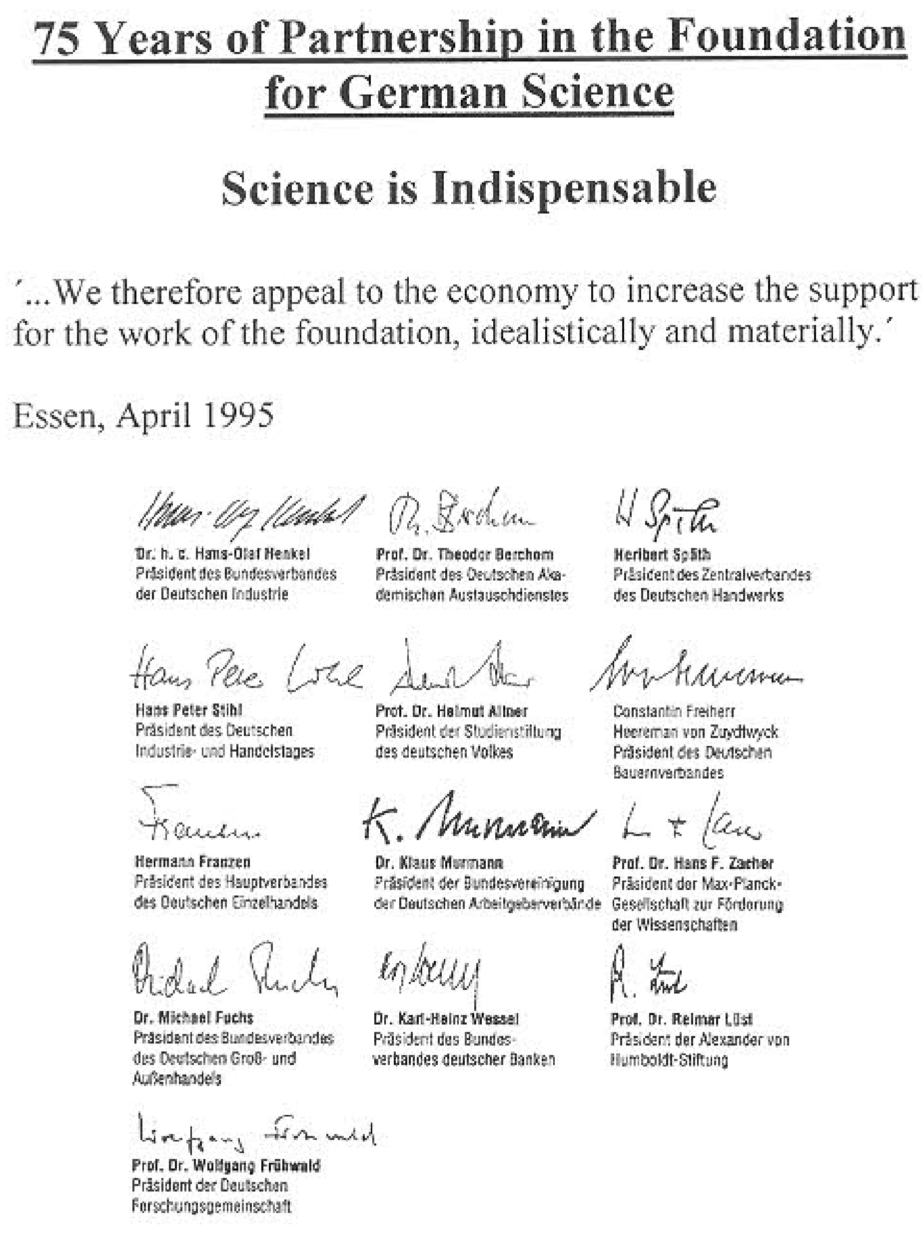
This common responsibility is the base for the need of close and effective links between science and industry.

THE DUALITY OF RESEARCH AND APPLICATION

The classical form of interaction between science and industry is born by the conviction that basic research is the humus from which the industrial development of technologies, processes and products grow, and so basically represents the basis for the welfare of the society (Fig. 2). For this concept of scientifically orientated technological development, industry runs R & D units in which the applied research necessary for development is pursued and scientific contact to public research institutes is maintained. In this concept, basic research is directed to the pure gaining of knowledge, and defined as a research area that doesn't lead directly to application or one that doesn't promise direct usage.

Looking back, basic research has proved itself on the whole to be very useful, despite its idealistic mission. History is in fact full of examples of how totally undreamed of and unforeseeable applications have resulted from fundamental research. Raimar Lüst expounded on this very impressively in a talk on the occasion of the 250th anniversary of the Universität Braunschweig.[1] Next to, or as it were, in the shadow of the more spectacular examples of the transfer of fundamental research into successful application was the continuous and unspectacular utilisation of basic research, not quantifiable monetarily, up to the present day whenever knowledge-based developments were concerned.

The traditional difference between basic and applied research is continually less suitable for an appropriate characterisation, not only of research itself, but above all of the co-operation between science and industry in the process of technical development. Science is being moved increasingly into the sphere of application and development. So basis-orientated research takes



75 Years of Partnership in the Foundation for German Science

Science is Indispensable

´...We therefore appeal to the economy to increase the support for the work of the foundation, idealistically and materially.´

Essen, April 1995

Dr. h. c. Hans-Olaf Henkel
Präsident des Bundesverbandes der Deutschen Industrie

Prof. Dr. Theodor Berchem
Präsident des Deutschen Akademischen Austauschdienstes

Heribert Späth
Präsident des Zentralverbandes des Deutschen Handwerks

Hans Peter Stihl
Präsident des Deutschen Industrie- und Handelstages

Prof. Dr. Helmut Altner
Präsident der Studienstiftung des deutschen Volkes

Constantin Freiherr Heereman von Zuydtwyck
Präsident des Deutschen Bauernverbandes

Hermann Franzen
Präsident des Hauptverbandes des Deutschen Einzelhandels

Dr. Klaus Murmann
Präsident der Bundesvereinigung der Deutschen Arbeitgeberverbände

Prof. Dr. Hans F. Zacher
Präsident der Max-Planck-Gesellschaft zur Förderung der Wissenschaften

Dr. Michael Fuchs
Präsident des Bundesverbandes des Deutschen Groß- und Außenhandels

Dr. Karl-Heinz Wessel
Präsident des Bundesverbandes deutscher Banken

Prof. Dr. Reimar Lüst
Präsident der Alexander von Humboldt-Stiftung

Prof. Dr. Wolfgang Frühwald
Präsident der Deutschen Forschungsgemeinschaft

Fig. 1: Appeal of high ranking representatives to the economy on the occasion of the 75th anniversary of the "Deutscher Stifterverband"

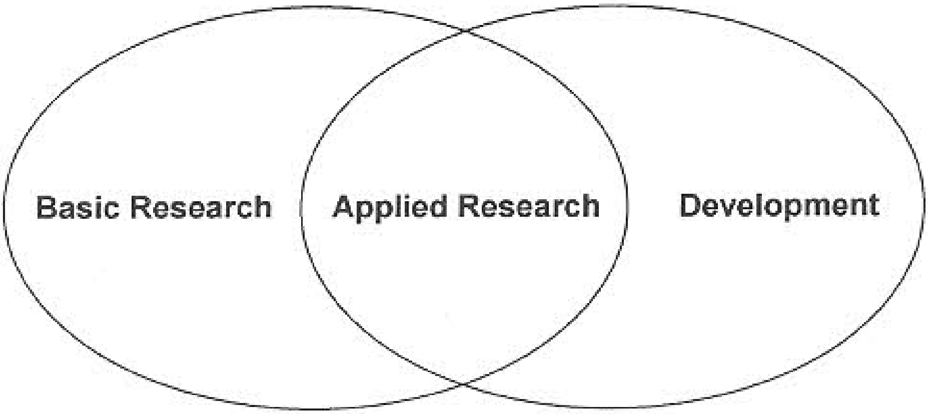


Fig. 2: The classic concept of scientifically-orientated development of technology

place also in industrial laboratories, and the findings of application orientated research promotes the interdisciplinary unification of the natural and engineering sciences, giving incentives for further development in the field of scientific theory.

The relationship between science and technology has also changed. Technology is no longer just a case of an application of science, but rather science has been decisively promoted through technology and new technologies with their precision of observation and mastering of complexities. Scientific research processes are not only dependent on technological knowledge and ability; they themselves are also increasingly being guided by them. Technology is not just an application of science but also a prerequisite.

Against this background it seems necessary to overcome the dualistic notions of basic research (as primarily publicly financed research) on the one hand and applied research (as established by the economy or primarily research covered by it) on the other. Mittelstraß[2] proposed the following three divisions of research:

- *knowledge orientated (pure) basic research,*
  i.e. research where no practical applications are expected from the results.
- *application orientated basic research,*
  i.e. research with which long-term applications are hoped for from the results and with which direct implementation for marketable products in the typical planing schedule of industrial companies cannot be expected, and
- *product orientated applied research,*
  i.e. research that either takes place with a view already to specific applications or has short-term expectations for such applications.

The boundaries between the quoted research types are, of course, not rigid, and the work from the various areas influence each other. It is no longer the disassociation from application that is

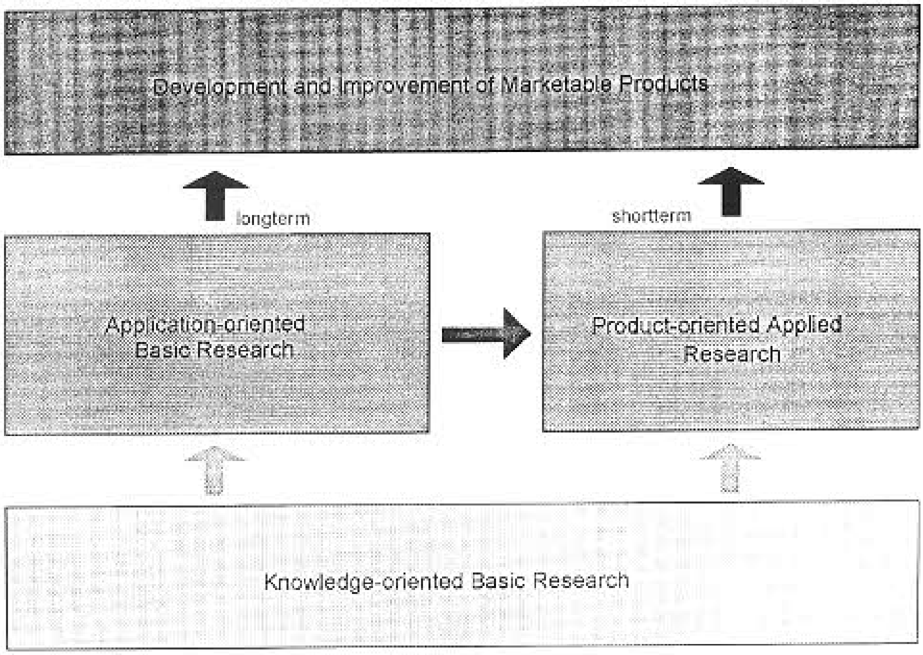


Fig. 3: Concept of knowledge-based development of products and technologies

so particular about the so-defined basic research, but rather the independence from direct utilisation interests.

From this differentiation in the quality of research, a modified concept of knowledge-based development of products and technologies is derived (Fig. 3). Technology-orientated research is conducted here in a planned manner for filling the gaps in the basic knowledge which is needed for the successful development of marketable products in a defined timeframe.

The concept of scientifically-orientated technological development on which the successful development of many of today's large enterprises are doubtlessly based is, however, more and more called into question on the part of many industrial representatives.

One of the reasons given for this are the market saturation in the industrialised countries and the subsequent globalisation of the markets with a resulting growth of world-wide competition. This general trend is combined with a shortening of the time needed for a successful start in the key technologies, the demand of the customer for a compatibility of the new technologies with the processes he already uses, and above all in the fact that the net product results no longer from the production of demanding technologies, but rather from their operation and the services that are realised through these technologies.

A demand-orientated innovations process is being implemented in industry at present in place of the classical scientifically-orientated development process in order that these changed frame conditions can be taken into account. Innovations are planned and developed in this process under the boundary conditions from market, technology and science with the help of a strictly organised management (Fig. 4).

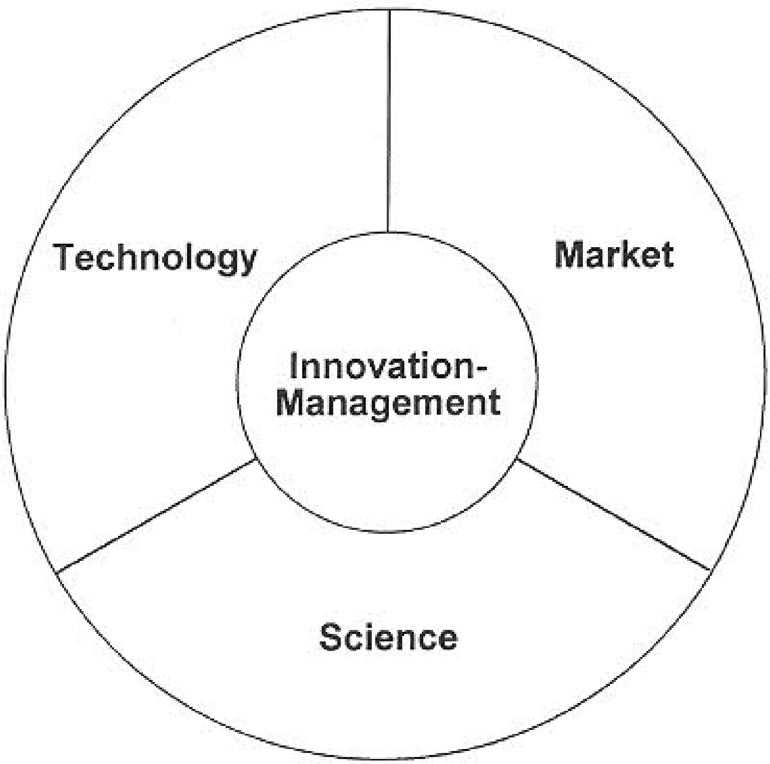


Fig. 4: Concept of the demand-orientated innovation process

This concept seems to be successful for industry but is brought into question when combined with a demand for a resources planning of the public research institutes together with industry where all of the participants are in agreement as a part of an integrated innovation process. To put it simply, the state funded research institutes should be there, according to the protagonists of this demand, totally at service for the realisation of temporary innovative ideas from industry.

Apart from the fact that the chances for future possibilities resulting from basic research would be forfeited by the consequent realisation of these demands, there is also the question of whether the innovations planned by today's industrial protagonists really prove themselves to be the right ones of tomorrow. This question cannot be answered in the affirmative without reservation, as is shown in the following hypothetical train of thought example: if scientists in the first half of this century when tube technology was a key technology had concentrated all resources on the further development of this technology, then it would not have resulted, at least at that time, in the discovery of the transistor and all the technologies that developed from that. In fact an unimaginable scenario!

This is with reference to a long-term research commitment, not against the necessity for co-operation between public research institutes and industrial enterprises. But one should do one thing and leave the other. This has been long acknowledged by both the protagonists and the public sponsors. Important sponsors (EU, BMBF, various federal states, foundations, recently also the DFG) have therefore formulated the readiness of the institutes to co-operate with industry as a political research goal, so that the extensive relevant state research resources are available alongside the materials from industry, thus fulfilling the purpose of the combined projects.

It can be seen in all industrial societies that apart from the traditional goal of gaining knowledge by research, technology-political goals able to instrument research and see it in broad terms as primarily a method to increased prosperity have taken the lead. The medium and long-term applied research projects are more strongly emphasised by politics and the economy, and research areas with proven or suspected relevance for technological and economical developments receive more funding.

RESEARCH ESTABLISHMENTS AND FUNDING IN GERMANY

The Federal Republic of Germany has at its disposal an extensive, versatile and, in many areas, a very successful system for research and its funding.

The expenses for research and development last year, according to the Ministry for Research, amounted to 81 thousand million Marks. It is worth noting that the percentage from the economy in this sum is continuously falling, and that the Federal and States' governments finance today just 39.4 percent of the total research costs in Germany. It is interesting that the small and medium enterprises have increased their costs in R & D overproportionally in recent years, the drop in the significance of research going therefore totally onto the accounts of the large companies.

The public research takes place in a multitude of research and development establishments, some important ones of which are shown in Figure 5. The named research organisations cover the whole spectrum, from basic research striving to gain knowledge, right up to product development. Their institutes are good as a rule, and a number of them are most excellently equipped and have at their disposal outstanding qualified personnel. These establishments constitute, in the view of industry, a potential with enormous over-capacities for research which make industry research in part obsolete, and are therefore used in increasing amounts for buying more research and development. The Fraunhofer society's institutes are specialised in these projects and are financed largely in this way. But also the materials science institutes of the universities, large research establishments and even the Max Planck society, intended for the furthering of science, work today to a large extent on relevant applied questions and together with industry.

The Max-Planck-Institut für Metallforschung, for example, is financed over the year to a great extent by third party moneys (Fig. 6), a considerable part of which coming from industry (Fig. 7).

- Universities and technical highschools
- Max-Planck-Gesellschaft zur Förderung der Wissenschaften (MPG)
- Wissenschaftsgemeinschaft Blaue Liste (WBL)
- Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF, former AGF)
- Fraunhofer-Gesellschaft (FhG)
- Federal research institutions (e.g. BAM)
- Industry-linked institutes

Fig. 5: Major non-profit research organisations in Germany

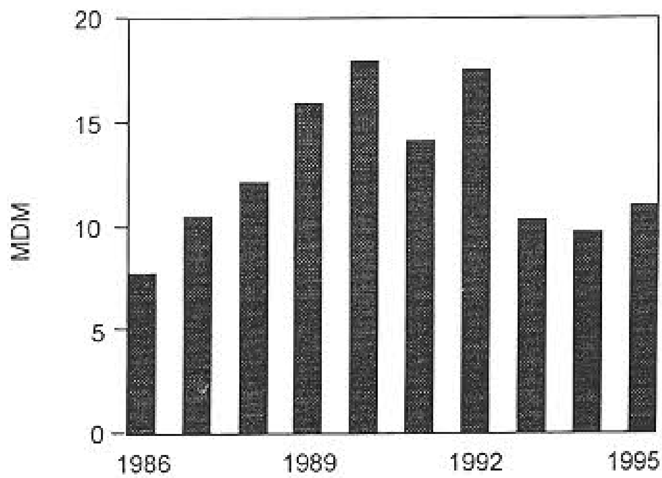


Fig. 6: Project money over the years of the Max-Planck-Institut für Metallforschung, Stuttgart

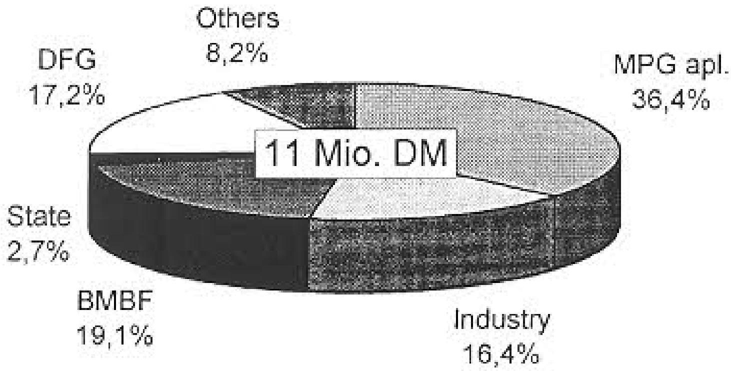


Fig. 7: Sources of project money in 1995 of the Max-Planck-Institut für Metallforschung, Stuttgart

- Federal ministries (e.g. BMBF)
- Research ministries of the federal states
- Deutsche Forschungsgemeinschaft (DFG)
- Alexander von Humboldt-Stiftung (AvH)
- Deutscher Akademischer Austauschdienst (DAAD)
- Katholischer Akademischer Austauschdienst (KAAD)
- Volkswagenstiftung

Fig. 8: Major research-funding organisations in Germany

The field of establishments for research support and sponsorship programmes in Germany is also diverse. The major national research-funding organisations are summarised in Figure 8. First in line in materials research come the research programmes Matfo[3] and MaTech[4] from the federal ministries. The Matfo-programme, which ran for 10 years and was equipped with support amounting to 1.1 thousand million DM, was replaced in 1994 by the MaTech-programme, which should likewise run for 10 years and be supported by 1.5 thousand million DM. Both programmes are directed prioritarily towards the materials based industries and fulfil a bridging function between the basic research of public research establishments and the self-financed development work of the industrial research laboratories.

The ceramic research especially experienced a strong support in the co-operation between industry and research institutes through the co-ordinated projects from both programmes. Next to these, the European Union programmes extended the thoughts of the co-ordinated projects to an international team work in order to strengthen European industries' competitiveness. In a similar way, the research emphasis of the federal states Baden-Württemberg, Bavaria and recently Saxony have to be pointed out. Their goal is to use the public research establishments for the support of the local resident industries. In the field of ceramics, the collaboration between about 25 institutes of the universities of Stuttgart and Karlsruhe as well as the Max Planck society (MPG), Fraunhofer society (FhG) and the German Aerospace (DLR) with a number of large and medium-sized companies is supported by the so-called „Keramikverbund Karlsruhe-Stuttgart" (Fig. 9) which is worth mentioning.

The German research society (DFG) has also since recently the goal of improving the cooperation between state and industry. This distinct research organisation is in the process of giving up the previously practised strict separation of basic and applied research and trying out new instruments with the aim of opening up the basic research to prototype development.

Many other programmes of sponsoring establishments named in Figure 8 although not directly aiming at supporting the industry relevant research, do, however, have an indirect effect in that they provide a possibility for the research institutes to considerably extend their resources, so they at least in the as-defined application relevant material research areas indirectly increase the support for the co-operation possibilities with industry.

TYPES OF CO-OPERATION

The quality and extent of the co-operation between the economy and science is very varied. There are traditionally very close links between scientists in research institutes and industrial companies in individual areas of materials science.

The form of the co-operation between the economy and the publicly financed research institutes is very diverse (Fig. 10). Here must be decided between large enterprises and concerns on the one hand which mostly have extensive research and development departments at their disposal, and small and medium-sized enterprises on the other hand which often have no research and development resources of their own.

The commonest form of collaboration is an open co-operation without great financial connections, which arise due to questions of mutual interest raised in their scientific discussions.

The most important form of co-operation is found however in the combined planned research projects. Funding for scientific personnel and equipment are often provided for the research establishments in the framework of such projects by the industrial companies themselves and/or by public support establishments.

Under the level of the combined research projects comes much collaboration in the form of frequent, short-term, scientific advice and service activities, where the institutes put their scientific expertise and/or facilities at the disposal of the interested companies.

Keramikverbund-Karlsruhe-Stuttgart (KKS)

Stuttgart

- Universität Stuttgart
  - Institut für Anorganische Chemie
  - Institut für Fertigungstechnologie keramischer Bauteile
  - Institut für Nichtmetallische Anorganische Materialien
  - Institut für Physikalische Chemie
  - Institut für Textil- und Faserchemie
  - Staatliche Materialprüfanstalt
- Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR)
  - Institut für Bauweisen- und Konstruktionsforschung
- Max-Planck-Institute Stuttgart (MPI)
  - MPI für Metallforschung, Pulvermetallurgisches Laboratorium
  - MPI für Festkörperforschung

Karlsruhe

- Universität Karlsruhe
  - Institut für Keramik im Maschinenbau
  - Institut für Thermische Strömungsmaschinen
  - Institut für Werkstoffkunde I
  - Institut für Werkstoffkunde II
  - Institut für Zuverlässigkeit und Schadenskunde im Maschinenbau
  - Zentrallaboratorium des Instituts für Keramik im Maschinenbau
  - Institut für Chemische Technik
  - Institut für Technologie der Elektrotechnik

Freiburg

- Fraunhofer-Gesellschaft
  - Institut für Werkstoffmechanik

Fig. 9: Research programme in the field of ceramics sponsored jointly by the state of Baden-Württemberg and industry enterprises

- Open Research Cooperations
- Jointly Organised Research Projects
- Technology-Transfer Centres
- Scientific Advice and Service Activities
- Supervision of Masters and PhD Theses in Industry
- Employment of Graduated Staff
- Short-term Research Placements for Institute Employees in Companies
- Research Placements in Institutes for Researchers from Companies
- Conferences, Colloquia, Seminars and Workshops

Fig. 10: Types of cooperation between science and industry

The intellectual transfer of knowledge takes place primarily by companies taking on graduates or employees with doctorates. This is certainly the most comprehensive form of „co-operation", not least due to the very often life-long contact of a former employee with „his" institute which can always be used for continual and normally not quantifiable help.

Short-term research stays of institute staff in companies would also be an ideal form for a comprehensive know-how transfer and an in-situ increase in understanding for the necessity of the industrial research needs. However, these ideals frequently fail due to hindrances by public service rights or concerns of secrecy on the part of the companies. Special recent support models of the BMBF (talent safeguarding programme) and the Federal States that employ on a short-term basis young scientists who haven't been able to find work in the recent decline in the economic situation, could obviously however dispel these doubts.

The diverse instruments of technology transfer are a particular form of interaction between industry and research institutes, aiming for the quicker implementation of research results into marketable products. It is interesting that this occurs not only through state support in so-called technology parks where an existence can be founded but also increasingly through ways organised by private economy. In this context the Steinbeis-Stiftung, resident in Baden-Württemberg, is particularly worth mentioning. This foundation e.g. provides the possibility especially for small and medium-sized enterprises to carry out product development in a research environment of an institute with highly valued personnel and equipment by the instrumentation of technology transfer centres set up in co-operation with the university institutes. The foundation is now also very successful over the state borders with this concept.

The BMBF has recently started out on similar paths so that this general concept of a product orientated co-operation of industry and research institutes may be able to spread further.

PRESENT PROBLEMS FOR THE COOPERATION BETWEEN ECONOMY AND SCIENCE

There were seldom such high expectations set for education, science and research as there are today. We expect from science not only help for overcoming diseases and hunger, leading to a changed lifestyle in harmony with nature. We expect from science above all the decisive stimulant for continuous growth, for high employment and for a life of prosperity.

The efficiency of the education and research system in Germany is, on the whole, undisputed. The implementation of research results into marketable products that create work places is, however, often complained of as insufficient, and is ascribed to an increasingly more unsatisfactory readiness of economy and science to co-operate. This is lamented as a special German problem, particularly in the media, and blame-accusing discussions hide any view of the reality and the fact that implementation is less a question of yes or no, rather much more one of where, when and how, and above all a question of extent and whether it helps the job situation in the country.

The market saturation in the industrial countries and the therefore growing globalisation of the economy and the ever-stronger world-wide competition has led to tremendous restructuring in the last few years for companies in the classically industrial countries (Fig. 11). The competitive ability is increased at least temporarily by a concentration on the key businesses and goals that promise short-term economic success, a strong orientation to the topical enquiries paired with a neglect of the technologically possible innovations, the saving of costs at any price and moving products and as a result recently also research and development establishments abroad. This tremendous restructuring has, however, increasingly serious effects on the innovation process and therefore on long-term development, especially on R & D in the companies. In detail, the temporary development in industry is characterised by the following trends:

- economisation of internal and external research costs in conjunction with an in part drastic reduction of research and development capacities and a cut in quality
- restructuring and therefore redundancy, early retirement or transfer of qualified research and development personnel to other functional areas of the company
- introduction of a consequent research and development project management directed to short-term goals and a breaking up of the classical subject departments that served to carry the know-how and could keep an overview
- a preferential treatment of short-term projects that serve to protect the continued existence of established business fields before longer-term, orientated plans that would open up new business fields
- introduction of a pure engineering management in conjunction with the total break-up of the corresponding laboratory facilities and the giving up of the general competence for recognition of innovative ideas in the research
- transfer of parts of the research and development units abroad out of reasons of costs and /or to bring the product development closer to the markets
- placing of development orders abroad
- frequent changes to the organisation and personnel responsibilities in the research and development areas.

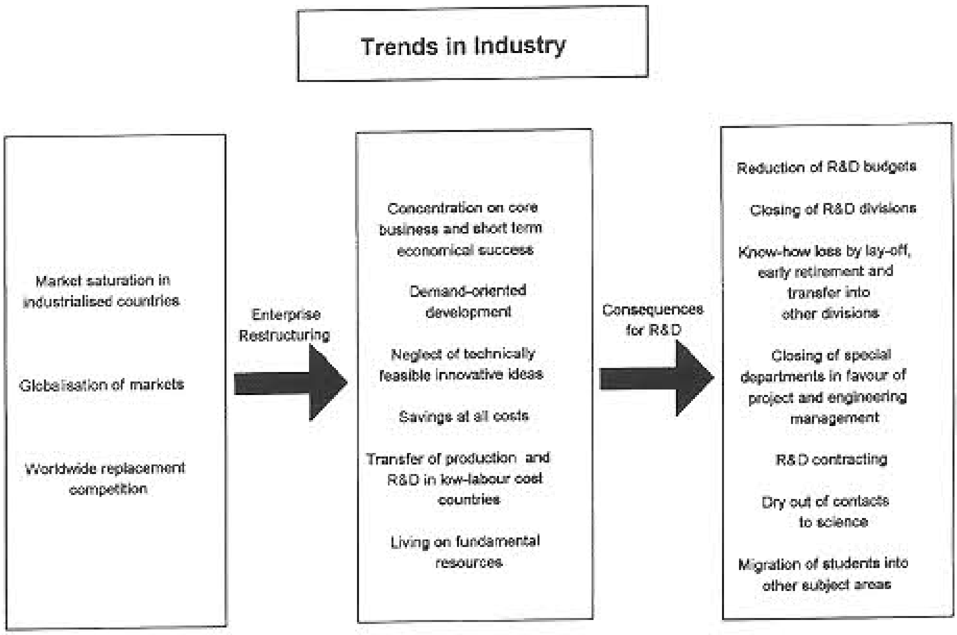


Fig. 11: Temporary developments in industry

The classical research and development know-how carrier in the companies are dying out with these trends, who up till now fostered the contact to the research institutes, acknowledged external research results as relevant for his company and through his position catalysed their conversion into improvements of the existing products and development of new ones. The partners have found up till now no adequate concept for overcoming this gap, where it exists. The strengthened and often eager co-operation of the research institutes brought in are not seen on the part of science as an alternative solution to fundamental questions in connection with setting short-term and permanently changing goals of the present research and development project management of the company as they don't have the self-conception that comes from research opened up by the long-term chances that produce continuity.

These serious, qualitative changes to the situation of the co-operation between economy and science described are strengthened by a qualitative change in the top management levels. This is not just a change in generation but rather an exchange of the classical support teams, characterised by technology-natural science, by purely salesman-orientated managers who have less and less understanding for developments promising to be expensive and only rewarding in the long-term. The economy strategists presume that the research performance and results are always available and can be bought as needed and so they therefore do not need to spend fixed costs to keep the continuity of research.

Whether this form of co-operation can be an alternative to the classical interaction between economy and science for the fulfilment of the expectations for science, as above recapitulated, will be proven by the future.

SUCCESSES OF THE CO-OPERATION BETWEEN ECONOMY AND SCIENCE

The described problems for the co-operation between the economy and science shouldn't, however, be understood to mean that there is no (more) co-operation between the two. There still exists a great number of well executed co-operation projects and successful co-operation occur today as ever before between economy and science, alongside the necessary search for new forms of co-operation as alternatives to the restructuring happening in industry. Someone recently conducted a study on behalf of the BMBF[5] about the effect of the indirect project support within the framework of the Matfo programme, in which the quality of co-operation with the institute partners was judged by industry to be overwhelmingly good. The results of this study were based on a survey of companies with in total 176 collaboration projects of the Matfo programme. From this survey, 93 percent of the projects were assessed to be scientifically successful, and 71 percent as technologically successful (Fig. 12). 27 percent of the projects had been commercialised by the time of the survey and an economic implementation was expected for a further 26 percent (Fig. 13). In summary, a medium-term commercialisation rate can be judged as a success for over 50 percent. This is impressive against the background of a generally long-term and cost intensive development phase in materials research. The corresponding numbers of the ceramic relevant projects with a total commercialisation rate of about 40 percent is even more impressive in view of the particular difficulties in introducing new ceramic products.

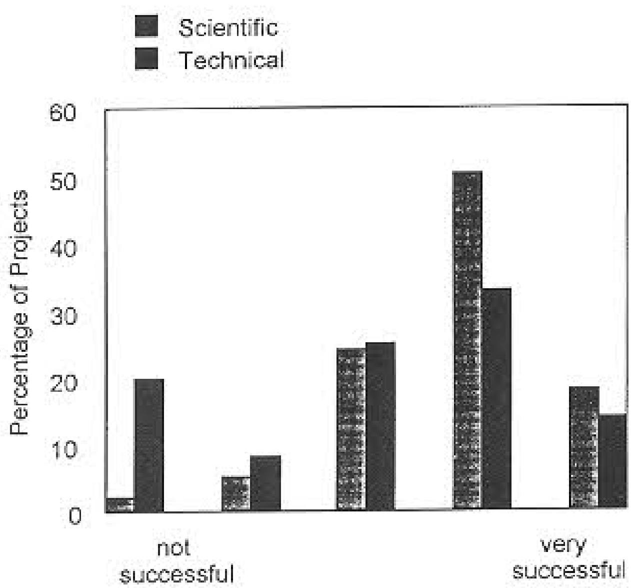


Fig. 12: Estimation of the scientific and technical project success in the Matfo-programme

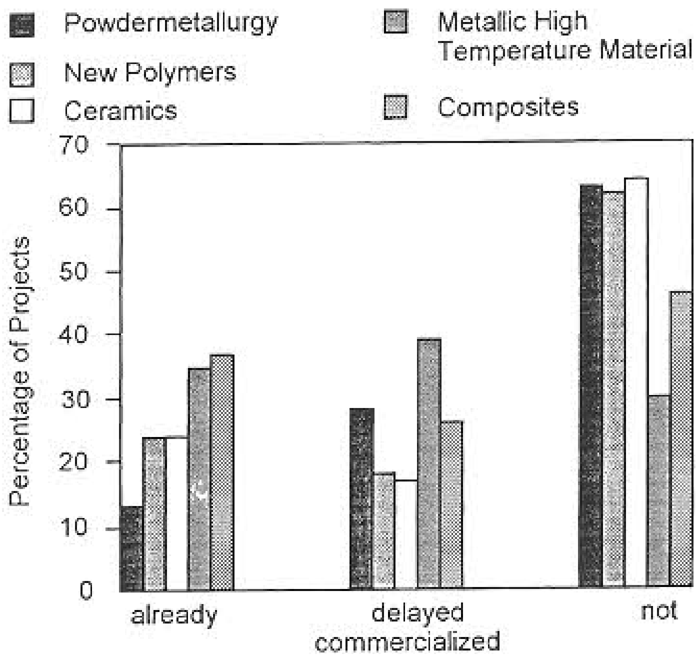


Fig. 13: Commercialisation success of the projects based on various material classes in the Matfo programme

One example for a successful co-operation between science and industry in the field of ceramics dealt with the development of materials for engines.[6] This project wasn't included in the study due to a later completion date, but should be clarified due to its extent and the fact that it excellently portrays all the characteristics of a co-ordinated project. Various large companies which were, in part, competitors (Bayer AG, Hoechst AG, Daimler Benz AG and MTU) were successfully brought together for a coordinated research programme in collaboration with a research institute in 1987. The work that was run for a period of seven years at the MPI für Metallforschung had expenses of about 17 million DM in total which was met half by BMFT and half by the four companies mentioned above. The aim of the institute's work was to gain a clearer understanding of the behaviour of the ceramics during their manufacture and application, parallel to the intensive development work of the companies for the manufacture and testing of valves for internal combustion engines. The combined activities of the partners resulted in the end in the success of the German ceramic manufacturers at the end of the 80s being able to not only catch up with the Japanese competitors in the production of engine parts with sufficient reliability, but also to fulfil the requirements for ceramic valves to be used in a standard built engine by Mercedes Benz, planned to be introduced commercially in 1998.

CONCLUDING REMARKS

The main task that a society concerned with quality of life and continuous prosperity should set itself is innovations ability. Basic research is necessary in the first line for this, and the successful interaction of science and industry in the process of implementing research results for new products, safeguarding jobs.

The serious changes that have been brought about by the revolutionary features of the economic globalisation make it urgent to find a permanent optimisation for the form of the interaction.

Acknowledgement

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