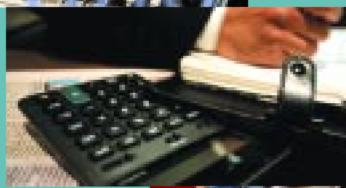
SPEKTRUM

SPECIAL

SPECIAL RESEARCH

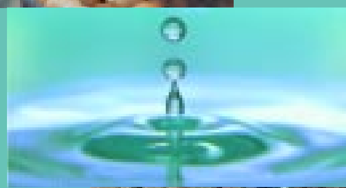
Information as an economic resource

Organisation of enterprises



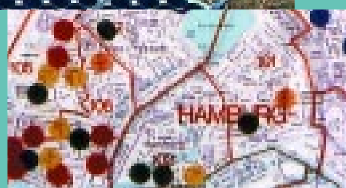
Production and process integrated environmental protection

Sustainable management of natural resources



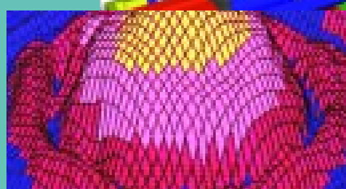
Advanced energy systems and energy management

Sustainable urban structures



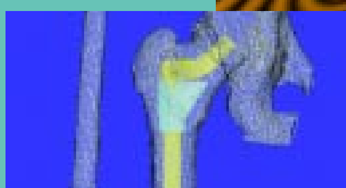
Systems of transport and logistics

Advanced communication technologies



Advanced materials and microsystems

Biotechnology and biomedical engineering



TUHH
Technische Universität Hamburg-Harburg

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Research 2001+

The Technical University Hamburg-Harburg (TUHH) was founded as a university focussing on research activities and it has maintained that character up to this day. In pursuance of its founding principles – priority of research, interdisciplinarity, regionality, innovation and internationality – the TUHH has adopted an innovative structure in deviation of the traditional one of universities: the matrix structure.

Research and teaching activities are structurally separated but not as regards the personnel. Research activities are conducted in six research departments with the scientific sections – as the smallest organisational units of the TUHH – being integrated into these major fields. This structure allows interdisciplinary cooperation in research and teaching activities at the TUHH.

In 1980, the first professors at the TUHH set out to devote their research and development activities to maintain and create jobs of high technical standard in growth industries aiming at strengthening regional scientific competence. Looking back on 20 years of research activities at the TUHH it is obvious that these goals have been reached. So far, the TUHH has been able to add three collaborative research centers, two research units as well as two Graduiertenkollegs (research training centers) sponsored by the Deutsche Forschungsgemeinschaft (DFG) to its research program. These examples show that the TUHH has become firmly established in basic research.

Applied research and development have become the second focus of the TUHH. Numerous projects in cooperation with the Federal Minister of Education and Research (BMBF), industry and foundations are proof for the successful collaboration between the TUHH and the business community as well as public institutions in addition to the effective transfer of technology by "brains" and the establishment of technology-oriented companies.

The TUHH is determined to make the most of that excellent starting position so that it will be just as successful in performing its functions in the years to come. To do so, it has defined ten strategic fields of research describing the interdisciplinary framework for future research activities.

This booklet SPEKTRUM special is to serve two purposes: to go back over the past twenty years and to look forward to the years to come. The TUHH's prospects are bright. I wish to emphasise that the TUHH sees itself as an innovative future-oriented university giving priority to the development of trend-setting fields of research and the increased transfer of technology and networking.

Prof. Dr.-Ing. Christian Nedeß
President of the TUHH

Science and Internationality

For the development of science, fruitful discussions within and with the scientific community is a “conditio qua non”. To enhance research programms, to integrate new ideas from outside, to fascinate young scientists from abroad, a university and its researchers must be part of the international scientific discussion within the specific disciplines. Without this international context and exchange there will be no fresh ideas.

The climate at the TUHH is open-minded and all of the scientists are working in international scientific networks. The scientific exchange is done via contributions to international conferences, workshops, seminars and meetings. It is put into reality by giving lectures on the campus of the partner universities, it is done in mutual research projects as well as in student exchange programms. All of these activities are facettes of an open university well-integrated in the production process of science.

The strategic areas of research which were defined under the vice-presidentship of my colleague, Prof. Werther, describe the interdisciplinary framework in which research at the TUHH is to be developed. The framework can be taken as a strategic orientation allowing the integration of new developments and ideas. We think that the discussion process started at the TUHH should be made public to the world; so we decided to translate our guidelines in the “lingua franca” of science. We hope that these strategic fields of research may lead to internal and external discussions resulting in hints for future developments of research at the TUHH. I would like to ask you - our partners abroad - to be part of these discussions facing the challenges the TUHH will have to match in the next years to put the strategic plan into realistic milestones.

Up to now we are working to set up new cooperative research groups to develop the TUHH further as a research university of high standards. Together with the strong intention to be in the top group of excellent universities, with the valuable advices from our international partners and the chance to set up new professorships in the near future, I am sure that the success story of TUHH will continue in a very international and inspiring campus atmosphere.

Prof. Dr.-Ing. Otto von Estorff,
Vice-President Research

Future with Science

Our motives for presenting the research activities at the TUHH in this booklet SPEKTRUM special are twofold. For one thing, it is time to pay tribute to 20 years of research and development activities at the Technical University Hamburg-Harburg. In 1980, with the appointment of the first professors, research activities started at our university. That alone would be reason enough to make a survey of what has been accomplished so far.

However, a review of past events alone seemed to be inappropriate for the TUHH in view of it being a young and dynamic Technical University. Thus, the idea was born to focus on the future when presenting the development of our research activities and link them with the ten strategic fields of research at the TUHH agreed upon and defined in December 1999. These fields of research are to be viewed as strategic guide-lines to allow the inclusion of new developments and ideas in basic research and applied research in future as well.

A strategy commission of the TUHH set out to redefine the research and development activities at the TUHH together with the research departments of the TUHH. The outcome of these discussions are the ten strategic fields of research each of which is described briefly in this booklet.

In addition, research projects in cooperation with external partners, special research projects like collaborative research centers, research units and Graduiertenkollegs (research training centers) are being presented apart from the TUHH's activities related to technology transfer and business start-ups.

Those cooperative projects described are just a few examples for the interdisciplinary research activities at the TUHH. The necessity of focussing on specific research activities prevented us from presenting all internal cooperative projects in research and development at the TUHH, such as the "European Center for Transportation and Logistics (ECTL)" combining the expert knowledge at the TUHH as regards transportation systems and logistics. In the "environmental technology center (etc)" scientists of the TUHH and the GKSS are working together to find solutions for environmental issues. In biotechnology the research group "Technical Microbiology and Microsystems Technology (TMM)" has been established and at present a "Center for Maritime Technology (CMT)" is being set up to combine the resources at the TUHH with respect to shipbuilding and maritime technology.

There are various other research activities in cooperation with partners from industry, society and other scientific institutions the presentation of which would go beyond the scope of this booklet. All those interested in research and joint research projects are referred to our research report giving detailed information on these activities.

This booklet is to present the present activities at the TUHH focussing on the future. In addition to describing our guidelines it is to arouse interest and curiosity for engineering and technological issues and to encourage possible cooperation partners to pursue a closer collaboration with the TUHH. Finally, the effects of the TUHH's activities on the metropolitan region of Hamburg – on the business sector and the society as a whole – should be pointed out as well. Thus, we hope that this booklet might be the starting point for lively discussions.

Last but not least, it is essential to inspire young people in particular with enthusiasm for the fascinating tasks and challenges of technology and science. Clearly, to meet future challenges there is a growing need for technical innovations on the basis of excellent research activities in close cooperation between industry, economy and science. And this may only be done, if we can motivate the best heads to put their minds to solving technological problems.

The TUHH is open to all persons interested in our activities; you are always welcome to visit and talk with us.

Prof. Dr.-Ing. Joachim Werther

Research for the Benefit of Mankind - Innovation for the business location

In the era of market globalisation universities are increasingly playing a very special role, as the economic development of regions – more so than national economies - such as the metropolitan region of Hamburg with its tradition of viewing itself as the "Gateway to the World", depend on the intelligent use of the decisive production factor: the "human intellect" or "brainpower". Scientific research and development activities as well as future-oriented teaching programs are vital factors for innovation.

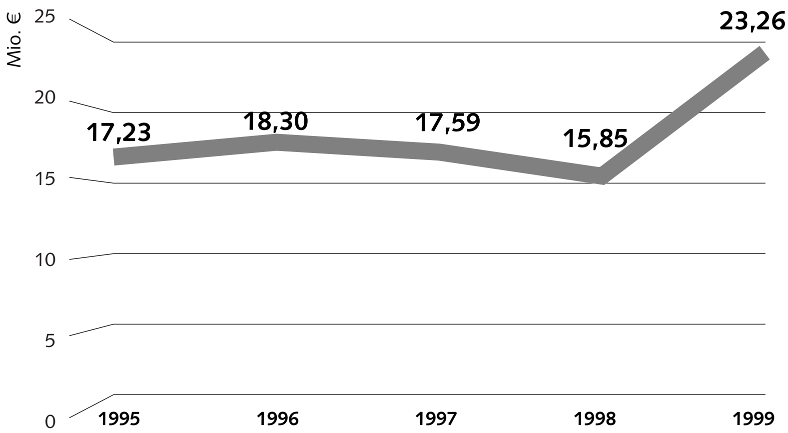


Fig. 1
Total funds granted by third parties to the TUHH and the TUHH Technologie GmbH

Investments in science and research are investments in the future. Economic growth will be increasingly dependent on the regenerative resource of the "human intellect", on the permanent renewal and extension of knowledge and the development of new products, processes and technologies. In pursuance of these objectives the Technical University Hamburg-Harburg (TUHH) is committed in its research and development activities to develop new technologies for human benefit.

At the TUHH, receiving a total sum of € 53,17 million in 2000 from the Federal State of Hamburg to cover its teaching and research activities, 60 % of these funds are used for research and development activities. These funds are being profitably invested, the more than 70 dissertations presented each year are but one of the obvious results of the ongoing research activities. The additional financial resources granted by third parties for research and development activities are another proof for the productive use of these funds. In the course of the past years, the total amount of these external financial resources could be steadily increased to € 24,54 million in 1999 (see fig. 1). The source of these financial resources granted by third parties may be seen from figure 2. With regard to basic research activities the Deutsche Forschungsgemeinschaft (DFG) is the main financial backer with almost € 7,67 million in 1999, a figure indicative of the quality and competitiveness of the research activities at the TUHH, in particular as regards pure basic research. Among the financial backers for applied research projects, which are normally carried out in cooperation with the business sector, the major one was the Federal Minister of Education and Research (BMBF) with more than € 9,20 million having been granted by that Federal Minister and other Federal Ministries in 1999, whereby industry contributed a total of about € 4,60 million. Research promotion by the European Union - € 1,02 million in 1999 - is still playing a relatively minor role but is gaining in importance.

In comparison to other technical universities the TUHH has gained a top position as regards its research and development activities. According to a survey made by the DFG the TUHH is placed 4th looking at the research funds per capita and scientist made available by third parties. In a university guide published this spring the quality of research done in electrical engineering, for example, is rated to be above average (start, the university guide by stern and CHE, 1/2000).

The innovation potential of any region and thus its position within the international competitive struggle as regards innovations, technologies and efficiency which is steadily increasing in severity is dependent on science and research. When being asked about the technological future of Hamburg a major role must be attached to the Technical University Hamburg-Harburg being a young and modern university with the expressive task of contributing to the technological development of Northern Germany. The large-scale technology-oriented projects 'HafenCampus Harburg' and 'Channel Harburg' recently established in the vicinity of the TUHH are clear proof that it has been most successful in that respect. A new industrial site for modern high-tech companies is emerging south of Hamburg closely linked to the TUHH.

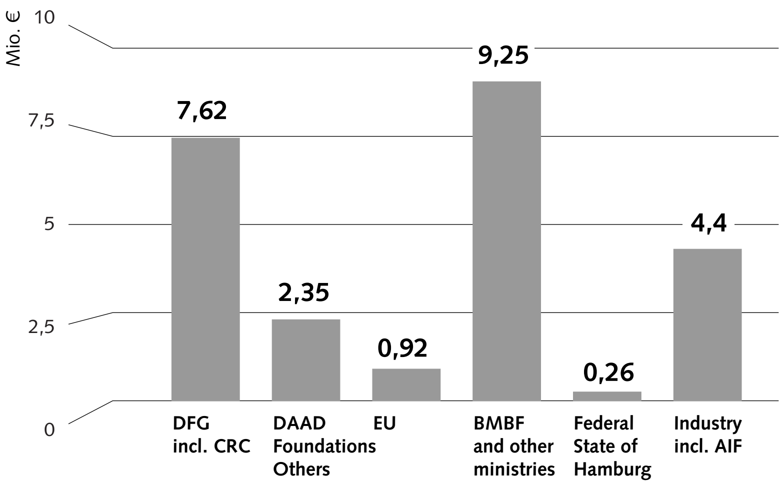


Fig. 2
Funds granted by third parties to the TUHH – sources (1999)

To maintain innovative strength and ability of the region it is necessary, however, not to focus research activities exclusively on issues readily applicable in industrial production. Future-oriented research should rather aim at a productive mix of applied research and development and knowledge-oriented basic research. To meet the challenges of tomorrow the TUHH has defined ten strategic fields of research:

- Information as an economic resource
- Organisation of enterprises
- Production and process integrated environmental protection
- Sustainable management of natural resources
- Advanced energy systems and energy management
- Sustainable urban structures
- Systems of transport and logistics
- Advanced communication technologies
- Advanced materials and microsystems
- Biotechnology and biomedical engineering

These ten fields of research define the interdisciplinary framework in which research is to develop. This framework is to be taken as a strategic orientation allowing the future integration of new developments and ideas. Furthermore, the TUHH believes that the evaluation of technologies done at the TUHH is essential for reviewing its own performance.

The strategic field of research 'information as an economic resource', for example, allows for the fact that in our post-industrial society economic performance is increasingly dependent on controlling information. Development and operation of innovative multimedia information services call for system-oriented solutions by far exceeding traditional network, databank and software technologies. What is required today are the dynamic supply and the efficient access as well as the flexible and cooperative application of a broad range of resources in the network (information, methods, equipment etc.) while maintaining a high standard of availability, consistency, authenticity and confidentiality.

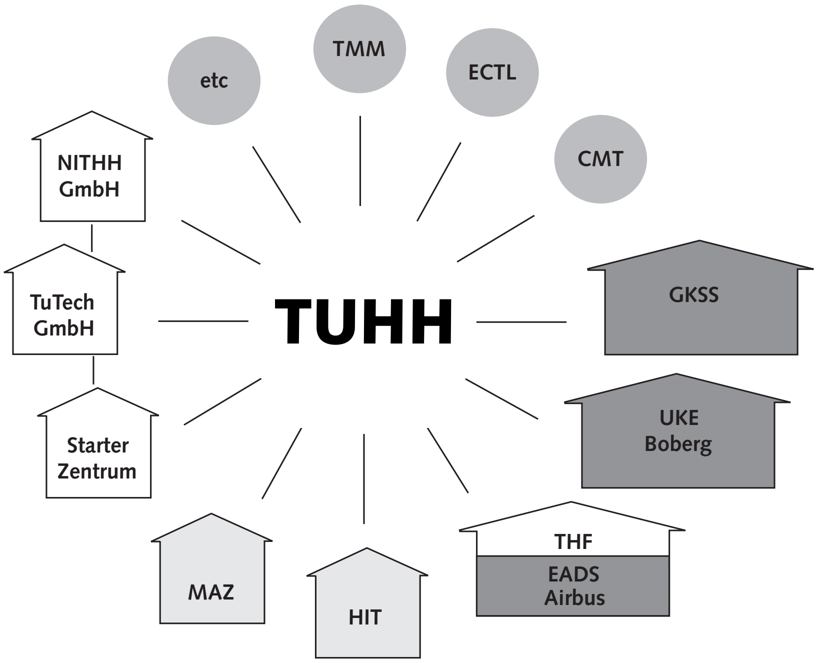
At present, a new donated professorship under the title "safety in technical applications" which will research safety issues in networks is being integrated into that field of research. Another strategic field of research is, for example, 'biotechnology and biomedical engineering' uniting new approaches and conceptions as regards 'life science'.

Research findings will have to be transferable, if trade and industry and society are to benefit thereby in view of increasing globalisation of markets and internationalisation of competition. This transfer will best be effected via minds, as the human capital is the decisive productive resource within any company and, simultaneously, its biggest innovation potential.

In view of short product cycles and complex systems for maintaining competitiveness companies will be more and more in need of maintaining and intensifying their cooperation with universities and other external sources of technology in addition to gaining access to human capital. The establishment of efficient networks for the transfer of technology with national and international partners has become an essential part of a new innovation culture in Hamburg. On account of its high potential of scientific know-how the TUHH bears a great responsibility for regional business and industry and their future economical and technical development.

For more efficient cooperation and networking with its partners the TUHH has concentrated its research resources and know-how in various centers. The cooperation network of the TUHH and some of its cooperation partners from the business community are illustrated in fig. 3 and 4, such as the cooperation relating to aviation research – e. g. technological issues and components of aircraft systems - with the EADS Airbus GmbH in the Technology Center of Hamburg-Finkenwerder. The cooperation projects with the shipbuilding industry aim at the design of efficient ship constructions and manufacturing methods as well as the reduction of pollutant emission during ship operation. The cooperations with the GKSS Research Center of Geesthacht and the Microelectronics Application Center MAZ are examples for a successful research collaboration with other research institutions.

By establishing its subsidiary "TUHH-Technologie GmbH" the TUHH has created a very successful tool for efficiently transferring the research results of many research and development projects, one method is by assisting in the setting up of new companies. With the help of the TUHH Council of Founders effective instruments are made available to young engineers assisting them in starting up their own companies. In 1999 alone, 11



etc	environmental technology center
TMM	Technical microbiology and microsystems engineering
ECTL	European Center for Transport and Logistics
GKSS	GKSS Research Center
UKE	University Hospital of Hamburg-Eppendorf
THF	Technology Center of Hamburg-Finkenwerder
HIT	Hamburg Institute for the Promotion of Technology
MAZ	Microelectronics Application Center
NITHH	Northern Institute of Technology
TuTech	TUHH Technologie GmbH

Fig. 3
Development of the Hamburg network of the TUHH

companies were newly established.

The organisation of research and development projects in cooperation with small and medium-sized firms is another function performed by the TUHH-Technologie GmbH. The TUHH's research and development potential and its expert knowledge is made available to the regional business sector for problem-solving innovative processes and new system configurations. As a subsidiary of the TUHH the TUHH-Technologie GmbH is able to directly approach the scientists who are the source of expert knowledge.

To maintain the position gained as regards research and development activities and the transfer of technology and to continue the TUHH's success story it is essential to attract the best creative minds from business, society and industry. Moreover, excellent research work is a major factor of the quality of university education.

Furthermore, it is of vital importance to be able to cope with future requirements in the market of external research promotion. Public funds for research projects are more and more granted subject to a self-financing quota of 50 % except for the DFG that, however, requires adequate basic facilities. Therefore, it is important to ensure that the TUHH will continue to have access to applied research programs and funds which are essential for the TUHH to fulfil its task, as a university can only bring forth competent engineers, urgently needed by business and industry, if its teaching activities are combined with applied research. Such engineers are able to produce new ideas and approaches and contribute largely to any innovative capacity of industry and the economy as a whole. Moreover, applied research is one of the keys to the exchange of persons and ideas between universities and the business community constantly called for by experts.

In line with its mission the TUHH will firmly adjust its research structures and resources to meet future challenges both as regards quality and originality in order to play a leading role in science, economy and society in future as well. Technological research for human benefit is useless without applying its findings and developing innovative products and processes. The TUHH sees itself as a motor of innovation.

(Johannes Harpenau)

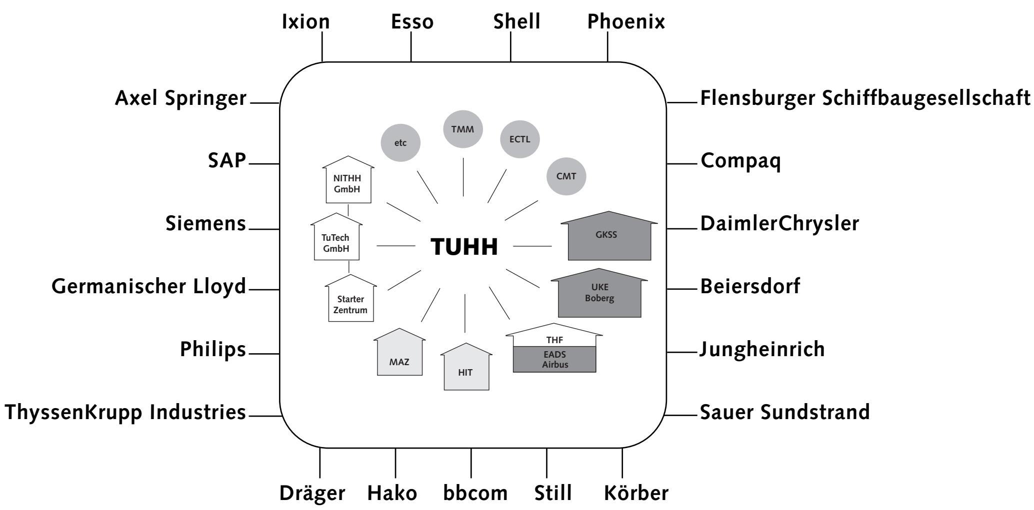


Fig. 4
Industrial network of the TUHH (selection)

The Significance of Research for the Development of the TUHH

The history of the TUHH is beyond doubt a success story without precedent, I for one don't know of any other newly founded university in the Federal Republic of Germany which has successfully established itself in such a short time as the TUHH.

Basis and motor of this development has been the TUHH's research performance which from the beginning has been the distinctive characteristic of the young TUHH and something to be justly proud of. However, we should not fail to see that engineering sciences are still not held in high regard in the traditionally commercial city of Hamburg. The TUHH will need much staying power in its efforts to cause a permanent reorientation. In this respect, the generally deplored imbalance between Northern Germany and Southern Germany appears to be a long-standing one, as Max Brauer, Lord Mayor of Altona, then belonging to Prussia, in his memorandum "The Technical University in the Lower Elbe Region" deplored as early as in 1928 that there were almost three times as many places to study engineering sciences in the region south of the river Main than in Northern Germany. Presumably, this proportion is still valid today, just as the essential statements of the memorandum are still relevant. That memorandum ended with the words: "If we wish to stimulate the economic development in the Lower Elbe Region initiated by Prussia a major factor will be, in our opinion, the establishment of a high-ranking intellectual center, a Technical University of Altona, to be established and operated on the basis of time-tested principles and the latest scientific findings."

As is well known, the Prussians were never quick to act and, in general, the competent politicians were apparently not exactly delighted with this idea of a new technical university. This must have applied to both the Prussians and the Senate of Hamburg, since when Max Brauer became Lord Mayor of the Free and Hanseatic City of Hamburg after the Second World War there was no more talk about a technical university in the Lower Elbe Region. It was mainly due to scientists of the Hamburg University that the idea of establishing a technical university gained acceptance in the seventies. We, in particular, have to give them full credit for their courage and far-sightedness to fight for a new technical university, as that university inevitably had to enter into rivalry with the other universities and colleges in Hamburg, in particular with the Hamburg University, exactly what has happened in the last years. This is not the place to judge who has or has not benefited from this competition, but this much is certain, at least in my view, without the TUHH Hamburg's academic life would be much poorer and no university or college in Hamburg would be in a better situation both financially and otherwise (in all probability Hamburg's budget for education and research activities would rather have been reduced by the budget of the TUHH).

Before Hamburg's Lord Mayor Hans-Ulrich Klose submitted the bill for the establishment of the TUHH to the City Parliament in 1978 comprehensive surveys and experts' opinions on the required capacity, research profile and courses of studies to be offered had been prepared. A major result of these preliminary inquiries was the matrix illustrated below taken from the 'additional report on the basic structure of courses of studies to be offered at Hamburg-Harburg' (1976, printed paper of the City Parliament 8/2745).

It turned out to be an excellent concept for a technical university contributing largely to its later success. However, it had to be put into practice by the TUHH itself and that it did so well right from the beginning was not only due to the efforts and enthusiasm of its scientists but also to that of all its employees. What were the main "ingredients" of that concept?

I would like to focus on two elements in particular, mainly because they were of vital importance specially in the initial phase.

One element is the open structure of our university which is not organised in faculties but matrix-orientated. Each scientist is assigned to a research department or "Forschungsschwerpunkt (FSP)" managed by the FSP-Secretary and the FSP-Council and to a school of study managed by the Dean and the School's Council. Thereby, everybody has to come to terms with various groups of persons at different levels. Thus, one knows what most of the others are doing, a major factor for being able to identify oneself with the TUHH as a whole.

The second element is the way the TUHH was set up step by step starting with the vertical line of the matrix, the research departments. In a second step the horizontal line of the matrix, the teaching activities, were added. Academic assistants as well as doctoral candidates were part of the original team, some of them started their work before their professors. Thus, the TUHH has had at its

Courses of studies: 1 Production engineering; 2 Design engineering; 3 Materials engineering; 4 Communication engineering; 5 Computer science; 6 Measurement engineering, automatic control engineering; 7 Process engineering; 8 Chemical engineering; 9 Civil engineering; 10 Architecture; 11 Urban planning and development, town planning

Research departments		1	2	3	4	5	6	7	8	9	10	11
Plant engineering, apparatus engineering and production engineering including related basic operations of process engineering	1	X	X	X		X	X	X	X	X	X	
Materials physics including materials research and polymer physics as well as related design engineering	2	X	X	X	X		X	X	X	X	X	
Safety technology, reliability technology, technology of labour protection and environmental protection	3	X	X	X	X	X	X	X	X	X	X	X
River and Coastal Engineering, Ocean Engineering and related biotechnology	4		X	X		X	X	X	X	X		
Building construction	5		X							X	X	X
City restoration and preservation	6									X	X	X

Fig. 1
Matrix structure of 1976

disposal from the beginning the creative potential of young committed people assigned to specific projects for a limited period of time which is the major advantage of research activities at universities in comparison to other research institutes. These human resources were a real blessing for the newly established TUHH and its meteoric rise has been largely due to them. Before the first students took up their studies at the TUHH more than one generation of doctoral candidates had already passed through the TUHH.

In the following, I would like to point out some other aspects illustrating the beneficial effects of having started with research activities. On the one hand, this made it possible to recruit qualified and experienced scientists, the most important factor of all. The appointment procedures could be handled without being subject to the restrictions of the "Kapazitätsverordnung" (KapVO) (Capacity Regulation) and without having to consider curricular norms and teaching requirements thus being able to concentrate on the qualifications of the persons to be interviewed, a principle the Max-Planck-Gesellschaft has already successfully applied for quite a while and which has been to the great benefit of the TUHH as well. The research activities are the basis for the reputation of every university and an important criterion for the quality of its teaching activities, as the quality of teaching is based on the quality of research, a fact obvious in graduate courses but also valid for all courses of studies at universities. The TUHH did well to focus at the beginning on research activities with the result that an efficient team could be recruited in no time at all.

We know from experience that makeshift conditions are a breeding ground for creativity and in that respect the situation at the TUHH was optimal right from the beginning. Many will remember the initial conditions in the birthplace of the TUHH, the Schloßstraße 20, with elevators allowing only the transport of persons and files, with floors of a stability not even bearing the weight of a testing machine, with no adequate ventilation facilities preventing the storage of chemicals, with many passages and doors being too narrow to allow the transport of even medium-sized equipment so that the majority of our equipment had to be moved in through the windows by cranes, naturally after removing the window frames. Optimal conditions for putting technical knowledge to the test. All our efforts were curiously watched and accompanied by flippant remarks by quite a large number of pigeons feeling harassed by our invasion of their traditional living quarters. Most of us will remember as well the hanging labs in the hall of the engineering school, one of the biggest attractions when showing visitors around. A few years later, the TUHH occupied about 20 buildings of mixed architecture – vacant schools, old factory buildings and cavalry barracks - located within the city area of Harburg, the inland port area and even in the Elbchaussee. In these circumstances it would have been impossible to open the TUHH for students at full capacity. If we had done so, its further extension would probably have been organised by administrative courts on account of missing rooms for lectures, tutorial classes and practical training. Our research activities, however, were flourishing and became the driving force to speed up construction and extension of our premises.

When the TUHH finally became legally independent in 1986, the point of no return was already well past. Even though the construction and extension work was far from finished – the new buildings within the present university campus were still under construction – inconsistencies in the internal organisational structure already became evident caused by necessary changes of the original plan to adapt to recent trends of development. The research department 4, for example, – river and coastal engineering, ocean engineering and related biotechnology – had adapted to the rapid changes in these sectors that had been impossible to foresee when preparing the TUHH-masterplan. German industry had not conquered the expected market shares as regards off-shore technology and the related biotechnology (fish farming etc.) had not developed as hoped for. The course of studies of biotechnology finally established at the TUHH totally differed in substance from the original curriculum. There had also been alterations as to the courses of studies to be established, architecture and chemical technology had been dropped and marine engineering had been included. The matrix structure had to be revised and new paths had to be opened. And the young TUHH was able to do this, as it enjoyed the confidence of state and federal politicians.

In its first year of legal independence the TUHH had an externally financed research budget – mainly by the DFG, the Federal Ministry of Research and Technology and the business sector - of almost € 20,45 million, a sum equalling more or less the yearly budget the TUHH received from the Hamburg government (excluding investments). Such figures were top among German universities and I doubt that anybody thought the new TUHH in Northern Germany capable of doing so well when in 1980 the first professors were appointed. Such figures speak for themselves and inspired enormous confidence.

The TUHH made good use of that confidence and never fell short of the expectations placed in it, as far as I know. Thus, the City of Hamburg has always kept its financial commitments as regards the TUHH, even though sometimes long in coming, and has often paid more than promised even in times when public funds were scarce.

When in 1988 the TUHH presented its concept for the reorganisation and extension of the research departments prepared after intensive internal discussions, it was generally approved by the competent politicians and authorities and submitted to the Wissenschaftsrat, the German Science Council, for appraisal. Following its inspection and assessment of the TUHH's facilities the TUHH's performance was rated so highly that the plan submitted was approved and the extension of its buildings – 4th phase of construction – was included in the national framework plan for university construction and given highest priority.

During that phase the interest in joint research projects with the TUHH markedly increased both with respect to other academic and research institutions and the business sector. Whereas initially most offers of cooperation to the business community had quite naturally come from the TUHH, now this trend was reversed. The negotiations initiated by the present EADS Airbus GmbH resulted in the establishment of a new course of studies, namely aircraft systems engineering, and the respective donated professorial chair as well as in the establishment of the Technology Center of Hamburg-Finkenwerder, a concept closely evaluated and finally approved by the Wissenschaftsrat. Since then, many joint research projects have been proof of the effectiveness of that center.

At the initiative of the orthopaedic department of the General Hospital St. Georg and in cooperation with the University Hospital Hamburg-Eppendorf a course in biomechanics was included in the TUHH's curriculum which was greatly supported by the Hamburg Ministry of Health and the Berufsgenossenschaft. At the instigation of the Hamburg Ministry for Environment a professorial chair for water management and water supply donated by S.O.F. – Save Our Future - Environmental Foundation – was set up now coordinating the cooperation projects with the German technical and scientific organisation on Gas and Water (DVGW). Thus, the TUHH had become firmly established in the business community of Hamburg with a variety of cooperation

Research Departments and their Sections

Research Departments and their Sections	Schools of Studies: Mechanical Engineering	Electrical Engineering and Information Technology	Process and Chemical Engineering	Civil Engineering	Vocational Subject Education
1 Town, Environment and Technology: *Environmental Technology, Waste Management, Town Planning, Urban and Regional Economics and Sociology, Object-related Town Planning and Urban Ecology, Ergonomics, Water Management and Water Supply, Transportation Systems and Logistics, Technology Assessment, Process Technology and Vocational Education, Geotechnical Engineering and Construction Management, Technology and Innovation Management*	X		X	X	X
2 Systems Engineering: *Measurement Engineering, Optics and Instrumentation, Process Automation Techniques, Theoretical Electrical Engineering, Aircraft Systems Engineering, Bioprocess- and Biochemical Engineering, Biotransformations and Biosensors, Microwave Engineering, Mechanics*	X	X	X		
3 Civil Engineering and Marine Technology: *Fluid Mechanics, Ocean Engineering, Mechanics and Ocean Engineering, Production and Manufacturing Technology, Ship Structures and Structural Analysis, Concrete Structures, Steel Constructions and Timber Constructions, Building Physics and Building Materials, Applied Structural Engineering, River and Coastal E ngineering, Structural Mechanics, Fluid Dynamics and Ship Theory, Ship System and Information Engineering*	X		X	X	X
4 Information and Communication Technology: *Software Systems (STS), Microcomputer Technology and Data Processing Structures, Programming Languages and Algorithms, Telecommunications, Communication Networks, Micro Systems Technology, Technical Electronics and Vision Systems, Materials in Electrical Engineering and Optics, Telematics, Distributed Digital Systems, Mathematics*		X			
5 Materials, Design and Manufacturing: *Central Division Electron Microscopy, Engineering Design I, Engineering Design II, Production Organization, Production Technology, Materials Science and Technology, Physical Metallurgy and Materials Technology, Advanced Ceramics, Polymers and Composites, Biomechanics, Production Operations Management, Technology of Manufacturing*	X				X
6 Processing Technology and Energy Systems: *Solids Processing, Separation Processes, Process- and Plant Engineering, Chemical Reaction Engineering, Plant System Design, Energy Systems and Marine Engineering, Energetics, Electrical Power Systems and Automation*	X		X		

Fig. 2
Present matrix structure

Fig. 3
Many prominent persons – statesmen and businessmen – have visited the TUHH over the years

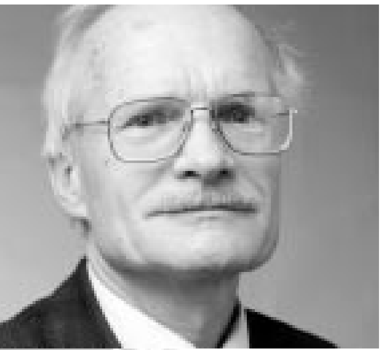


Fig. 4
Justus Woydt, former senior administrative officer, whose services to the TUHH cannnot be rated highly enough

Fig. 5
The nucleus of the TUHH: the building located in the Harburger Schloßstraße 20

Fig. 6
A view of the TUHH campus

projects with the shipbuilding industry, the semiconductor industry and many medium-sized mechanical engineering companies. Ship of the future, sludge deposits in the Hamburg Harbour, sewage treatment, treatment of the waste dump at Georgswerder and Forum on Materials were some of the projects still well remembered. Joint research projects with the other academic institutions in its vicinity, in particular Hamburg University, Hamburg University of Applied Sciences and the GKSS Research Center in Geesthacht had become a real tradition.

A mere decade had passed since its foundation and the TUHH was already held in such high esteem that the Hamburg Government was willing to accord it unusual rights and privileges enabling the young TUHH to plan its future development on its own responsibility.

As the first university in Germany the TUHH was given the right to manage its own finances in the form of a so-called global budget. This system has the advantage of affording a high flexibility but, on the other hand, makes great demands on the TUHH as regards the management of the budget funds, willingness to cooperate and a high discipline in spending. The technology transfer office of the TUHH handling, among other things, research contracts was converted in 1992 into a subsidiary (private limited company [GmbH]) of the TUHH, a novelty within Germany. That company has been very successful in conquering the market and has continuously been growing for the past 8 years.

The Hamburg authorities have always been open to such novel ventures and mostly approved them without imposing complex or restrictive conditions. This applies even to the youngest offspring of the TUHH, the Northern Institute of Technology, a private educational establishment supported by members of the TUHH.

I have tried to illustrate the role of research in the initial phase of the TUHH, the way I see it. I did not attempt to document it and I might have overdrawn one or the other aspect and even left out some events.

The TUHH has developed into a fascinating university with a solid base and exceptional perspectives. Today, the construction phase is over and it's time for some organisational changes to prepare the TUHH for present and future challenges.

The TUHH will be well advised to maintain the basis for its extraordinary success: high quality research in the field of engineering sciences. I believe that the vision outlined in the beginning of this article has become reality, though not in Altona but in Hamburg-Harburg: a Technical University in the Lower Elbe Region established and operated on the basis of time-tested principles and the latest scientific findings.

(Heinrich Mecking,
President of the TUHH from 1987 until 1993)

10 Strategic areas of research

Information as an economic resource 1

Organisation of enterprises 2

Production and process integrated environmental protection 3

Sustainable management of natural resources 4

Advanced energy systems and energy management 5

Sustainable urban structures 6

Systems of transport and logistics 7

Advanced communication technologies 8

Advanced materials and microsystems 9

Biotechnology and biomedical engineering 10

Information as an Economic Resource

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8 Advanced communication technologies
9 Advanced materials and microsystems
10 Biotechnology and biomedical engineering

In the business world of post-industrial society, the resource "information" is playing a more and more crucial role. The fast development of innovative information services impressively highlights the importance attached to this field of research: Mastery of the resource "information" is program.

Development and operation of innovative multimedia information services require system-oriented solutions by far exceeding traditional network planning, database and software technologies. What is required today are the dynamic supply and the efficient access as well as the flexible and cooperative application of a broad range of resources in the net (information, methods, equipment etc.) while maintaining a high standard of availability, consistency, authenticity and confidentiality. This includes process-oriented software systems, multimedia information systems, scalable component architectures as well as safe information and communication systems. These issues are the core of the TUHH's research activities. Applications cover multimedia information and news services, business transactions with legally binding effect, cooperative work-flow management in distributed organisations as well as information management for multi-modal production and logistic series. All these applications aim at rendering information – as an economic resource – technically controllable and usable.

The control of information plays a key role in other technical fields of application as well. In the field of production engineering the research areas 'cooperative product engineering and tele engineering' are aiming at the usage of shared knowledge and distributed engineering potentials. Global engineering networking enables development engineers to have the global supply of solution elements for their engineering tasks online at their disposal, thus permitting simultaneous work on the same construction object. Moreover, today with the fast translation of ideas into marketable products becoming ever more important, the research area of product design with the extensive use of integrated software systems including virtual and rapid prototyping is of vital importance.

Typical examples for real time systems are mechatronic systems taking up signals, modifying them, interpreting them and reacting to them according to the situation. Real time systems/embedded systems owe their special performance abilities to their linkage to information processing systems. Optimum solutions require a comprehensive view at system design: Solution algorithms have to meet real time demands and have to take safety aspects into account.

The research field 'control and operation of complex process and production engineering' finally includes dynamic modelling of complex systems, simulation and analysis of such systems as well as process operation and control. For this purpose procedures have to be developed which are based on quantitative models (differential equations) as well as event-oriented models. The research approach extends from mathematical fundamentals to the development of diagnostic systems and the design of devices as well as to security technology for technical systems and procedures of process and production engineering. In the areas of research presented the scientists at the TUHH are working on the development of new technical solutions.

Information technology plays a unique role in this. Finally, the lack of engineers as well as of information scientists and computer science experts to be observed in Germany has brought to public attention that the level of knowledge attained in information science or technology is linked directly to the economic potential of highly developed industrial countries.

So far, the profile of information technology has been linked on the one hand to technical computer science and on the other hand to scientific computing. This resulted in the division of the field of information technology into information technology as a computing method for engineering sciences (computation technology) and information technology as an independent engineering science including technical computer science as well as the computer science of system and software engineering (information technology).

In the first case scientific calculating regarding issues of primarily automatic information processing is given priority, in the second solving actual problems in information processing within technical and commercial margins. The planning and execution of research work and the conception of courses of study as regards systems & software engineering must be in line with the following objectives :

- Creation of high-quality digital products and services for the market
- Design of systems of high professionalism along with adequate control of expenses and schedules

Therefore, research and development in the area of systems & software engineering cover a broad spectrum of issues. In systems & software engineering pure basic research (i.e. type theory, modal logic, formal languages, automata theory) is to be distinguished from application-oriented basic research. Typical examples for the latter are formal and semantic models for programming languages and techniques and issues of algorithmics, precision, formal specification, verification, formal description, the generality of process models in the formal sense and the presentation of specifically applicable mathematical models. In addition, theoretical statements concerning methods of software engineering, for example concerning the completeness of various coverage algorithms in software testing, are communicated.

Quantitative matters in systems & software engineering complete the research spectrum of basic research. In order to judge the merit of certain approaches and procedures in systems & software engineering, dimension figures as to costs, quality and time-limits are crucial.

These figures won empirically are valuable references for comparing and selecting appropriate procedures for practical application.

The central task of research, however, is providing new methods and devices for the implementation of systems & software engineering including, among others, CAD tools, programming languages, instruments, analytical procedures and approaches. Moreover, there are specific findings for the realisation of information processing systems, such as component based system & software architectures and design patterns. Many of today's instruments and methods still have an ad-hoc character, are not sufficiently systemised and therefore strongly in need of improvement. Thus, it is a matter of crucial importance to research and development activities in systems & software engineering to improve, evaluate and classify practical methods and to develop and test new methods. By carrying out controlled experiments we come to additional scientific findings, e.g. concerning statements of qualitative proof of concepts and the quality of new procedures.

The research field 'information as an economic resource' touches matters of different scientific disciplines. A common denominator of almost all research projects is the necessity of interdisciplinary cooperation – complemented by the expertise to be contributed by the business community. TUHH's interdisciplinary structure and its openness toward cooperation with industry and economy will contribute to quickly translating innovative ideas into new products, methods and innovative services.

(Friedrich Vogt)

[1] *Compare M. Broy, J.W. Schmidt: Informatik: Grundlagenwissenschaft oder Ingenieurdisziplin, Informatik Spektrum 22, Springer 1999*

Organisation of Enterprises

The Factory of the Future – Research for the Production of Tomorrow

1 Information as an economic resource
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Increasing globalisation is changing the economic base of the traditional industrial nations. In addition to the global markets which the companies have to conquer they now have to accept another challenge: the global production of goods. Capital and consumer goods are being manufactured all around the world supported by modern information and communication technologies. The changes in company environments are omnipresent.

New fascinating opportunities for the design of products, processes and services aiming at tomorrow's markets are emerging. Enterprises that wish to succeed in their business activities in view of these new economic conditions must be able to identify in advance products and services which will be in demand in future by using operational planning strategies. Furthermore, they have to use new technologies in their product and process development and to increase efficiency by including all aspects and key partners along the value added chain at an early stage. Thus, they might be able to achieve unique market positions which cannot be easily upset by competitors.

Holistic Approach of Production engineering at TUHH

The Technical University Hamburg-Harburg (TUHH) is able to address the issues raised by the changes in the business environment using a holistic production technological approach which extends over the whole value added chain. Problems are not tackled by isolated specialists but by interdisciplinary cooperation using the expert knowledge of development and design, production and assembly engineering, organisation and business administration.

The following is a summary of the future-oriented research subjects dealt with at the TUHH.

Corporate network as a new form of corporate organisation

NApart from the increasing globalisation, the individualisation of needs of customers and the rapid changes in the state of markets and competition make new demands on the organisation of companies. Speed and flexibility become crucial criteria for the competitive strength of a company. Due to the tendency of focussing business activities on strategically important core competencies an increasing number of companies need partners to fulfil their customers' specific demands. Therefore, new forms of close cooperation of all partners in all phases of the value added chain have to be developed. This can be achieved by enterprises joining up to form so-called corporate networks.

The use of new information and communication technologies is an essential prerequisite for enterprises having specific core competencies joining up for a limited period of time in order to market joint products or services. This temporary network of independent companies is also called virtual enterprise.

Managing such networks requires a high degree of coordination and communication. Efficiency of production is fundamentally determined by the functionality of the interfaces between the various modules, therefore technical and organisational compatibility of the units working together must be ensured. Business processes in corporate networks are company-overlapping, this results in complex problems. To handle the related technical and organisational challenges a varied interdisciplinary research is necessary. The relevant research activities at TUHH extend from designing decentralised innovation and development processes, preparing adequate production and logistics plans to the provision of suitable information and communication systems.

Design of innovation and development processes

Innovation and development processes are increasingly no longer restricted to one company but are decentrally run depending on the respective core competencies of the network partners. In particular during the early phases of complex innovation projects it is necessary to implement a continuous coordination procedure between the parties involved for the defining of targets and for control purposes. High failure rates of new products and services show that it is necessary to involve the customer in the development process to a greater extent than is usual done to ensure that the customer's needs and requirements can be taken into consideration from the beginning. Current research projects at TUHH investigate the systematic creation of ideas in early phases of innovation and the involvement of customers using information technologies like CAD, Virtual Reality (VR) and Internet.

Apart from offering innovative products at competitive prices and in the quality required by the customer, the speed of the product development process is - today more than ever - decisive for a company's economic success. Essential potentials on the way to faster development procedures can be tapped by using the principles of simultaneous engineering for the design of efficient processes. Those approaches available today basically refer to the optimisation of internal company development processes. For corporate networks the technical and organisational design of simultaneous engineering processes must be considerably improved.

Product design

Product design has to be carried out as a systematic process. All aspects which are important during the life-cycle of a product (such as materials, construction, product engineering, application, disposal) must be considered. Scientific tools and procedures for practical implementation must be developed. The design of

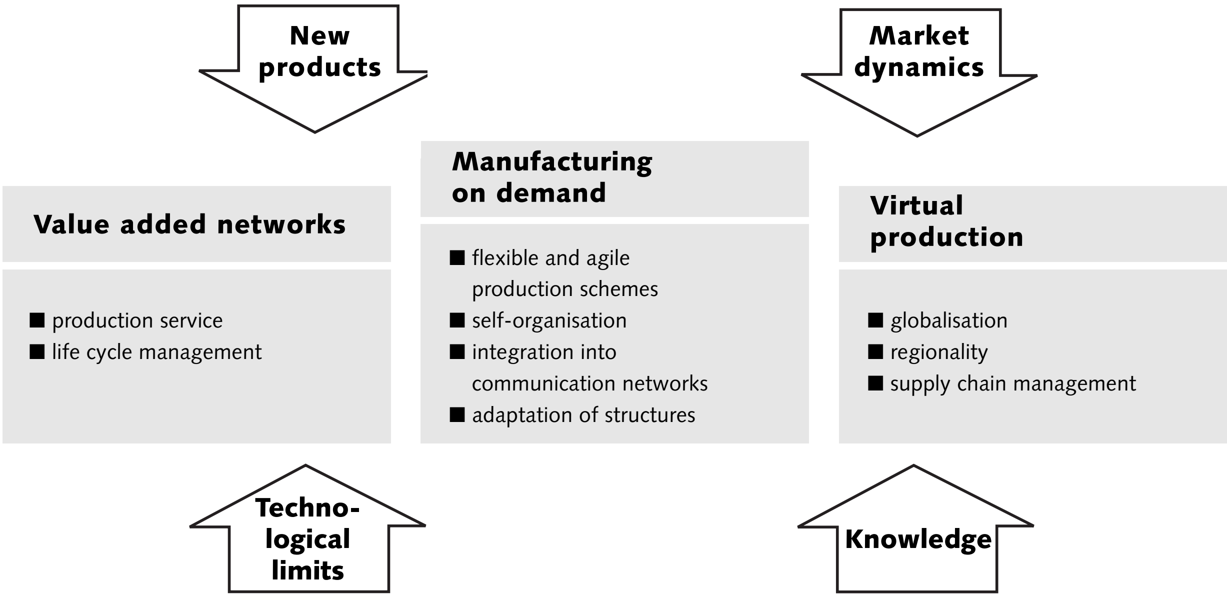

Fig. 1
Elements of adaptability

product structure (modularization, platform strategy) is gaining more and more in importance in order to economically meet the customers' demand for a specific design of products with a controllable amount of parts and modules. The integration of electronic and information technological components into products of mechanical engineering will play a major role in complying with the manifold requirements. Therefore, a platform combining the various disciplines has to be created for the development of such products.

Today's product design is mainly done with the aid of computers – namely CAD, FEM / BEM, simulation and VR. However, every design process, as a rule, still has to be completed by physically testing the prototype. An important area of research at the TUHH is to find out to what extent the properties of virtual and real products are in conformity thus reducing the prototype testing. VR is still a relatively new research tool. An interdisciplinary research project presently carried out at the TUHH investigates the practical usability of this technology in the areas of product, service, and process development.

The Importance of Production engineering

Production engineering is of prime importance for the whole of industrial production. It has a key function for the implementation of new technologies and for finding solutions to production problems. The increasing integration of information and communication technologies as well as the creation of an efficient and global infrastructure of information offer new opportunities for increasing productivity in development and production processes and for prompt and direct communication with customers and suppliers.

Data-processing equipment, e.g. NC machine tools, can be integrated into networks of communication technology. The knowledge thus gained of the actual status of machines and equipment allows diagnoses and correction of possible failures from afar. Whereas this technology is already used in space travel by using robots to repair and assemble equipment in space, it is just a matter of time until such technologies will be in common use in plant and machine engineering. Current research projects at the TUHH are dealing with the configuration of assembling plants and the use of VR for assembling.

New opportunities for creating value, especially in the after sales sector, are being offered by telework and teleservice, such as services offering remote computer-aided quality control, programming, reconfiguration, planning or even the remote operation of plants. This is also an important area of research at the TUHH.

High-performance production plants and machines are of essential importance for competitive production in Germany. Current construction requirements for plant and machinery are, for example, a higher dynamic ratio of movable machine parts made possible by improved actuation concepts, an optimised oscillation behaviour as well as a reduction of weight due to the use of new principles of design (lightweight construction) and materials. In view of the increasing importance of environmental protection, industrial emission control as regards noise, heat, particles and pollutants is to be aimed at. A further requirement is the attainment of a higher level of safety and availability which may be achieved by improved condition monitoring, prediction of failure and loss prevention systems. In terms of operational efficiency the minimisation of costs over the whole life cycle of machines – design, manufacture, use, reuse, recycling and disposal – is a major factor as well.

The efficiency and communication level of the whole plant must be increased by integration of sensorics, actorics and local intelligence thus simplifying as well maintenance and servicing. The implementation of more complex controlling methods facilitates the realisation of higher speeds.

On account of the automatic compensation of systematic defects of fabrication an increase of precision (exactness) as

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well as a simultaneous decrease of production costs is possible today. To a certain extent, it is also practicable by using neural networks to install in the machines a certain degree of "ability to learn" for self-optimisation.

Logistic performance as a crucial factor of success

In most markets the only constant factor is permanent change. Within the strategic plan logistics has a key function as regards reactivity of a company. In view of the increasing uniformity of product technologies and range of products as well as the faster imitation of technical innovations high performance in logistics can be a deciding factor of success in the market. Apart from the achieved level of performance in logistics the speed at which the whole system is able to adapt and change plays a major role. In view of the value added chains being spread on a world-wide basis and constantly changing, the technical and administrative harmonisation of the whole logistic system and the reduction of interface problems are issues to be solved in the future. To do that, new plans for material, goods and information flows have to be developed and existing ones have to be modified. Existing coordination and information plans for logistics management have to be extended and adapted to meet the resulting need for coordination and information.

Factory Planning

Today's production schemes are still determined by the targets and technical solutions of the past. The full integration of production was mainly directed at decreasing the production costs within the whole production process. The related planning scheme is a multistage process in which the phases of creative planning, modelling and evaluation of planning are separated. In future, this approach will not be sufficient any more. On the one hand, a more integrated continuous procedure of factory planning must be developed, on the other hand, the future must be "integrated into the present". The underlying basic idea is to gain learning effects - such as the optimal outlay of assembling plants - by simulation of processes in a virtual world before the actual production is started. If it is possible to anticipate later improvement requirements by including them already in the production planning phase, significant benefit will be derived thereof.

Supply chain management

Networks of companies require an intercorporate coordination of material and information flows along the whole supply chain. This starts with the distribution of production tasks between the corporate partners and ends with the planning and controlling of the production network. In this situation, companies have to continuously adapt to new demands and procedures coming from outside without their own production scheme getting disordered.

Communication and information technologies open up new potentials

New information and communication technologies, like the internet, are opening up a multitude of new opportunities. In networked corporate structures the issue of IT networking which is directly linked to organisational issues has to be clarified. An example thereof is the research area of electronic business currently dealt with at the TUHH. An increasing number of companies from different sectors of industry are beginning to use this new type of trade to reduce their processing time and costs in purchasing and selling. The optimised design of supply processes as regards time, costs, quality and flexibility is to be viewed as an important competitive factor. The development of internet technologies is offering interesting possibilities for a faster design of processes at lower costs. The implementation of internet technologies in processing and purchasing not only implies their application to traditional processes and structures but also a revision of these processes and structure. This is the only way to make sure that the new potentials are fully utilised.

Knowledge as a Resource

Knowledge has become a strategic factor of success. It gains in substance and value by frequent use and selective exchange, but differs from other resources in that it quickly becomes obsolete. For optimising the processes in a company and for product innovation it is essential to identify the existing knowledge within a company, to make it available, to use it and to develop it systematically. Holistic knowledge management includes the totality of all processes concerning the knowledge available within an organisation and is therefore subject to manifold influences. Essential prerequisites are a "knowledge conscious" company culture, knowledge-oriented personnel management strategies, organisational structures with optimised flow of knowledge as well as new information and communication technologies. These aspects are the basis for current research activities at TUHH.

Intercultural Cooperation

Another important issue for networked companies is intercultural cooperation. In our era of globalisation the number of organisations entering into intercultural cooperations or even mergers is steadily increasing. Schemes have to be prepared for overcoming cultural barriers and inducing synergetical effects when uniting differing company cultures.

The Factory of the Future

The factory of the future including any production and assembling units must be adaptable and flexible (see figure 1). This objective can only be achieved, if production units are seen as self-organising and self-optimising complex systems which must be permanently and quickly adjustable to any particular order situation with the aim to always operate at the economically optimal operational point using all available resources. Self-organisation, self-optimisation, target orientation and possibly self-controlling as well are the characteristic structural features of future factories and production networks.

The factory of the future works on demand, that is, customer-oriented, and is run by those who are the best to understand and manage the complex system and are able to adapt it at short notice. New technologies in the area of production as well as in the areas of information and communication are continuously being integrated. Its new business processes will be characterised by not being based on the old thought schemes optimising areas of operation but by designing the value added chain as a complex unity by interdisciplinary cooperation integrating the so-called soft factors.

By overcoming obsolete thought and behaviour patterns and by breaking down inefficient structures and procedures the conception of the "New Factory", which has been developed at the TUHH (see figure 2), with its principles of a consistent focus on customers needs and the creation of values, of minimisation of complexity, of permanent improvement and of considering human labour as the decisive productive factor, can be put into practice.

*(Eva-Maria Kern,
Wolfgang Kersten,
Klaus Rall)*

*Fig. 2
The New Factory*

Production and Process Integrated Environmental Protection

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It is of vital importance that we stop to view our environment as a restrictive factor and start to see it as an important part of our efforts to achieve sustainable economic success in creating products and production processes supplying our basic needs. If we change the way we view the environment, the design of products and processes will be improved and simultaneously the damaging effect on the environment will decrease.

These aspects are fully included in the research programs and lectures at the TUHH. A general view is only possible when including environmental technology, biotechnology and the assessment of technological consequences into research activities.

Furthermore, corporate policies should be focused on the responsible care for their production methods and products including the commitment to public welfare, provision for emergencies, prevention of emissions, ensuring process safety, assuming responsibility for the distribution and use of its products as well as safeguarding security and health of its employees.

Thus, methods or processes of production will be designed, developed, chosen and assessed in such a way that they will satisfy these requirements including the protection of the environment. Our natural resources air, water and soil will be preserved by way of sustainable methods and processes. By carefully choosing and designing processes emissions will be kept within the required limits. Sewage clarification and air cleansing will no longer be necessary. Biocompatibility will be guaranteed by the type of the materials processed and produced.

New techniques and processes have to be developed using renewable resources to satisfy our basic requirements. This may be done, for example, by using ingredients of renewable raw materials (plants). In addition, materials with possibly damaging effects have to be replaced by inherently safe ones, e.g. by substituting supercritical fluids for liquid solvents. Process technology research activities at the TUHH focus on these issues. A general methodology for the design, selection and assessment of methods and processes has to be developed according to the criteria given above. The known methods have to be adapted accordingly.

In biotechnology, another main field of process technology research activities at the TUHH, scientists are working on biocatalysis, circulation systems of organics and the use of microorganisms as natural microreactors.

There are no production processes without any interactions with the environment. Chemical, physical, biological and technological limits preclude an industrial production that is nondetrimental to the environment. There are no production processes without any emissions, but it is possible to minimise them. The strategic field of research "production and process integrated environmental protection" aims at developing and improving the methods necessary for production processes most compatible with the environment.

This is the goal that cannot be reached all at once but must be approached step by step in a persistent and purposeful manner. Apart from excellent professional qualifications, the ability to perceive all aspects and implications of a given problem is a major criteria in selecting candidates for professorial chairs at the TUHH.

In the sixties, the planning and design of processes was based on the dominating role of the required process sequences (i.e. chemical reactions and separation processes). Everything else was preset as a restriction or a product specification. In the eighties, another parameter, namely efficient energy usage, was taken into consideration as well. In the nineties, the accepted order of aspects to be considered was as follows: primarily waste prevention followed by waste reduction and waste reclamation and finally waste disposal, if prevention or reduction was not feasible technically or economically. Some examples for successfully applied process-integrated environmental protection are given below:

- In the production of polypropylene, polymerisation is done solvent-free with new highly efficient catalysts thus avoiding the high amount of pollutants in outgoing air and water as well as residues produced so far.
- Product separation is done by crystallisation instead of by salting-out. Thus, the process material can be recycled.
- A synthesising process is being modified: neutralisation is done by using carbon dioxide instead of sulphuric acid thus allowing the recycling of the mother lye.
- Reaction in a large-scale production of vitamins is optimised by a careful examination of the principles of reaction and kinetics. Thus, inconvenient by-products are eliminated, process-integrated recycling is improved, product yield is increased as well as economic efficiency by saving energy and raw materials.
- The by-products of an organic synthesising process are turned into a saleable and valuable substance thus minimising the amount of residues formerly produced.
- In the production of titanium dioxide products, the digestion process of raw materials using sulphuric acid (sulphate digestion) produces large amounts of diluted waste acid. Production was converted to a low-waste manufacturing process. The diluted acid is now being recycled and used again. Thus, the dumping of diluted acid into the North Sea could be stopped.

The 21st century requires a more comprehensive approach, as the environment influencing planning and design processes are becoming much more complex (see fig. 1). One of the basic ideas is to reverse the design process, that is, starting out from the products to define raw material requirements (reverse engineering).

Efforts are still focused on the basic processes as well as on the efficient utili-

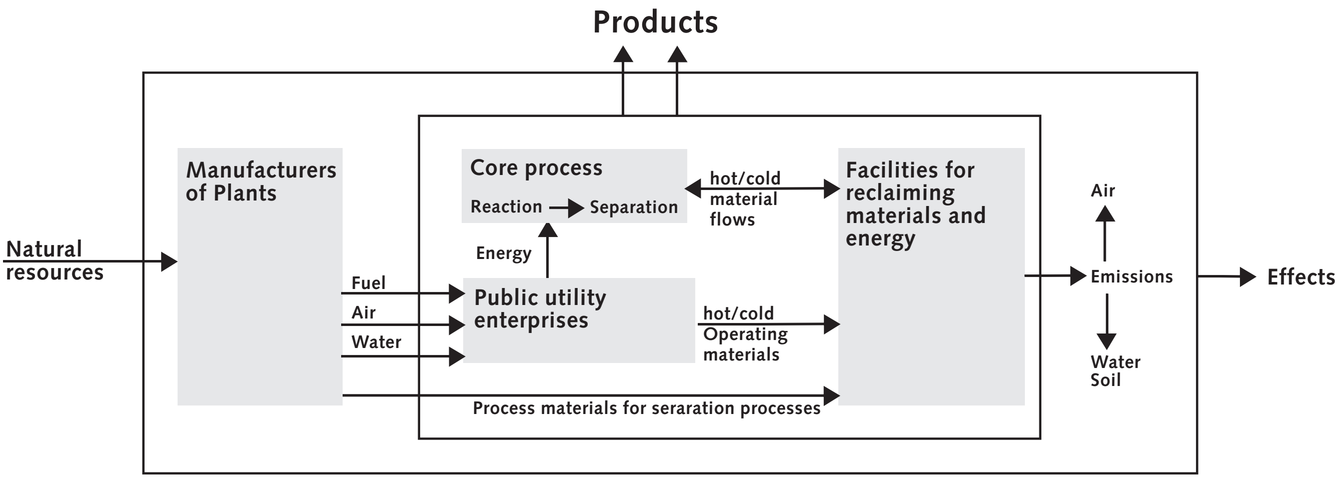

Fig. 1
Environments for planning and designing processes

sation and recycling of energy and materials. In addition, however, the processes upstream and downstream the production are being considered. Upstream the supply chain for raw materials is to be considered and downstream the product life cycles and the fate of the products themselves.

For example, in the production of several polysubstituted benzene derivatives a new process design starting from the products succeeded in finding a wholly new method resulting in a radical reduction of waste and a significant increase of profits.

Apart from the design and construction of new plants, a main goal of process technology is to improve existing processes and plants and to retrofit them to adapt to changed requirements and new products. Research is to provide methods of how to use the existing equipment in view of the new planning approach. On account of the availability of very effective algorithms for the solution of optimisation problems, retrofitting, for example, can be done using a much more comprehensive approach.

The remarkable progress in the field of mathematics (combinatorial graph theory) and in the field of network optimisation renders it possible to master the additional complexity and to find the "best" way to meet the requirements of a high yield of process technology and better compatibility with the environment. In doing so, the conception of unit operations has to be replaced more and more by the conception of unit processes, e.g. in reactive distillation in which reactor and separation column are being combined in one process.

Therefore, the area to be researched will be the systematic development of methods for integrating processes in the chemical process focussing on the selection of the "best" production path.

In process planning, elements of risk management and economic imponderabilities have to be considered as well. Therefore, the aforementioned modern methods have to be applied interdisciplinarily in design cooperation centers uniting the basic methods of process technology, such as elementary processes and generation of data on material specifications, with the methods of process simulation using up-to-date computer and media technologies. This integral approach will simultaneously improve process economy, decrease detrimental effects on the environment and increase acceptance by society.

(Gerd Brunner)

Sustainable Management of Natural Resources

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Meanwhile, the flows of anthropogenic materials caused by industrial production and human consumption by far surpass the geogene materials flows caused by natural processes. The increased flows of anthropogenic materials are directly linked to a growing consumption of resources and endangerment of the environment. If we wish to leave future generations any development options in line with the basic idea of sustainable development, it will be necessary to reverse this trend by disconnecting consumption of resources and economic growth. Engineering sciences are called upon to take a share in reversing that trend.

Thus, the development of resource-conserving technologies and pertinent technology/management conceptions have to be advanced. Our knowledge of materials flow systems and principles of reaction of natural and xenophobic substances in the environment must be deepened. Plans for defining and evaluating existing problems have to be improved and devices and procedures for problem-solving measures have to be developed. In the field of measurement engineering the development of adequate instruments as well as pertinent translation and evaluation methods have to be speeded up.

The strategic field of research "sustainable management of natural resources" is to utilise the existing strengths of the TUHH in the aforementioned areas of research.

Sustainable management of water resources for regional hydrologic units

Internationally, we are faced with the fact that in a situation of an already existing shortage of water resources the population growth will further increase water consumption in the future. In countries of a high economic growth rate water consumption will rise on account of increased production in agriculture and industry. Simultaneously, the quality of the water resources is deteriorating on account of acidification, oversalination, eutrophication and pollution with organic and inorganic substances.

Within the EU these trends will be reversed in future by an adequate management of water resources at the level of river drainage basins. The respective EU outline directives on the management of water resources are expected to take effect in the middle of 2000. Thus, the issue of regional management of water resources (in drainage basins) will become the focus of discussions everywhere in Europe and "concepts of regional sustainability" (see fig. 1) will be needed. In the field of research "sustainable management of natural resources" matching management strategies are being developed. In November 1999, an expert colloquium was held on "sustainable management of water resources". In particular, problems of matter flow balances in local drainage basins are being studied. Respective balances are increasingly being prepared with the help of geographic information systems (GIS) including pertinent modelling programs.

A major issue in our research activities is the modelling of groundwater flow and transport as well as the modelling of reactive substance transport processes studying in particular the subject matter of oversalination of groundwater and the related modelling of density-dependent flows. Thus, a comprehensive report on the geogene oversalination of groundwater in the porous sediment aquifers of Northern Germany was issued.

At present, model computations on various water extraction configurations and the dynamics of the saltwater-freshwater limits are being done. In an international research project the problem of salt water intrusion into the limited groundwater reservoir of the coastal metropolis of Cebu City (Philippines) subject to a high pressure of consumption on account of urbanisation and industrialisation is being investigated using a numerical model. The modelling of reactive substance transport processes is done, among other things, in connection with the quality deterioration to be observed in groundwater on account of increased sulphate concentrations being caused by anthropogenic pollution (by agriculture or old deposits etc.)

New forms of waste water management

The present waste water management system has remained basically the same since it was introduced more than 100 years ago apart from some modifications and improvements. It has never been subjected to a thorough evaluation. Water cycle and food cycle are not kept separate which is in contradiction with an appropriate substance flow management contributing to water pollution, dislocating fossil resources into the seas and contributing to acidification of the soil on account of organic substances not being returned. In addition, the traditional systems are very expensive and inflexible.

At present, source control systems are being studied at the TUHH, some of them as pilot projects. If towns and their waste water and substance flows are viewed from the point of view of industrial waste water treatment, unforeseen perspectives as regards new technologies will be opened up. A major starting point is the totally uneven distribution of matter in the technically separable partial streams. In this context, acceptance and economical conditions have to be examined. In figure 2 waste water flows from private households with their respective pollutant loads are illustrated.

It becomes clearly visible that the characteristics of waste water from toilets

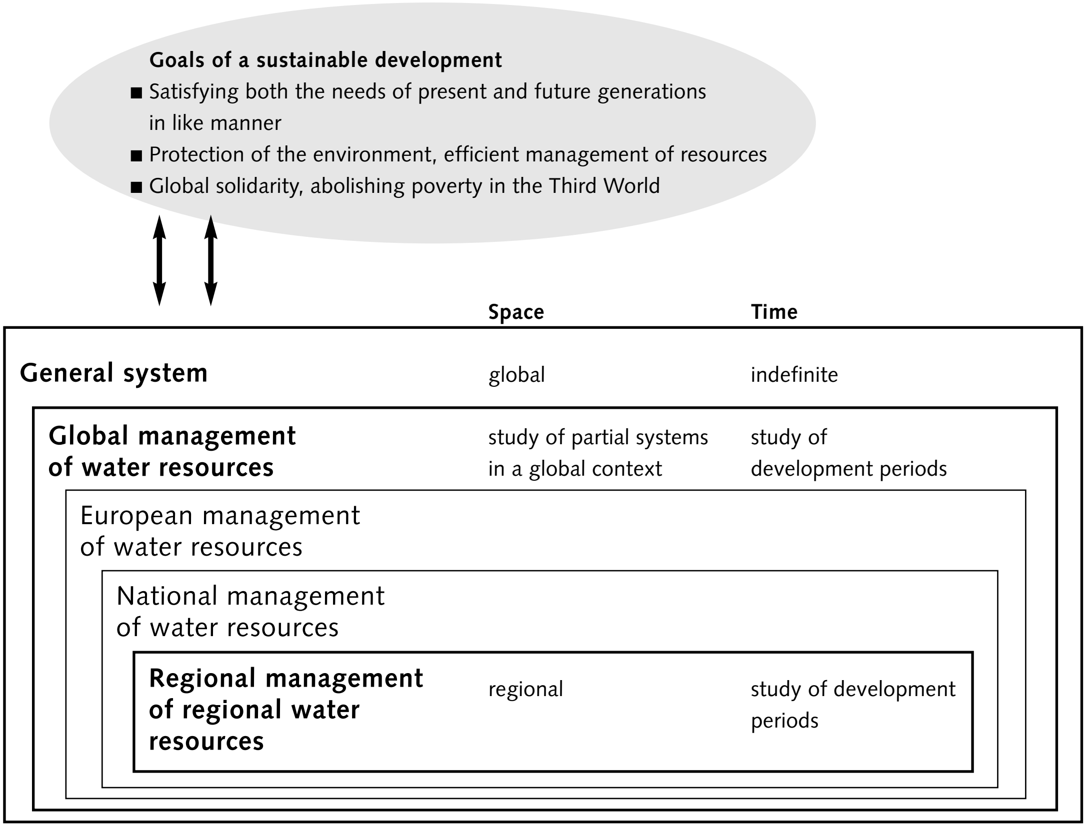

Fig. 1
Partial system "regional management of water resources"

(black water) are totally different. If this can be collected in a low-diluted form and processed into fertilisers, the grey water will be a resource for reutilization. This will be of great importance especially for many countries world-wide in which water is or will be an extremely scarce resource. Another major argument for new forms of waste water management is the possibility of substituting fossil fertilisers on the market. Separate treatment of faeces in a low-diluted form, in particular, can produce a hygienic product, even when using low-tech treatment methods. When diluted or mixed with other waste water this is not economically feasible in most cases. There are methods to be found as well to effectively prevent the risk of infection by the consumption of polluted water which at present causes the death of more than 4 million people, in particular children, world-wide every year according to the World Health Organisation (WHO).

In addition, some research projects are concerned with the production of usable materials and products by recycling household waste water. Urine, in particular, that can be collected in an undiluted form by using separation toilets and water-free urinals, is easily processed with the help of physical, chemical or biological processes. Other research projects are dealing with the reutilization of grey water (waste water without toilet waste water).

Long-term behaviour and assessment of pollutants in the environment

Pollution control technology as an interdisciplinary and futureoriented method to preserve natural resources includes the definition and evaluation of problems, the design of devices and procedures for problem-solving measures as well as the development of adequate concepts and instruments for long-term monitoring.

In the DFG-financed Collaborative Research Center "Treatment of Contaminated Soil" mechanical, chemical, thermal and biotechnical methods have been developed to treat soil and waste water contaminated by oil, hazardous organic pollutants or heavy metals. According to the principles of sustainability special attention is paid to minimise the amount of waste water and residues and to recycle them efficiently and at low costs using, for example, circulation processes (see fig. 3). Technological soil protection has meanwhile developed into an own discipline for the development of problem-solving techniques using the expert knowledge and experiences of various disciplines – civil engineering, chemistry, microbiology, mineralogy, geology as well as environmental technology and management.

In this context, studies to define treatment goals are essential as well. This is done, for example, by preparing pollution balances, determining ecotoxicological limits and quantifying bioavailability for organisms as well as the potential groundwater pollution. In addition, ecological/planning evaluation criteria for treatment procedures are being established.

Future strategies of pollution control technology have to conform to the principles of sustainability. The analytical framework is based on the concepts of "dematerialization" reducing materials and energy consumption – primarily at the beginning of a product life cycle – and of "industrial metabolism" focussing on dissipative material losses to the environment (in particular of biologically degradable substances of a relatively short utilisation phase). In the long-term safe storage of non-recyclable residual waste or bulk waste the amount of construction materials and process chemicals to be used may be reduced by selecting appropriate environmental conditions or quasinatural aggregates. By improving analytical methods predictions of the long-term behaviour of pollutants in soil and water can be made and by using ecotoxicological and chemical tests treatment costs can be limited due to a realistic evaluation of risk potentials.

Instruments for researching weather, climate, and atmosphere

The comprehensive and vital research area "protection and preservation of the

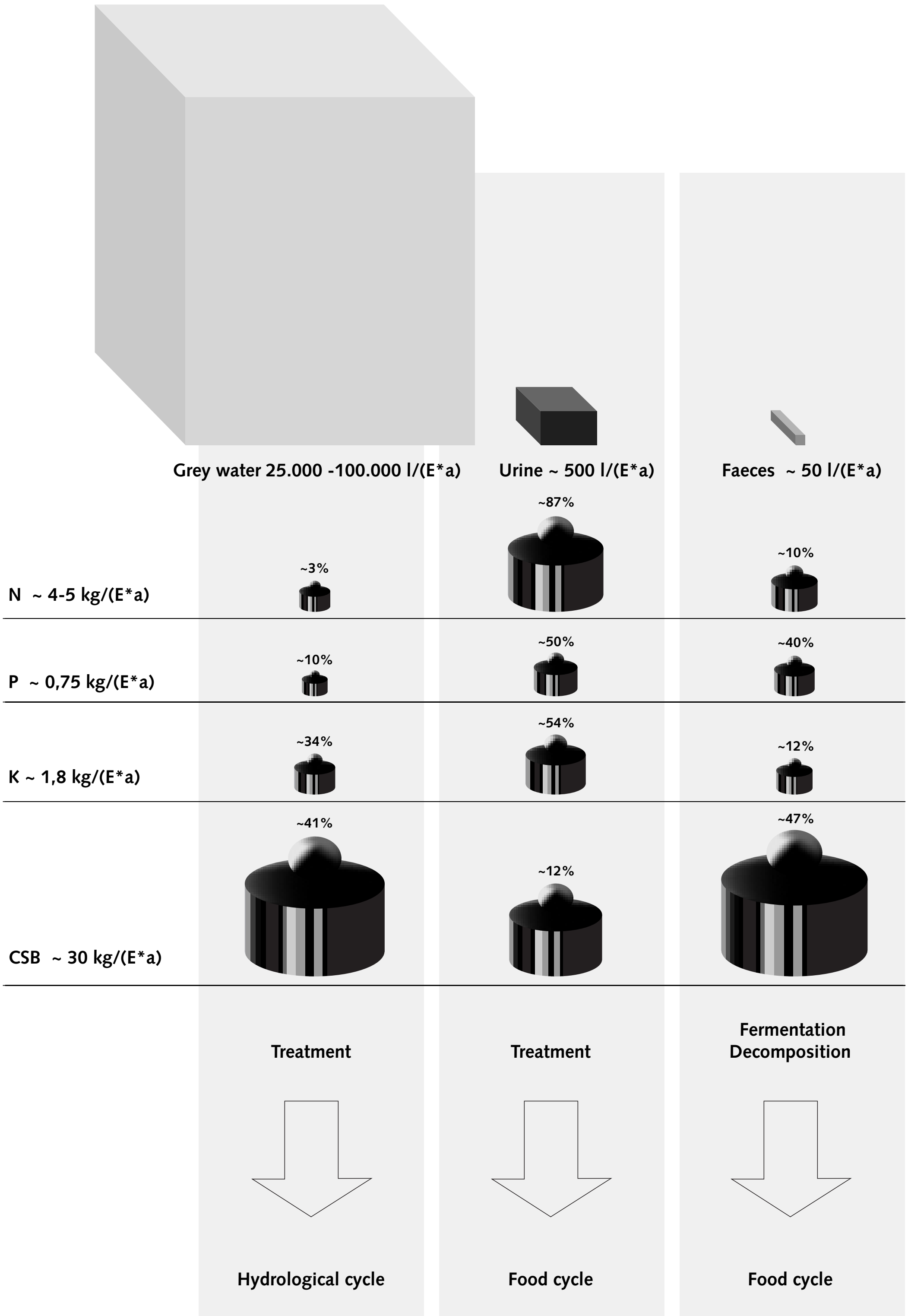

Fig. 2
Waste water streams from private households with their respective pollutant loads

environment" includes as well studying composition of and changes in the atmosphere, medium- and long-term climate changes as well as its short-term manifestation, the weather. If we wish to study conditions and in particular changes to be able to make short-, medium- and long-term predictions, we will need precise and complex measuring devices, which may be supplied by utilising the potentials of microwave engineering. To acquire reliable measuring data, measuring platforms located on ground, in planes, and on satellites are being used.

In meteorology, energy and water circulation in the atmosphere are being registered and, based thereon, predicted by measuring airflow fields (the "wind vector") as well as cloud formation and the distribution of temperature and precipitation. Climatology is mainly concerned with identifying imminent climate changes before they become evident as a basis for predictions. Therefore, the past climatic history of the earth is being studied. This history may be deduced from the ice and snow deposits in Greenland and the Antarctica. On the basis of their thickness and occasional embedments, dating is possible with the help of measuring methods to be developed. Urgent and obvious issues in the research of the atmosphere are composition of the atmosphere, volume and concentration of gaseous pollutants, or thickness of and distribution of density within the ozone layer.

How can the measuring tasks outlined above be performed by using electromagnetic waves? This is done by exploiting two different effects: On the one hand, every material emits electromagnetic radiation of a power density ranging from 0 hertz to about 500 billion hertz independent of the frequency. In the frequency range above 10 billion hertz, with the help of a socalled radiometer it can be measured with an especially high degree of accuracy. On the other hand, electromagnetic radiation is influenced in its intensity and polarisation by passing through a material or following a reflection within that substance. To register that change, an electromagnetic wave or a powerful wave packet is generated and radiated against the material distribution under study. The reflected and/or transmitted signal is then compared with the radiated signal. The respective device is called radar.

The activities at the TUHH to design instruments for researching weather, climate, and atmosphere may be divided into two groups: In the frequency range of less than 100 billion hertz, the activities focus on issues regarding system aspects, because radars and radiometers have been in use already, sometimes even for decades, whereas in the frequency range of more than 100 billion hertz, the activities focus on researching primarily physical fundamental principles, because radars and radiometers have not yet been designed for operation in that frequency range. In a Collaborative Research Center which will be established in the near future covering the TUHH research sections of microwave engineering, semiconductor engineering, optics, electronics, and communication engineering, microwave measuring devices to solve meteorological problems will be supplemented by those of the partners in order to be able to gain knowledge and make accurate statements on issues so far uncertain, such as the issue of water distribution in a cloud. The research team of that Collaborative Research Center will be composed of meteorologists from the TUHH as well as the Hamburg Max-Planck-Institute and Hamburg University.

*(Wolfgang Calmano,
Ralf Otterpohl,
Klaus Schünemann,
Knut Wichmann)*

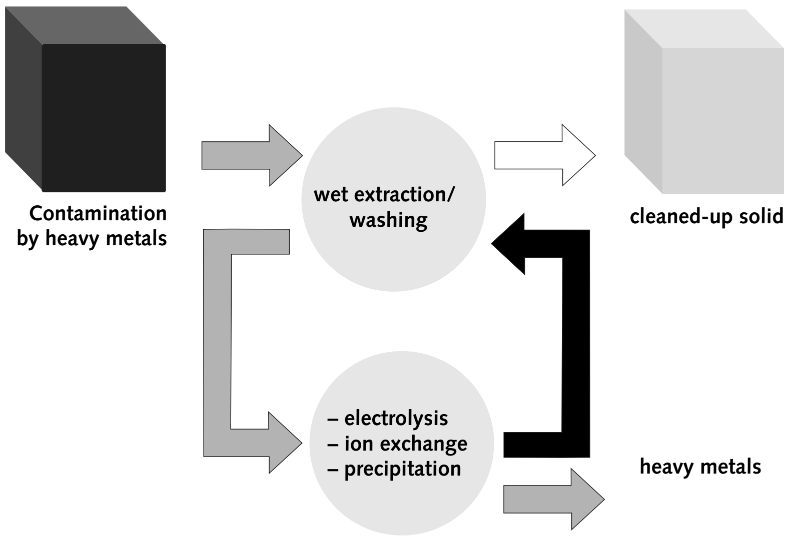

*Fig. 3
Circulation process for treating solids contaminated by heavy metals*

Advanced Energy Systems and Energy Management

The world-wide supply of electrical and thermal energy is an important task to ensure the standard of living and the economic and technical development. For the generation of these high-quality energy types there are various primary energy sources available. These resources are limited and their individual energy conversion processes are more or less detrimental to the environment.

In the last 25 years guidelines and laws for air pollution control and for the recycling of residues have been issued resulting first, since the early eighties, in a reduction of the SO_2 emissions by using wet flue gas desulphurization plants and later on, since the mid-eighties, in a reduction of the NOx emissions by taking primary measures in firing systems and the use of SCR plants. Since the early nineties efforts have been mainly focussed on the reduction of the CO_2 emissions which will be essentially achieved by the improvement of the efficiency of power plants and the use of appropriate fuels. In view of the global demand for energy to be met, the technical standard of the power plants for the various primary energy sources and the existing guidelines and laws the following future energy scenario may be outlined:

- In spite of its high CO_2 emissions coal will continue to be the basis for meeting world-wide primary energy demand.
- Compared to bituminous coal-fired power stations power plants using natural gas will produce only appprox. half the amount of CO_2 emissions to generate the same amount of electric power, if the natural gas is fired in a combined gas/steam turbine process. Therefore and also due to the fact that the debt service period is very short with plants of that type, the use of natural gas has increased more rapidly than the use of any other fuel, and it is predicted that this increase will continue.
- Even though nuclear energy does not generate any CO_2 emissions, its use will in all probability remain at approximately today's level world-wide because of political restrictions.
- Although renewables only meet a very small part of the entire world-wide energy demand, their use is the main alternative for an environmentally sustainable energy supply not endangering the climate. Energy policy therefore focuses on steadily increasing its generation with a 10 % share of renewables in electric power generation for Germany in the year 2010 and a further increase of 10 % per decade till the year 2050. In order to achieve this objective biomass fuel use with its equalised CO_2 balance has to make an essential contribution.

In view of these considerations as regards the significance of the various primary energy sources for energy generation world-wide and the CO_2 reduction targets agreed upon at the Climate Conference in Kyoto and the liberalisation of the energy markets in Europe the following conclusions for the future development of primary energy use and the techniques of energy conversion employed can be drawn representing simultaneously future areas of research at the TUHH:

Coal

Since an essential part of the primary energy demand world-wide will still be met by coal in the future, it is crucial to develop methods for improving the efficiency of coal-fired power plants and to implement those that immediately lead to a CO_2 reduction (fig. 1).

With regard to the conventional steam power process a target for the next 10 to 15 years should be the further increase of the steam parameters pressure and temperature up to a level of 350 bar/700 ºC.

A new development trend in firing lignite is to dry raw lignite in an energetically favourable way before feeding it into the steam generator. Such a drying process considerably increases the efficiency of lignite thus reducing the CO_2 emissions by more than 10 %. Two types of processes, which can be employed for this purpose, are presently being tested in demonstration plants.

Since the techniques of conventional power plants have been successfully improved during the last years, a lot of pressure has been brought to bear on coal-fired combined cycle power plants. Apart from the present activities as regards the pressurised fluidised bed combustion in the plant Cottbus, the optimisation of the cycles of such combined cycle plants is regarded as a further area of research at the TUHH with respect to this subject

Natural Gas

In order to produce even less CO_2 emissions when using natural gas, the efficiency of the natural gas-fired combined cycle processes (fig. 2) has to be further increased either by raising the gas turbine inlet temperature or by an optimisation of the water/steam process. Because of the rising steam pressures in the multi-pressure processes, the once-through technology in waste heat steam generators, which has to be adapted to the boundary conditions of this process, is increasingly being applied. In the medium run, the interest in the exploitation of unconventional gas reserves, such as the gas hydrates which are to be found under ice sheets and particularly under the seabed will rise. They represent a huge energy reservoir for the future. Its exploitation might, however, cause major environmental problems as well. Thus, there will be a great need for research activities, which could be covered to a great extent by the TUHH on account of its available know-how and competence as regards marine engineering.

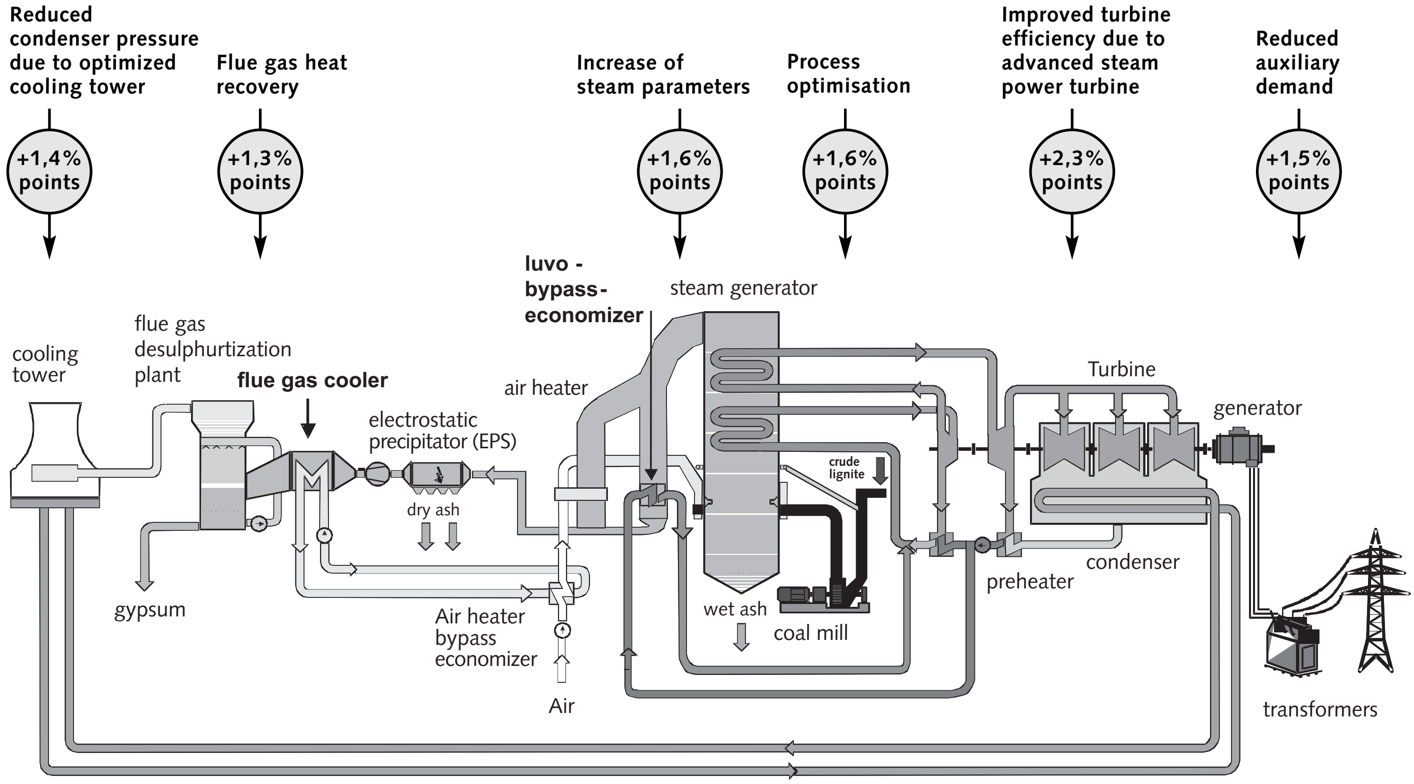

Fig. 1
Efficiency improvement
in conventional
coal-fired power plants

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Biomass

The generation of electric power and heat using biomass yields an equalised CO_2 balance. Therefore, the integration of biomass combustion plants and of biomass gasification plants into decentralised or industrial grids is being promoted particularly in Europe. Based on already existing activities at the TUHH regarding the combustion and gasification of biomass in the fluidised bed it has been decided to construct a further combustion and gasification plant as well as a lab. In the new plant the behaviour of combustion, gasification and emissions of different types of biomass will be tested and optimised and characteristic parameters for these unconventional fuels will be defined and made accessible in a database. Thus, a competence center will be available to operators of biomass plants being able to give advice as regards the selection and the application of biomass and also as regards the optimisation of the mode of operation, in particular that of gasification plants.

Solar Cells

At the present state of the art the technique of direct transformation of solar energy into electric energy is mainly based on solar cells fabricated from mono- and/or poly-crystalline silicon because of their relatively high efficiency and reliability at still acceptable costs. The manufacturing cost of these cells can be further reduced by lowering the material losses during fabrication (sawing, polishing). This may be achieved by a new procedure, which is being developed in the research section Micro Systems Technology in collaboration with the Hahn-Meitner-Institut in Berlin. Requirements are a certain thickness necessary for high efficiency and sufficient mechanical stability and the simultaneously produced large area and directly connected cells based on crystalline silicon.

Fuel Cells

In the last decade, different types of fuel cells for differing applications and fuels have been developed and important operational experience as to their behaviour in practise have already been gained in parts. Since the costs are still very high, however, the optimisation of methods of membrane manufacturing and of fuel cell plants is subject of intensive research activities. At the TUHH a direct methanol fuel cell (DMFC) on the base of plasma-polymerised and ion-conducting membranes will be produced. It is of the same type as those required for applications in motor vehicles and mobile low power systems. By using a specific thin-film process high-effective integrated fuel cells with low content of precious metals can be produced.

Another important target of research is the integration of fuel cells into conventional plants in order to be able to optimally adapt smaller decentralised plants to the demands of consumers. It is intended to integrate a PAFC fuel cell with a capacity of 200 kWth into the supply grid of the TUHH. The operational behaviour of the cell in combination with gas engines, solar cells and a refrigeration system is to be examined and to be optimised. For the entire system which might also be of interest to other decentralised grids, e.g. for public buildings, clinics or sports facilities, a management system is going to be developed ensuring an economically optimal mode of operation of the system with respect to all generators of electric power, heat and refrigeration.

Energy Supply of Buildings

One main subject of the research activities at the TUHH relating to the energy supply of buildings is the investigation of the relationship between user and technology. The undeniable success in the development of advanced energy systems in the area of energy supply to households and small-scale consumers has not yet resulted in a reduction of energy demand on an overall basis. Obviously there are factors, such as user behaviour, that counteract the positive effect of advanced energy systems in buildings, for example new ventilation systems. In studying this influence new methods of simulation for modelling thermodynamic systems are being used. In contrast to those simulation tools which are exclusively based on control engineering, for example Simulink, new programming languages based on object-orientation, such as Smile or Modelica, make it much easier to ensure the fulfilment of the equations of the preservation of mass, impulse and energy. These new simulation tools are also used for the development of new types of facade elements allowing an intelligent use of incident solar energy but also being able to cool, if required.

Apart from the optimisation of domestic plants and processes the idea to implement measures for the efficient use of energy wherever they are most climate-effective is gradually taking shape. An example hereof are the activities of the TUHH for the optimisation of air-conditioning systems in Shanghai using the technique of "desiccant wheels". These are adsorption wheels which pre-dry the air using waste heat. A demonstration plant is now being built in Hamburg. Later on, this technique should be tested in Shanghai, too.

The research activities of the TUHH in the area of energy systems will deal with vital issues regarding the development, optimisation and integration of advanced energy systems apart from those projects in the field of conventional power station technique and thus will contribute to achieving the desired goals of CO_2 reduction and further environmental protection.

(Alfons Kather)

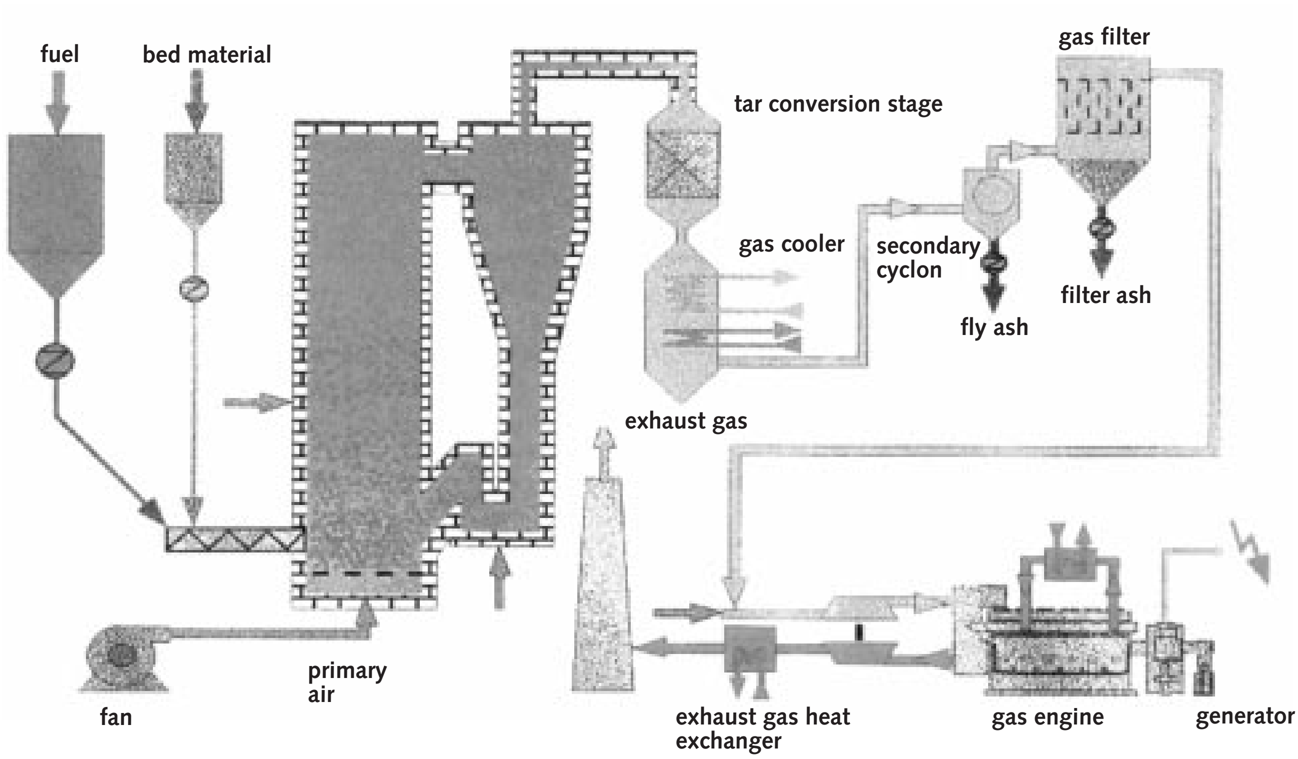

Fig. 2
Cogeneration with wood and biomass combustion plants (circulating fluidized bed technology)

Sustainable Urban Structures

Approaches and Research Issues

On its "Earth Summit" of Rio de Janeiro in 1992 the United Nations Conference on Environment and Development put down on the agenda the principle of sustainable development and with the "agenda 21" formulated courses of action for a development policy which is to reconcile social efforts to achieve prosperity and social security with our natural basis of existence and the protection of the regenerability of our ecosystems. In line with this principle social development will be sustainable if it does not overstrain the absorption and regeneration capacity of our ecosystems.

The antinomical principle of sustainable development addresses the difficult balance between maintenance and development expecting that present and future ecological, social and economical problems may be solved without postponing them to future generations or shifting them to other continents. The central feature of the "agenda 21" is the attempt to combine ecological, social and economical development goals and to solve the resulting conflicts by social processes of careful consideration in which pros and cons are weighed. In view of the guiding character of the principle of sustainable development and the necessary adaptation periods we should distinguish between goals and solutions. The goal of sustainability can only be reached by long-term search and adaptation processes. The required ecological, social and economical adaptation processes may be described as "ways leading to sustainability".

Urban development and sustainability

At the beginning of the 19th century, about five per cent of world population lived in cities, whereas today more than fifty per cent of mankind is living in cities and by 2030 approximately 80 % of the population world-wide will be city residents. In view of the crucial importance of cities for the living and working conditions of mankind a sustainable development world-wide is hardly possible without an ecological transformation of these cities. The production of goods, consumption of energy and materials, intensive utilisation of land and transport services are concentrated in cities. Thus, damages to the environment are most evident in urban areas. The density of land use and the high level of pollution affect not only the natural and man-made environment but also indirectly the forms of social interaction and the personal development and health of city residents.

Pollution in urban regions is being shifted to other regions. Whereas formerly air pollution was more or less locally effective, it now increasingly causes regional, national and global problems. Acid rain, ozone layer depletion and climate warming are proof for local and regional problems gradually turning into global hazards.

HABITAT II, the United Nations Second Conference on Urban Settlements held in Istanbul in 1996 took up the idea of sustainable development and made it the central maxim of housing policy and urban development. In 1998, the principle of sustainable urban development was included in the amendment of the building and regional development law in Germany. To begin with, sustainable urban development stands for improving local quality of life while simultaneously satisfying the needs of present and future inhabitants without impairing the demands of people in other regions.

In Germany, approximately 80 per cent of the population is living in urban regions. Urban development in Germany is governed by the principles of a society characterised by high technology, a high degree of division of labour and individualisation. The following trends are to be viewed as the greatest challenges for an urban development based on conserving resources and compatibility with the environment:

- A "land devouring" settlement dispersion by the expansion of settlement into the rural areas surrounding agglomerations;
- An increasing spatial and functional separation of residential areas, places of work, supply facilities of articles of daily use and recreational facilities and
- The increase and extension of motorised passenger transport and carriage of goods.

To base urban development on the principles of sustainable development requires a total reorientation. Production methods, consumer habits and forms of mobility have to be revised, new management concepts and new political practices are required to open up new paths to reconcile economic, ecological and social development. Methods of construction, architecture, settlement structures and town planning have to be re-evaluated pursuant to the goals of sustainable development, apparently sound criteria and standards have to be questioned.

Which proves to be useful on a short-term basis, might be counterproductive and not viable in the future; individual buildings that appear ecologically sound might prove to violate the principles of sustainable development seen on a larger regional scale and what was developed as a suitable strategy for creating new housing in a specific sector might prove to be inappropriate considering all aspects.

Combining ecological, social and economical development goals in the sector of "industrial and residential construction and living conditions"
(Commission of inquiry "Protection of human life and environment" of the 13th German Bundestag [Parliament])

Economical development goals
- Minimising the life cycle costs of buildings (construction, operation, maintenance and repair, recycling etc.)
- Reduction of expenses for structural alterations, repairs and maintenance in relation to the costs of new buildings
- Optimisation of expenses for technical and social infrastructure
- Reduction of subsidies

Social development goals
- Providing adequate residential accommodation considering age and number of persons living in a household; reasonable expenses for living accommodation (in proportion to the income of individual households) even for lower-income groups.
- Creation of an appropriate residential environment, social integration, avoidance of ghettos
- Settlement structures integrating residential areas, places of work and recreational facilities
- Healthy living conditions at home and outside
- Increase of home ownership quota without increased consumption of land.
- Creating and safeguarding jobs in construction industry

Ecological development goals
- Reduction of land consumption
- Stopping the despoliation of the landscape by building activities, keeping any additional sealing of the soil at a low level and promoting renaturation schemes
- Subjecting material streams in the building sector to the goal of conserving resources; avoiding the use of pollutants in new buildings, structural alterations and repair and maintenance activities; observance of these principles in the circular flows of building materials
- Reduction of carbon dioxide emissions of buildings in line with the Federal Government's Resolution referring to a total reduction of carbon dioxide emissions by 25 % until 2005.

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Research areas and deficits:
Implementation of sustainability
The area of research "sustainable urban structures" focuses on issues of sustainable urban development and, in particular, on designing new building technologies and methods. It is closely linked to facility management systems and sustainable transportation systems and logistics.

"Sustainable urban structures" imply that urban development and urban settlement structures will be subject to the principle of conserving resources and being compatible with the environment. The ecological objectives firstly focus on the manner of how resources are used in towns, secondly on exchange processes between cities and the countryside, in particular the city's hinterland, and thirdly on urban structures of land use and spatial organisation. Those existing structures demand land in a significant way, they are partly inefficient energetically and they produce an increase in transport activities.

There are research deficits as regards the differentiation of social action chains resulting in the high consumption of resources and environmental pollution and as regards a differentiation of materials, sources of energy, biophysical and chemical cycles. The deficits are even more significant, however, as far as the application of this knowledge is concerned (implementation know-how). It is a matter of consequently implementing the circular-flow principle and to change the urban "throughput economy" into a "circular-flow economy".

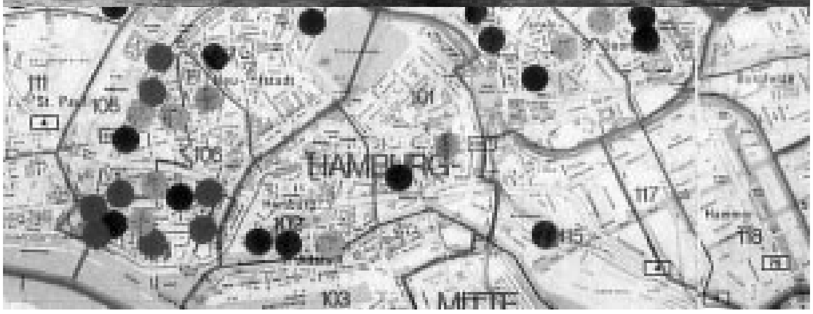
Economic and social goals of a sustainable urban development focus on strengthening self-adaptability and regenerability of economy and society with regard to "open futures" and to counteract economic and social polarisation and segmentation trends (strengthening economic and social coherence while simultaneously maintaining diversity). The slogans "efficiency revolution" and "sufficiency revolution" highlight the complementary aspects of a new manner of utilising energy and resources on the one hand and the resulting changes in production methods, consumer habits and ways of living on the other hand.

Research has so far failed to develop appropriate regulation mechanisms (feed back mechanisms) which make it possible for people to see the ecological and economical consequences of their behaviour and to assume responsibility for it. There are also major deficits as regards the related implementation know-how, i.e. the development of new dialogue-oriented forms of politics, the development of problem-oriented cooperation and action structures and the promotion of "local" initiatives and responsible acting.

New facility management systems and concepts take a share as well in urban development, as the inter-linking of formerly separated household technology systems will lead to new locally integrated systems. The goal is to design and operate the supply of households with heating, water, air, electricity and information services in such a way that raw materials and energy are used economically and efficiently and residues to be disposed of are minimised while optimally satisfying the users' needs. To achieve this, the technical, operational, organisational and personnel requirements as well as the socio-economical and political outline conditions have to be improved. Technical requirements include the planning, installation and operation of systems for a decentralised production of energy and the use of regenerative energies including automatically controlled energy distribution systems. Integrated household technology systems still to be researched relating to energy production and to supply and disposal networks and facilities result in locally integrated systems whose design and operation are important components of sustainable urban structures.

The development of new building technologies and methods is another essential element of sustainable urban structures. Improving building methods and types for varying constructional tasks, in particular by researching the fundamental principles of the physical nature of building materials and components and their carrying capacity and deformation behaviour and by formulating the necessary engineering models with computation and construction rules regarding usability and stability are topics of this area of research. In addition, research activities include selective improvement of the properties of building materials and components with regard to handling, production, service life, health effects, sustainability and recyclability.

The area of research "sustainable transportation systems and logistics" is an essential part of any concept of sustainable urban structures and includes the integrated design of regional transportation systems and logistics. As the transport infrastructure is not expandable at will (due to both costs and land use conflicts in urban areas) new ways and solutions have to be found. By optimising information flows and by appropriate superior regional structures including spatial patterning and transportation infrastructure the new research area "logistics and passenger transport" is to be developed. The new possibilities offered by information technology allow mobility and transport consulting as well as demand management.



Finally, proven sustainability indicators for analysing urban and settlement structures are still missing. Sectoral, temporal and spatial aspects are to be integrated into indicators, operationalisations and criteria of quality that may give information about changes, deviations, successes and failures. The most precise indicators are useless, however, if there are no related data. Indicators have to be clear, i.e. communicable and accurate.

Cities should not export their problems but harmonise imbalances at local level. A structural change in line with the principles of sustainable development, however, will only come about, if we succeed in simultaneously altering the economic structure and way of living in our cities. Thus, the economic and social implications of a sustainable urban development policy together with the structural changes involved must be subject of scientific research and public discussions.

(Dieter Läpple,
including contributions by
Eckhard Kutter, Joseph Pangalos,
Jürgen Pietsch and Dirk Schubert)

Systems of Transport and Logistics

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Efficient systems of transport and logistics are a typical feature of modern industrial societies and economies. To maintain mobility certain planning and technological requirements have to be satisfied including future-oriented plans for traffic telematics and autonomous robot systems as well as researching essential technologies and new materials for the transportation sector.

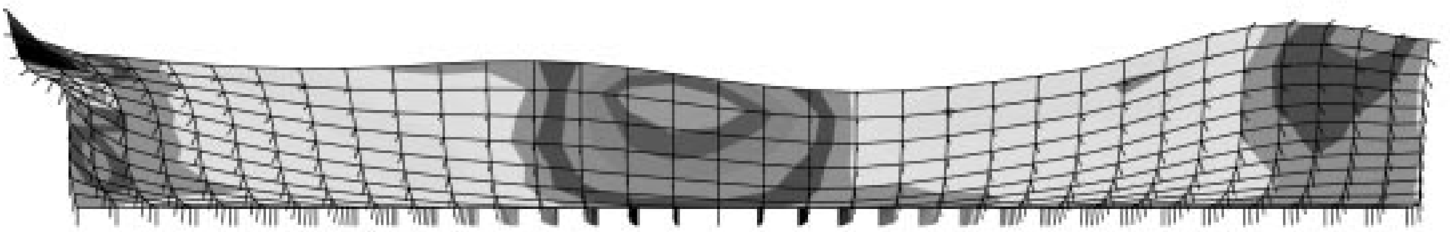
A major area of research at the TUHH as regards integrated systems of transport and logistics is mobility management by traffic telematics. The efficient control of transport and traffic activities is a prerequisite for competitiveness of the European countries with regard to each other and any other country world-wide. It is a prerequisite as well for meeting the high demands regarding mobility of people and goods in the long run. As regards transport activities the main focus should be how to obtain a high load factor, whereas traffic activities should focus on significantly improving the infrastructural utilisation rate. These requirements can only be met, if all types of transport and traffic are combined in a joint and closely linked intermodal system. This objective may be achieved by an intensive use of modern information and communication systems. Simultaneously, issues of system modelling have to be tackled and technical systems and components have to be developed, such as broadband mobile communication systems and traffic telematics by using high-capacity sensors and communication equipment.

A significant approach in this area of research is the development of autonomous robots and robot systems, even though these technical systems may be used as well in many other important sectors, i.e. biomedical engineering and production engineering. Autonomous robots are objects in which mechanical structure, various driving mechanisms, analogue and digital control systems in connection with sensor technology and various methods of autonomous power generation and storage are being applied. Respective research goals are reduction of power consumption, increase of precision, self-adaptation of control parameters, increase of reliability and prolongation of service life. Autonomous robots are controlled by outside influences, thus methods of image processing, image digitising and signal transmission are just as important as self-monitoring of robot systems with the purpose of early identifying imminent failures and preventing a break-down of the robot system by early intervention.

Another focus of this area of research at the TUHH is the development of technologies for the transportation industry. In close cooperation with the business sector systems and system technologies for aircrafts, vehicles and ships are being further developed and optimised with regard to resulting operational improvements (safety, emissions, operating cost). These integrative research activities require, apart from the development of new materials, the application of new technologies and system architectures as well as the development of efficient design and analysing tools, such as virtual prototyping and adaptive neural networks. For new ship types and offshore platforms as well as their production procedures the development of innovative construction in ship and marine technology is essential. In addition, there are developments of numeric simulation techniques for applications with regard to various flow computations as well as problems of optimisation of technical and economical aspects, for example in the case of a complex chain of transportation means by land and by sea. Research activities at the TUHH cover as well methods for the reduction of pollutant emission and special issues of marine technology.

Recent changes in ship technology seem to offer good prospects for that sector of industry in the near future. We have had seagoing boats or rafts for at least 30.000 years, otherwise the early colonisation of Australia by aborigines would have been impossible. Nevertheless, shipbuilding technology is still making rapid progress. The TUHH is involved in various innovative projects both alone and in association with the business sector and other universities, such as its productive cooperation with the company Germanischer Lloyd.

Fig. 1
Changes in resistance when modifying the hull form. Each change in shading corresponds to an additional 2.5N change in resistance per 1 mm outward shift of a mesh point.



A long standing goal in shipbuilding is to design ship hull shapes and their necessary "appendages" rudder and propulsor that need less propulsion power thus reducing costs for propulsion machinery and fuel as well as environmental pollution by exhaust gases. But only within the past few years it has become possible to substitute the time-consuming and expensive model experiments by reliable computations. Using methods developed at the TUHH it is now possible to predict ship resistance and propeller efficiency by fluid flow computations with an error ratio of a few percent, i.e. with nearly the same accuracy as predictions based on model tests. A prerequisite for applying such computations in practical ship form improvement is that they are less time-consuming than model modifications. Viscous flow computations considering fluid viscosity and flow turbulence are still too time-consuming for that purpose: they still take several days of computing for one flow condition. By using a combination of potential flow methods with empirical means of determining the viscous resistance, similarly as is done in predictions based on model tests, it is, however, possible to attain the necessary accuracy in a computing time of approximately one hour. In addition, an innovative method developed at the TUHH allows to determine the changes in ship resistance when slightly changing the hull form at will (fig. 1) without any significant additional efforts thus getting exactly those data required for ship shape improvements.

As the required propulsion power depends not only on ship resistance and propeller efficiency but also – to a substantial part – on the interaction between hull and propeller, the next project to be carried out will be the study of this interaction based, primarily, on potential flow computations. As in future viscous flow methods including turbulence will also become feasible for practical hull optimisation, we plan to further develop such methods as well. Again, the aim is not only to determine ship resistance and interaction coefficients between hull and propeller but also, without much additional CPU time, the change of these results when changing the hull shape at will. These research topics will be among the first to be pursued by the CMT, the "Center for Maritime Technology" being established at the moment.

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Naturally, the rapid progress in fluid flow computations is or will be applied as well to various other problems of marine structures, i.e. for forecasting and optimising the manoeuvrability and wave-induced motions of ships and offshore platforms, for determining the effects of wind forces on floating structures, for optimising room ventilation, as regards safety against capsizing of vessels at sea, for forecasting the time a damaged vessel is able to remain afloat at sea and the distribution of heat and smoke in the event of fire. The aforementioned hazards are attracting much attention at present both on account of recent spectacular accidents (e.g. Estonia) and due to the fact that the number of passengers aboard ships now in the planning stage (up to 10,000) will exceed by far previous passenger numbers. Without valid forecasts as to the safety of ships in cases of average the construction of such ships appears to be irresponsible. Modern flow computations form the basis of such forecasts.

Innovations in ship structures

For the structural components of large ships and floating offshore structures steel is still the best-suited material. But which type of steel? So far mild steel with a minimum yield strength of 235 MegaPascal (MPa) and "higher tensile steel" with a yield strength of 355 MPa have mainly been used. For very fast ships which are designed as passenger vessels, ferries (for the transport of vehicles and trucks) and ro-ro-ships (mainly for the transport of trailers) light-weight construction is mandatory. In this context, an EU project with 13 partners has been initiated to research how steel with a yield strength of 690 MPa – almost double the strength of "higher tensile steel" used so far – can be applied to ship structures. Will it be possible to thus reduce the structural weight by almost 50 %? Hardly so without fundamental changes in structural details, in the configuration of the whole structure and in joining techniques (welding, possibly bonding). Special attention will have to be paid to the strength under fluctuating loads (fatigue strength), the buckling behaviour and the corrosion protection. In the EU project that is to prepare the practical application of high tensile steel, HTS690, ship structures are being designed, analysed, produced and tested (fig. 2).

In order to competitively build ship structures in a country with high salaries, the required man-hours for production have to be continuously reduced. So far, a significant part of the man-hours is spent on manual post-treatment of inaccurately manufactured structures. Although the components can be cut from plates with a high degree of accuracy, there is shrinkage on account of welding which frequently exceeds the acceptable tolerances as regards the unevenness of plates and the fitting accuracy of edges to be welded. Several strategies are being applied to minimise this costly post-treatment, such as forecasting the distortion on account of welding and allowing for it when cutting or forming, and the application of welding methods with a low heat input thus creating less distortion.

Research is performed at the TUHH to contribute to a solution of these problems as well, for example the forecasting of welding shrinkage using up-to-date computer-based analysis methods and, in cooperation with industrial partners, the development of a method to identify quickly and reliably those critical structural zones prone to fatigue.

Another project is dealing with the data-flow in all constructional phases including initial design, dimensioning and a comprehensive product data model describing the ship conforming to standards for the purposes of building the vessel (often done at various sites) and for later repair purposes and also for the derivation of data for numerically controlled production plants.

Conclusions

Without regular innovations in various areas the German shipbuilding industry would not have been able to face the severe international competition. Research on ship technology has contributed largely to keeping the world market share of the German shipbuilding industry at a more or less constant level – except for some short-term fluctuations - during the last two decades. Increased productivity has not resulted in a reduction of the added value or the number of engineers. Far from it – the demand for shipbuilding engineers by far exceeds the number of those graduating from German universities. Research will continue to be a major factor in the competitive struggle between shipyards and it will also be an incentive to talented young people to decide in favour of naval architecture. Research in ship technology as a basis for innovation is necessary and also an essential requirement on account of the growing popularity of sea cruises and the growing safety need. In view of the increasing demands by modern industrial societies effective systems of transport and logistics– in addition to the use of new communication systems – will remain the backbone of infrastructure.

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(Lars Sjöstedt, Heinrich Söding, Wolfgang Fricke)

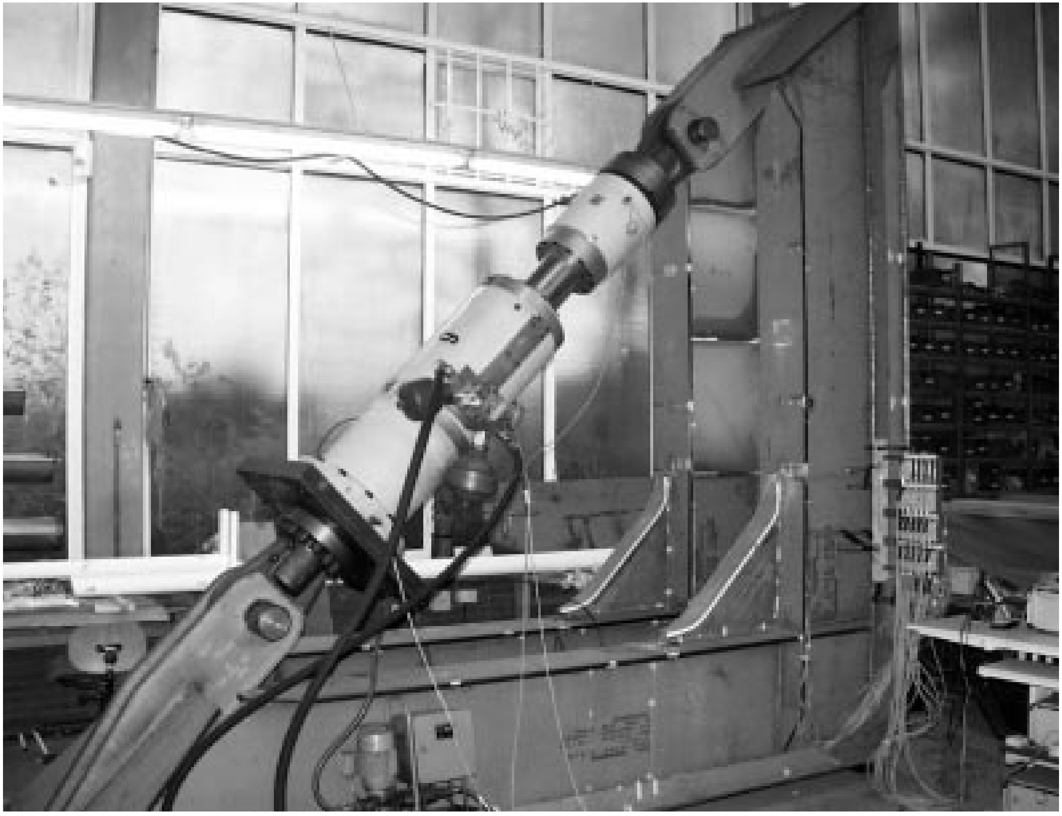

Fig. 2
Rig for testing frame corners made of high-tensile steel

Advanced Communication Technologies

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The exponential increase in the number of users of mobile radio telephone networks and of the Internet characterises the communication networks as pacesetters on the way to the information society. The strategic field of research "advanced and communication technologies" is creating the basis for the future development of information exchange in wire-line and wireless networks complying with the wishes of modern societies to get into contact with other persons at any time and place and to quickly access huge amounts of data.

All applications have in common a steadily growing demand for transmission speed and simultaneously, data transfer reliability.

In the access network the transfer rate is dependent on the volume of data of each individual user, whereas in the wide area network aggregate data volumes have to be processed. With regard to both network areas innovations are being studied and tested to increase both the available capacities and the utilisation efficiency.

In view of the growth rates in recent years the air interface of wireless networks is in the center of interest. The present state of the art as regards wireless communications is characterised by the existing digital but narrowband GSM and DECT systems. The available useful data rate per user, however, is restricted to about ten kbit/s. Our present research activities regarding new mobile radio systems are focused on digital broadband systems allowing access to video channels and Internet services.

Important issues are the selection of a suitable bandwidth and the selection of a suitable transmission technology (single-carrier or multi-carrier systems) for the systems and applications under consideration.

In the past the Universal Mobile Telecommunications System (UMTS) was developed. The respective system designs are presently being put into practice in the major industrial companies and the corresponding mobile phones are being produced. The useful data rate per user of this new generation of mobile phones amounts to a maximum of two Mbit/s.

The technical break-through for real broadband communication systems will come about in the near future. In the Orthogonal Frequency Division Multiplexing (OFDM) transmission technology being studied at the TUHH data are distributed within the radio channel over many subchannels in which they are transmitted in parallel at a relatively low data rate per subchannel. The resulting advantage is a low processing complexity in the receivers. The Hiperlan/2 -system, standardized by ETSI, is also based on OFDM. It features an adaptive modulation level and a bidirectional transmission rate of 50 Mbits/s. Current and future research activities at the TUHH are focused on optimising this technology for stationary and mobile radio systems in different application areas (Fig. 1).

All these developments are concerned with the design of new transmitting and receiving structures taking into account that the radio channel is characterised by fading phenomena. Therefore, an accurate modelling of the statistical properties of this channel is an essential subtask.

Apart from the obvious problem of high-rate transmission at a low error rate, the optimal utilisation of the available network resources is another important aspect. In wireless networks this aspect is represented by the so-called multiple access problem. In competition with other users a user has to establish initial contact with a base station organising communication within the cell allocated thereto. In very recent proposals base stations and cellular network structures will be abandoned altogether. Individual autonomously working mobile stations will organise access to the radio channel. Thus, mobile radio networks will become very flexible allowing efficient utilisation of the radio channel. This idea of self-organising radio networks will find direct use in transport systems (aviation, shipping, rail and road transport) but also in communication systems (there better known as so-called "ad hoc" networks). In this case, communication engineering is to organise multiple access to the radio channel using only decentralised intelligence.

A basically different approach to providing additional capacities for radio communication is to make additional ranges of the electromagnetic spectrum accessible for communication purposes, namely the terahertz frequency range presenting totally new challenges to high frequency engineering.

To provide transistors covering the terahertz frequency range two modifications will be necessary. Firstly, the dimensions of the active components of transistors have to be reduced to less than a micrometer, so that the transit time of the electrons across the component may be kept considerably lower than the period of the A.C.signal. Secondly, the transistors have to be constructed using layers of different material combinations thus creating a higher electron mobility in the preferred direction. Reduction of dimensions and increase of mobility both aim at reducing the transit time of electrons. At a frequency of one terahertz the period amounts to no more than 10^{-12}s and the transit time has to fall short of that value by at least one order of magnitude. Studying the transport properties of electrons in complex and geometrically extremely miniaturised semiconductor systems is one of the research subjects when developing receiving structures for the terahertz frequency range.

In the backbone networks an exponential growth of network load is observed, a problem which in the past has always been solved by optical transmission technology:

In field tests, transfer rates of one terabit/s have already been successfully achieved using single optical fibres; in lab tests, the transfer rates of more than 3.5 terabit/s over a distance of several hundred kilometres are reported. The long-term goal in this area of research is the

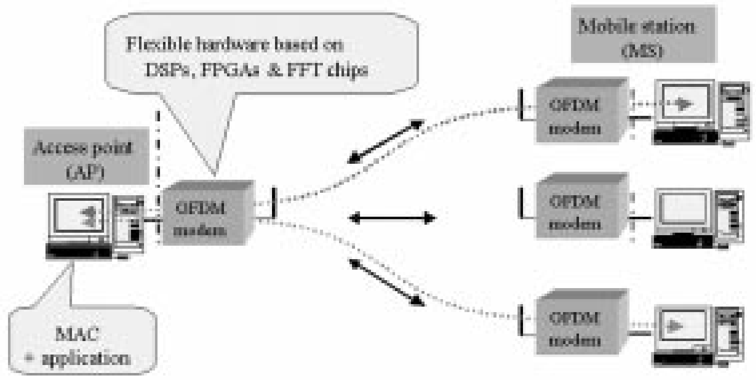

Fig. 1
Experimental Hiperlan/2 system using OFDM transmission

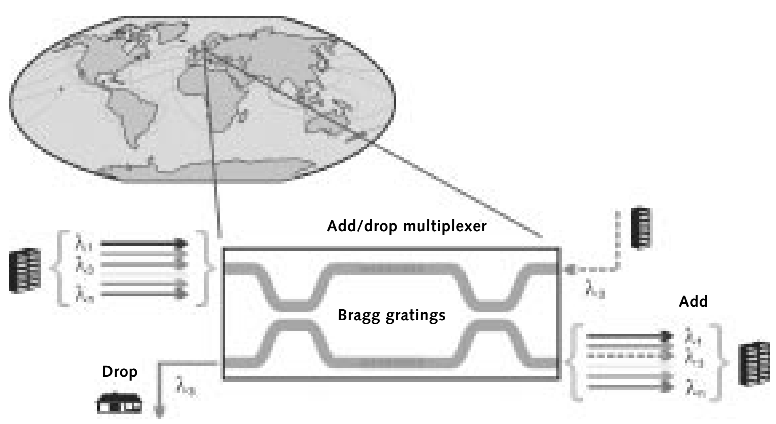

Fig. 2
Integrated optical add/drop multiplexer

data transmission in the wave length range of 1200 nm – 1700 nm. Theoretically, transfer rates of more than 25 terabit/s via individual optical fibres would then be possible. In pursuance of that goal research focuses on High Density Wave length Division Multiplex (DWDM) with many autonomous channels on a single circuit. To this end research is focussing on tuneable sources, wavelength-independent amplifiers, wavelength-selective components for multiplexing and demultiplexing as well as components for compensating various fiber-typical dispersion mechanisms. TUHH is contributing largely to such developments, often in cooperation with the industry. To give an example, Figure 2 illustrates the principle of an add/drop multiplexer based on Bragg gratings. With this integrated optical component specific channels out of the many wavelength channels transmitted are dropped but also added. Thus, it is possible to realise "data highway approaches and exits" on a few square millimetres.

Apart from the provision of high capacities their efficient use is just as important. This is reflected in various research projects on network planning and network controls. Network planning responds to the question of which resources (wavelength channels, bandwidths, radio frequencies) are to be allocated to which known data traffic streams in a network. This allocation may be of static or dynamic nature. However, one is regularly faced with the problem that the computation time needed is growing exponentially with the network size excluding exact solutions for realistic network configurations. To solve this problem, stochastic optimisation methods, such as genetic algorithms, are successfully being used at TUHH. This method translates the procedures of selection, mutation and crossover known from the biological theory of evolution into algorithms in order to generate after several "generations" "descendants" with a quality of solution coming sufficiently close to the optimum.

Communication networks are controlled by the network nodes controlling the routing, the service quality of the respective applications and – linked thereto – avoiding overloads in the network. The corresponding control loops have a minimal response time determined by the signal propagation time. Parallel to the success of optical communication engineering, the bandwidth delay product describing the amount of data already "on its way" and thus evading control is gaining ground. As these quantities have already reached the region of Gbits, new concepts for highspeed communication protocols will be necessary.

Moreover, all control systems which are to guarantee the desired service quality of the respective applications have to contend with a problem of scalability: network nodes are not capable of collecting and processing any number of status information of connections. Current strategies to avoid the imminent collapse of the Internet use the following approach: in the nodes of the user access area detailed information of (not too many) users are being processed; the nodes of the inner network, however, are operating on data of already aggregated traffic. They exploit buffer occupancies to make decisions as to buffer management, scheduling, flow control and routing. Current research activities in Harburg are aimed at optimising the behaviour of the various node types and their coordination. This requires a deeper insight into the integral effect of the algorithms carried out at various locations in the network as well as a quantitative analysis of their effect as regards service quality, network utilization and fairness. Our scenario studied is the German research network: Figure 3.

(Ulrich Killat)

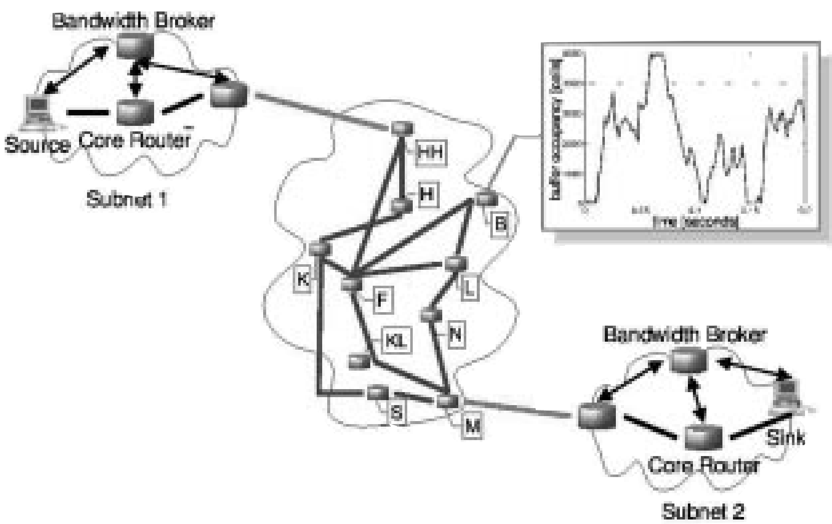

Fig. 3
Networking simulation scenario

Advanced Materials and Microsystems

Materials research and technology

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Materials research and technology are considered as key technologies for innovative products. According to international experts, the majority of product and process innovations in the next two or three decades will be based on new materials. Therefore, a productive materials research sector will be of vital importance for the German economy[1]. Apart from safeguarding existing jobs and creating new jobs, the development of new materials is a major contribution to the necessary ecological reform measures, i.e. by conserving resources and reducing pollution caused by transport activities as well as energy production.

In view of the typically long transfer periods from idea to innovative product in this area, materials research is a long-termed investment. On account of its crucial importance for the national economy, materials research and development is accorded top priority in public funding in all technologically leading countries. Materials research as cross sectional technology will prove most effective, if it is independent and interdisciplinary and innovation-oriented[2]. Thus, it is an ideal area of research for a Technical University with a largely application-oriented research profile.

The development of new materials at the TUHH is increasingly performed on the basis of thermodynamic computations and the physical correlation between atomic structure, microstructure and properties profile, and less by empirical research. Within the scope of systematic basic research, the microscopic mechanisms are being investigated determining the application-relevant properties of materials. On account of the complex nature of this research field, scientists and engineers are working together interdisciplinarily in national and international networks. Guided by the concept of simultaneous engineering, the development of materials is linked to the development of specific production and processing technologies (often in co-operation with industry). As a result, materials innovations may be utilised in technical products within a short time. The new materials to be developed at the TUHH include both structural and functional materials.

Structural materials

As regards structural materials - mostly developed at the TUHH for application in transport technology - the improvement of the complex mechanical properties is the main focus of research activities. Conventional materials are being optimised and novel materials are being developed including all classes of materials, i.e. metals, intermetallic compounds, advanced engineering ceramics, polymers and composite materials of various types. The related fundamental engineering principles are being developed in the collaborative research center "Micromechanics of Multiphase Materials".

As regards metallic structural materials, research and development activities are focused on aluminium, titanium and magnesium materials as well as intermetallic compounds based on aluminium and titanium. These activities aim at developing property profiles especially tailored to the requirements of specific applications. Thus, in co-operation with the company Otto Fuchs Metallwerke, a new heat-resisting aluminium alloy was developed, for example, to be used in aircraft components resisting intermittent temperatures of up to 200°C. For components of cast titanium, a novel annealing process was developed allowing a significant improvement of various mechanical properties (yield strength, dynamic strength and creep resistance). In co-operation with the casting company Tital, the results of the materials development are presently being utilised for highly stressed fixing devices in aircraft construction in initial prototype components. In co-operation with the GKSS Research Center and industrial partners, wrought and heat-resisting magnesium alloys are developed for ultra lightweight vehicles.

Intermetallic compounds based on titanium aluminides represent a new type of high-temperature lightweight materials with properties in between those of metals and ceramics. They are characterised by a high specific elasticity and temperature strength up to about 750°C, and offer a high oxidation resistance. The development of the alloy as well as the corresponding production and processing technologies are done in co-operation with the GKSS Research Center and major industrial partners. Initial prototype components for aircraft turbines, such as rotating blades of the high-pressure compressor, are being tested in practical operation. They are to replace the presently used rotating blades made of nickel-based alloys of double the weight thus contributing to a significant reduction in weight and fuel consumption of aircraft turbines.

As regards structural ceramics, research and development activities are focused on the development of aluminium oxide composites using, in particular, low-cost reaction syntheses and net-shape processes which are relatively easy to be applied in large-scale production. Aluminium oxide composites offer a broad range of applications: The current developments include a new generation of brake disks, of novel injection nozzles as well as ceramic dental implants. Several newly developed materials, such as reaction bound aluminium oxide and AI203 reinforced by intermetallic compounds, are being evaluated as to their practical application by industrial partners. These composite materials called 3A (AI203-aluminide alloys) are being produced by reaction casting in conventional diecasting or squeeze casting machines by pressing liquid aluminium into porous ceramic preforms. Thereby the preforms, which consist of low-cost ilmenite ($FeTiO_3$) for example, react with Al to Al_2O_3 and Ti-Al-aluminides, i.e. a high-quality metal-ceramic composite is being produced at low process temperatures (<700°C) that may be used in lightweight construction at high temperatures (>700°C).

Furthermore, ceramic nanocomposites are being investigated with regard to developing new abrasion-proof and high-temperature materials. Significantly higher strengths than monolithic materials (e.g. Al_2O_3, Si_3N_4) are achieved by the addition of a second nanocrystalline phase (e.g. SiC). Thus, the service life of cutting tools in production technology and of highly stressed components in the hot zones of turbines can be significantly improved.

As regards polymer structural materials, research and development activities are focused on the development of novel "polymer alloys" produced from traditional polymers. New property combinations can be created, if one succeeds in uniting different polymers in the physically optimal manner. The reduction of costs by tailoring the properties to market requirements is another important aspect. Current research and development activities aim at developing combinations of different polymers by using block copolymers lowering interfacial tension, also referred to as coupling agents. Polymer blends are of particular importance in transport technology. In future, weight and manufacturing costs of aircraft will be reduced. Within the program funded by the BMBF "Aviation Research Guidelines" new high-temperature blends and halogen-free, thermoplast-modified, catalytically hardening epoxy resins are being developed to allow new sandwich structures in aircraft construction when being used together with temperature-resistant polymer foam. Recent results have demonstrated that reasonably priced polymer nanocomposites can be produced by bringing in surface-treated bentonite (cat litter). At the TUHH such nanocomposites are being developed in co-operation with industrial partners for fenders and other body parts of vehicles. Advantages are higher scratch resistance in combination with higher penetrating power of the dye and lower weight, but also possible applications with an improved flame resistance.

As regards polymer fibre composites, the development is focused on the physical modelling of the mechanic properties and their dependence on fibre arrangement and polymer matrix. In future, this will allow a computation of strength, an optimisation of arrangement and a more reliable prognosis about the service life of components made of fibre composites. The related numeric methods are being improved in co-operation with aircraft industry, producers of wind power stations and the licensing authorities.

Functional materials

In view of their increasing economic significance, functional materials are more and more gaining importance in comparison to structural materials in the research activities at the TUHH. This applies to all types of functional materials, even though, in particular, to metallic and ceramic functional materials. Other than in the case of structural materials, the electrical, magnetic and optical properties of the functional materials are of special technological significance.

As regards the metallic functional materials research and development, activities at the TUHH are focused on nanocrystalline and nanostructured materials. In co-operation with international industrial partners and the GKSS Research Center, nanocrystalline light-metal hydrides for the storage of hydrogen in future emission-free vehicles are being developed which are characterised by a high weight-related storage capacity of up to seven weight per cent and by short loading and discharging periods. A respective hydrogen prototype tank was successfully tested by the end of 2000.

As regards the ceramic functional materials, smart materials for combined applications as well as components for micro-systems and biomedical engineering, for optical communications engineering, for photo-voltaics and energy technology are being developed. The design of these functional materials and functional systems often requires the development of specific thin-layer techniques. Apart from reactive sputtering processes, thermal and plasma-supported gas phase deposition processes based on metal-organic compounds are preferably being used to produce, in particular, layers of silicon, aluminium, titanium oxide, titanium nitride and titanium oxinitride with optimised physical and chemical properties. Plasma polymerised layers are produced from silicon organic fluorocarbon compounds and organic acids among others.

Glassy layers are used, for example, in integrated optical circuits and systems for optical communications engineering. Plasmapolymer layers are, on the one hand, used as selective high-temperature resistant membrane layers in chemical sensors, and in direct-methanol fuel cells as well as gas-phase chromatographs. On the other hand, ceramic layers are utilised in mechanical sensors (e.g. for low and high-temperature stable pressure and stress sensors) or as high-temperature superconductive layers for magnetometers with improved sensitivity. In photo-voltaics, preference is given to crystalline thin-layer silicon solar cells.

Special emphasis in research and development activities at the TUHH is laid on analysing and predicting the service life of highly stressed ceramic functional materials. The service life of piezo-ceramic multilayer agents, for example, which are to be used in the injector of the next generation of the common-rail injection system, is being assessed by fatigue tests and fracture mechanical tests. The methods thus developed will be used in quality control and optimising manufacturing processes. Apart from these projects carried out in co-operation with industrial partners, basic research on the non-linear electromechanical behaviour and crack growth of ferroelectric ceramics is being performed.

Composite materials and material systems composed of various material types are of major technological interest for functional applications, as they offer unusual combinations of properties which formerly could not be achieved. The property profile of such material systems is often not only determined by the properties of the individual materials,

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but also by the distinct interface between the materials. Thus, in co-operation with the GKSS Research Center and the AXS Bruker GmbH the TUHH is developing synthetic nanostructured metal-ceramic multilayers. They are successfully used in diffractometry and spectrometry as novel X-ray mirrors and have already revolutionised these analytical methods. Metal-ceramic composites are also used in wearing protection; such layers resistant to wear even in extremely corrosive environments are increasingly growing in importance in machine construction. In co-operation with the GKSS Research Center and the University of the Federal Armed Forces in Hamburg the TUHH is developing nanostructured metal-ceramic composites powders which are used for the production of wear-resisting coatings by thermal-spraying techniques. Of major technological impact is as well the development of electro-conductive polymers. At the TUHH, research is done as to the electrical and mechanical properties of duromer matrix systems for glass fibre composites which exhibit electrical conductivity by adding carbon nanotubes, conductivity soot, nanofibres or carbon fibres recyclate. The technology developed is already used in components of airbus aircraft to prevent electrostatic charges. In co-operation with industrial partners, future development activities aim at qualifying this innovative technology for specific applications - ranging from the development of electrically conductive varnishes to the production of large-sized tubes for chemical plants.

These examples illustrate that materials with novel functional properties offer a very broad range of technological applications. In addition, it becomes increasingly obvious that the new type of nanostructured materials and nanocomposites will be another cross-material link in materials research at the TUHH.

Microsystems engineering

Micro-systems engineering is presently developing into one of the basic technologies for the fusion of complex sensorics, actuatorics, fluidics and micromechanics with microelectronics and optical systems. Apart from widely known micro-systems, such as the "airbag sensor", a micromechanical sensor picking up acceleration with integrated electronic evaluation and triggering the propellant cartridge, or the "elk test" sensor, a rotating rate sensor of similar technology, applications in biomedical engineering in particular, such as in minimum invasive surgery and in "smart" implants, e.g. artificial pancreas, are known. By combining novel materials generally in small amounts – especially as thin layers – a great variety of new applications not only in medicine and automotive but also in environment technology, electrical and optical communications engineering, industrial process monitoring and control as well as biotechnology and process technology are rendered possible. High reproducibility and low costs of producing microgeometrical forms in high numbers as well as the interactions not attainable in macroscopic dimensions are additional factors promoting this technology. At the TUHH, such micro-systems or components for these applications and systems are being developed, often in co-operation with industrial partners.

In the research section micro system technology micro-systems are being developed, starting with the simulation of mechanic, optical, fluidal and thermal systems, the development of new processes for realising materials and micro-systems to the design of complex systems for methods of analysis, optical communication technology, biomedical engineering and biotechnology. In cooperation with industrial partners, components, such as active valves and channels, diaphragm pumps and distribution systems and systems of cm^2-dimensions, are being designed. Such systems include optical spectrometers and mass spectrometers, gas-phase chromatographs, mass flowmeters, flame ionisation detectors, flame emission and absorption spectrometers. Complex sample injection systems, gas meters based on semiconductor sensors and infrared measured sections, biosensors and DNA chip replication systems are also objects of research and development activities at the TUHH.

In addition, novel UV-sensors are being researched and developed that do not present the disadvantage of measuring a relatively small UV-signal together with large quotas of the visible spectrum. In line with the principle of luminescence conversion UV-radiation is first converted into light of longer wave length. Then, the luminescent light is conducted to the detector. The detector is protected from direct radiation. As luminescence can only be stimulated by short-wave UV, the sensor system described above is insensitive to daylight except for direct stray light coupling. Two material systems were developed using both the luminescence conversion and the light conduction to the detector and which are compatible as well with the silicon technology: the first system is composed of amorphous luminescent silicon carbon layers which in co-operation with a producer of microelectronics are in the last process phase integrated in the plasma on a silicon chip to a sensor with photodiode and amplifier circuit at the periphery of a sensor field of one mm^2 .

The second material system is composed of europium doped glass fibres extracted from silicon-compatible soft glass. Given suitable glass composition the UV-energy absorbed in the glass is quantitatively transmitted to the europium ions which dissipate it again as red luminescence. This red light is conducted by the glass fibre to a silicon photodiode and detected there. With photodiodes at both ends of the glass fibre and a system of photodiode cells and comb-like structure of glass fibres UV-detection may be achieved. In addition, with non-linear optical polymers components for wavelength demultiplexer (WDM) networks are being developed in co-operation with an U.S. company.

In the area of research "micro-systems engineering" photon crystal structures (PBG) based on polymer and silicon wave-guides are being studied as well including the design and simulation of PBG structures in optical wave-guides, the development of nanostructuring processes for realising major aspect relations and the characterisation of optical transmission characteristics of telecom wavelengths in near infrared. The goal of these research and development activities is the application of such structures as wavelength sensitive components in optical data networks and – in co-operation with several companies – the development of an optical sensor system for measuring surface reliefs to be used in industrial production. Research and development activities include as well studies of integrated optical systems based on silicon oxinitride, aluminium oxide and titan oxide wave-guides for the realisation of integrated optical transceivers, wavelength demultiplexers, optical intensifiers and electromicromechanically selective broadband laser sources.

In co-operation with high-frequency engineering high-frequency circuits and complete communication and measuring systems for submillimeter waves -using thin dielectrical membranes – are being developed to close the gap in the used frequency range as regards infrared transmission.

A micro-system is completed by integration of specific evaluation electronics. Thus, in co-operation with industrial partners a microchip has been developed at the TUHH, simulated and later on tested in a semiconductor plant that has a central function in a newly developed medical electronic product recently put on the market. The microchip (ASEEG) has been designed in such a way that it may be used in a broad range of medical applications. The ASEEG disposes of ten channels that on account of their extremely low internal noise allow the highly-sensitive amplification and A-D conversion of important signals emanating from the human body, such as ECG (electrocardiogram), EEG (electroencephalogram), EP's (evoked potentials), EMG (electromyogram) etc..

The ASEEG was designed in close co-operation with the company Schwarzer GmbH (medical measuring devices, Munich) and in the context of a European project from specification and prototypes to use in marketable products within two years. Integrated into a new electrocardiograph produced by Schwarzer GmbH the ASEEG is ready for mass production and available on the market. Other devices based on the ASEEG are being designed. By future improvements of the ASEEG an ideal component for mobile medical applications may be made available. Its high integration, flexible architecture and unique variety of channels form the basis for a low power consumption, low space requirement and high reliability of telemedical applications.

An interesting field of application is also the present project "smart internal fixator" developed in co-operation with the Berufsgenossenschaft Hospital for Accident Cases of Hamburg. The object of this project is the development of a device for monitoring the load capacity of fractures in the lower extremities during the healing process via wire strain gauges in an implant screwed up in fixed angular position, evaluating the data in an integrated electronic device and transmitting the data by telemetry through an hermetically sealed capsule outside. These examples illustrate the fascinating possibilities offered by micro-systems engineering and simultaneously the future research approaches of the TUHH.

*(Rüdiger Bormann,
Jörg Müller)*

[1] *Recommendations for the promotion of materials research at universities, Scientific Council, Köln, 1993 and Evaluation of non-academic material research in Germany, Scientific Council, Köln, 1996*

[2] *New materials for key technologies of the 21st century – MaTech, program of the BMBF, annual report 1999/2000*

Biotechnology and Biomedical Engineering

Key technologies for the future

Biotechnology as an interdisciplinary cross-sectional technology is one of the future key technologies with a broad application spectrum ranging from the production of pharmaceutical products to medicine and environmental technology. Together with the silicon and the information technologies it is viewed as a megatechnology.

In line with this significance the areas of research within biotechnology cover a broad range of practice-relevant subjects, the projects are interdisciplinary and tied into a great number of national and international cooperations, in particular the Collaborative Research Center "Treatment of Contaminated Soil" and the DFG-Graduiertenkolleg "Biotechnology". The EU cooperation project "Extremophiles as Cell Factories" and the cooperation project "Biocatalysis" of the German Federal Foundation for the Environment are additional examples.

For putting the research findings into practice it is essential – apart from the great number of joint projects with industrial partners - to promote start-ups. Thus, nine of about 60 former scientific assistants at the TUHH have set up their own business in recent years. At present, 46 scientific assistants, including ten from abroad, are working in the research sections of biotechnology at the TUHH, 32 of them funded by third parties.

A central research object in bioprocess technology is the development and design of tower reactors for anaerobic waste water treatment for manufacturers of pharmaceutics and food products. The design principle is modular with removal of the biogas in the lower zones of the reactor.

In addition, the research and development activities include microbio-logic, reactive and hydrodynamic tests aiming at a controlled scale-up of processes. In fig. 1 a pilot reactor is pictured designed in cooperation with an engineering office for waste water treatment in yeast production.

Moreover, processes for the fermentation of micro-organisms are being studied, in particular the use of semipermeable membranes to remove metabolic products which might have an adverse affect on the growth of micro-organisms by dialysis (fig. 2). Thus, it is possible to achieve an extremely high density of micro-organisms: E. coli 180 g/l, sulfolobus shibatae 115 g/l, pyrococcus furiosus 3 g/l, marinococcus M52 132 g/l, lactobacillus fermentum 120 g/l (dry weight). At the moment, we are working on putting this promising technology into prac-

Fig. 1
Tower biogas reactor for anaerobic waste water treatment – pilot plant (Deutsche Hefewerke, Hamburg)

Fig. 2
Dialysis membrane reactor for high cell density fermentation of micro-organisms

tice in cooperation with an industrial partner.

In addition, processes for the cultivation of animal cells, e.g. for the production of monoclonal antibodies through hybridoma cells or therapeutic substances with recombinant cells, are being researched including engineering problems of reactor configuration, scaling-up as well as process control. A major area is the design of fixed-bed reactors, in which animal cells are immobilised in macroporous carrier materials. Dialysis membranes are used for supplying substrates and disposing of toxic metabolic products. Kinetic studies on suspended and immobilised cells are being done and described in models to serve as a basis for computerised process control.

In an interdisciplinary project on biohybrid articular surfaces a novel procedure for treating cartilage damages by surgically implanting cartilage grown extracorporeally with the methods of tissue engineering is being developed (partners: University Hospital of Hamburg-Eppendorf, company Merck Biomaterial, Darmstadt). A bioreactor designed at the TUHH will be used to grow the pellets.

The research and development activities in technical microbiology are focused on studying physiology, metabolism and enzymology of micro-organisms capable of growing under extreme conditions (temperature: 0-120°C; pH: 1-12; salt concentration: up to 30 %). Another goal is optimising the production of biotechnologically interesting enzymes, such as proteases, amylases, lipases, hemicellulases and cellulases.

These enzymes with their unusual properties of extreme thermophilic and hyperthermophilic micro-organisms (growth temperature: 60-108°C) are being isolated and researched. In cooperation projects within the framework of the EU project "Extremophiles as Cell Factories" we succeeded in cloning and expressing genes for thermostabile hydrolytic enzymes in E. coli. Crystallographic studies were done to clarify the relationship between structures and functions. Another major subject of these research activities are tests on DNA-binding enzymes of extremophile archaea that are of particular interest for molecular biological processes. A hyperthermostabile DNA polymerase from the archaeon thermococcus aggregans (growth temperature: 88°C) was cloned and characterised in detail. Apart from identifying the structure, the use of this enzyme in the polymerase chain reaction (PCR) as well as the molecular biological modification of the biocatalyst to optimise processivity and fidelity are being researched.

The cooperation project of the German Federal Foundation for the Environment "Industrial Use of Biocatalysts" (project start: May 2000) is composed of 30 research groups within Germany and is to prove the effectiveness of new methods used in the integrative cross-sectional discipline biotechnology. Focal areas are fine chemicals, active substances and textiles. Apart from coordinating the work of these research groups the TUHH participates with two own research projects:

In an innovative process high-quality amino acids and peptides are to be produced of hen's feathers. In this biotechnological process the extremophile micro-organism fervidobacterium pennivorans is playing the decisive role. In addition, regenerative raw materials, such as starch, cellulose and hemicellulose are to be converted into high-quality carbohydrates (e.g. cyclodextrines, linear and branched dextrines or defined monosaccharides and oligosaccharides) using biocatalysts based on the thermoalkaliphile bacterium anaerobranca gottschalkii. Together with traditional protein chemical and molecular biological methods new methods, such as genomics, PCR evolution and protein design are being used. The production of selective biocatalysts based on the bacterium anaerobranca gottschalkii is to be optimised by overexpression in bacillus subtilis.

Furthermore, the DNA-chip technology is to be established and optimised for various applications. DNA-chips allow the quick and reliable identification of a great number of nucleotid sequences in a very confined space. The proposed method of analysis is used for expression analysis and the quick identification of bacteria in complex communities, e.g. the intestinal flora.

1 Information as an economic resource
2 Organisation of enterprises
3 Production and process integrated environmental protection
4 Sustainable management of natural resources
5 Advanced energy systems and energy management
6 Sustainable urban structures
7 Systems of transport and logistics
8 Advanced communication technologies
9 Advanced materials and microsystems
10 **Biotechnology and biomedical engineering**

In biotransformation and biosensorics various biotransformations are being researched: hydrolysis and synthesis of peptide antibiotics (cephalosporin, penicillin) and peptides catalysed of free and immobilised enzymes; production of optically clean substances from racemic compounds; hydrolysis of proteins for regulation (processing); extraction of polycyclic aromatic hydrocarbons from soil and biopolymers from waste water. The appropriate biocatalysts for these tranformations are produced from natural enzyme sources or by transferring genes into suitable organisms. The product yields resulting from biotransformation are analysed as function of the properties of the biocatalysts, substrates and reactions. To do this, both the molecular and enzymatic properties of free and immobilised biocatalysts and the kinetics, mechanisms and structural-functional relationships of the reactions are being researched. Based on these data "better" enzymes may be constructed and produced by mutagenesis.

Research and development activities are focused as well on the development and modelling of enzyme reactions for equilibrium and kinetically controlled processes with low concentration gradients and the development and modelling of multi-phase enzyme reactors for biotransformation in aqueous solutions with pure substrate and/or product phase and enzyme reactions for biotransformation in hypercritical gases (CO_2) and under high pressures. Another major object of research is product and biocatalyst reprocessing. For such use fast substance-selective separation processes (including affinity chromatography with monoclonal antibodies and continuous simulated moving-bed chromatography are being developed and modelled.

Technical biochemistry focuses on the biological transformation of pollutants and residues aiming, on the one hand, at understanding and accelerating the decomposition process of such substances in the environment and, on the other hand, at discovering new biocatalysts (enzymes) that can transform these substances into useful products. These biocatalysts may be used in new biotechnical processes thus contributing to an effective disposal of such environmentally harmful substances. In order to detect such new biocatalysts environmental samples (soil, sewage sludge, river sediments, water samples) are being mixed with samples of the substances to be decomposed. If a decomposition or transformation takes place, the responsible organisms will be isolated and characterised. With the help of these organisms the decomposition process is clarified by identifying the intermediate products of decomposition. On the basis of such findings the new biocatalysts in these organisms can be identified. Then these can be used again for new processes. With this procedure a number of enzymes could be isolated in recent years that specifically remove chlorine from chlorinated hydrocarbon, such as chloropheniles, PCP (pentachlorophenol), chlorinated benzoic acids, chlorine alkane acids and chloroparaffine), thus detoxifying these substances. In the decomposition process of iodised radiographic media enzymes could be identified that specifically remove the iodine thus allowing biodegradation. A patent for a corresponding process has been applied for. Studies on the degradation of polyvinyl alcohol used in the strengthening of thread in weaving textile fabrics resulted in the development of a process by which those compounds are completely degradable in sewage treatment plants. Based on studies on the decomposition of hen's feathers an enzymatic process could be designed allowing the production of fire extinguishing substances from horn clippings by using enzymes. That project has so far successfully processed a few hundred kilograms of horn clippings in a pilot plant. In future, this process will be translated into large-scale production.

In an interdisciplinary project – in cooperation with technical microbiology - funded by the EU a number of new enzymes could be extracted from bacteria degrading mineral oil components, e.g. phenolic acids and alkanes, at high temperatures. These enzyme are presently tested as to their usability in technical processes. In addition, in cooperation with bioprocess technology a new process for thermophilic degradation of fats is being designed and – in cooperation with the research section waste management at the TUHH – various fungicides are being researched as regards the decomposition of treated citrus fruit peels.

All these projects aim at producing new materials out of residues by applying new biochemical processes or, at least, removing these environmentally dangerous substances. New sustainable and environmentally beneficial processes will improve the environment in the future.

Biomedical engineering

Biomedical engineering is a very interesting field of research. At the TUHH it is reflected in the field of biotechnology – e.g. tissue engineering – and, above all, in cooperation projects with the Center for Biomechanics. In addition, it deals with integrating electronics to develop "smart implants". By linking material properties, sensorics, electronics and microsystems engineering including telemetry implants, such as fixators, endoprostheses, prosthetic bypass grafts, are to be actively monitored thus accelerating the healing process. In interdisciplinary cooperation with the Hospital for Accident Cases Boberg and the General Hospital Harburg systems are being developed and tested that, when integrated into such implants, will significantly increase the patient's safety and reduce the period of convalescence. In addition, the facilities of minimally invasive surgery are to be extended by localising active surgical probes in imaging and image processing systems. A respective research project is planned in cooperation with the General Hospital St. Georg and the company Philips Medizintechnik.

Based on present activities, future research and development activities in biotechnology and biomedical engineering at the TUHH will probably focus on the following areas: on the one hand, increased utilisation of biokatalysts replacing or supplementing chemical processes or the development of high-performance operations for fermentation of micro-organisms. In combination with medical applications, such as in the production of diagnostic agents or therapeutic substances or in tissue engineering, i.e. production of artificial tissue, e.g. skin, cartilage, liver or vessels, interesting opportunities might arise. Another future-oriented research object is the integration of new measuring and controlling methods for process optimisation. As regards biomedical engineering "smart implants" as well as the advancement of minimally invasive methods of surgery, in particular, will be future areas of research.

All these areas of research require a high degree of cooperation between the disciplines of biology, chemistry, engineering and medicine. As the TUHH is firmly integrated into regional and supra-regional structures and thanks to its many international contacts it is well prepared to meet these requirements.

*(Ralf Pörtner,
Jörg Müller)*

TUHH-Technologie GmbH

TuTech was founded in 1992 by the Technical University Hamburg-Harburg, which holds 100% of the shares. The TUHH's concept of a privately organised, technology transfer and exploitation company run by the university itself, the first of its kind to be established in Germany, has now developed into a model for a number of other German universities.

The supervisory board of the TUHH-Technologie GmbH updated the corporate objectives of the company in December 1999:

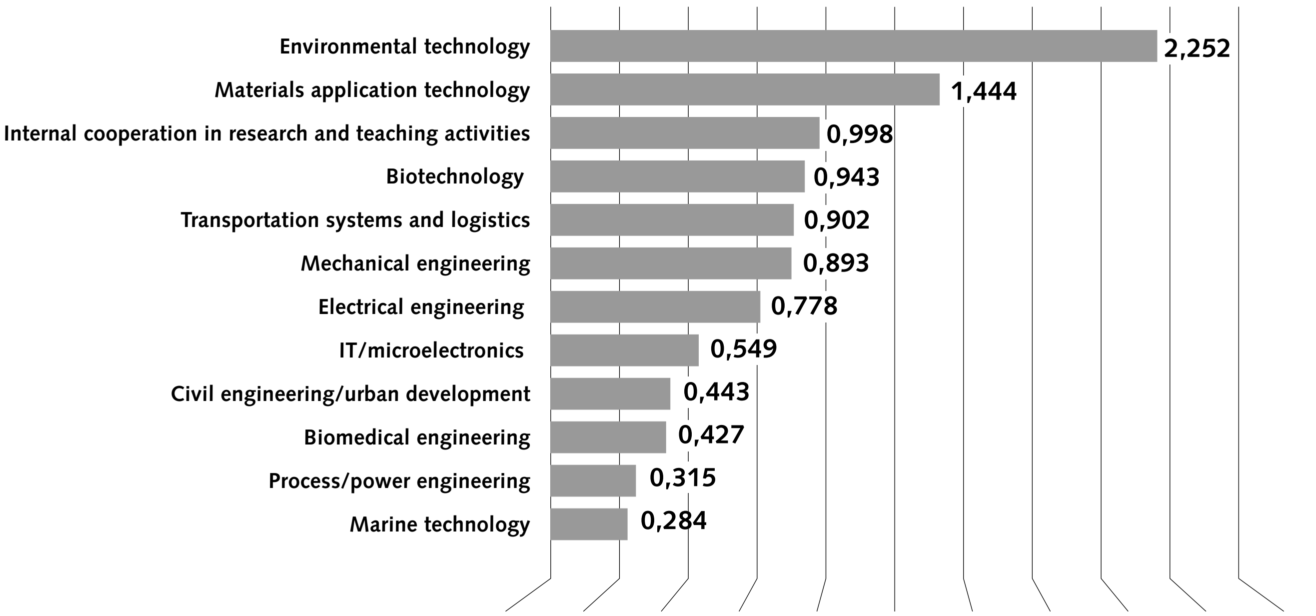
Objectives

1. Promotion of technology transfer between the Technical University Hamburg-Harburg and other research institutions and the business sector
2. Implementation of technologies developed at the Technical University Hamburg-Harburg and other research institutions in the business sector, exploitation of R&D results
3. Supporting the development and expansion of regional focal technologies in cooperation with scientific establishments and companies
4. Giving expert advice mainly to small and medium-sized companies as to technical issues and the management of innovations, consulting services for and active support of innovative company start-ups
5. Organisation and holding of training courses on technology and technology management topics

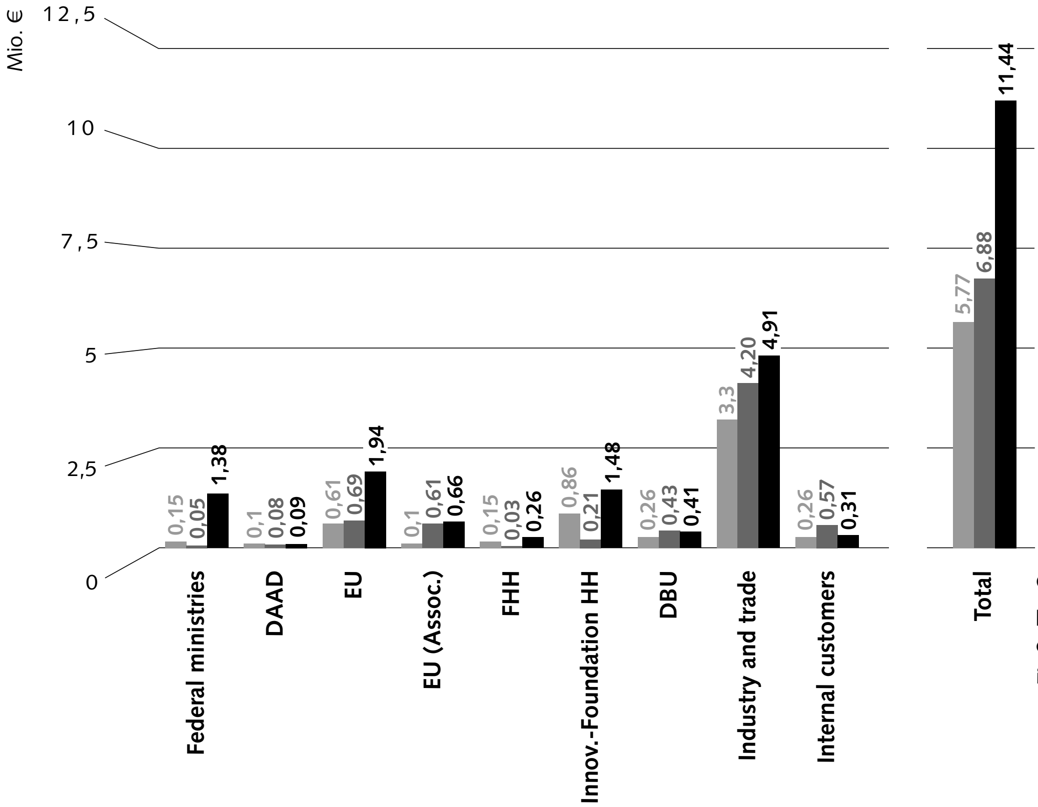
The following fields of activities for achieving these objectives were approved:

Central goals of TuTech

- Acquisition and project management of contract research and development projects in association with the TUHH and other research institutions.
- Administration and co-ordination of national and European joint research projects
- Prototype development, construction and operation of pilot systems and plants
- Obtaining patents for and exploitation of R&D results
- Finding, developing and conveying solutions to technical problems arising in companies
- Technology-oriented consulting of companies
- Support of and participation in innovative company start-ups as a business incubator
- Consulting on sponsorships for universities and KMU (EU and national programs)
- Development and holding of advanced training courses on technical/scientific topics and technology and innovation manage-ment
- Organisation of joint exhibition stands for North Germany at technology trade fairs
- Acquisition and organisation of technical/scientific congresses
- Establishment and expansion of an internet-based technology information system on the range of technological products and services offered by regional scientific/academic institutions and the business sector in collaboration with North-German partner organisations



Orders in 1999 by sector



Orders for R&E projects and consulting services in 1997-1999

TuTech is now a "one-stop shop" for technology transfer in Hamburg, offering a comprehensive range of technology transfer services in association with the Technical University Hamburg-Harburg, the University of Applied Sciences Hamburg, the Christian-Albrechts University of Kiel and other research institutions as well as other partners. Together with its partners TuTech is in particular active in the following fields of technology: biotechnology, civil engineering and building activities, information technologies, mechanical engineering, biomedical engineering, physical technologies, system technologies, transportation systems and logistics, environmental technology, process and power engineering, and materials application technology.

Figures for 1999

In 1999 the company's turnover amounted to € 9.97 million about 70% of which was attributable to contract research. 724 new contract research projects and orders for development/consulting services of a total value of approximately € 12.42 million could be newly secured. About € 9.05 million of this is attributable to projects connected with the research sections of the TUHH.

Cooperation with trade and industry

In cooperation with research sections of the TUHH and institutes of Hamburg University of Applied Sciences and the Christian-Albrechts University of Kiel TuTech was able to secure 698 new orders placed by private companies in 1999. The volume of these orders amounted to about € 5.22 million. The customers of TuTech/TUHH include not only many renowned German companies but also a large number of small and medium-sized firms mainly located in the economic region of Hamburg. Just under 70% of the orders are placed by industrial customers located in Northern Germany; these projects account for about 53% of the total volume of orders. Of the total number of 337 customers in the business year of 1999 25% were small, 42% medium-sized and 33% large companies.

European research programs

The EU office of TuTech supports scientists from the TUHH in submitting applications for EU research projects drawing on its experience gained in more than 50 projects it has so far successfully handled as part of EU research, innovation and training programs. At present, TuTech is involved in 20 ongoing European research and technology projects acting as a co-ordinator in five of them. An outstanding example was the project "Extremophiles as Cell Factories" with 58 partners from universities, research institutions and industrial companies. In addition, TuTech is carrying out various national research projects and studies together with the TUHH (Federal Ministry of Education and Research, Federal Ministry of Transport, the Federal Environmental Agency, the German Federal Foundation for the Environment (DBU), the Hamburg Ministry of Economics etc.).

StartUps

TuTech acts as a business incubator for launching technology-oriented companies. On the basis of R&D results and technical know-how of its scientific partners TuTech translates corresponding business ideas into commercial activities together with the founders. Successful business sectors are hived off with TuTech accompanying the new enterprise in the seed phase as one of its shareholders. Current examples are biotex, an R&D service and product center for extremophile biotechnology, and IWS Service GmbH doing business in the sector of materials application and welding technology, which was founded in December 1999 with cooperation partners from the Institute for Material Science and Welding Technology of Hamburg University of Applied Sciences.

In March 1999, TuTech opened the "TuTech-StarterZentrum" located in Harburg's inland port area, in which spin-off companies from the Technical University Hamburg-Harburg take the first steps towards their entrepreneurial venture.

(Helmut Thamer)

Promotion of business start-ups

at the TUHH-Technologie GmbH

Business start-ups ensuing from universities and research institutions have become a major aspect of the technology transfer activities of TuTech.

As a central information and consulting agency for business start-ups ensuing from the TUHH TuTech supports the activities of the TUHH Council of Founders and extends them by a customised, commercially oriented consulting and assistance service for newly established companies, e.g. by finding coaches from the business sector or financial partners, by integrating these new companies in R&D or service cooperation, by providing or arranging for floor space, by joint trade fair presentations and by procuring orders.

TuTech also acts as a business incubator for start-ups ensuing from the TUHH. Business ideas can be developed as profit centers at TuTech and hived off with the participation of TuTech with the aim to achieve a return on investment in a second round of financing. These activities of TuTech are integrated in the Channel Harburg Initiative. With the TuTech Starter Center located on the premises of a former freight station TuTech has created a first focus for innovative start-ups ensuing from the TUHH. At present, five start-ups from the TUHH are located in these premises occupying an area of 1500 m^2 and having created a total of almost 30 new jobs. Three companies are engaged in the sector of environmental technology, one company in biotechnology and the fifth company in the field of material development.

Hamburg EXIST Program

As one of the twelve projects of the EXIST competition held by the Federal Ministry for Education and Research, the Hamburg EXIST Program (hep) has been actively promoting and supporting innovative start-ups ensuing from universities and research institutions since the beginning of 1999. Hep is supported by the universities of Hamburg and partners from business, finance, politics and public administration. The hep network now includes around 80 persons who have set up their own businesses as well as 250 experts from business and science promoting start-ups as coaches, mentors, jurors and investors.

As project coordinator of hep, TuTech is offering - together with the other hep partners – a great variety of information and support services to persons from universities and research institutions who are setting up in business.

Hep is a comprehensive program for promoting company start-ups ensuing from universities. Adapting the existing general consulting services in Hamburg as regards the establishment of new companies, specific measures for innovative start-ups ensuing from universities and research institutions are developed and implemented focusing on the establishment of technology-oriented enterprises. However, hep has also set itself the aim of promoting persons setting up in business with an innovative service concept.

Process-oriented support of company foundation and development

Motivation, information and imparting of the required economic/legal knowledge and social skills as part of the lectures and classes at the individual universities and special seminars are supplemented by practical measures based on a network of competent partners and intended to significantly increase the chances of success for start-ups ensuing from universities. Elements of this process-oriented promotion are:

Twinning

In many start-ups the founders lack sufficient business administration know-how and fail to take market mechanisms into account in good time. In line with the teaching model "entrepreneurship" of the Hamburg University of Economics and Politics graduates in business economics, engineers, natural, cultural and social sciences are brought together. For example, parallel to the foundation of a company a thesis might be written on matters of economic viability or the market. This offers not only the opportunity of contents-oriented cooperation, but also for bringing together people (twinning) who jointly set up the company.

hep founder jobs

In the preliminary and initial phases of a company start-up, the universities offer their graduates "founder jobs", i.e. part-time employment, so that the graduates have a secure economic existence when starting their business and still have access to university resources (library, special research equipment etc.). At the end of this promotion phase a mature business plan should have been prepared.

hep Business Plan Competition

The aim of business plan competitions is to discover and develop new ideas, evaluate them and support and promote these concepts until their implementation. Hep also uses the instrument of business plan competitions. Together with its Hamburg partners of the nation-wide startUp Competition hep has timed the hep Business Plan Competition with startUp with both events sharing resources. The first hep Business Plan Competition was held in May 2000 awarding a prize to two hep start-up teams.

(Helmut Thamer)

Council of Founders and Founders

In the summer of 1996 the Council of Founders was established by the Academic Senate of the TUHH. The Council of Founders has made it its business to consult and assist academic employees and students as regards the realisation of their plan to set up their own business.

First, a group composed of professors, employees, students and employees of TuTech was formed to discuss organisation and scope of services to be offered. As a result, two seminars "business formation" and "business founders" were set up, data on start-ups ensuing from the TUHH were collected and a concept for possible financial assistance was prepared.

The seminar "business formation" is held in the winter semesters with experts lecturing on business plans, financing, promotional programs, law, taxes, patents, sales, marketing and personnel management, thus imparting the basic knowledge young businessmen and businesswomen should dispose of. The seminar "business founders" held in the summer semesters affords those wishing to set up their own business the opportunity of talking with entrepeneurs from the TUHH about their personal experiences.

In addition, data on start-ups ensuing from the TUHH were collected. In the past ten years 35 businesses with a total number of 220 employees were set up. Some of these new start-ups are being visited in the course of the summer seminar. These start-up activities have also led to the TUHH's commitment to the Hamburg Ministry of Science and Research to set up five companies every year. With eleven start-ups in 1999 this target was surpassed by far.

For the Hamburg universities and research institutes the activities of the Council of Founders and the TuTech have led to the Hamburg EXIST Program hep. Hep is now successfully in operation giving young founders the opportunity of getting financial aid for preparing their business plans. Apart from the product idea the business plan is the most important prerequisite for setting up a business and raising the necessary funds.

Fig.1
Promotion of start-ups by the TUHH

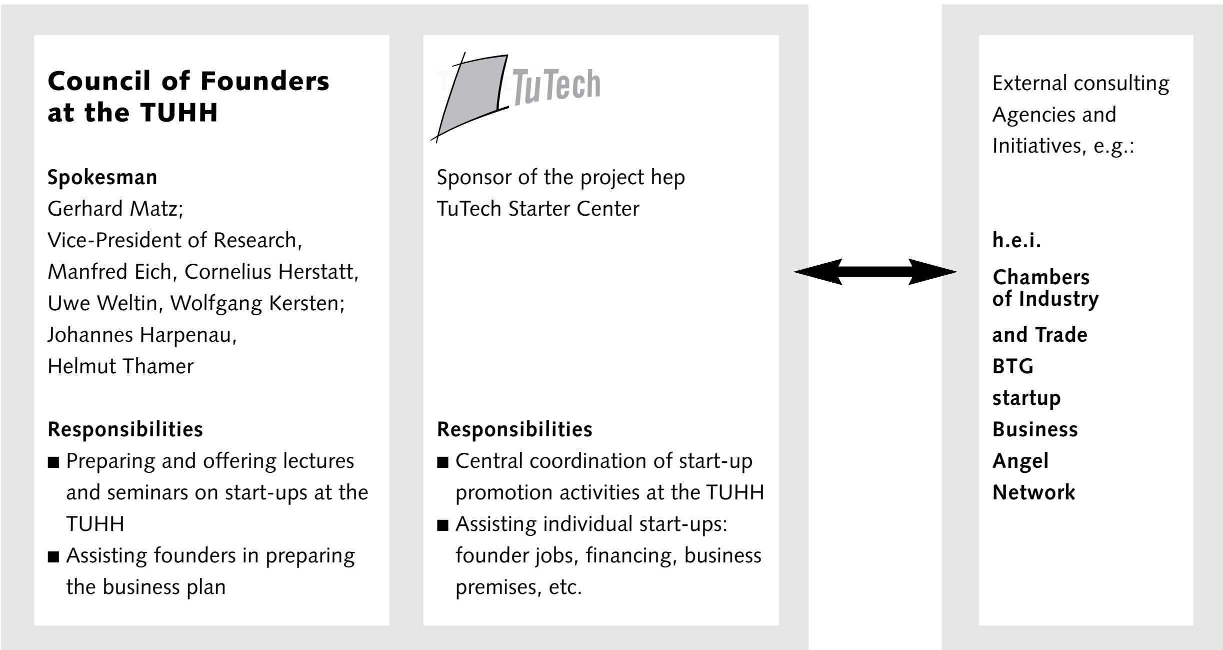


Fig. 2
The founders Klaus Dybeck and Ralf Nagel

Successful start-up: Dynatechnik – from research to product design and business establishment

The company Dynatechnik had to do without hep when Klaus Dybeck and Ralf Nagel decided to set up their own business. As scientific assistants of Prof. Hermann Singer they had worked on the DFG projects "analysis of distribution of sizes of microparticles" and "measurement of mass transfer rate in technological processes". These projects were to establish the basic principles for the use of new measuring systems based on the electrostatic charge of particles and their measurable electrostatic induction. Thus, the mass transfer rate and the velocity of pourable solid matter in transport conduits can be contactlessly measured. This new measuring system is applied in filling plants for synthetic granules or fertilisers or for burner control in large power stations heated with powdered coal. The expert knowledge acquired in their research activities and their know-how resulted in an innovative product now marketed by them with the help of six regular employees. But first they had to raise the necessary funds and solicit customers, a tough job in the case of such an innovative product. An initial help was their winning the prize of the German Founders Fund in 1995 – an initiative of Rhone-Poulenc and Impulse. The founders received financial aid in the amount of 35.790,43 € for their innovative product. Raising the funds for transforming the prototype into a marketable product proved to be more difficult than expected. They finally succeeded in procuring financial assistance of the Hamburg Ministry of Economics and loans by the Hamburg Bürgschaftsgemeinschaft. With these funds they were able to design a very promising product and to solicit their first customers and distributors.

Their financial funds had to be increased again last year for financing the launching of their innovative product and to establish a marketing network. They overcame that obstacle by working out a mature busi-ness plan with the help of Prof. Sonja Bischoff of the Hamburg University of Economics and Politics who successfully "twinned" the engineers with two students of applied economics. These two did their thesis on preparing a business plan for Dynatechnik. This plan was so sound that the Schleswig-Holsteinische Kapital-Beteiligungsgesellschaft could be induced to invest in the company Dynatechnik. In addition, an internationally operating distributor – Global Weighing Technologies – could be won to distribute one of the product lines. Now, with the financial backing and the help of Dipl.-Kfm. Meerstein, who prepared the business plan and is now a management consultant, the company can expand and, hopefully, market a product based on the research activities at the TUHH.

(Gerhard Matz)

Microelectronics Application Center

MAZ
Mikroelektronik
Anwendungszentrum
Hamburg GmbH

The Microelectronics Application Center (MAZ) – Ideas for conquering the market: 10 years of successful cooperation TUHH-MAZ:

The idea for establishing the Microelectronics Application Center - MAZ - in 1990 by the Free and Hanseatic City of Hamburg, which is still relevant today, was to promote the transfer of know-how from the universities to the business sector in Hamburg and to synchronise industrial requirements with research and teaching activities at the universities. Until the end of 1994 this idea was put into practice by R & D projects executed by MAZ meeting the demands of small and medium-scale companies and financed by the EU and the BMBF.

The management of MAZ was assisted by scientific directors all recruited from professors of the TUHH and the Hamburg University. In the initial phase, the focal areas were digital image processing, digital signal processing, artificial intelligence, ATM technology and ASIC System Design and Test.

To facilitate a close linkage with the academic sector MAZ was located in the vicinity of the TUHH. As of 1995 innovative product and business ideas have ensued quasi automatically from the projects initially focused on pure research by successively including commercial aspects resulting in the establishment of a first subsidiary in 1996. In 1997, the Internet Services GmbH & Co. KG was founded, one of the first internet providers in Germany, that recently – meanwhile merged with the ISION AG – was admitted to official listing at the stock exchange.

In 1998, the company bbcom GmbH & Co. KG was established as a result of the basic research activities of the TUHH in the field of ATM technology meanwhile employing more than 100 employees.

As of 1998 with the development of the New Market and the increased provision of risk capital the MAZ developed into a so-called business incubator, a greenhouse for high technology, having so far “hatched out” nine companies. The income from the sale of shares is fed back into the MAZ via a type of “technology bank” and used for financing new activities. Thus, in the vicinity of the MAZ and the TUHH the Channel Hamburg was developed where many high-tech companies have set up their offices apart from the companies hatched out by the MAZ.

Presently, the MAZ is operating a TUHH start-up and supporting projects of Hamburg University and TUHH. In return, professors help evaluate innovative business ideas and support the activities of the MAZ management by acting as members of the supervisory and advisory boards. Together with the scientists of the TUHH a “market of ideas” is held regularly to develop new basic ideas and visions and to find solutions for technical/scientific problems in dialogue form. The fact that almost all professors of the TUHH have formerly been active in the business sector is particularly helpful.

The close linkage between MAZ and TUHH is illustrated as well by the fact that a former subsidiary of the MAZ, the TC Trust Center GmbH, will provide the money for a professorial chair in cryptology.

The Free and Hanseatic City of Hamburg, as promoter and initiator of MAZ[1], will transfer it to private ownership - presumably this year - to provide talented and enterprising young people from the university with access to the capital market via the “greenhouse MAZ”. And in this context the TUHH will again be of major importance for MAZ: on account of its high practice-related standard of education it is not only a source of new talents but also of new impulses for the new company.

(Michael Lübbehusen, Sören Denker)

1 MAZ is now split up into the private owned MAZ level one company and the c:channel business services company.

Co-operation
with the GKSS Research Center of Geesthacht

The co-operation between the TUHH and the GKSS Research Center of Geesthacht is of strategic importance to both partners. As their respective personnel, technical and administrative structures and resources ideally complement each other, it is possible to develop comprehensive solutions for complex problems; innovative results of basic research may be put to practical use and economic exploitation without delays.

The GKSS Research Center is a mainly application-oriented national research center. It is part of the Helmholtz Association of German Research Centers (HGF) and is located in a near-by town, in Geesthacht. The present research and development activities of the GKSS are focused on:

- materials research: lightweight construction in transport and energy systems
- environmental research: water and climate in coastal areas
- separation and environmental technologies: membranes in process engineering

as well as on the strategic projects:

- biotechnology and biomedical engineering
- neutron and synchrotron diffraction

In 1982, the collaboration between the TUHH and the GKSS Research Center was initiated by a co-operation agreement. Since then it has been continuously strengthened and includes all aforementioned areas of research, in particular materials research. In projects funded by DFG, BMBF and EU, scientists of the TUHH and the GKSS Research Center are working together interdisciplinarily; international seminars, meetings and conferences are jointly organised. In addition, the co-operation is supported by the GKSS university program by which the GKSS Research Center currently spends about 204,516 € each year to finance research contracts with the TUHH.

In the area of materials research, the TUHH and the GKSS Research Center have developed novel materials, such as intermetallic high-temperature materials based on TiAl alloys, since 1984. Based on application-oriented basic research in close co-operation with industrial partners, also the required production and processing methods are developed jointly. On account of these developments, the TUHH and the GKSS Research Center of Geesthacht have built up an international reputation in the area of TiAl materials.

This successful concept – simultaneous development of alloy compositions and of appropriate production and processing methods – will be applied as well to the future development of new polymer materials and light-weight magnesium alloys. The complementary experimental equipment of the TUHH and the GKSS Research Center (including the neutron source of the GKSS research reactor) are being utilised - in co-operation with the application industry - to enable the competitive development of these material types technologically highly interesting for the car industry.

The co-operation with the GKSS Research Center in the area of materials research led to the establishment of the Collaborative Research Center ("Sonderforschungsbereich") "Micromechanics of Multiphase Materials" funded by the Deutsche Forschungsgemeinschaft (DFG) since 1994. This Collaborative Research Center is characterised by a high number of projects (25 %) that are investigated jointly by scientists from the TUHH and the GKSS Research Center. The networking by projects has significantly stimulated and intensified co-operation in the area of materials science.

Thus, the co-operation with the GKSS Research Center resulted in an institutional link with the participation of the application industry to demonstrate the technological exploitation potential of the intermetallic Al_2O_3 composite materials developed in the scope of the Collaborative Research Center. From 1996 to 1999, the institutional link was funded by the BMBF with a total sum of more than € 1,53 million. The obtained research results have been put into practice in bilateral industrial projects and (since 1999) in a joint research project aimed to produce ceramic reinforced die cast components for automobiles (total volume: € 1,94 million).

In the network "NanoMat" (composed of 17 partners of science and industry) established in 1999, scientists of the TUHH are closely co-operating with the GKSS Research Center in the area of nanotechnology to put novel nanostructured materials into practical use. First applications are envisaged for X-ray optics (diffractometry, spectrometry), for hydrogen storage in emission-free vehicles and rechargeable batteries as well as for nanostructured metal-ceramic wear-resisting coatings in mechanical engineering.

The TUHH and the GKSS Research Center jointly initiated the "Hamburg Materials Network", a network of various research institutions aiming at a better communication of research results in joint events. In 2000, these activities were substituted by a "Network of Competence in Materials Technology - Hamburg / Schleswig-Holstein" to give a user-oriented presentation of the R & D activities in the areas of materials development, materials engineering and materials application in Northern Germany. The network includes research institutions in the Metropolitan Region of Hamburg (TUHH, GKSS Research Center, TUHH-Technologie GmbH, University of Hamburg, University of the Federal Armed Forces in Hamburg, University of Applied Science of Hamburg) and research institutions in Schleswig-Holstein (Christian-Albrechts University of Kiel, University of Applied Science of Flensburg, Kiel and Lübeck, among others) and serves as a liaison agency for industry and trade, in particular small and medium-sized enterprises. By net-working the scientific communities to industry, it is intended, on the one hand, to accelerate the process of utilising research innovations for industrial products and, on the other hand, to better assist the industry in Northern Germany in solving complex problems related to materials engineering.

As regards the area of separation technology, the co-operation with the GKSS Research Center extends from distinct projects such as the development of membranes for highly selective separation processes, the plasma treatment of membranes and the development of diaphragm reactors to broader projects related to optimisation of processing technologies. In addition, it is planned to jointly organise the European Membrane Conference in 2004, with preliminary talks already being conducted with the Advisory Council of the European Membrane Association.

In the field of environmental research and technology as well, many co-operations have been initiated and funded by third parties. As of 1998, the GKSS Research Center has participated in the Collaborative Research Center "Treatment of Contaminated Soil" of the TUHH and University of Hamburg. In a three-years research project, the GKSS Research Center is designing a steam stripping process that may be used for decontaminating residues from the extraction of raw materials, in industrial production and treatment of soil. Within the framework of the program "Management of River Drainage Basins" funded by the BMBF and the joint project "Dynamics of Fine Sediments and Mobility of Pollutants in Running, Estuary and Coastal Waters" (co-ordination: research section Environmental Technology of the TUHH), the GKSS Research Center will be responsible for areal measurements and the modelling of sediment rearrangements in groin fields of the Elbe River as well as of the transportation of sediments and pollutants by the tide in the Elbe River. In co-operation with the GKSS Research Center, the research section Marine Technology of the TUHH has developed a standard procedure for determining the erosive properties of cohesive sediments under natural and ship-induced flow conditions. In addition, the TUHH and the GKSS Research Center are working together in the Environmental Technology Center (etc) established in 1999.

As regards the fields of biotechnology and biomedical engineering, the first joint projects dealing with the recovery of new raw materials and active substances from marine resources are being executed. On a long-termed basis it is planned to establish a regional expertise center together with other institutions.

There is also a close co-operation as regards the personnel. Leading scientists of the GKSS Research Center are regularly giving lectures and seminars at the TUHH, and professors of the TUHH participate in the external evaluation of scientific programs at GKSS and are members of the committees of the GKSS Research Center, e.g. they served as members and chairman of the technical and scientific advisory board.

In the area of materials science, three positions have been jointly appointed. The section Materials Technology of the Institute of Materials Research at the GKSS Research Center and the research sections Materials Science and Technology at the TUHH are headed in personal union to facilitate a better co-ordination. An intensive personnel exchange (for short and longer periods) at all levels and joint visiting scientists are to ensure a regular transfer of know-how and a networking of the research activities. Thus, candidates for a diploma and doctor's degree of the TUHH are using the experimental and technical facilities of the GKSS Research Center in preparing their theses.

These manifold collaborations are based on co-operation contracts and framework agreements emphasising the strategic significance of the close and long-termed collaboration between the TUHH and the GKSS Research Center in Geesthacht. It may be viewed as exemplary for a successful co-operation between a university and a national research center. *(Rüdiger Bormann)*

Aviation Research

Cooperation with the EADS Airbus GmbH

In April 2000 was the tenth anniversary of the signing of the cooperation agreement between the former DaimlerChrysler Aerospace Airbus GmbH (DA) and the Technical University Hamburg-Harburg.

With that agreement the TUHH, as a modern research-oriented university, and the large-scale company DA that has played a major role in the technological and economical success of the AIRBUS-program decided to combine their know how and resources cooperating in the following two joint areas of interest to strengthen the position of Hamburg as an aviation center: demand-oriented education of engineers and business-oriented personnel as well as research activities relating to the development of new aircraft technologies by applying broad scientific basic principles and methods to aviation-specific problems.

Key elements of this unique and future-oriented successful public-private-partnership between DA and TUHH are:

- Establishment of the Technology Center of Hamburg-Finkenwerder (THF) as a platform of this partnership
- Setting up the Europe-wide unique study program "aircraft systems engineering" within the Department of Mechanical Engineering at the TUHH and a new research section
- Cooperation as regards advanced training courses.

The amount of investments at the beginning of the partnership and the costs of its long-term financing are proof of its high bilateral significance. Apart from the joint investment expenditure of about € 15.34 million for the THF the TUHH bears the costs for the research section "aircraft systems engineering" and the DA finances a professorial chair for the head of that research section and provides a budget for current bilateral research projects (fig. 1,2).

In the Technology Center of Hamburg-Finkenwerder, inaugurated in September 1994, the TUHH has about 1200 m^2 of test labs, computer rooms, workshops and a research hall at its disposal apart from two floors in an office section.

This space can be used as well for research activities other than aircraft systems engineering that are closely connected to the DA and are especially research-intense. Thus, two research teams with young scientists of the research sections 'polymers and composites' and 'mechanics' are located there. This illustrates the broad range of technological research issues that are objects of the cooperation between various research sections of the TUHH with corresponding development and manufacturing departments of the DA. These research activities may be divided into three areas of research that will be characterised in the following and which simultaneously represent major technology needs in modern aircraft engineering.

Materials technology and structural engineering

Apart from modern, efficient metallic light-weight alloys fiber composites have only found limited application in primary aircraft structures critical for safety purposes and highly demanding of manufacturing processes. The research projects 'Materials Research for CFK (Carbon Fiber Reinforced materials) -Fuselages' and 'Degradation Behaviour of Fiber Composites under Dynamic Stress' aim at designing materials systems for comprehensive, stress-resistant CFK application in line with production requirements or at developing models to describe the failure mechanisms and cumulative damage under dynamic stress of these materials. The findings of prior research activities of the TUHH as to the replacement of conductive varnishes by conductive glass fiber reinforced prepreg systems will be applied in the series fabrication of the vertical tail nose structure as of autumn 2000. The potential and the application limits of multi-layer composite tubes instead of heated steel tubes for fresh water systems of large transport aircraft, such as the airbus, have been researched and evaluated as to their material, design and functional requirements. The German airbus partner plays a leading role as regards this materials application; nevertheless, these examples show the need for and significance of the research activities at the TUHH.

Systems engineering

This most comprehensive and interdisciplinary area of research reflects DA's interests in the airbus program, i.e. to design competitive and superior aircraft and aircraft systems.

In flight control and energy systems research focuses, on the one hand, on how to design higher performance, more functional and reliable system architectures by applying new drive and control principles. Research projects on these mechatronic systems are, for example, low-power electrohydraulic drive units for the control surfaces, secondary controlled hydraulic motors in high lift and other flight control systems, new robust control of surface actuators in aeroelastic environment to influence structural dynamic modes as well as bidirectional electrohydraulic power converters for power and redundancy management of the energy systems in a 'more electric aircraft'.

Another complementary focus are computerised development tools specifically designed for systems engineering, analysis and evaluation: the 'virtual iron bird', a coupled, hybrid simulation system for flight mechanics and systems design, multi body dynamics simulation based methods for synthesis and dynamic analysis of flap system mechanisms as well as research activities on evaluation strategies as regards new systems technologies in aircraft design.

Modern large aeroplanes raise completely new demands on aircraft and cabin systems. With increased cabin comfort, better information and communication facilities on long-distance flights and more sophisticated control of the thermal system 'cabin' the technological requirements to be met as regards the thermal and acoustic situation in the cabin area are increasing. The current research projects in cooperation with the DA "Integrated Aircraft Cooling Systems based on CO_2 as a Refrigerant", "Modelling Heat and Humidity Transport in Cabin Wall Materials" aim at developing improved insulating materials. "Research and Modelling of the Vibro-acoustic Transmission of Aerodynamic Flow Noise through Cabin Wall Structures" establishes a basis for computer based analysis of interior noise. A project to develop system concepts for a redundant and high-performance integrated communication network in the cabin based on ATM (asynchronous transfer mode) technology illustrate the variety and complexity of the problems in this area. A typical example for the application of basic research results to practical problems – in this case in semiconductor technology (measuring techniques) - is the research project "Wire Strain Gauges for Force Measuring Purposes in Cryo-Wind Tunnel"; based on ceramic thin layers a force-sensing device could be designed with high-resolution throughout the entire temperature cycle without any measuring inaccuracies.

Development and production processes / manufacturing technology

Development and production processes have to be flexible, reactive to disposition interventions and controllable as to their quality. This is essential for products of high lead times and quality standards as in aircraft production. Prior and current research and development activities aim at finding solutions for the specific requirements of an aircraft constructor, e.g. quality marks in development and construction, closed data chain from construction to quality assurance and benchmarking, quality management and machine and process monitoring for a flexible manufacturing system. The integration of modern computerised tools, such as graphic simulation and animation, is part of the joint research project "Virtual Reality in Assembly" to make sure from the beginning of the design phase that the specific parts can be assembled and to reduce faults in the assembly process.

Fig. 1
Building of the THF in Finkenwerder, built and used jointly by DA and TUHH

Fig. 2
The research section "aircraft systems technology" has contributed as well to the development of the latest Airbus aircrafts

Summary

As a direct or indirect result of our joint research activities with DA a great number of projects in cooperation with other universities, manufacturers of equipment and semifinished goods or the German Aerospace Center (DLR) have ensued.

The patents granted in connection with these research activities are proof of the innovative character and effectiveness of this research cooperation. Simultaneously, the thus developed network as regards aerospace-related research is a sound basis for the future development of applied research activities at the TUHH. The present total amount of € 4.60 million in research funds from third parties – direct research contracts by the industry and aeronautics research programs – is evidence of a positive development in this sector at the TUHH.

The objective of this research cooperation, i.e. to strengthen the technological basis of the aerospace industry in Hamburg, has been achieved. Future research projects – in connection with the A380 and further aircraft projects – indicate a prosperous expansion of the cooperation between DA and TUHH.

(Udo Carl)

The Center for Biomechanics

Research within Engineering Sciences for Medical Problems

The Center for Biomechanics at the Technical University Hamburg-Harburg (TUHH) and Hamburg University (at the University Hospital of Hamburg-Eppendorf, UKE) was established in 1989 with the objective to enhance the position of Hamburg in research and economy.

The Senate of the Free and Hanseatic City of Hamburg based its decision on the thought that innovations and improvements in surgery and orthopaedics can only be achieved by a close cooperation between clinical users and theoretical and engineering sciences. Since the establishment of the Center experienced physicians have been offered the possibility to work for a limited period of time in a well-equipped technological environment to find solutions for a clinically relevant problem assisted by experts of various disciplines of the TUHH.

The existence of such an institution in Hamburg is of major importance for the standard of regional medical facilities, the quality of implants and the innovative capacity of manufacturers of surgical implants, instruments and devices. Operating techniques and implant materials are being improved, as research activities can draw on the combined know-how of biomechanics, materials sciences, mechanics, computer science, measurement engineering, design and production technologies. Hospitals have access to the latest findings in research and development thus improving the general standard of training of their personnel. Safety, efficiency and quality of new and existing implants will be improved both clinically and technically. To achieve these goals with a reasonable expenditure of time and materials interdisciplinary teamwork of highly qualified experts is indispensable.

By establishing the Center for Biomechanics the partners (TUHH, UKE, Hamburg Ministry of Health and the Berufsgenossenschaft, Hospital for Accident Cases of Hamburg) created an institution of interdisciplinary cooperation between scientists enabling joint use of facilities and devices free of charge and promoting mutual teaching activities. Starting as a joint project of two universities the Center has developed into an association of many scientific institutions. When delegating physicians to the Center the primary goal is to establish a new research area in the respective hospital department that after the return of the physician can be continued with the assistance of the Center.

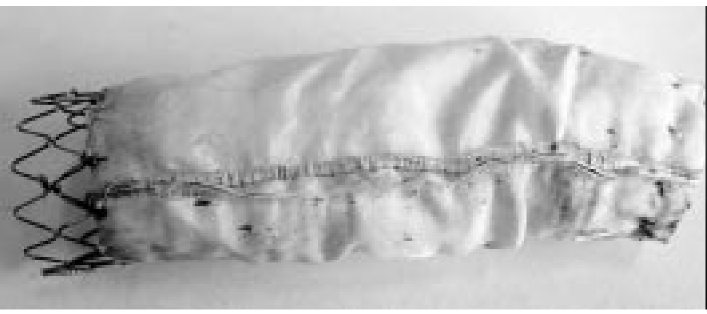
Apart from this basic promotion of innovation existing clinical procedures are subjected to a comparative experimental or theoretical examination. Thus, the Center is engaged both in basic and applied – mainly patient-oriented - research activities on the biomechanics of the supporting and locomotor system focusing on the areas of osteosynthesis, endoprosthesis, prosthetic bypass grafts and biological materials considering, in particular, load capacity, strength, interfacial tension and regulatory mechanisms of implants, bones and other connective-tissue systems.

At the TUHH, a special concept for project execution was introduced: each project is headed by a physician and an engineer the latter being responsible for technical issues and the former for medical aspects. This close cooperation has proved to be extraordinarily effective and didactically valuable.

At the TUHH, the research section 'biomechanics' is responsible for coordinating joint projects with particular tests being carried out as well by the research sections electrical engineering, design engineering, production engineering, polymers and composites, optics and instrumentation, marine technology, automatic control, computer science, industrial ceramics, mechanics, materials physics and technology. At the UKE, the anatomy department, clinic for general surgery, orthopaedic clinic and clinic for dental surgery form the biomechanical research team coordinated by the department of osteopathology (Prof. Dr. Günter Delling).

There are also non-university hospitals cooperating with the Center, above all the General Hospitals of Altona, Harburg and Barmbek and the Hospital St. Georg, a collaboration made possible by the funding of the Hamburg Ministry of Health. The Hospital for Accident Cases of Hamburg also delegates physicians to the Center and accommodates engineers of the TUHH for projects dealing with the specific issues of a hospital for accident cases. There is also a close cooperation between the Center and the Clinic for Joint Replacement (EndoClinic) initiated two years ago.

The team work of medical and biomechanical researchers will be essential, if we wish to solve the multitude of problems we are faced with today:



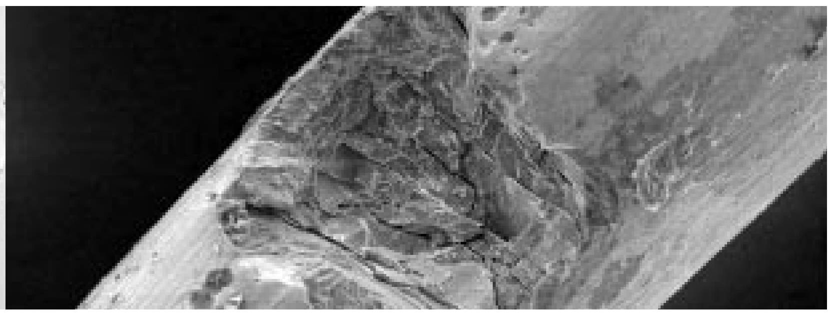
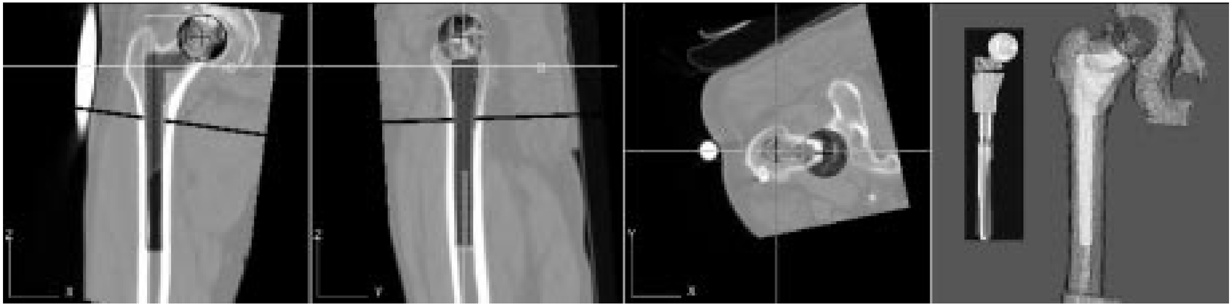


Fig. 1

(On the left) Removed prosthetic bypass graft due to failure

(On the right) Corrosion of a NiTinol wire in a prosthesis. It is not yet clear, whether such defects are responsible for failure.



- Loosening of joint replacements due to osteolysis caused by wear particles (e.g. polyethylene) comprises clinical problems since revision (i.e. replacement) is required. Due to the decreasing age of the patients receiving joint replacements this problem will increase in the future.
- There is a great demand for implants to replace degenerated intervertebral disks.
- In view of the steadily increasing life expectancy implants (endoprostheses, prosthetic bypass grafts [fig.1]) have to be designed that meet these higher requirements
- The introduction of cheap generic prostheses and implants caused by growing cost pressure requires an improved standardisation and quality protection.
- The use of expensive methods (e.g. use of robots [fig. 2] or navigation procedures) have to be justified by quantifiable improvements for the patients.

These few examples represent only some of the vast number of issues to be solved in future. They illustrate as well that many social groups and a great number of people, sportsmen and -women, working people and elderly persons, are all profiting from the activities of the Center for Biomechanics.

(Michael Morlock)

Fig. 2
Determination of the position of the shaft of a hip-joint endoprosthesis in the femur on the planing station of an operating robot for reaming the cavity in the shaft during the operation.

Collaborative Research Center
"Treatment of Contaminated Soil"

In the Federal Republic of Germany there are a great number of contaminated sites, such as former industrial sites, where mainly in the past highly environmental damaging production residues were stored or dumped improperly. Without treatment of the soil and possibly the groundwater or, at least, blocking the spillage of polluting substances into surrounding soil and groundwater these sites are a major hazard and they are not available for diversified use. Soil protection is a task to be awarded top priority.

This subject matter is researched in the Collaborative Research Center (SFB) of the DFG "Treatment of contaminated soil". A great variety of research projects have been executed interdisciplinarily in close cooperation between Hamburg University, the GKSS Research Center Geesthacht and the TUHH as project coordinator. This interdisciplinary cooperation of structural engineers, process engineers, chemists, microbiologists, pedologists, geologists and environmental technologists has lead to an enormous increase in technical know-how, new research approaches and interdisciplinary results.

The SFB was devised to develop the scientific basis for various methods already used, to optimise them and to select the appropriate procedures and devices for the respective applications. In addition, new processes were to be developed focussing on biological processes and their possible combination with chemical and physical methods.

To achieve these goals it was necessary to optimise, above all, analytical and measuring techniques to be able to determine the degree of pollution, to establish limits and to quantify the degree of successful treatment. In this context, the research activities on treatment goals are relevant as well. To define them, balances of pollutants have to be drawn up, ecotoxicological limits have to be defined and the pollutant availability of micro-organisms has to be quantified.

The problem-solving procedure used can be divided into four phases. In the first phase, types of soil that had been artificially contaminated by oil were analysed. This approach was considered appropriate, as the variety of soil structures and contaminations does not allow universally applicable treatment procedures. Thus, methodical procedures for the treatment of soil were to be developed. In the second phase, various soil types contaminated by other substances, in particular by polycyclic aromatic hydrocarbons, were examined. During the third phase, the research activities were extended to actual contamination, both by organic and non-organic substances. In the fourth phase, treatment procedures were developed, optimised and extended. Apart from soil contaminated by organic and inorganic substances soil of mixed contamination was treated. The development of procedures was done practice-oriented and with a view to minimising costs. Apart from mechanical, chemical and thermal treatment processes biological treatment processes were of major importance focusing on how to improve the bio-availability of the pollutants found in the soil. Other aspects researched were geological conditions to gain insight into the efficiency of the processes taking place. All research activities were accompanied by thorough and efficient chemical analyses focusing on improving and extending rapid methods of analysis, on defining treatment-relevant guiding parameters and on issues of mobility and establishing pollutants with regard to the matrix of humic matter in the soil.

Section A
Development of
chemico-physical processes

Section B
Development of
biological processes

Section C
Fundamental principles and evaluation
criteria for processes

Section D
Scientific fundamental principles
for process development

Central section Z
Central tasks of analytics and administration

Fig. 1
Organisation of the Collaborative Research Center

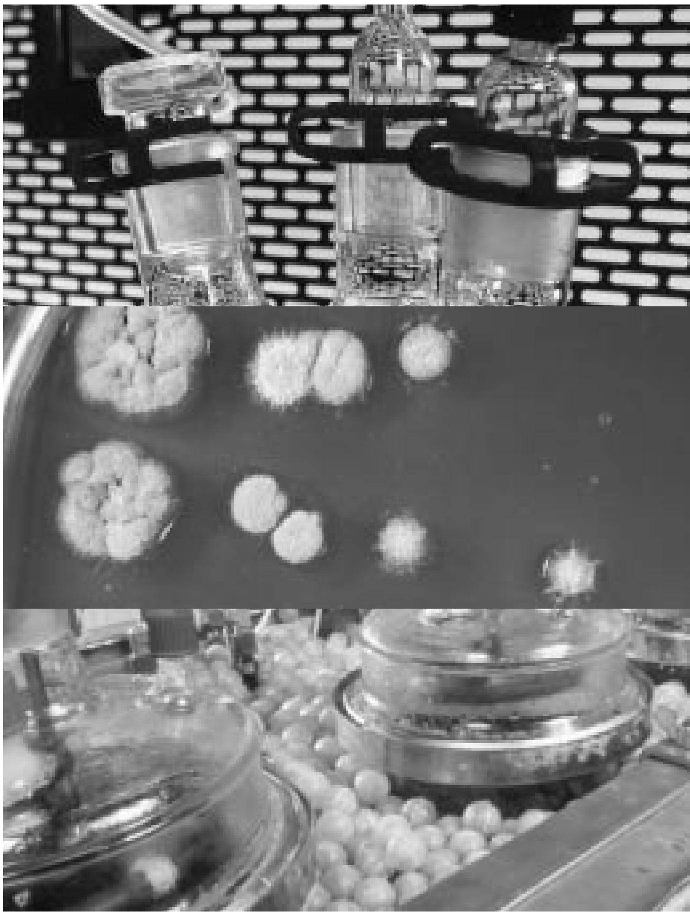
Which results could be achieved? In the sector of biological treatment of soil various procedures for optimising degradation processes and increasing bio-availability were developed. On account of the gaps in the pollutant balances intensive research was done on bound residues. Comprehensive scientific basic principles for wet treatment of soil were established. Thermal procedures were developed for treatment of highly contaminated concentrates extracted by wet treatment of. Procedures for successfully treating soil contaminated by heavy metals are now available. Very extensive research was done in the sector of analysis resulting in findings on measuring accuracy and velocity, on measuring minimal concentrations and on identifying metabolites. The issue of "natural attenuation" of pollutants in the soil was researched as well.

Apart from the gains in knowledge described above some other aspects of that joint research project are worth mentioning. The SFB distinguished itself from the beginning by intensive interdisciplinary collaboration. Working groups were formed jointly researching various issues and coordinating joint experiments. Colloquiums were held regularly. SFB conferences that were always attended by external scientists were held with great success. Workshops (with colleagues from Wageningen, with the DECHEMA, the GBF Braunschweig and the BMBF) as well as the presentation of findings at national and international events and conferences are proof of the successful collaboration.

During the running the Collaborative Research Center received about € 13.29 million in funds from the DFG employing a scientific staff of 51 with three of them receiving an appointment to a professorial chair. A great number of papers were published: 51 dissertations, 244 publications, 117 lectures and posters as well as 109 theses. In addition, four workshops and four conferences were held. The SFB was formally closed by a final conference held at the Technical University Hamburg-Harburg with the participation of international scientists at which the results of 12 years of research were presented.

The conclusion of that project did not, however, represent the end of the interdisciplinary cooperation described above, the know-how developed will be the basis for future research projects.

(Rainer Stegmann)



Collaborative Research Center, SFB 371

"Micromechanics of Multiphase Materials"

The Collaborative Research Center (CRC) "Micromechanics of Multiphase Materials" is a joint interdisciplinary project of the TUHH and the GKSS Research Center in Geesthacht aiming to strengthen the position of Northern Germany in the field of materials science and technology.

At present, seven research sections of the TUHH and three departments of the Institute of Materials Science at GKSS Research Center are involved with a total of 52 scientists of various disciplines working jointly on 16 projects. Since 1994 the CRC has been funded by the Deutsche Forschungsgemeinschaft (DFG) with about € 1,53 million every year.

The research program of the CRC is focused on determining how materials under stress react, how exterior forces are transferred within the micro-structural components, what local forces result thereof and how the materials react by elastic deformation, plastic flow, porosity, cracking and crack propagation. Such issues are of vital importance for process design in the production of semi-finished goods and components, as the safety of critical components has to be guaranteed, in particular when the stress limits have to be upgraded on account of higher technical, economical or ecological requirements.

Technologically, the CRC aims at optimising conventional materials and developing novel materials based on a better understanding of the mechanical interactions between the micro-structural components and their effect on the macroscopic behaviour. Thus, the CRC is contributing to the science-based development of structural materials of advanced performance within the spectrum of properties required: high strength, tough, ductile, light, economical, ecological and reliable. This properties' profile includes partly contradictory materials requirements, therefore the optimisation of the materials structure requires a basic understanding of the micromechanical interrelationships.

The CRC is characterised by focusing, on the principles of micromechanics, locally established expertise at the TUHH and the GKSS Research Center relating to production methods, optimisation and – in particular – application of multiphase metallic and intermetallic alloys, ceramics and polymers.

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The CRC 371 is organised in four project sections including a total of 16 projects.

Project section A

"Microstructure and mechanical properties" was focused on experimental investigations of the relationship between materials microstructure and mechanical properties and, based thereon, establishing the mechanisms of deformation and fracture. These research activities were concluded in 1999. The findings are being used in the new projects of the sections C and D to design special microstructures expedient for technical application by novel manufacturing and processing technologies and to develop structural materials and technical products of advanced performance.

Project section B

"Modelling and simulation" includes those projects focused on micromechanical modelling and modelling of deformation and fracture processes. Based on the specific microstructure, computational models are developed. Numerical simulation of the experiments allows to validate and verify the applied models. There is a close and, in particular, methodical cooperation between all projects including those of the sections C and D.

Project section C

"Microstructural design and processes" focuses on tailoring specific materials microstructures to technical applications by utilising novel manufacturing and processing technologies. Based on the results of section A and B as regards the relationship between material microstructure and mechanical properties, the deformation and fracture behaviour of technical and/or application-related materials is optimised by process engineering. Apart from improved performance of components, low-cost processing and net-shape production processes are envisaged.

In **project section D**
"Applications of micromechanics" the findings of the CRC are utilised for optimising existing and developing novel materials and components by a science-based approach. Practical applications are manifold from endoprotheses in medicine, high-temperature lightweight materials in energy and transport technologies to indexable inserts and wearing protection coatings in mechanical engineering.

The CRC has been planned from the beginning to shift activities from basic research in A and B to application-oriented research in C and D. In the present research period of 2000-2002, this goal is approached by concluding nine projects and starting eight new projects based primarily on prior research results of the CRC and by integrating the sections production technology and electrical engineering of the TUHH into the CRC, thus gaining a more application-oriented profile.

In the past years, a close collaboration of the scientists involved has developed. On the basis of joint scientific issues to be solved and methods to be developed, manifold co-operations between the projects, the research sections involved and, in particular, between the TUHH and GKSS have ensued. An intensive exchange of experience and problems takes place at regularly held events of the CRC (seminars, colloquiums) and at meetings of the task groups (modelling, metal-ceramic materials, TiAl). The co-operative and interdisciplinary manner of working in the CRC is expressed as well in the fact that four new projects are joint projects of various research sections of the TUHH and of the GKSS.

In general, a comprehensive infrastructure is offered by the institutions involved, the TUHH and the GKSS, and has been partly improved by funds of the CRC. In particular, this applies to the processing of materials by powder technology and casting metallurgy, chemical analysis, x-ray and neutron diffraction, micro-structural analysis, light-microscopy, electron microscopy, scanning electron microscopy, mechanical testing and component testing. Modelling is based on extensive know-how as regards computer programs using analytical approaches, FE methods and other numerical simulation techniques. The computing capacity available has been continuously extended.

On the other hand, the CRC has a major impact on medium- and long-termed plans of the institutions involved. The CRC has been a major factor in the Institute for Materials Research at the GKSS playing a key role for the long-termed development of the GKSS into a technology-oriented Helmholtz Center. Thus, the most important new organisational development at the GKSS has been the "Center for Materials Application and Technology (WATZ)" founded in 1996 and the establishment of a third research department "Materials Technology" that are both to strengthen the utilisation of research results for technical applications. Due to the CRC, materials research has become one of the focal areas of research at the TUHH. With regard to education, materials science has been taught traditionally, as part of the school of study "Mechanical Engineering". Within this framework, the research findings of the CRC are directly incorporated in the teaching activities. In addition, a joint seminar is offered titled "Micromechanics of Multiphase Materials". Furthermore, materials science is offered as a module in the new international course of studies "General Engineering Science" for students graduating with a Bachelor of Science Degree. Students may continue their studies acquiring a German diploma in materials science (Diplom-Ingenieur für Materialwissenschaft) or a Master's Degree by taking the international graduate course in materials science (taught in English). The Master's Program is integrated as well in the university courses offered by the newly established "Northern Institute of Technology (NIT)" addressing, above all, foreign students.

In general, six years after its establishment it can already be concluded that the CRC has contributed to promoting local co-operations in materials research, making it a regional focal area of research and teaching activities. In addition, it has become quite obvious that the CRC has given new impetus for the development of materials research and technology in Northern Germany.

(Rüdiger Bormann)

Research Unit
"Submillimeter Wave Circuit Technology"

In September 1998, the Deutsche Forschungsgemeinschaft (DFG) established the Research Unit "Submillimeter Wave Circuit Technology" at the TUHH for a period of six to eight years. It is composed of the research sections 'microwave engineering' and 'semiconductor technology' as well as the two institutes of microwave engineering of the University Erlangen-Nürnberg and the Technical University Darmstadt.

In the first project phase of three years, six research projects are dealt with, four in Hamburg and one each in Erlangen and Darmstadt. The objective of this Research Unit is to make the frequency range of submillimeter waves (extending from 100 to 1000 billion hertz) accessible for technical applications, as it has so far been used only for scientific applications (radio-astronomy). The frequency range of millimeter waves of less than 100 billion hertz is already being used by technical appli-cations, e.g. satellite communications, radar systems for weather watch, mapping of earth's surface, and environmental monitoring, in addition to various industrial and medical applications. Millimeter wave systems are small, light, and suitable for mass production and thus favourably priced. Their electrical properties, such as sensitivity of receivers, effective radius of transmitters, accuracy and resolution in measuring various physical values, are often unparalleled.

The situation is different, however, in the case of the frequency range of submillimeter waves: as the frequency is higher now by one order of magnitude and hence the circuit dimensions are lower by the same order of magnitude, the circuits have to be so tiny that a favourably priced technology with comparably excellent electrical properties is not yet known. There is another major problem, the lack of sufficiently large electrical signal power. Such power should be produced by semiconductor sources, like transistors. As the output of individual transistors is too low, the principle of power combining was proposed more than 30 years ago. The output of many semiconductor sources is added up with the help of a suitable circuit and fed to a single output port of the summation circuit. The known circuit principles, however, do not work in the case of miniaturisation and are thus not applicable to the frequency range of submillimeter waves.

There are, however, many important and also fascinating technical applications in this frequency range: monitoring of terrestrial environment and atmosphere, weather watch and forecast, research of climate – its past and future development, monitoring of ozone layer, applications for controlling robots, communication between satellites, hundreds of which will be installed in a network encompassing the earth for the purposes of mobile radio telephone services, the installation of so-called microcellular communication networks with the individual cells and cell groups being connected by glass fibers and the communication between the base stations of the individual cells and the "mobile stations" being done via radio communication using the high frequencies of submillimeter waves, and numerous other applications.

The basic research activities of the Research Unit are to establish the basis for the future introduction of these applications starting from a brilliant and simple idea conceived by Mahmoud Shahabadi in his Ph.D. thesis at the microwave engineering section of TUHH in 1998 solving the problem of power combining at arbitrarily high frequencies (i.e. for laser oscillators as well). The individual sources are arranged in free space in a matrix scheme, radiating their output power through a transparent dielectrical or metallic grid with the same periodicity as the source matrix. The surface of the grid shows a two-dimensional relief structure with parallel grooves thus combining the power of any number of individual sources to a single beam with combining efficiency of approximately 100 per cent. The problem to be solved then is the computerised generation of this structure which cannot be attacked by any of the known methods of electromagnetic theory. A solution is offered for the first time by the aforementioned Ph.D. thesis, which on account of its extraordinary creativity and future technological impact was awarded the "Price of the North-German Metal and Electrical Industry for 1999".

Based on the idea described above, the Research Unit is developing a high-quality electrical circuit technology for the frequency range of submillimeter waves suitable for mass production at reasonable costs. The measuring and communication systems required in the applications described are all composed of transmitters and/or receivers in which the functions generation of oscillations, their modulation, reception, and processing are all performed by semiconductor devices. These circuits are divided into two parts, into the housings of the semiconductor devices and the so-called passive circuit for forming and influencing signals. At the TUHH, both parts of the underlying circuit technology are being researched and developed. Planar multi-layer structures for housing the devices are being designed on the basis of microsystems technology, also referred to as membrane technology. These are super-thin layers with photolithographically defined metal structures for housing and pretuning the tiny semiconductor devices. Their output signals are coupled to the passive circuits in which the various circuit functions are realised quasi-optically with grid structures and mirrors. Thus, oscillators, amplifiers, frequency multipliers, mixers, filters and signal splitters and/or combiners are structured. Simultaneously, some semiconductor devices for this high frequency range still have to be developed. This is done by the partner in Darmstadt and in a joint project between the TUHH and the research center of DaimlerChrysler in Ulm. The measuring devices required for circuit design are developed by the partner in Erlangen.

The research activities of the Research Unit will make one of the last unexplored sectors of the electromagnetic spectrum accessible to technical applications. Following from both the research goals and the technical applications, there are many fascinating aspects to be researched by students and engineers. On the one hand, basic issues of an especially high scientific standard in electromagnetic theory, microsystems technology, microwave engineering, circuitry, and microwave measurement techniques have to be researched requiring great creativity of doctoral candidates, who will thus enrich and complete their scientific education on an extraordinarily high level. Simultaneously, there are a multitude of partial projects, which may be dealt with by students preparing their M.Sc. thesis. These projects are challenging and hence especially suitable for acquiring and practising knowledge on design, realisation, or measurement of a component or subsystem. The students can directly put the knowledge and experience gained to commercial use when they enter working life later on. On the other hand, these applications mostly relating to problems of vital impact on our future social and economic development can fascinate young people, in particular, thus helping them to discover the beauty of a discipline researching fundamental principles of engineering science

(Klaus Schünemann)

Graduiertenkolleg

"Biotechnology"

Since 1990 Graduiertenkollegs (Research training centers) have been funded for a maximum of nine years by the Deutsche Forschungsgemeinschaft (DFG) for graduates in natural and engineering sciences offering them the possibility to prepare their doctoral theses within the framework of an interdisciplinary research program under the guidance of several professors. Furthermore, by attending an additional curriculum they are able to acquire profound knowledge in the scientific field they chose for their theses. Interdisciplinarity is an essential goal of the study program.

So far, 38 biologists, chemists and process engineers have obtained a doctorate at the interdisciplinary Graduiertenkolleg (GK) Biotechnology located at the TUHH and Hamburg University. Now, more than 50 per cent of these former graduates are employed in the business sector, about 20 per cent at universities, about 15 per cent in public service and three have set up their own business.

The curriculum developed in the course of the GK with the participation of the doctoral candidates is composed of a course of studies of one semester held in blocks to be taken in the first year of the program. The interdisciplinary structure of the GK is strengthened by regular meetings of the doctoral candidates with the lecturers on excursions and at workshops, at which the work done so far is presented and discussed at least once a year, as well as in seminars held throughout the graduate program. The GK is designed to prepare the graduates for their later professional activities in the sector of biotechnology in which scientists of different disciplines have to cooperate in research activities.

Apart from the two professors assisting them in preparing their theses the doctoral candidates have other experts at their disposal in the GK to discuss and solve problems benefiting therefrom in the interdisciplinary research program

- "Application, characterisation and optimisation of cells and enzymes for the production of bioproducts and in environmental biotechnology" and
- "Optimisation of production, extraction and disposal of bioproducts using enzymes or cells in bioreactors and processing plants.

The GK encourages the students to present the findings of their doctoral theses at scientific meetings and conferences. In the course of their graduate studies each doctoral candidate, on an average, attends at least two conferences at which he or she presents his or her own findings. The quality and originality of scientific results obtained in the GK are further documented by the fact that meanwhile they have resulted in more than 70 articles published in international peer reviewed scientific journals.

(Volker Kasche)

Graduiertenkolleg
"Marine Engineering Structures"

Marine engineering structures are inshore and offshore structures of various types, e.g., dams, oilrigs or platforms. The Graduiertenkolleg (Research training center) is aimed at contributing to the solution of problems arising in marine engineering structures. It was established in February 1995 and is funded by the Deutsche Forschungsgemeinschaft (DFG) for a maximum of nine years.

Eight highly qualified holders of postgraduate scholarships in engineering sciences and mathematics are currently pursuing various related research topics leading to their doctoral degrees. The fellows, graduates from mathematics and engineering, benefit from the ongoing education within the Graduiertenkolleg. The broad area of research enables external members from various departments to participate in the research activities.

Marine engineering encompasses a great variety of areas both as regards the underlying fundamental principals and their application in practice. Hence, the fundamental intent of the Graduiertenkolleg is interdisciplinary and interdepartmental teamwork. Mathematicians and engineers jointly develop new models, establish the mathematical background and translate these models to numerical simulations. This approach is validated extensively by experiments, especially in the area of new welding techniques, measurement engineering and automatic control.

The research activities of the Graduiertenkolleg are focused on the following issues:

- Fluid-structure-interaction in marine engineering
- Dynamic behavior
- Damage identification
- Evaluation and retrofit of damaged offshore structures

These focal issues are interconnected and highly correlated. Progress and success in perception and understanding is only possible through teamwork and joint efforts. For example, the design, construction, testing and evaluation of offshore structures require detailed knowledge of the structure's dynamic behavior and its load-bearing-capacity. Effective mathematical tools are essential for the numerical simulation of real-life offshore structures.

The fellows' progress in research is supported and assisted by customized extensive studies. Selective seminars and lectures either held by external experts from research and industry or by the fellows themselves are offered. Research and teaching activities within the Graduiertenkolleg focus on imparting the following abilities: recognizing system interrelationships, perceiving the "big picture", use of latest computer systems, learning and developing related computing techniques, utilizing state-of-the-art software systems for multiple aspects in construction, material science, damage detection and evaluation, fatigue life analyses and hydrodynamics.

An increasing need for analysis, evaluation and retrofit of off-shore structures is expected within the next few years. In addi-tion, disposal of such structures is an important issue. Therefore, appropriate methods have to be developed and improved thus promoting scientific progress, training highly qualified engineers and strengthening the competitive position of German industry and trade in the field of marine engineering structures.

(Otto von Estorff)

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