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IT Research 2006

Funding Programme for Information and Communications Technology

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Note:
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Preliminary Remarks

1. *By funding IT the Federal Ministry of Education and Research aims to offer motivated researchers at universities and in institutes and companies the opportunity and the means to jointly put their creativity and expertise to work to strengthen Germany's position as a technology location, thus using top-level research to develop innovations which will benefit people and create new jobs. This paper is an invitation to the science and business communities to jointly shape the future of the knowledge-based society.*

2. *When formulating the "IT Research 2006" programme it was important to identify those research topics and areas of innovation in the field of information and communications technology from which Germany could expect to gain advantages, from both the point of view of location and competition, and which would also enable society to shape the dynamism of globalization and the structural change associated with it, taking into account sustainability.*
   Information and communications technology are the key technologies for a host of other areas of innovation funded by the Federal Ministry of Education and Research. Software systems in particular play a crucial role in the fields of production engineering, biotechnology and healthcare research, for example, and are therefore also funded within the corresponding programmes of the Federal Ministry of Education and Research. This aspect was to be taken into account when formulating "IT Research 2006".
   The "IT Research 2006" funding programme is the result of close dialogue between the science and business communities. The individual areas of funding were discussed and set out in concrete terms in numerous workshops and specialist meetings. In parallel with this, goals and issues of procedure which enable research funding to take a new direction were discussed with internationally recognized specialists from the science and business communities. Industry associations, unions and research institutions all took part in drawing up the programme.

3. *"IT Research 2006" is a flexible and open programme which learns as it goes along. The research areas listed are neither complete nor finalized. The development of information and communications technologies is so dynamic that it must remain possible for amendments, such as shifts in priorities, to be made during the entire five-year life of the programme. The results of research establish the preconditions for new technologies and applications which are not foreseeable today. Against this background, the Federal Ministry of Education and Research also intends to continue the dialogue with industry, research institutions and unions during the course of the programme in order to be able to respond promptly and in unison to technical, economic and social changes.*

4. *The implementation of the programme – in the same way as its formulation – will involve concentrating funding from the Federal Ministry of Education and Research on those projects which are expected to have the greatest economic effect. The Federal Ministry of Education and Research will once again be supported in making this assessment by specialist advice from experts in the fields of business and science.*

1 Introduction

Investment in education and research is the basis for growth, employment and social advancement. Research is a prerequisite for Germany's competitiveness on an international level, in particular research in those core areas of innovation of the 21st century (such as information and communications technology) which demonstrate a high market and employment potential, are increasingly penetrating all areas of society and are driving both economic and social change.

The Federal Government laid the foundations for Germany's path into the knowledge-based society with its "Innovation and Jobs in the Information Society of the 21st Century" action programme, which gave priority to information and communications technology in education and research.

In 2000, the Federal Ministry of Education and Research identified the necessary focal points for educational policy in its "IT in Education – Connection not Exclusion" action concept. With the "IT Research 2006" programme, the Federal Ministry of Education and Research is setting the course for research funding in the field of information and communications technology for the period 2002 to 2006.

The goals of IT Research 2006 are as follows:

- To boost the quality of science, research and technological development and expand Germany's role in IT research as an international partner and competitor.
- To establish the basis for the preservation and creation of jobs.

This will involve in particular

- expanding needs-oriented basic research in addition to funding from the German Research Association (DFG),
- bringing together players from companies and public research institutions in order to combine resources and expertise,
- putting research results to economic use as quickly as possible,
- investing primarily in future areas of interest and future markets, thereby giving priority to those innovative research topics which have a good chance of leading to the creation of new, high-quality jobs or the founding of new companies,
- creating a climate of innovation which encourages researchers to remain in Germany or attracts them to Germany.

However, the effects of research in the field of IT go far beyond technical and economic aspects. Information and communications technologies are changing our society, the way we live, learn and work, and how we use our leisure time. They are creating new scope for shaping society, and can, for example, be the motor for improving the quality of our education and healthcare systems, for more effective science, but also for a more efficient and more transparent public administration. Below are some examples:

- High-resolution animated picture transmission is already being developed and tested for both medical training and medical practice.
- Science lives on information and communication. Faster and targeted access to specialist information or high-speed data networks for grid computing and work in virtual laboratories open up new perspectives, not only for science and research but also for how the results of this research are applied.
- The Internet facilitates the fast provision of publicly available information and simplifies communication between individuals and companies, for example communication with public authorities.

We know little about the information society of the 21st century, but one thing is certain: without the development of innovative new products and services by qualified people, Germany will not only lose its ability to compete but also its ability to shape its society. Research and education are the basic prerequisites for this ability. Intelligent, needs-tailored strategies are required for utilizing the results of research. At the same time, the central question today is that of training those people who deal with the new technologies and their applications in their work and everyday lives. This means training young students and young researchers by involving them in research projects at an early stage; however, it also means providing basic knowledge in the field of the new technologies and their multimedia applications in schools and institutions of continuing education, as well as the thorough modernization of the dual training system.

"IT Research 2006" and the "IT in Education – Connection not Exclusion" action concept do not just complement each other therefore, they are mutually dependent. The fact that there has been a shortage of IT experts since the mid-1990s shows just how strong this interdependency is.

The shortage of IT experts, and in particular of graduate computer scientists, has proved to be a substantial obstacle to the development of, but in particular to the use of, new information and communications technologies in Germany. It is only thanks to the joint efforts of the Federal Government, industry and the unions in the "Alliance for Jobs" and in the "Immediate Action Programme to Cover the Demand for IT Experts in Germany" that it has been possible to gradually overcome this problem.

Advances in information and communication technology are, in turn, dependent on scientific, technical and economic developments and social processes. This is very evident in the example of mobile communications:

- Highly efficient mobile IT systems require powerful, reliable, portable power supplies. The development of such compact, portable power sources is not part of the "IT Research 2006" programme, even though mobile communications will depend considerably on this key technology.
- Regulation and deregulation have a considerable influence on market events, can hamper innovations, but may also accelerate them. For example, the boom in mobile communications in the 90s was very closely linked to the deregulation of the telecommunications markets in Europe.

The digital revolution is by no means over. This gives Germany considerable opportunities to build on its expertise and secure markets. Innovations in the fields of information and communications technologies create new markets, but also help to stimulate the "old economy" in the long term.

As part of its "eEurope" initiative, the European Union has set Europe the goal of becoming the most competitive and most dynamic information economy in the world and overtaking the USA in the field of IT. This programme will contribute towards achieving this goal.

2 The Current Situation in Industry and Research

Framework data on the industry

Between 1997 and 2000, the market volume of information and communications technology grew world-wide by 50 %, from 1,343 billion Euros to 2,012 billion Euros. During the same period, the market volume in Europe grew from 396 billion Euros to 576 billion Euros; Europe's share of the world market for this period remained the same at 29 %.

A further rise in market volume of between 6.5 and 7 % can be assumed for 2002. The significance and dynamism of the information and communications industry in Western Europe is evident from its share in the gross domestic product (GDP), which rose sharply from 4.6 % in 1996 to 6.3 % in 2000.

The economic significance of the information and communications sector in Germany today is already comparable with that of the car industry. At around 10 %, the average growth rate over the last few years is several times the macroeconomic growth rate. Companies in the field of information technology and telecommunications saw an 11 % increase in turnover in 2000. In 2001, turnover in the sector in Germany totalled 140 billion Euros.

Taking the car industry as an example, it becomes clear that information and communications technology provides crucial growth stimuli for other markets. The market for vehicle electronics will grow from its current volume of 18 billion Euros to 31 billion Euros by 2005 (Booz Allen & Hamilton 2001) – a considerably higher rate of growth than anticipated for the vehicle market itself. This means that more than 30 % of the total value added in car production will then be attributable to electronics.

According to information from the industry association Bitkom, around 820,000 people were employed in the fields of hardware, software and IT services in 2000. This does not include the number of employees in the media sector, which is around the same. The Bitkom analysis showed that employment in the IT sector has grown by 10 % compared with 1999 figures. Further growth in employment in this sector is expected in 2002, albeit at a much slower rate. The motors for increased employment in this sector in Germany are the fields of software and IT services in particular. In Germany, the number of employees in these areas totalled around 400,000 in 2001 – almost one in two employees in the ICT sector. This is almost double the number in 1996.

By comparison: An average of approximately 746,000 people were employed in the German car industry in 2000; they achieved a turnover of approximately 185 billion Euros. The ICT and the media sectors are therefore one of the largest employers in the German economy.

The high rate of growth of the ICT market in Germany and its comparatively good position with regard to the scientific basics has enabled Germany to become an attractive location for ICT production and research over the last three years and has been a contributory factor in decisions by leading international companies to select sites in Germany.

This is also reflected in patent activities in Germany. Looking at the applications for patents during the 90s, the field of mobile communications was by far the most dynamic sector; the same can be said for the Internet and data security fields. Germany occupies a good position in all three areas, but must expect increasing competition. The potential to take the lead in individual fields is there and must be utilized.

Despite current moderate growth, the ICT sector continues to be the most dynamic branch of the economy in Germany. The technological and economic potential has not yet been exhausted by a long way. We are therefore only at the beginning of a development which will combine evolution and revolution to an equal extent.

Germany's position in the microelectronics sector

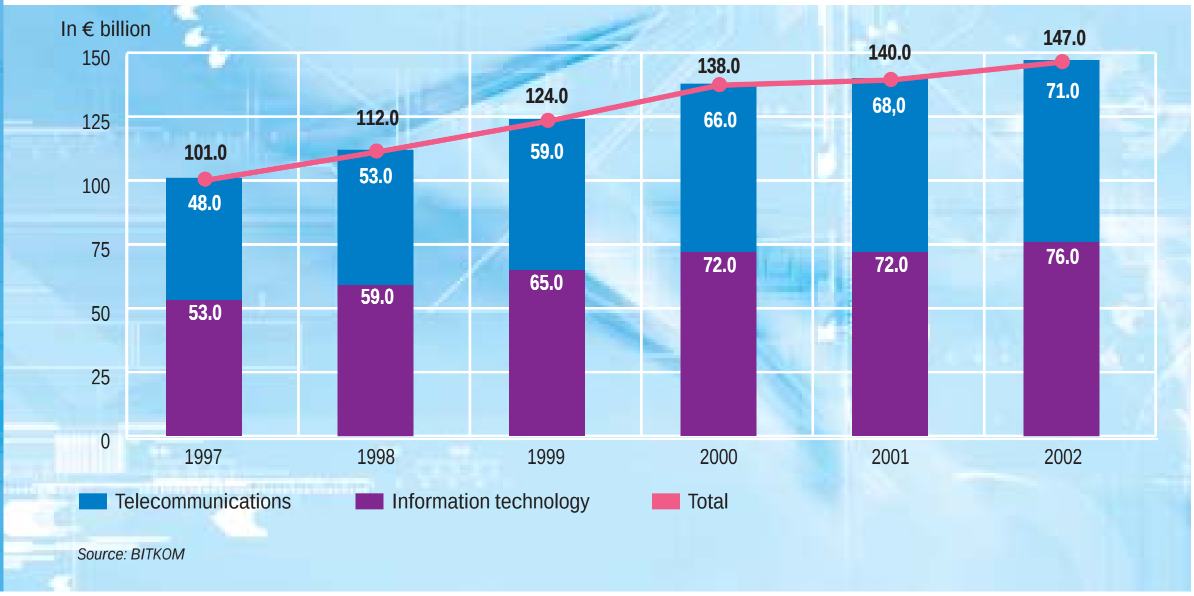
European electronic initiatives such as JESSI and MEDEA have enabled Germany and Europe to assume and maintain a world-wide leading position in selected fields, particularly those important for system know-how. However only a comparatively small proportion of the electronic parts and components required by German industry come from domestic production. Against this background, it must be Germany's aim in the future to acquire an over-proportionate share of further anticipated world-wide growth.

The situation regarding electronics has changed for the better in Germany over the last decade. Thanks to joint efforts on the part of industry, research and the government, Germany has become a internationally recognized partner and driver for the development of semiconductor technologies and chip and system know-how. This is illustrated by the following examples:

- Leading position in the development and use of 300 mm wafers (Infineon, Wacker),
- A host of medium-sized semiconductor manufacturers who are very active in specific markets (e.g. ELMOS, Xfab, PREMA, Atmel),
- Leading supplier for the construction of new factories and clean rooms (Jenoptik / M+W Zander),
- Relatively strong equipment industry consisting of

Figure 1. World market for information technology and telecommunications 1998-2002

Figure 2. ICT market in Germany 1997-2002



small and medium-sized enterprises (e.g. Süss, Wolters, SZ Testsysteme),

- One of the largest microelectronics locations in Europe, in Dresden,
- Important location for foreign investors (e.g. FCM in Freiberg, AMD in Dresden, Melexis in Erfurt, Atmel in Heilbronn, Vishay in Itzehoe, Motorola in Munich, Philips in Böblingen and Hamburg),
- Leaders in the field of systems-on-chip for specific sectors (automotive, communications, chipcard),
- Leading position in the introduction of new lithography processes (strategic alliance with ASML in the Netherlands),
- Leading player in the field of power electronics,
- Leading manufacturers of semiconductor materials, both in the Si and GaAs fields. Good potential in materials research for semiconductor technology,
- Committed manufacturers of semiconductor and equipment who are active in MEDEA+ and PIDEA and also on an international level in SEMATECH,
- On the whole an outstanding research scene,
- Internationally noted services in the field of wafer reclaim,
- Internationally competitive research in the field of magneto-electronics.

However, some weaknesses are evident:

- less than 50 % of chips in Europe are supplied from domestic production,
- deficit in design methodology for complex application-specific chip systems,
- hardly any CAD industry in Germany,
- too few key patents in Germany,
- deficits in digital circuit technology in the gigabit range,
- deficit in processor technology,
- the gap between the largest and second largest German semiconductor manufacturer is considerable,
- the majority of semiconductor manufacturers are subsidiaries of companies outside Europe,
- share of most German equipment manufacturers in world-wide turnover is insignificant.

Whilst Germany played virtually no part in development activities in the 70s and 80s, the MEGA project and participation in the nationally sponsored Eureka projects JESSI and MEDEA in the 90s resulted in considerable progress. Today this involvement has enabled the German semiconductor industry to be part of the leading group (with all the opportunities that this presents), whose task it is to meet the R&D challenges posed by nanoelectronics.

If DRAM memories were the technology drivers of the 80s, then in the 90s, the key to success was the linking of a user idea with front-end technology. This marked a shift from chip to system. It is here in the field of system technology, a field which has presented opportunities to medium-sized companies in the semiconductor industry in particular, that Europe has been able to gain a lot of ground over the last few years, especially in comparison with Japan. Over the next decade, the automation of system-oriented design will be another major aspect of nanoelectronics, as will the mastering of the technology and system knowledge. One factor that cannot be overestimated for economic success is the ability to design chip systems with billions of transistors quickly, effectively and without faults.

Developments in electronics have a dynamism that has never been seen before in the entire history of the industry. This is manifested in the two-figure growth rates in turnover and

- a drastic reduction in unit prices,
- a sharp increase in complexity and performance capability,
- a reduction in energy consumption,
- a considerable increase in R&D and production expenditure, and
- a shortening of life cycles

notwithstanding the cyclical peaks and troughs which are typical for the sector.

Electronics are approaching a turning point in their development: We can already foresee a time in their largely evolutionary development when electronics will reach the limits as far as any further structural miniaturization is concerned. One way around this could be to introduce new innovative ideas from the field of basic research; another could be to take an integrated approach with regard to mastering technology, system knowledge and design capability.

The simultaneous effects of factors such as the shortening of cycle times and rising R&D costs, or even the penetration of the semiconductor market by other countries, increase the risk for all competing companies. Users demand a cheap, flexible and comprehensive product range which has to be continually renewed and adapted to meet requirements. As a result, there is an increasing trend towards international alliances. In Europe, there is currently MEDEA+, which has a significant German input, and PIDEA for construction and joining technology; in the USA, SEMATECH, also an industry-supported organization, is currently the most important body for setting standards. Co-operation with European, and especially German, partners is becoming increasingly close, as SEMATECH's efforts to set up a European branch (possibly in Germany) make clear. This is evidence that, on an international level, the leading role in microelectronics has shifted from Japan to the USA and to some extent to Europe.

In addition to participation in European projects in MEDEA+ and PIDEA, global co-operation, for example in committees or in research projects, will be of increasing importance for semiconductor and equipment manufacturers. German companies and research institutions are in great demand as partners in this sphere.

Germany's position in the software sector

The information society, with its increasing need for the efficient identification, processing and storage of information, has led to a rapid increase in the number of companies which devise and supply software and multimedia products. In addition to this fast growing primary software sector, the importance of software development is also coming more and more evident in all the secondary software sectors, where software has a growing presence in all processes (e.g. procurement), products (e.g. vehicles) and services (e.g. telecommunications, financial services). Software writing expertise has become the crucial key skill for competitiveness in virtually all sectors.

Germany plays a leading role in individual areas of research; it also plays a leading role in the practical implementation of that research. Examples of sustained success achieved as a result of the funding of software system research by the Federal Ministry of Education and Research include:

- In the 90s, the "software engineering" part of the funding programme sponsored preliminary work for CASE systems; sales of one such system have since reached 24,000. In October 2001, a software expertise network was set up with 7 partners under the overall supervision of the Fraunhofer Institute for Software Engineering in Kaiserslautern; the wide range of SMEs operating in this field will be supported with the help of this network.
- As far as industrial applications of "supercomputing" are concerned, and in particular technical simulation and process simulation, we in Germany are amongst the world leaders, just behind the USA. This is despite the fact that we do not have any computer development activities of our own.
- In the field of "intelligent systems", funding has considerably helped to maintain and create innovative jobs over the last few years, thanks to newly developed systems for handwriting recognition/document processing and autonomous robots.
- Internationally recognized success was achieved in the field of "voice processing" with the key project "Verbmobil", which has since been completed. There were 20 spin-off products from this project alone, 7

companies were founded, 245 new high-tech jobs were created and a total of 900 highly qualified specialists were trained for industry and research. The scientific results of "Verbmobil" produced 800 scientific publications, 238 degree dissertations, 164 doctoral theses and 16 post-doctoral theses. In 2001, "Verbmobil" won the Federal President's "Future Prize".

- The 6 key projects commenced in 1999 on the subject of "Man/Technology Interaction" (one of which, "The Multimedia Workplace of the Future", is sponsored by the Federal Ministry of Economics and Technology (BMWi)) will look at the interaction of people with the computer and other IT systems, ranging from the mouse and menus to direct multimodal interaction by means of naturally spoken language, facial expressions, gestures, haptics and visualization. The projects will be entering new scientific territory and will open up considerable potential for products in the IT industry and other sectors of industry, which are possibly even crucial from a market point of view. The results so far are as follows: 36 patent applications, the creation of 3 start-up companies, the development of 3 spin-off products and 250 scientific publications.
- The German Research Centre for Artificial Intelligence (DFKI), with locations in Saarbrücken and Kaiserslautern, which was set up with project start-up funding from the German government, and which has since been supported with project funding, has so far produced 16 new companies in the highly innovative field of knowledge processing and has created over 590 additional high-tech jobs in companies which work with the DFKI. In addition, former employees and doctorate students from the DFKI have taken up 33 professorships in Europe to date.

Germany has several research institutions of international standing both in the public sphere (e.g. specialist IT departments at universities and non-university institutes of the FhG and MPG) as well as in the private sector. It also has leading expertise in the implementation of research by companies in the primary sector (e.g. software houses) and secondary sectors (e.g. mechanical engineering industry, car industry, telecommunications industry, banks and insurance companies). Further comprehensive expertise can be created and expanded on this basis in Germany.

In many industrial sectors the shift in focus from hardware to software means that software engineering is well on the way to becoming the "production engineering of the 21st century", or to supplementing traditional production engineering.

The widely established ability to efficiently supply or produce software products and software-intensive processes, products and services in the secondary sectors will ensure the creation and maintenance of a host of jobs. This ability encompasses both technological expertise (= software engineering) and workforce expertise (suitably highly qualified software engineers). The past has thrown up some positive examples of these close ties between technical expertise, competitiveness and jobs, such as in the car industry and the mechanical engineering industry. In the Information Age, shortfalls in the field of software engineering would not just put jobs in the primary software sector at risk, but would also particularly endanger jobs in the many secondary software sectors.

The core tasks in Germany lie in the field of embedded systems. In the vehicle sector in particular, this involves bringing individual systems together to form networked systems, and in the near future, a complex network of all IT modules and software modules in the vehicle. In today's vehicle sector, innovative systems such as safety braking systems, energy-saving fuel injection systems, environmentally-friendly combustion, and safety systems such as airbags or online diagnostics systems would be inconceivable without complex software. They require a high level of software expertise. Software expertise will be one of the crucial factors determining whether, for example, the supplier industry in Europe can still be competitive in 5 to 10 years' time. The current trend towards networked functions in vehicles (where, for example, the stability control system does not just activate the braking system but actively intervenes in the engine management system as well) has resulted in a further considerable increase in complexity. Similar situations have arisen in other transport applications such as the aeroplane and the train. Where these so-called "large" systems are concerned, there is such a wide diversity of variants that it shapes the entire development process.

Embedded software is playing an increasingly important role in products manufactured in Germany. For example, almost all technical products contain a significant amount of software. This is particularly so in the case of medical engineering, plant and automation engineering, telecommunications installations and vehicle electronics.

Telecommunications systems are among the most complex man-made products. Not only this complexity, but also the large number of variants and their long service life place high demands on software engineering.

IT systems, and thereby software, form the very basis of the operations of many other sectors (e.g. mechanical engineering, production engineering, medical engineering) and many service sectors (financial service providers in particular, but also the retail industry). Without information technology, these companies would no longer be able to operate. New technologies (Internet, Web) and changing corporate strategies (globalization, acquisitions, company mergers) mean that there is a continual demand for new application systems. These must have sufficient flexibility so that they can be adapted and expanded. They must be designed so that existing standards and off-the-shelf products/components can be used. To achieve this, frameworks must be defined for specific sectors and companies. This will enable a reduction in both production depth and width for application systems without losing the necessary flexibility in these systems. This is the basis for prognoses on the future growth of the software engineering market.

Germany's chances of becoming the leading production location for software in the primary and secondary sectors are good. Whilst the market leaders in system software products (e.g. operating systems) are now primarily outside Europe (particularly in the USA), Germany has a very good starting position where application software is concerned. Germany is able to combine a high level of application expertise and engineering tradition in the secondary sectors, such as mechanical engineering or electrical engineering, and leading production expertise in the creation of high-quality customer-tailored special software solutions with a traditional systems philosophy. If these efforts are successful, and in particular if the ability to produce variants at an assured level of quality is also applied to software components, which are becoming increasingly important, then not only has the ground been prepared for a progressive German software industry, but the secondary sectors concerned can also assume a good position with regards to future competition.

New opportunities for Germany will also result from computer research: In 6 to10 years time, the computing power of the PCs used by the average user at his or her desk will equal that of today's supercomputers, such as those currently used to support the work of large research groups. Looking at initial developments in multiprocessor technology for PCs (SMP nodes), it is foreseeable that PCs and workstations will enter the lower end of the supercomputing range.

The "supercomputer on the desk" will mean the availability of a powerful user-tailored system via a so-called personalized interface. This system will, amongst other things, enable voice processing and speech translation applications to be executed in real-time, preliminary design studies and entire design work to be carried out on the workstation, and simulations up to a certain level of complexity to be run on the PC. Because of the emerging trend towards using the same types of processor for PCs and supercomputers, it is foreseeable that application software will be developed on a sliding scale for a wide range of computers.

The excellent conditions which already exist in the field of speech technology, man/technology interaction and supercomputer applications in Germany mean that a new sector is emerging in German industry.

Implications for jobs in the field of communications engineering and microelectronics

Microelectronics and communications engineering are good examples of how research funding can sustainably strengthen Germany's competitiveness and thus contribute towards safeguarding and creating jobs. Research funding is the basis on which innovative products are developed and subsequently converted into products suitable for the marketplace. The question as to how the results of this research might be translated into products and systems arises early on, at the project selection phase; as a result, this issue is one of the main criteria when deciding on funding.

The relationship between R&D funding and the emergence of a high-tech region with the associated creation of jobs is particularly evident in Dresden's microelectronics district. The 300mm wafer technology, developed jointly by Infineon, Motorola and Wacker, has led to a dramatic increase in productivity in semiconductor manufacturing. This technology was developed in Germany with support from the Federal Ministry of Education and Research and a number of international research partners. The 300mm technology has in the meantime attracted further R&D activities to Saxony. It has thus been possible to strengthen the advantages already offered in the region - traditionally strong technical universities and well-trained specialists. This, in turn, has encouraged leading manufacturers in the semiconductor industry to settle there. In addition to DRAM and ASIC production at Infineon, the processor manufacturer AMD has also settled in Dresden and is manufacturing copper-metallized chips there – the first such production worldwide. As a result of these activities, over 4000 direct jobs and at least a further 4000 indirect jobs have been created in Saxony so far. Dresden has meanwhile become the leading microelectronics centre in Europe.

- **Lucent Technologies, Nuremberg**
  Expansion of the location in Nuremberg over the last 3 years has resulted in an increase in jobs from 1,000 to approximately 2,000. Preliminary funding in the field of optical technologies and networks since 1995, in the funding programmes Photonik (photonic systems) and KOMNET.
- **Osram Opto Semiconductors, Regensburg**
  Construction of a new opto-semiconductor plant in Regensburg with 500 jobs for the manufacture of light-emitting diodes, laser diodes and sensors based on III-V materials such as gallium nitride and silicon carbide. Long-term R&D funding in the field of these new semiconductor materials has created the conditions for this successful business division of Osram.
- **FCM GmbH, Freiberg/Saxony**
  FCM Freiberg is currently one of the world leaders in gallium-arsenide materials, which are required for the manufacture of high-frequency circuits for mobile communications. The BMBF funding of this company's R&D efforts in the new German states has been a significant contributory factor in the safeguarding of approx. 200 highly qualified jobs.
- **Aixtron AG, Aachen**
  Aixtron is currently the world's market leader in manufacturing installations (MOCVD installations) for highly complex semiconductor structures. Many of the new innovative approaches taken by Aixtron have resulted from the company's preliminary involvement in BMBF funding focal points in co-operation with universities and industry. A few years ago, Aixtron built an completely new factory in Herzogenrath near Aachen, creating around 300 jobs.
- **Carl Zeiss, Oberkochen**
  Zeiss has become one of the world's leading companies in the manufacture of precision optics for semiconductor lithography, not least thanks to European co-operative ventures as part of the JESSI and MEDEA programmes. Today, Carl Zeiss employs around 1,100 people in the development and production of optical equipment for lithography and expects to see further substantial growth in employee numbers.

Funding of research-intensive spin-off

Figure 3. Spin-offs

Company	Established/year	Products
VPI Systems GmbH Berlin/Holmdale USA	HHI Berlin, 1998	Software for the planning of optical networks,
u^2t GmbH Berlin	HHI Berlin, 1998	Optical components (high-speed receivers and transmitters)
Epi Nova GmbH, Freiburg	FhG IAF Freiburg, 1999	III/V semiconductor layers for electronic components
TES AG Berlin	FBH Berlin, 1999	III/V semiconductor layers for electronic and opto-electronic components
Lumics GmbH Berlin	Max-Planck-Institute Stuttgart, 2000	Optical components (diode pump lasers)
IPAG AG Duisburg	University of Duisberg, 2001	Electronic components (InP electronics)
m^2kLaser GmbH	FhG IAF Freiburg, 2001	High-performance diode lasers/ laser bars

companies in the field of communications engineering

The number of new companies being set up in the communications engineering sector has increased considerably over the last few years. New companies have been created from existing industrial companies as well as from research institutions. Unlike companies in the fields of information technology and the Internet, which deal mainly with software development or services, new companies in the field of communications engineering are frequently involved in the production of components. The process of setting up a new company is therefore more difficult, because normally it not only involves recruiting staff but also building a production plant. The initial investment in such cases is particularly high since production often has to be carried out in clean room conditions.

The successful companies founded from research institutes over the last three years reflect both basic research (Max-Planck Society) and applied research (Fraunhofer Gesellschaft and Leibniz Association). The jobs created by these new companies are normally of a high quality and, due to the technology involved, have safe prospects for the future.

The Multimedia Gründerwettbewerb (new entrepreneur competition) run by the BMWi has also supported particularly promising research-intensive new companies founded from research institutions.

Funding of small and medium-sized enterprises (SMEs)

One of the focal points of the Federal Government's research funding in industry is the funding of small and medium-sized enterprises. The volume of funding for SMEs totalled 569 million Euros in 2000 (1998: 554 million Euros). Approximately 55 % of the funds which the BMBF and the BMWi jointly spend on research and development in industry goes to small and medium-sized companies. By contrast, companies with less than 500 employees and institutions for joint research only account for around 15 % of industry's own R&D expenditure. As a result, the Federal Government's funding of small and medium-sized enterprises is disproportionate in comparison with industry's own efforts.

One IT sector where SMEs feature greatly is that of microsystems technology (MST). The number of industrial MST applications and MST products is increasing over-proportionately worldwide. Germany's internationally competitive infrastructure in the car industry, electrical engineering, mechanical engineering and chemical industry offers a favourable environment for the use of microsystems. Here, Germany can secure and build on its excellent current position by continuing to concentrate on these traditionally strong sectors and by simultaneously utilizing its outstanding research results to conquer new markets. The funding of "Microsystems Technology 2000+" by the Federal Ministry of Education and Research is being done in parallel to – but closely co-ordinated with - the various areas of the "IT Research 2006" programme. The programme aims to develop new areas of application for microsystems, expand co-operative networks and overcome barriers to innovation (for further details, see: www.bmbf.de).

In addition to the "IT Research 2006" and "Microsystems Technology 2000+" programmes, the Federal Ministry for Industry and Technology is in particular sponsoring the development and testing of multimedia technologies in SMEs (for further information, see: www.bmwi.de). ICT is also one of the main fields of technology in the BMWi's open-technology programmes. The application of modern ICT penetrates virtually all projects (for further information, see: www.bmwi.de).

3 Research Funding: A New Direction

The highly dynamic nature of information and communications technology leads to fast innovation cycles and allows only limited predictions to be made with regard to both technical and economic development. The social effects are also difficult to forecast. The time scales in which technical developments and economic and social changes take place are considerably shorter than the time needed for politics to react. The primary requirement, therefore, is for a policy which encourages adaptability and competitiveness. This has repercussions on modern research funding in particular.

Traditional funding programmes and procedures are only suitable for the Internet age to a limited degree. Innovations processes and market events are often faster than the reaction times of conventional programme planning. Research funding by the Federal Ministry of Education and Research in the IT sector will therefore undergo fundamental reform and will be adapted to meet these conditions.

Hardly any other sector can boast such an international research environment as information technology; only the natural sciences have a comparable international network. The research topics of the future are not just discussed in national committees but at international congresses, workshops and in numerous bi- and multilateral meetings within the specialist community as well as publicly worldwide.

Consistent with this, the main focal points of the various national and international research programmes differ only slightly from each other. However, it is a well-known fact that programmes which are geared towards the same topic do not always achieve the same level of success. It is not only the “what”, but the “how” that decides on the success of a programme.

Attractive research requires above all scientific scope and flexible infrastructures. Competitions of ideas and between research teams should feature highly in IT research, rather than focussing narrowly on methods and topics. Essential criteria for selecting a project are the quality of the project and the expertise of the team. The general basic rule is: Sponsor people not institutions. But there must also be a willingness to support any clusters and networks that form; likewise, there must be the courage to allow the formation of regional focal points arising as a result of these clusters and networks.

Against this background, modern project funding, suitably adapted to the dynamic development of the IT sector, must aim to follow these guiding principles:

- Tailor-made funding tools are required for the individual focal points of the funding programme. Acknowledged experts from industry and science must select and monitor work in the case of strategically positioned collaborative projects. They should not just act as experts, but also as mentors in order to ensure that the agreed goals are adhered to and that the projects can adapt to changing framework conditions.
- The duration of the projects must be adapted to take account of shorter innovation cycles, i.e. a short funding period is required especially where there are no generally recognized roadmaps. Decisions regarding applications for funding must be made quickly – if possible within one month (medium-term goal), especially in particularly dynamic fields such as the Internet and software engineering.
- Effective project funding, in particular by means of strategically positioned attractive projects, so-called “lighthouse projects”.
- Expansion of an efficient research infrastructure.
- More intensive co-operation between industry and science to quickly translate research results into marketable products.
- Small and medium-sized enterprises should be involved in research programmes from an early stage. For young research-intensive, technology-orientated companies, it is vital that they are incorporated in the knowledge network of existing research institutions and funding projects as early as possible.
- Increasing the flexibility of the German science and research system through the further development of its structures in order to maximize the effectiveness of the research resources used. One example are skills networks in software engineering.

In addition, the following points have been given priority for the new IT programme:

- Greater use will be made of trend analyses. In this process, know-how from industry and research is brought together, future scenarios are devised and roadmaps defined on a project level. The aim is to make timely use of the generation change in technologies and services in order to open up (or re-open) markets.
- Entire innovations networks – spanning basic research, applied research and market launch – will be created through interdisciplinary and vertical co-operation. The aim is not to create individual solutions but interconnected solutions involving business processes, contents and technologies (e.g. for IT services). Potential for exploitation will be considered, and companies set up as a result of the research will be supported.
- Intensive use will be made of opportunities for interdisciplinary R&D projects for innovations as well as opportunities to take on-board new research topics in Germany.
- Special consideration will be given to junior scientists; this includes support of junior IT professors and the early involvement of young researchers from universities and other state research institutions in R&D projects in order to facilitate independent scientific work and to achieve the required technology transfer through the founding of spin-off companies.
- Greater involvement of research institutions and companies in international (quasi) standards.
- Research marketing is to become an integral part of the projects so that the benefits of the research for people become visible. Prominent projects will be presented specifically as “lighthouses”.

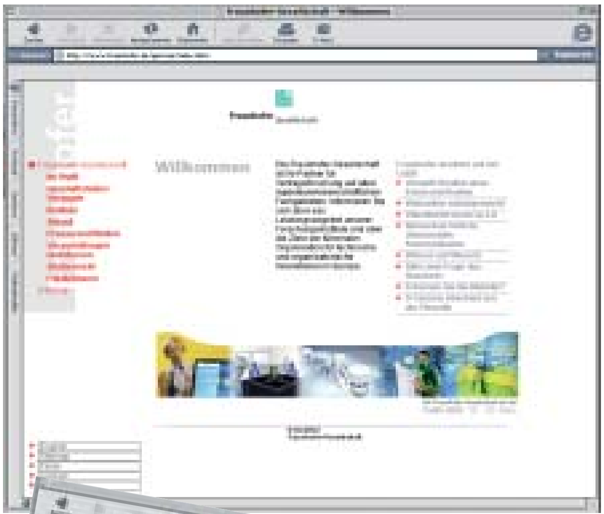
Non-university research: a new direction

- **Merger of FhG and GMD**

New programmes also require new structures in the research landscape. The merger of the IT research groups of the Fraunhofer-Gesellschaft and the German National Research Center for Information Technology (GMD) created the largest European research organization in the field of information and communications technology, with over 2,500 employees and an annual financial volume of over 200 million Euros. It is helping to concentrate and strengthen state-sponsored research in information and communications technology and will lend new impetus to the research base for Internet-specific topics which in the past has been too weak.

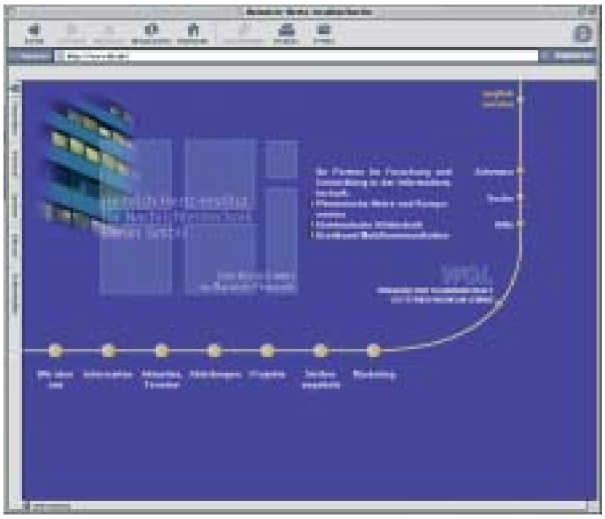
With this step, the Federal Government has created the conditions which will enable Germany to operate at the very highest level on the world stage in IT research. The enlarged FhG has created a unique research environment for information and communications technology in Germany. The strengths and skills of both institutions, i.e. FhG’s logical market-oriented philosophy and GMD’s expertise in basic research, have been successfully brought together in what is now the largest IT research organization in Europe.

FhG and GMD are joining forces in an area that is also expected to stimulate considerable growth in the world economy over the next few decades. The merger of GMD and FhG is therefore making a significant contribution towards safeguarding and creating jobs in Germany – jobs that will have a future.



Heinrich Hertz Institute for Communications Engineering (HHI)

In order to meet requirements and standards for ICT developments, the areas of hardware and software technology research must be brought closer together in the future. Research at the HHI focuses on all the main ICT areas, ranging from applications through system technology for fixed and mobile networks right through to components. These research focal points correspond to work on hardware and software as well as user-related work (human factors). Against this background, the planned integration of the HHI into FhG will serve to strengthen ICT research in Germany even further.



Helmholtz Organization (HGF)

Funding of the Helmholtz-Gemeinschaft (HGF) will also take a new direction. Up till now, the basic financing received by HGF centres has been geared towards the costs of existing capacities. In future, the centres will compete for funding which will be geared more towards topics and goals. International committees of experts appointed by the HGF senate will, in future, assess the programmes and projects presented by the centres. This new system of programme funding will be introduced gradually from 2003. The two research centres, at Jülich (which focuses on new components based on semiconductors and superconductors, materials and coating systems for information memories, supercomputing for scientific applications, electronic communications networks) and Karlsruhe (which focuses on microsystem technology), are particularly active in the IT sector.

International co-operation

In times of globalized markets, there is a need for the greater internationalization of science and research. International co-operation in the field of research will support the close business ties that German companies have with overseas companies. Thanks to co-operative ventures in R&D and the resulting presence and high visibility of German science and research, this international co-operation will make Germany more attractive as a location for production and research. As a result, incentives will be created for investment from abroad. International co-operation will therefore make a significant contribution to Germany's competitiveness.

The increased internationalization of research in the field of ICT and its applications is likely to raise the potential of this area of research to increase the competitiveness of the German ICT industry on the world market even further (in its capacity as a motor for the ICT industry, a sector with enormous growth prospects for the future). Internationalization can make both a concrete contribution, e.g. by expanding scientific networks, and make active use of this situation, e.g. by dividing work on an international level to tackle technological challenges.

The tools available for international co-operation range from the EU framework programme for research, technological development and innovation, a programme initiated within the EU, with the political aim of creating a "European research landscape", through the multilateral framework ventures of EUREKA, COST and OECD, right through to bilateral co-operative ventures, including those based on respective agreements for scientific and technical co-operation and those which have no formal international agreements (e.g. within the framework of bilateral consultations, the funding of bilateral projects, or the setting up of joint or overseas institutions/institutes).

If the intention is for international co-operation in the field of ICT research and its applications to be more strategically oriented, these tools will need to be deployed in a subtly differentiated way; as a result, a varied method of approach will be required that will be dependent on the R&D task in question. In addition to having scientific and technological co-operation established on a firm footing and supported by research institutes and industry, it is also essential for Germany, as a location for science and innovation, to co-operate with the best partners throughout the world and to participate actively in international networks of excellence.

In knowledge-based industrial sectors such as ICT, it is particularly necessary to focus more on bilateral and multilateral strategic projects, which bring together goal-oriented forces, geared towards exploiting results on a work-share basis. An important strategic element are the structures, in the sense of "critical mass", that are created as a result, and which assist the numerous small – particularly in comparison with corporate structures in the USA – companies in this sector in securing a lead in the competition for future technologies. Ultimately, however, international co-operation must be determined by European and national research and economic policy goals.

Co-operative ventures which aim to develop common standards play an important role, particularly in the software and Internet sector. Only those which carry out successful R&D can influence and set standards in the fast developing ICT market. National "go-it-alone" initiatives are less promising in Europe simply because of the small domestic markets there.

In this respect, the MEDEA+ and ITEA programmes, as part of EUREKA, represent initial attempts to use "umbrella" or cluster projects to bring together the national R&D efforts of the individual partners. It is important that this process is expanded further. The so-called "integrated projects" launched under the 6th EU Framework Research Programme are a suitable tool for promoting the goal identified at the beginning – i.e. that ICT research should be strategically placed on a more international footing. It is important to use Germany's advantage (which it has thanks to funding structures that are geared towards networked, interdisciplinary co-operation in projects) to ensure that European research in the ICT sector is aligned more strategically. This also means that German companies and research institutions have to be prepared to take the helm more frequently in European projects.

Considerable strategic significance is also attached to bilateral co-operative ventures outside Europe. In addition to dividing work up within Europe, it is also necessary to establish strategic alliances with other economic and research regions (e.g. the USA), particularly in those areas where roadmaps exist, such as microelectronics (e.g. Sematech). This will enable the necessary critical mass to be achieved and full access to manufacturing depth and system know-how gained and utilized. The same applies to international co-operative ventures with the Asian growth markets, as can be seen from the example of communications technology (e.g. bilateral co-operation with China in the field of mobile communications).

The alignment of “IT Research 2006” with these strategic elements for a progressive internationalization of ICT research - both bilaterally and multilaterally as well as in a European context - will help to successfully transfer products to the world markets using a joint European platform as a base, and will enable Europe to occupy a leading role in this field, along with the USA.

A central tool of this strategy for “internationalization” is the creation and expansion of research networks worldwide. It will be a major challenge for the GEANT project, which is part of the 6th EU Framework Research Programme, to build on the considerable efforts already made by the EU member states in order to create an efficient European research network and link up with the research locations distributed throughout the world and to use the integrative effects of such an infrastructure to promote the strategies of international co-operation.

National research programmes stand to gain a lot through the division of work on an international basis. The “IT Research 2006” research programme is open for international co-operation, jointly formulated and supported by industry and research institutions in Germany.

Criteria for success

The success of a programme can be best assessed or even "measured" in retrospect if verifiable, quantitative goals and assessment standards are established at the very beginning. Although this is hardly a new discovery, only a few (research) programmes in the world fully meet this requirement. The "Innovation and Jobs in the Information Society of the 21st Century" action programme was the first major IT programme in Germany to define quantitative goals. But even this revealed that, in the field of research, it is difficult to define goals which go beyond mere technical parameters (e.g. the development of purely optical networks by 2005) and which might be used as a basis for a meaningful "measurement of success". Economic parameters, such as sector-related turnover, shares in GDP and developments in employment are too unspecific, and are also dependent on too many other macroeconomic framework data as well as on specific developments in individual sectors, some of which are difficult to forecast. Even patent applications and the number of publications and citations can only give a limited idea of the quality of research results and, above all, of whether these can be implemented.

It will also be difficult to measure the success achieved with "IT Research 2006". Primary indicators, such as the number of patents and the number of scientific publications and citations of these, will be used initially in order to measure success, as will the number of spin-off companies founded from the research institutions involved in the programme, insofar as they can be attributed to individual projects or programme focal points.

A sound assessment cannot be based on these indicators alone, however. Only internationally recognized experts who are familiar with the dynamic development of industry and research worldwide are ultimately in a position to carry out an assessment of the programme's success, albeit only a qualitative one.

It has therefore been decided to hold evaluation round-ups at regular intervals as part of "IT Research 2006" in order to determine the current position of the research results achieved. This will enable a ranking of the projects to allow international comparison. The assistance of both national and foreign experts from industry and research will be enlisted for this purpose.

4 Research Areas

Several developments in information technology can already be foreseen today, even if it is still unclear precisely how they should be realized. Focusing on “megatrends” and expected technological developments is just as necessary as the ability to break new ground. At the same time, we should bear in mind the later applications and fund above all those areas of application for which the state bears particular responsibility.

The focus of the “IT Research 2006” programme will be aimed at the “megatrends” that are relevant for research. These include:

- **Convergence**
  The convergence of information, communication and media technologies with networks, end devices, software solutions and applications requires high levels of interoperability, whereby the Internet Protocol (IP) plays an outstanding role as the dominant protocol.
- **Complexity**
  The increasing complexity of IT systems demands new approaches in order to optimize functionality, reliability and security at design level. The trend for increasing complexity has resulted in design processes becoming increasingly mathematical and IT becoming increasingly important.

It will be important to ensure that the internal complexity of the system is not perceptible to users. One feature of IT systems is that they are still not user-friendly, particularly in the case of software-dominant processes and products with more and more functionality. We need new cognitive systems to integrate human and machine communication into applications and services. This includes, for example:

– Improved concepts for human/machine interfaces
– Intelligent autonomous systems, especially assistance systems for the human-being and personalised interaction systems
– New forms for representing and processing knowledge
– A secure Internet.

The development of IT systems and applications on the basis of these “megatrends” requires the availability of key technologies. These include:

– Next generation lithography as a prerequisite for structures in nanoelectronics
– Exploitation of new, physical effects in the transition from microelectronics to nanoelectronics
– Photonics, purely photonic networks from terminal to terminal (transport, switch)
– Intelligent, networked sensor and actuator systems

- Adaptive, universal air interfaces (software-defined radio, hardware and protocols)
- New types of components and architectures to minimize energy consumption
- New types of software architecture for the interoperability of heterogeneous systems and the formation of ad-hoc software services
- New types of methods to reduce complexity, such as aspect-orientated software development, and to acquire a higher level of functional and access security (safety and security)
- New systems of micro-/nanoelectronics, system on chips
- New design methods, such as model-based software development, to quickly convert ideas into usable systems and products.

The provision of new technologies also forms the basis for innovative and knowledge-based services, for example in procurement, customer service or organization, which will become increasingly important in future and will prove to be an employment driver.

The universal topics of security and durability will be given special consideration in all parts of “IT Research 2006”.

The further development of existing research fields and the formation of new ones are closely linked to technological advances which open up completely new perspectives; expected developments include:

- Mobile energy provision
- All-optical data processing (including data transport)
- New types of nanoelectrical components and systems
- New types of materials for sensors and actuators for switching and transmission
- Display technology with new, flexible displays, electronic paper or displays based on polymers (OLED)
- Adaptive software and application architectures, open adaptive transmission systems
- Self-organizing communication networks, broadband mobile networks
- New technical and organizational security concepts
- The development of contentware, context-dependent and personalized content
- New biological approaches to solving IT problems.

The IT research programme will not just fund short- and medium-term developments, but will also consistently support research projects whose technical and economic potential is still difficult to assess today, and which will therefore at best enter our everyday life in the longer term. These include:

- Quantum information processing, quantum structures, quantum computing
- New types of systems for optical processing (such as using photonic crystals)
- Spintronics
- DNA computers, biomolecular and bioanalogous computers, organic computing
- Neuroprosthetics and biohybrid systems
- Automatic generation of software from requirement specifications
- Bottom-up design, from atom/molecule to the system
- Self-organization at molecular level.

It is therefore necessary that results-orientated basic research is also carried out consistently.

The results of more than 30 workshops, expert sessions and consensus discussions with over 300 experts produced the main areas of focus of the “IT Research 2006” programme for information and communication technology:

- **Nanoelectronics and systems**
- **Software systems**
- **Basic technologies for communications engineering**
- **Internet – basics and services**

In particular, one should emphasize the outstanding role of software systems as a key and cross-application topic for all programme areas. Similarly, the programme follows system processes, in which holistic solutions are in the foreground and which require the individual programme areas to be closely networked.

These four programme areas, however, do not describe the whole field of innovation in IT – as was clear to all of the people who participated in the programme right from the beginning. The “IT Research 2006” programme is also effectively enhanced by the “Microsystems Technology 2000+” concept, which broadly covers a central application area relevant to SMEs. However, IT penetrates still further. IT applications are ubiquitous. IT is used and applied in large parts of private, economic and social life without any intervention or support from the state. IT applications require structured state initiatives especially in those fields for which the state is particularly responsible:

- Education / science
- Security / critical infrastructures
- Sustainability / environment
- Health
- Transport / mobility
- Public administration.

Application in the area of "education" is practically unquestionable. Modern information and communication technologies open up new types of communicative and structural options for education, training and further and higher education. With the concept "Anschluss statt Ausschluss – IT in der Bildung" ("Connection not exclusion – IT in education"), the Federal Ministry of Education and Research has already set the course and made a total of 700 million Euros available for the period 2000 to 2004.

Similarly, there is no doubt that the fields of security and durability require special attention from the state, and are important criteria for all parts of the "IT Research 2006" programme.

In order to further develop the knowledge society, it is essential that users have faith in the security of systems and their protection from misuse. The Federal Government is ensuring this by creating suitable legal frameworks. But in addition to legal aspects, such as consumer and data protection, it is also important to enable the technological prerequisites for robust and secure IT systems, since the acceptance of modern IT systems depends on their secure and reliable usability. The Federal Ministry of Economics and Technology has initiated appropriate support activities, such as VERNET (secure and reliable transactions in open communication networks).

The alignment of information and communication technology with the target of durability is crucial for a modern industrial state due to the tremendous economic and ecological potential involved.

Additional important fields of application for IT which directly affect humans and their everyday lives, such as the environment, health or mobility, require an intensive discussion of content design, since changes in society are not just a matter for researchers, science and research institutes – they affect us all. Developments in these IT applications require careful agreement and integration, not just on the part of experts, but also involving a wide cross-section of society. Only this can guarantee that the technical developments that are already taking shape in the laboratories of research institutes and companies will become useful applications for humans. It is the aim of the Federal Ministry of Education and Research to filter out central fields from the large number of possible ones, and to study those areas that can be plausibly researched or influenced. The evolution towards a knowledge society is being shaped jointly together with all socially relevant groups within the framework of the national research dialogue – the FUTUR process. Results which will later become established in the relevant Federal Government programmes are also expected in the field of IT applications.

The following visions are just a few examples of the applications which IT makes possible:

- Continuous and unobtrusive control of bodily functions that are relevant to health
- Biometric security systems
- Safe motor vehicles providing assistance in all traffic situations
- Secure and networked homes
- Simple and secure communication between man and technology.

FUTUR – The German Research Dialogue

In order to remain competitive, we must estimate future developments in society and technology in good time and prepare our country for the future. With the FUTUR research dialogue, the Federal Government has started just this process. We must discuss possible developments in society, which will determine the requirements for research results. From this, guiding visions for research policy can be derived, which can then be realized as part of concrete research projects.

Through research we are creating knowledge to shape the future. Whoever wants access to reliable knowledge tomorrow must ask the right questions today, and provide programmes and funding so that the required answers are available at the right time.

Participation is an important element of FUTUR. The future is too important for us to leave it up to just a few experts. For more information, see: **www.futur.de**

4.1. Nanoelectronics and Systems

The field of electronics produces the highest value-added of all the technologies offered by industry and science in all areas of society. The world market value of electronic components is currently valued at 350 billion Euros. A market volume of 260 billion Euros is expected for semiconductors by the year 2005 (Semiconductor Industry Association, 2002). This corresponds to a yearly increase of 8 %. It should be remembered, however, that this growth is not a matter of course, but a result of intensive research.

A high-tech location such as Germany can only retain its position if it attaches sufficient importance to electronics and its basic technologies, both within its own borders and within an international network, to also ensure a successful long-term development on the market. A wide range of companies are involved in the electronics value-added chain; the number of semiconductor manufacturers, on the other hand, is relatively small.

The semiconductor industry in Germany has only limited potential – at least over the next ten years – to assert itself as a leader in structural reduction. A pioneer role is of considerable importance for the location, since structural reduction ultimately taps the potential for increasing complexity and reducing power consumption, which enable high-level functions in system applications to be realized for mass markets.

The field of nanoelectronics – that is, microelectronics with smaller and smaller functional structures, with a feature size significantly less than 100nm – will enable the realization of almost any types of complex chip systems as functional and indispensable components of new products. These products are aimed not just at today's mass markets, but also at promising niche markets that have the potential to become mass markets of the future.

This means that the public funding of research results has the special responsibility of effectively supporting a technological field that is both research-intensive and, at the same time, has a considerable leverage effect for innovation.

The regularly reworked ITRS Roadmap, the basis for international electronics activities, is "mission critical" for the main stream of development. Every two or three years, the US semiconductor industry association (Silicon Industries Association, SIA), together with the most important "players" in the world's semiconductor industry, draws up a 15-year forecast, the so-called ITRS Roadmap (International Technology Roadmap for Semiconductors) for the development of all important technical, technological and economic microelectronic data. This is then constantly updated. It covers all facets of chip production, from implementing the component structures to packaging and measurement and quality processes.

At the core of the roadmap is the progressive reduction in structure size over the last few years as a basis for all increases in performance in the field of economics, complexity, power consumption and other criteria that are a prerequisite for developing mass markets. Expanding and maintaining a location, however, requires above all the necessary range of available technologies, which are not just based on reductions in feature size, but which must also meet the specific demands of various fields of application. This variety of system requirements is the main source of value-added in the field of electronics.

By providing technologies and processes that are ready to be used, electronics can stimulate the development of a number of technical fields and work with them in many disciplines.

As a technology and export-orientated country, it is important for Germany to carry out competitive research and development in the generic technology of electronics so that it can assert itself among the leading industrial nations in the world. Research funding in decisive, precompetitive – and therefore risky – fields can speed up this process considerably.

Further reductions in structure sizes and the problems that are related to this can often not be solved using evolutionary methods: new ways must be adopted. The Federal Ministry of Education and Research will therefore concentrate on the so-called "roadblockers", that is, on scientific and technical problems that cannot be evaded simply by using alternative technologies, but whose solution is absolutely necessary to achieve given objectives.

- Optical lithography reaches its limits at less than 100 nm – next generation processes are required, which also enable the production of "non-classical" structures (such as quantum mechanical components).
- A reduction in structure sizes and an increase in chip speeds require new materials for conductor paths, new insulating materials with high or low dielectricity constants, new material combinations that are adequate for silicon, and new architecture concepts for components such as transistors or memory cells.

- Controlling, that is, reducing energy consumption and operating voltages through the possible connection of power and information, and combining analogue and digital technology on a chip.
- From components to chips and systems: in addition to integration on the chip (complexity, structures, dimensions, speed), constantly increasing demands on overall performance mean that integration environments must be included – using new organizational and connection technologies, and their combination and interplay with other, non electronic (organic or inorganic) system sections.
- The challenge of almost doubling chip design productivity each year under these extreme conditions is further heightened by the need to take into account increasing interference in switch design, as well as by an increasing heterogeneity of systems and the varied environment in which chips will be used in future. The designer's knowledge of technology, system and circuits will become an important driving force for mastering this challenge.

A significant increase in the speed of development has been noticed in the roadmap for several years now: this confirms the trend of a two-year cycle (previously three years) from one IC generation to the next. At the same time in the field of lithography, the time from the first important publication to market maturity has been halved to 5 years (157 nm compared with 248 nm). Such aggressive further development is increasingly faced with fundamental deficiencies in the field of material and device technologies.

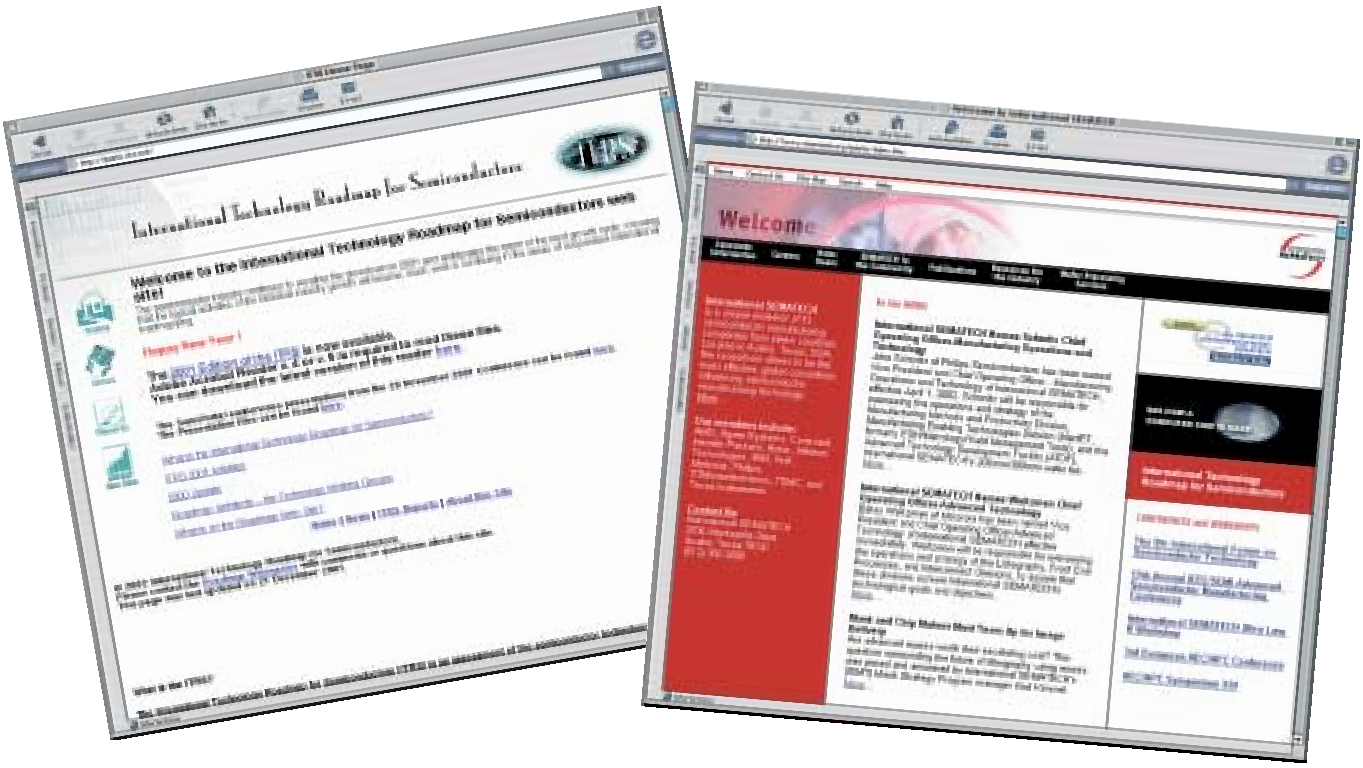
From a strategic point of view, funding must contribute to maintaining the location's ability to compete globally, that is:

- The technological ability of the semiconductor industry to spearhead developments according to the roadmap, and to cover the range of products necessary to lead the system
- The system abilities of the producer and user industry in their products and services
- The design abilities as a pivotal link between the technologies that are available and application-specific system requirements.

Furthermore, we must make sure that this remains the case in future in all of the named areas by ensuring the necessary level of basic research.

Public funding over the next decade is concentrated on the following areas, which help to design and support the expected capabilities of industry and science:

- Technologies and devices for electronic production
- New types of circuits and components
- Chip systems and design methods.



This three-way split considers all developments that are of strategic importance. These can be summarized by “higher performance – lower power”. This objective can only be achieved through successful research in all three areas. The Federal Ministry of Education and Research will concentrate its support within the three areas on those fields and projects from which one can expect the greatest economic leverage effect.

Funding to meet requirements in the area of nanoelectronics should not be merely restricted to the corresponding physical basic research. Depending on the task, relevant research disciplines – such as optics, material research, biotechnology, environmental technology – must be used if added value is to be expected when implementing nanoelectronic applications.

The “roadblockers” that stand in the way of the gradual implementation of this type of complex network today are defined by experts from industry and science as part of “IT Research 2006”.

Nanoelectronics is leading to new types of networks for human beings, both within and with their environment, whose design possibilities cannot yet be imagined. There are fascinating challenges for developments in nanoelectronics. These are challenges in the fields of structure, architecture, components and technologies. They will lead to the success of Germany as a location, providing that German research and industry can continue to co-determine the value-added chain in those areas with decisive know-how both as far as R&D are concerned as well as on the production side. “IT Research 2006” is intended to make a contribution to this by motivating and mobilizing.

“Nanoelectronics” refers to electronics based on silicon, with feature sizes of less than 100 nanometres. Alternative methods are only considered if they have already passed the first technical evaluation level This is shown by the fact that initial plans for the industrial implementation of concrete products are available. Magnetoelectronics and spintronics are currently being considered among the wide range of alternative approaches for future nanoelectronics. This approach applies new knowledge in the field of magnetism to electronics, and is currently the most promising method for enhancing silicon electronics in the medium term. Well-known manufacturers are expecting their first magnetoelectronic products in 2004.

The pillars for funding the field of nanoelectronics are based on the ITRS roadmap. The latest roadmap predicts structure sizes of 23 nm for DRAM components and 16 nm gate lengths for microprocessor technologies. Since a number of predictions have already been made in this area, this forecast should be regarded as relatively uncertain.

Since the semiconductor industry bases its long-term system planning on such trend curves, the trends were always realized in the past. However, over the last few years, it has become increasingly difficult to achieve the objectives set out in the roadmap, not just because of reductions in structure dimensions, but also increasingly because of problems that were regarded in the past as rather peripheral. These include the need to use new materials in the chips, or packaging that is adapted to chip performance.

4.1.1. Technologies and Devices for Electronics Production

Initial Situation

The basic prerequisite for competitive nanoelectronics is a competitive production technology. Research funding is concentrated in particular on the following points:

- Lithography processes for the sub-100 nm area
- Equipment, materials, semiconductor production technologies.

The particular challenges in these areas are:

- Improved utilization of production equipment using intelligent controls, interlinking, entering and processing measurement data
- Reducing masks and other technological steps
- Controlling higher temperatures, higher heterogeneity in the production process of new components
- New device and transport concepts, highly pure materials and so on, for larger and larger wafers with smaller and smaller structures
- Adapted test strategies and processes, new processes for lifetime and reliability tests
- More flexible inclusion of passive components in integration
- Wafer thinness, often linked with 3D integration
- Assembling (wiring, encapsulation) and testing to a large extent parallel at wafer level.

Need for Action and Objectives

Technical qualification is only a sub-goal of research funding. It is important that research partners jointly create favourable conditions for future business and production partnerships in Germany as an industrial location.
Funding is therefore based on the following criteria:

- Strengthening cooperation between component manufacturers, suppliers and equipment manufacturers, and involving efficient research institutes
- Obtaining and expanding leading positions that were achieved with processes and process steps (for example in wafer processing, component escalation, the use of new material systems, online process controlling)
- Obtaining and expanding international positions in the equipment and supplier industry, especially in wafer manufacture and structuring processes, up to next generation lithographies (NGL).

Research Topics

- **Lithography Processes for Feature Size Area up to 70 nm**
  – Research and development into the (presumably latest) optical lithography processes with laser beam wavelengths of 157 nm, expected to be suitable for feature sizes on the chip to 70 nm. Production around 2006.
  – R&D into laser sources, optics including optical materials, exposure devices (steppers), masks, photo finishes (resist) and wafer processes.
- **Lithography Processes for Feature Size Area 50 nm and Below (NGL)**
  – Transition to a completely new generation of lithography processes, suitable down to 30 nm and preferable for 300 mm wafers

Internationally favoured processes: EUV (extreme ultraviolet) processes with a wavelength of 13 nm: longer-term R&D projects in two phases for all process elements (EUV-source, focusing optics, masks, resist, wafer process, steppers, metrology, ...); productive use around 2010.

- **Lithography Processes for the Mask Process**
  – E-Beam (electronic beam) process for mask production and for representing even very small structures on the chip for prototypes and small numbers of items.
- **Innovative Process Technologies**
  – Reduction of mask and technology steps
  – Materials for improved manufacturing processes (liquid chemicals, gases, distilled water, precursors, slurries, semi-finished products for transport containers etc.)
  – Contamination-free process control
  – Continuous online controlling
  – Tests with highly effective test strategies
  – Processes for simulating technology and for modelling the equipment and the technological processes
  – Green Chip & Fab: Economical and environmentally-friendly use of raw materials, closed material cycles, retrieval of process chemicals from waste products, environmentally friendly disposal of waste products, ecological recycling options for wafers and chips.
- **Material and Layer Systems for Sub-100 nm Technologies**
  – Materials which can be found directly in the end product/circuit (material for metalization level, materials with extreme values with dielectricity constants - low and high kappa dielectricity, raw materials for housing and so on).
- **Merging Front and Backends**
  – Achieve optimal component properties in ultra high frequency engineering and power components
  – Transition to (parallel) component completion and tests at wafer level.
- **Third Dimension of Integration**
  – Innovative technologies and test processes to include the third dimension in integration to increase volume thickness, parallelization of signal processes and so on
  – Development of appropriate equipment.

4.1.2. New Types of Circuits and Components

Initial Situation

Milestones in miniaturization have been reached considerably faster in the current ITRS roadmap than in previous versions, whilst memory density has grown rather more slowly. These reductions in feature size below 50 nm will soon lead to initial components that go beyond classic CMOS electronics. This is being enhanced by alternative technologies for new functionality and is able to use or suppress quantum electronic effects.

The roadmaps show that in addition to growing requirements for memory size and computing speed, the exponentially increasing demand for frequencies and bandwidths is becoming an additional driver for cost-intensive research and development tasks, in order to meet the broadly formulated requirements of highest frequencies, memory densities and different memory requirements etc., up to the comparatively high performance linked to demands for energy conservation, loss minimization and minimum costs.

Need for Action and Objectives

The research funding is aimed above all at the following points:

- Super-integrated circuits and systems of silicon nanoelectronics
- Highly complex silicon circuit structures and systems for new application areas
- Magnetoelectronics and spinelectronics
- Components and systems innovation in silicon power electronics.

Particular challenges facing research are:

- Basic and circuit structures for new memory generations up to the 64 Gbit field with high data receipt times and system-on-chip support
- Silicon ultra high frequency circuits with working frequencies of more than 100 GHz
- Innovative basic and circuit structures for information processing (logic) circuits with the highest integration density and the lowest power dissipation
- Implementing highly integrated, persistent memories and logic components
- New types of configurations for merging sensor subsystems and electronic actuator systems with nanoelectronics.

Additional keywords are: Increased transit frequency, reduced parasitic effects, integration of passive components, high block-, low transmission resistance, increased voltage capacity, reduced power consumption, inclusion (improved consideration) of quantum electronic effects, reduction of conductor path influence. There has recently been an increasing tendency to develop new fields that can achieve the character of mass markets in the medium term via the classic fields of application of silicon electronics – such as computer technology, telecommunications, automation technology. These include micromechanical silicon circuits integrated in nanoelectrical circuits, as well as the direct use of silicon micro-chip configurations in chemical reaction technology, in biotechnology or in environmental analytics.

Here too, technological qualification is only a sub-goal of research funding. Alliances are already being promoted along the value-added chain in the field of joint research – particularly at a European level – so that:

- Cooperation between component manufacturers and suppliers is being established in order to enable a swift transfer of knowledge to as many multipliers as possible. Amongst the suppliers are many SMEs, which receive access to new technologies through the joint research.
- Cooperation with users from other branches (microtechnology, biotechnology, optical technologies) enables involvement across disciplines and quick profits from nanoelectronics.

Research Topics

- **Silicon Nanoelectronics**
  - Research into innovative memory cells, configurations and circuits, which are crucial for future developments in nanoelectronics (for example, they considerably reduce access times, non-volatility (Flash/EEPROM, ferroelectrical memories, SoC ability and so on)), including material research linked to nanoelectronics (such as new materials for trench/stack capacities, for bit and word lines and contact systems),
  - Research into new types of interconnections (such as low-loss connecting leads), and packaging (crucial for system performance; suitable for very high clock frequencies),
  - Research into new, silicon ultra-high frequency structures that are capable of integration with new materials which are compatible with silicon (such as Si/SiGe/SiGe:C) HBT, SiGe FET resonance phase transistors,
  - Silicon ultra-high frequency circuits including new types of passive circuit components (passive components MEMS) as well as adequate packaging (suitable for ultra-high frequencies) for mobile and telecommunication,
  - Basic structures that are highly capable of integration (active structures, new interconnections) for logic systems with the potential for system-on-chip

integration (information storage and processing with improved integration functionality, such as mixed lateral and vertical structures),
- Adjusted circuit systems with the particular challenge of low energy consumption (such as new SOI technologies).

Nanoelectronic Components for Lowest Energy Requirements

- Research into the integration ability of basic structures and configurations in the low nanometre area with null- and one-dimensional charge carrier confinement: for example, single (few) electron transistors, quantum wire transistors, RTDs, nanowires and nanotubes, as well as bistable molecular circuits,
- Circuit and link systems of these basic structures, in particular with the aim of enabling highly parallel information processing; interface design and types between these nanocircuits and external Si-microelectronics,
- Research into silicon-compatible, nanometrically structurable materials (such as nanocluster FET configurations) and interfaces for implementing new types of basic structures with electronic functions.

Magnetoelectronics

Magnetoelectronics is a new basic technology whose potential for enhancing semiconductor electronics with new functionality is particularly promising compared with other non-silicon technologies.

- Research into MRAM (Magnetic Random Access Memory): The information, that is, the memory cell bit is represented by the relative magnetizing of the magnetic layer and not, as is the case with DRAM, by the charge condition of a capacitor. MRAM has the same memory density as DRAM, but in contrast to DRAM is non-volatile like Flash memories and as fast as SRAM. The first MRAM products are expected in 2004.
- Research into embedded systems taking into consideration magnoelectronic components to establish a non-volatile logic. In addition, sensors and biochips as well as magnetic couplers can be developed, which are faster than the usual optical couplers. Due to their non-volatility, these systems consume very little power and are very robust thanks to their magnetic materials. This offers prospects for integrated multifunction electronics, especially in portable systems as well as in environments that require robustness.

Spintronics

To date semiconductor electronics only uses the electrical charge from the charge carrier. The current topic of research is a new type of electronics, “spintronics”, which uses the spin from the charge carrier as well as the charge to represent and assess information and which thereby offers new options. Spintronics is based on the possibility of “spin injection” in semiconductor materials which was discovered in 1999. Spin injection makes it possible to create spin-polarized currents in semiconductors, which have an additional level of freedom analogous to polarized light in the form of the spin direction, which can be used as an additional property. Although concrete devices that use this new property are not yet available due to the newness of this effect, varied applications are conceivable:

- Added-value logical concepts based on semiconductors
- Spintronic optoelectronic components to directly create or transform polarized light
- Integration of magnetoelectronic effects in semiconductor systems
- Use of the comparatively stable, coherent quantum nature of the spin-polarized current for quantum logical operations

By 2005, the current exploratory research into spintronics should create the basis for implementing the theoretical application options listed above.

Three-Dimensional Circuit Configurations and Basic Structures

- Research into new types of vertical transistor structures that can be integrated with lowest parasitics
- Vertical integration of circuit sub-systems (such as vertical system integration with thinned chips) with vertical interconnections, in order to increase volume density, parallelization of signal processes etc., and to surpass conventional methods.

Components and Structures with “Embedded Non-electronic Systems” and “Non-electronic Interfaces”

- Research into nanoelectronic basic structures with integrated converters for converting non-electronic sizes into electronic sizes (for example, to directly convert electrochemical potential into control potential for FETs)
- Vertical system integration of nanoelectronic components with microoptical and optoelectronic,

microacoustic, micromagnetic, micromechanic and microfluidic components, for example through "Silicon direct bonding" (SDB)
- Research into system-adjusted, silicon and converter-compatible materials.

Innovative Set-up and Connection Technologies (for Smart Cards and Smart Labels, for example)
- Research into innovative solutions for laminated chips or chips embedded in plastic, and chip systems for mass applications (for example, "intelligent" radio requestable product labels, "Body Area Networks")
- New solutions for reasonably priced set-up and connection technologies for SoP (MCM) systems for general, high temperature and ultra-high frequency applications
- Possible new types of optical inter- and intra-chip connections are being examined.

Innovative Silicon Semiconductor Power Electronics
- With new topologies, improved performance parameters (such as suitability for high temperatures), links with lowest power signal processing and memory electronics, minimized losses (such as the use of nanoscale substructures) and high intrinsic safety
- Research into adequate packaging / bonding materials (such as high temperature-proof packaging materials, copper bonding systems).

Microelectronic Components Based on New Basic Materials
- Such as polymers, amorphous / poly / microcrystalline silicon- or silicon material compounds that are suitable for mass market applications.

4.1.3. Chip Systems and Design Methods

Initial Situation

The chip systems are the real products of the semiconductor industry, which uses them to achieve turnover and sales revenue. On the one hand, they are used to measure the productivity and effectiveness of a semiconductor location; on the other hand, users can stand out from the competition with their electronic systems. Chip systems have an affect on both the systems and semiconductor industry.

Chip design is already one of the bottlenecks and roadblocks that frequently slow down development. On the one hand, a lot of effort is required; on the other hand there are also a lot of opportunities. It is crucially important to recognize the right trends: practically no trend should go unnoticed. Public R&D funding can help the location significantly here.

Europe has an excellent initial position for this application-driven development. German industry leads the way in the field of system architectures (system-on-chip), particularly in the fields of telecommunication, chipcards and the car industry. There are still weaknesses in quickly converting ideas into products. This is often due to a lack of tools, especially for automated chip design. Two approaches are necessary to maintain the leading position in the fields named, to be the first to develop new fields, and to take the lead in further fields:

- Increase design productivity and improve design ability through automation
- Develop new methods for designing chip systems.

These requirements must be met in order to be able to integrate whole systems including sensors, actuators and displays with all their different technical facets on one chip. Ultimately these new and reasonably priced "superchips" meet the requirements for a ubiquitous distribution of electronics.

Need for Action and Objectives

The development of technological options results in new technological and systems-based challenges for developing circuits:

- With the reduction of feature size and the increase in the size of chips, the number of transistors per chip exceeds the billion limit
- Frequency is increasing in areas that require the wave propagation of signals to be considered
- Housing is becoming an important component part and influences function and parameters
- Production cycles in the system area are becoming shorter
- The variety of functions to be integrated is rapidly increasing
- Newer and newer industrial areas are recognizing the uses of microelectronics for their products and introducing new demands on chip systems.

The public funding of chip systems and design methods does not just follow the sub-goal of technical qualification, but also:

- Helps expand Europe's leading position with systems-on-chip
- Develops the innovation potential of new systems
- Stabilizes cooperation between industry and science to quickly convert ideas and results from basic research
- Concentrates and increases EDA (Electronic Design Automation) activities
- Controls design ability right up to designing "superchips".

Wanting to design a "superchip" for, say, the year 2008 using today's design methods is comparable with developing a jumbo jet, from the point of view of complexity and costs. Furthermore, the extremely short cycle times in microelectronics intensify the problem. The research potential of this task is enormous: there will have to be a yearly increase in design productivity of up to 100 % in coming years.

Research Topics

New chip systems are faced with the most varied and in some cases contradictory demands:

- Integration of non-electronic components
- Low energy consumption (low power),
- High voltages and currents for power electronics
- Low voltage and currents for information electronics (low voltage)
- Consider housing and chip as a total system
- Real time software influences chip architecture
- High frequencies (giga technology) and bit rate processing rates up to terabits (terabit systems)
- Drastic increase in reliability.

The challenges of the new decade can no longer be met using previous design methods and internal chip design. Circuit design must become reliable, application-orientated, consistent from the system to the layout and highly automated. Completely new innovative approaches are being sought, resulting in the following tasks:

- **Chip Architecture and Circuit Technology**
  - New digital and analogue chip architectures to effectively use innovative algorithms of signal and data analysis
  - New circuit technologies to reduce energy consumption and to increase processing speed (including high speed CMOS)
  - Sensors, actuators and interfaces between optical signal transmission and optical signal processing for integration in closed systems.
- **New Chip Functions**
  - System platforms to provide flexibly adjustable macroblocks for different application scenarios, as well as to standardize complex systems (including intellectual properties)
  - Integration of previously separate subsystems for applications that point to the future (such as chip systems for i-centric networks)
  - Display technologies to overcome discrepancies between small volume and large images (for example, flat screens, and microlenses).
- **Creation and Handling Chip Complexity in Design**
  - Development of new design methods and steps for handling giga-complexity with its billions of transistors. We must conserve reliability in chip design by developing new and better forms of analysis, synthesis, verification and testing
  - Application-specific design processes to meet different requirement profiles
  - Unification of electronic, optical, mechanical and fluid specification including real-time software, to consider superior systems including local environmental influences.
- **Development of New Technologies**
  - Model formation and new simulation processes, whereby increasingly new physical mechanisms must be included
  - Consideration and possible use of parasitic effects in the design flow or for chip design.
- **Coordinated Company-Wide and International Cooperation**
  - Is necessary with tools and methods to automate design and to be able to increase designability.

4.2. Software Systems

The field of software development in Germany is characterized by high dynamism in an extremely broad field of companies which market software products or conduct software development for their own use. There are a total of approximately 10,500 companies in the primary branch of software development and around 8,700 companies in the most important secondary branches of mechanical engineering, electro-technology, vehicle engineering, telecommunication and financial services.

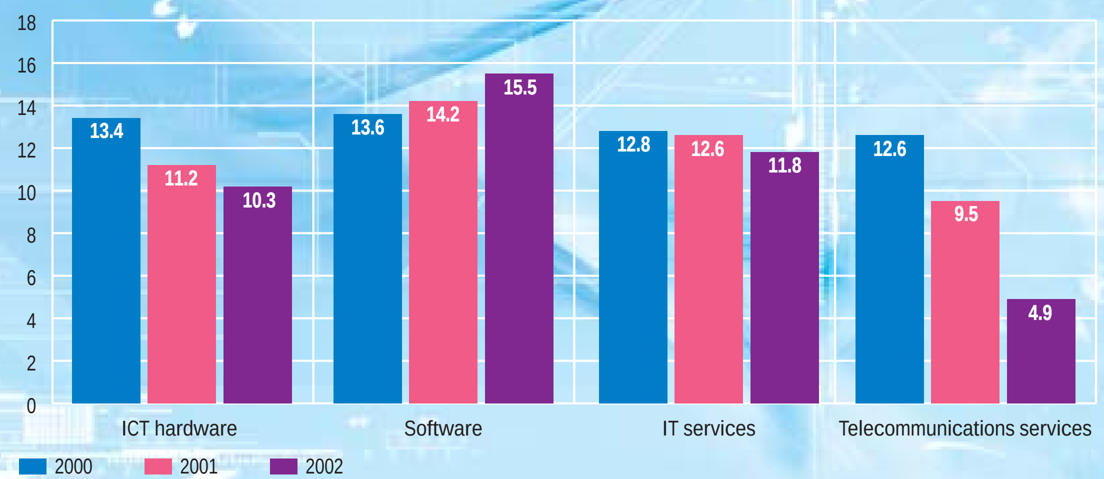
The primary branch is characterized by young companies; two thirds of the companies in this branch were founded after 1990. This also includes many spin-offs set up by employees from universities and research institutes, as well as many software departments hived off by established companies.

In 2001, the German market for software products amounted to approximately 16.5 billion Euros, the European market totalled approximately 57 billion Euros. It has experienced the highest increase compared with other areas of the information and communication technology market. Through software developments or adjustments in the primary and secondary branches, the gross net product in Germany currently amounts to around 25 billion Euros. The market volume of products that depend on software development can be estimated for all primary and secondary branches at approx. 500 billion Euros.

The software landscape in Germany consists essentially of small and medium-sized companies (98 % of the companies in the primary branch have fewer than 200 employees) and the innovation cycles in this area are shorter than in all hardware-orientated areas. Research measures must therefore take these special features into account.

- In general, funding is granted to combined projects from research institutes, universities and commercial companies, especially small and medium-sized companies. Cooperation can also come about from subcontracts from various partners.
- If possible, the starting point of any research project should be a concrete question regarding use, which can be solved by research and development. The user must be involved in the project right from the start, taking the lead if possible, and find a competent scientific partner for the consortium. This should close the current gap between software technological research in IT and software development in technical and non-technical application areas.
- Carefully structured and tight project management is required. The proposal should include a concept for acquiring and transferring know-how. In particular, it should indicate who will have the know-how in documented form at the end of the project (this is generally the task of the research institute).
- The duration of the funded research should take into account the dynamism of the software market, and

Figure 4. West European ICT market according to sectors



Market volumes 2001, € 597 billion.

Source: EITO 2001

cover a period of two to three years. In the case of long-term interdisciplinary, visionary projects, the research may cover between four and eight years.

- In "software engineering", special measures for simplifying the processes are being introduced for applications and their approval (once the complete documents are available). This should mean that the time required for the application and the time required for its approval should not exceed two months in either case – the medium-term aim is to process them within a month in the majority of cases. Tenders for "software engineering" are invited separately.
- To avoid critical situations caused by changes in staff, the amount of work per research group should not be less than 2 person-years (per year) if possible.

4.2.1. Software Engineering

Initial Situation

Software implements functions in products and supports services and all types of operational processes. The ability to develop reliable, adaptable and yet reasonably priced software has become a decisive core competence in almost all industries. In many technical areas software engineering is well on the way to becoming the "production technology of the 21st Century" thanks to the shift in emphasis from hardware to software.

Germany has very good opportunities as the leading production site for software in primary branches of the IT industry (such as software houses) and secondary branches (such as mechanical engineering, electrical engineering, motor vehicle industry, telecommunications industry, banks and insurance). In these areas, a high level of application competence in secondary branches based on a long tradition in engineering can be combined with a leading production competence for creating very high quality, user-adapted software solutions and the special ability for system understanding.

Research funded by the Federal Ministry of Education and Research has been highly successful in the past, for example the development of CASE systems. In future, the core tasks will lie primarily in the area of "embedded systems". It will be important to go from individual systems to networked systems and then to a complex network of all IT modules in a system.

Need for Action and Objectives

Maintaining Germany's position as a leading application software location requires focused efforts in the area of research as well as an increase in the number of qualified research staff. These efforts must be directed both towards top-level staff and towards creating a broader basis.

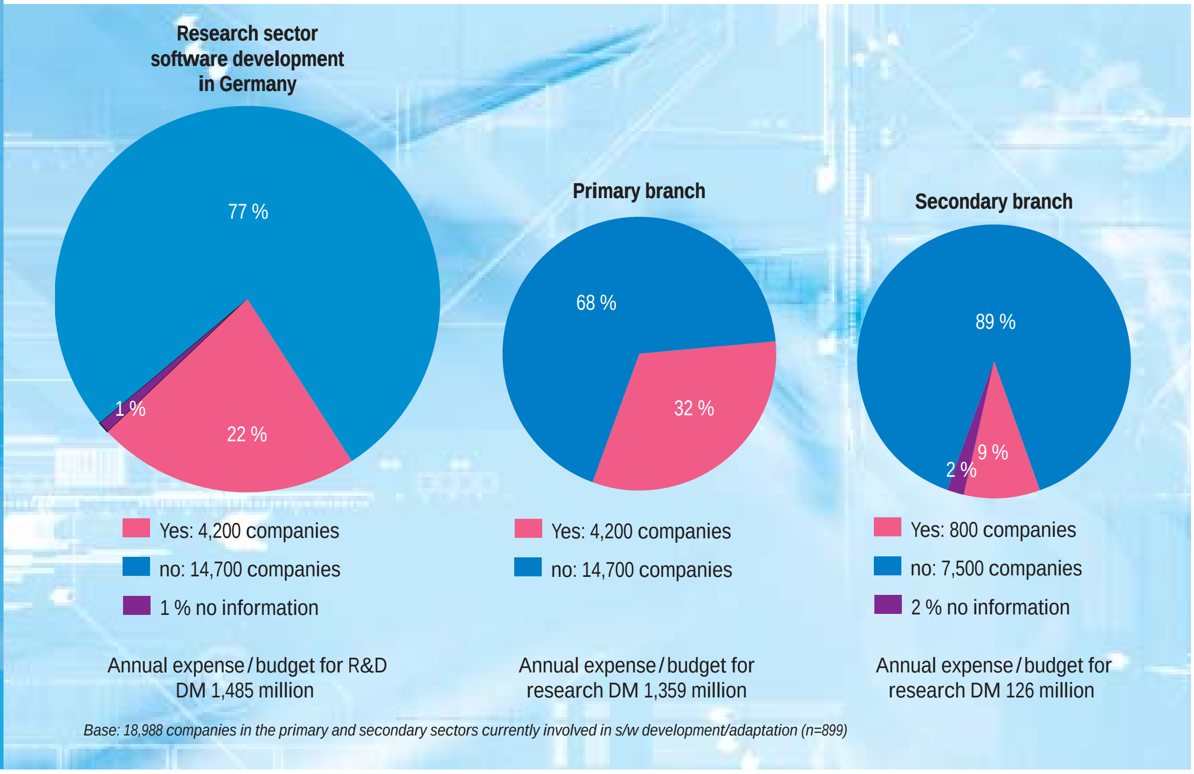
Building on existing research centres, measures must be taken to substantially expand top level scientific infrastructure in the field of software engineering at universities and research.

At the broader based level, we must transfer the latest software technologies to the bulk of German companies (until now only 30 % of companies have implemented

Figure 5. Software and gross net product

Software development contributes approximately DM 50 billion to the gross product	DM billions	Proportion	No. of companies
Gross product 1999 total*	**3,612.62**	**100 %**	**2,738 thou.**
Software development	**50.02**	**1.38 %**	**20 thou.**
Primary branch	37.28	1.03 %	11 thou.
Secondary branches	12.73	0.35 %	
Comparison*:			9 thou.
Agriculture, Forestry, Fisheries	42.77	1.18 %	
Production of goods			—
excluding building industry	890.27	24.64 %	
Commerce, Hotel and			390 thou.
Restaurants, Transport	621.47	16.95 %	
Source: Federal Statistics Office 1999; Base: 19,228 companies (n = 920)			807 thou.

Figure 6. Companies and software development



systematic processes with software development), as well as ensure an adequate number of software developers with different qualifications on a permanent basis.

Productivity in software development must be increased in the short to medium term and at the same time the quality of the software developed must be improved. In addition to the paradigms of software engineering, which predominantly concern the process of organizing performance, the paradigm of "industrial software production", which is focused on providing performance, should also be pushed ahead.

New integrated solutions must be researched and developed for the security of software development and also to secure IT systems.

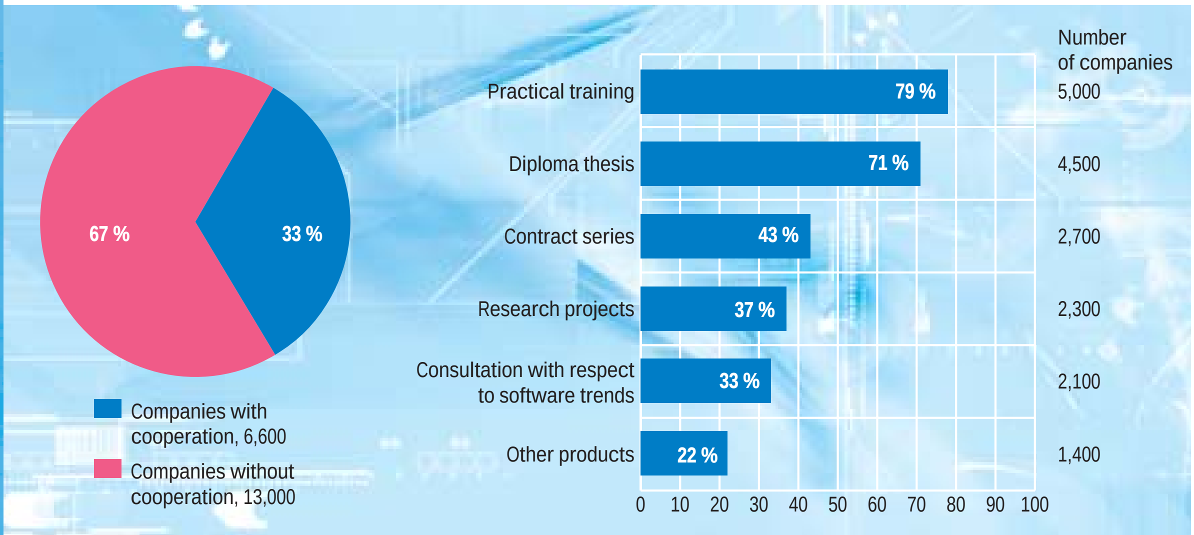
Even today, problems with software development (increases in costs, staff shortages which cannot be solved, expensive faulty developments) have reached dimensions which are of national and international concern. The hardware developments anticipated in the next few years (such as a processor whose complexity is increased threefold) will further intensify the problem. Fundamental new solutions, such as bioanalogous solutions, must be found in order to realize the objective of the reasonably priced production of efficient, robust and flexible software systems.

Research Fields

The following R&D areas should be funded on the basis of concrete questions concerning application/technology:

- **Accuracy, security and reliability of software systems (safety)**
  Processes, methods and tools for improving the quality of safety-critical software and embedded systems and technologies for:
  - Integrating methods of formal programme development (formal specification, transformation and verification, general reference model)
  - Developing verifiable application software components
  - System/software requirements analyses (requirements engineering)
  - Developing real time-enabled software systems.
- **IT Security**
  - Innovative, integrated IT security systems (secure creation, secure installation, secure configuration as well as secure operation of IT systems; protection of personality and trustworthiness)
  - Security with new IT methods/technologies such as ubiquitous computing.

Figure 7. Cooperation between universities and research institutes



Base: 18,988 companies in the primary and secondary sectors currently involved in s/w development/adaptation (n=899), multiple entries possible

- **Increased productivity using component orientation and reuse**
  Processes, methods and tools to increase productivity through:
  – Designing and managing processes to provide quality and productivity
  – Generative programming
  – Developing component-based software based on durable architectures
  – Systematic creation of rational software variants (product-line methods)
  – Re-engineering and maintenance of legacy software
  – Scalability of software in heterogeneous application systems.
- **Development of software systems in (physically) distributed environments**
  Development and specialization of software techniques for the physically distributed production of software through:
  – Process design and process management; adaptive modelling and specification processes
  – Methods based on the division of labour (such as inspections), whose communication requirements enable operation in distributed teams
  – Methods and tools for supporting early creative phases of cooperative system development.
- **Knowledge management in software development**
  Further improvements in communication and the exchange of knowledge between developers through:
  – Methods for knowledge acquisition, storage and transfer in software development
  – Methods and tools for knowledge management in software development
  – Preparing and representing information contents (contentware engineering)
  – Learning systems, self-adapting software systems.
- **Empirical testing of technologies, methods and tools for their suitability for various application areas**
- **Testing new processes in software development**
  – Adaptive software systems, proactive software,
  – Aspect-orientated software development, self-administrating software systems, interoperable software.
- **Set up and expansion of competence networks for software technology**

Important Areas of Application

- Man-machine interfaces that are tailored to the user’s requirements (human-centred engineering)
- Heterogeneous network infrastructures with scalable, adaptable performance/interoperability (network engineering)
- Computer-supported modelling, simulation and experiments for “real world” experiments (virtual software engineering laboratories)
- Software in products (embedded software, such as

automobile, mobile communications, avionics, budget technology, mechanical engineering, robotics)

- Software for supporting all types of operational processes (such as production, workflow, procurement)
- Software for supporting services (such as insurance, public administration, healthcare, media, procurement, planning and logistics)
- High performance data processing and transfer of large data sets (data engineering).

4.2.2. Supercomputers and Grid Computing

Initial Position

With funding from the Federal Ministry of Education and Research, Germany has, during the past decade, set up a technical, scientific and organizational infrastructure that is favourable for supercomputing and which is increasingly benefiting the economy. The development of economic applications for supercomputers is (internationally) relatively widespread in the numerical area. Extremely wide-ranging requirements can be expected in the next few years in the non-numerical field. There is still a lot of catching up to do in the field of training.

In future, supercomputers will almost exclusively consist of linked homogeneous SMP nodes (shared memory multiprocessors). As a result, supercomputing is increasingly becoming cluster computing, where the clusters become automatically heterogeneous through successive updates over the course of time. As a result of modern computing architectures, efficient data networks and distributed work and programme organizations, grid computing will play an increasingly large part in High Performance Computing (HPC).

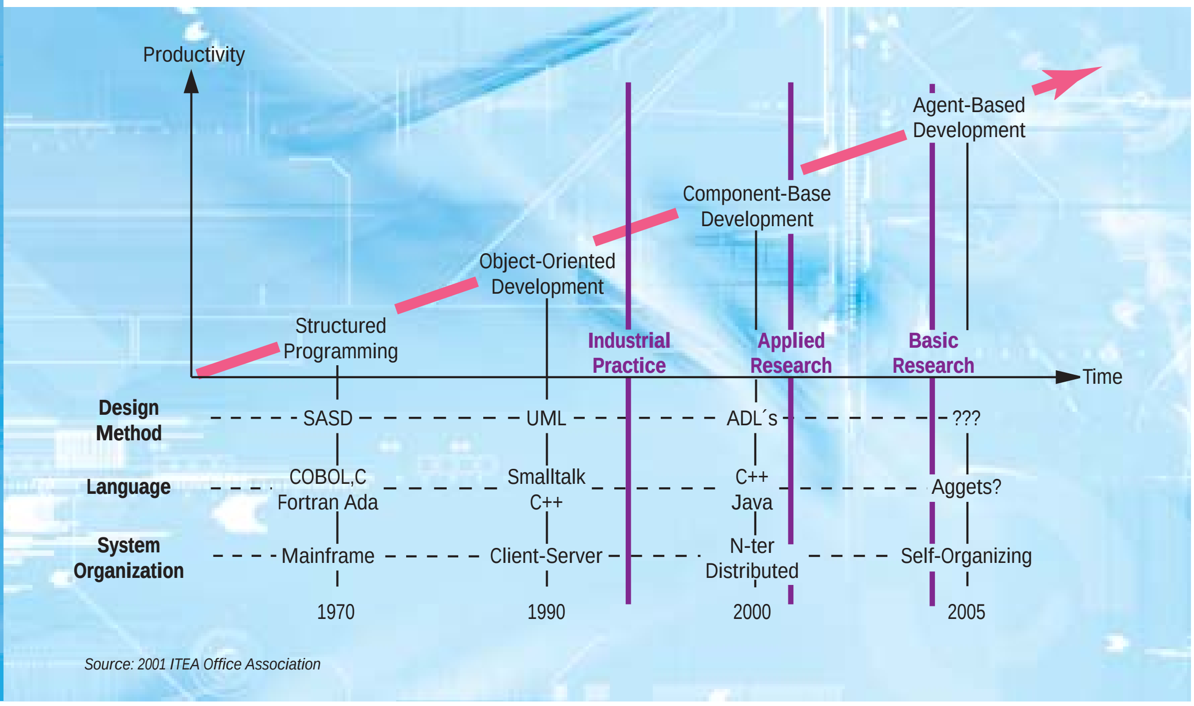
Software for high performance computers in distributed systems is, and remains, a critical resource throughout the world. This affects all areas – from mathematical processes right up to management software in heterogeneous environments. In future, manufacturers will only provide basic components of system software with computers.

In many cases, the results obtained for real application programmes in HPC are up to 80 % below the supercomputer's theoretical peak performance.

Need for Action and Objectives

The targeted organization of supercomputer centres in accordance with the Scientific Council's vote on "Recommendations for the future use of supercomputers" is indispensable for maintaining competence in the high tech area that is important for German science and commerce.

Figure 8. Roadmap; software paradigm change



A dedicated broadband network with guaranteed performance is required in the “high end area” in order to combine German supercomputers and competence centres.

In the absence of its own hardware development, it is of the utmost importance for Germany to stabilize and further develop software competence in HPC by international comparison. Software houses should be increasingly involved in research projects to transform R&D project results into software products. German software products still play too small a role in the fields of HPC and simulation.

Grid technology must be tested in daily, application-related use, not just as a means of demonstrating a principle. An efficient middleware is largely lacking for new application areas. Grid computing is developing equally in the scientific and industrial field, and thus places high demands on the transfer of technology.

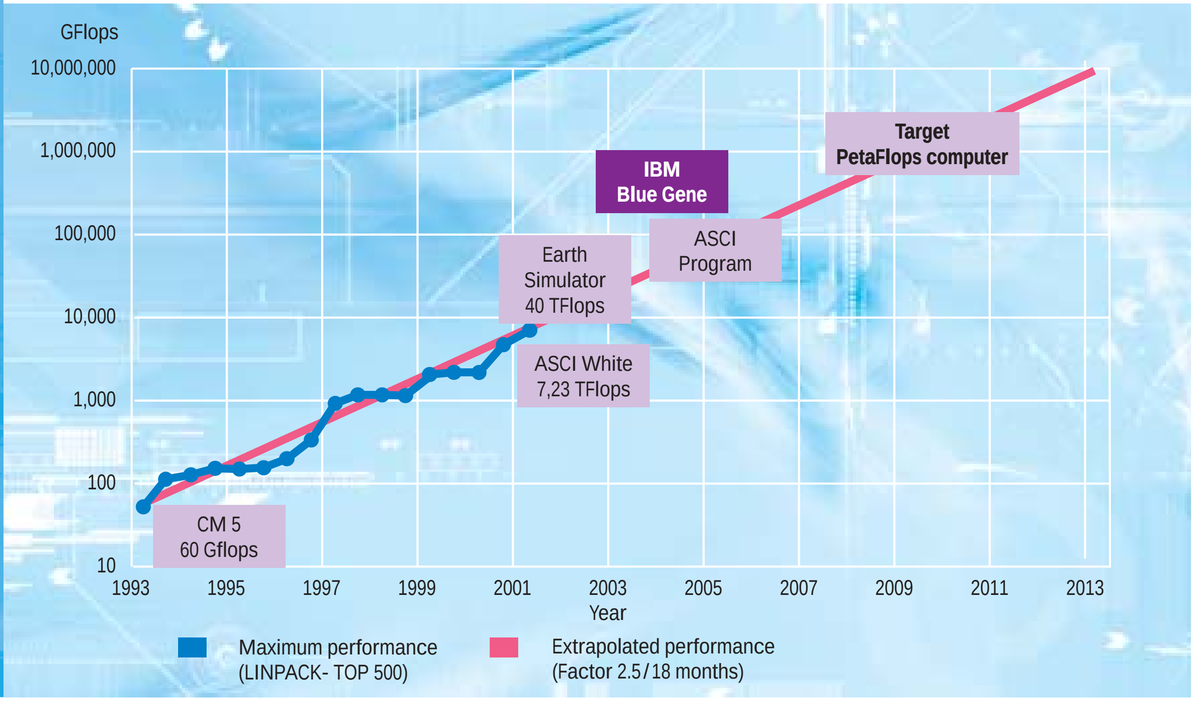
The scientific and user competence that is available in Germany for high performance and grid computing should be bundled and consolidated. Education and training measures will ensure that competence is maintained in the longer term.

In the non-numerical field, broad application areas should be exploited by developing suitable methods and processes (data mining, database applications, intelligent image processing, combinatorial methods and optimization, non-numeric simulation).

Research Fields

- **Numerical methods and stability**
  - It is only partly clear how today’s algorithms operate with 100 TFLOPS applications, that is, extreme numerical simulations. We should therefore examine to what extent mathematical model formation and numerical processes can influence the stability of results. Validation and verification methods are necessary for this.
  - Since the gap between increasing CPU performance and memory access performance is becoming ever wider, methods should be developed to reduce memory accesses.
- **Cluster and grid computing**
  - When programming large cluster systems and for grid computing, standardized programming models, cross-system programming environments, tools for developing and optimizing programmes, software modules for applications as well as new programming concepts for heterogeneous computing (functional analysis, mapping methods to the grid) should be supported. Important R&D tasks will be to examine the architecture of interfaced systems and to ensure the interoperability of cross-system components (integrating different approaches). Furthermore, cluster architectures for real time applications should be examined.
  - Networking high performance computers in supercomputer and competence centres remains one of the most important components of grid computing. Here, software solutions that are efficient and which can be intuitively operated by users should be further developed and established as standard.
  - For the diversified use of the grid, important applications should be made “grid enabled” and should be united with progressive network technologies in order to make grid computing a tool that can be used on a daily basis and to develop its performance potential.
- **Data management**
  - Funding should be provided for the development of efficient management methods for providing and processing large datasets between elements of supercomputers as well as in distributed systems.
  - New efficient parallel data mining methods for text, images, sound files, templates and websites for large datasets and databases should be supported. This includes new system approaches for distributed database architectures with parallel processing.
- **Parallel methods for non-numerics**
  - Reusable parallel libraries of standard optimization algorithms for problems of logistics and production should be developed to make further progress with the use of parallel optimization processes in industry and science, in banking and insurance. Simulation methods for discrete problems such as traffic simulation are also significant.
  - Concerning technical and natural scientific problems, parallel Monte Carlo processes and parallel algorithms for complex computer algebra problems should be supported.
  - Numerical simulation should be combined with non-numerical processes to analyse simulation results (through data mining, for instance).
  - New HPC methods should be developed for the biotechnologies.
- **Reliable high performance computing**
  - Multi-level reliability
  - Technical/organizational concepts and operator models
  - Availability optimization.

Figure 9. Increase in performance forecast for super computers



- **Competence centres, competence network**
  - Existing competence centres for numerical applications should be networked and enhanced with one or two competence centres for non-numerics.

Important Application Areas

- The largest application potential for numerical querying still remains in the scientific field (physics – solid state and multi-component physics, chemistry – molecular dynamics, quantum chemistry, active substances research), in environmental research (ocean currents, pollution) and in engineering and technical questions (flow simulation, structural mechanics, interfacing issues).
- In the non-numerical area, the search for image contents has an enormous application potential. Biological and medical questions are becoming increasingly important.
- Areas of use for database applications are not just commercial (finance and data warehouse), but also in geo-information systems and bio-databases.
- There is a lot of potential for optimization in the area of production and logistics chains.
- There are increasing requirements for widely integrated simulation environments in design and production.

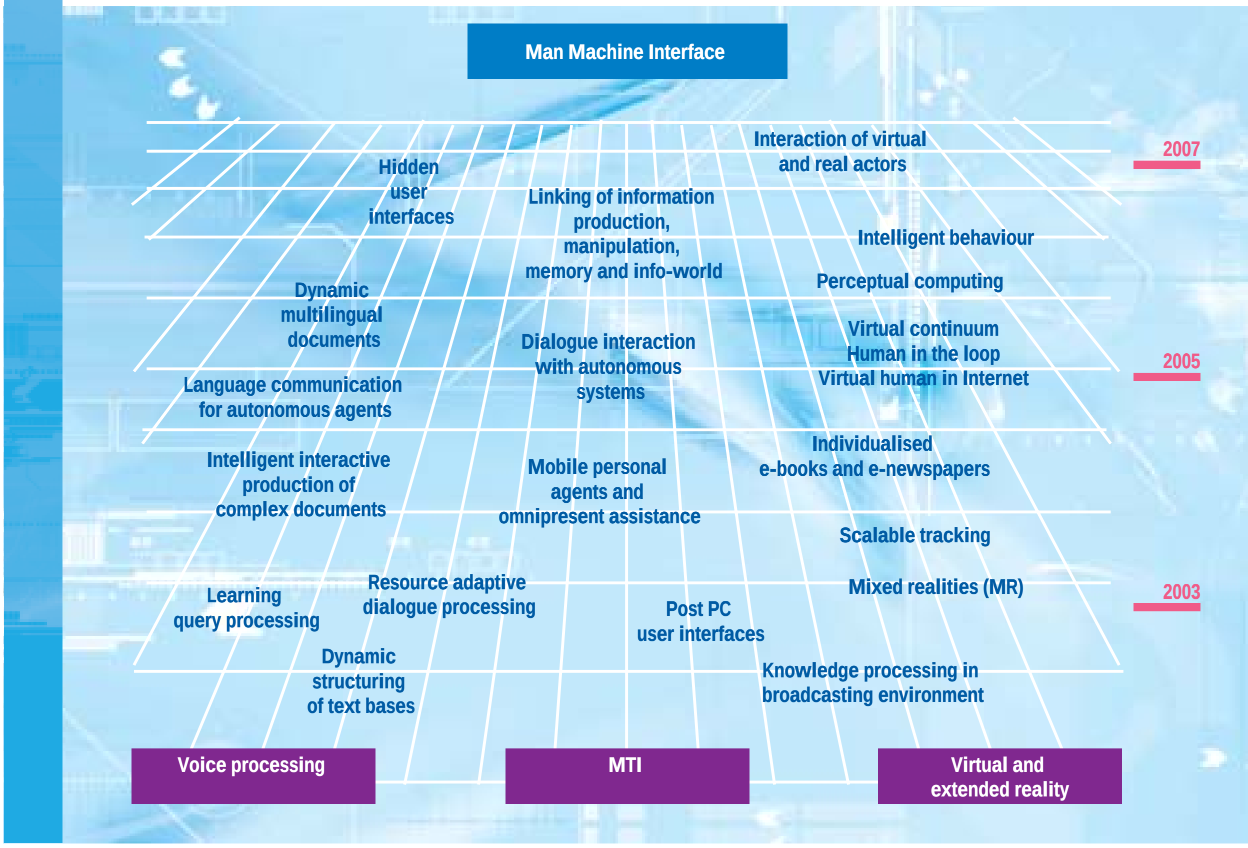
4.2.3. Human/Technology Interaction

Initial Position

Voice processing with IT devices is relatively far developed in the meantime. Germany leads the world in research into language dialogue translation. Progress in speech recognition is essentially based on developments in statistical processes. Language translation gains from interdisciplinary approaches, including methods of artificial intelligence. There are still unsolved problems with robust language recognition and processing in disrupted environments, with machine learning processes (expensive data collection, insufficient data and training data), with domain dependency, scalability with manual sources of knowledge and with language synthesis.

The expansion of speech control of devices to the full range of human interaction capabilities with gestures, facial expressions, haptics and visualization is still a fundamental field of research into human/technology interaction (HTI). Today's research prototypes still require excessive modification before they can be widely used. In future, research will be aimed at multi-modal and virtual interfaces capable of a broad range of communication and interaction. Internet and web-based services will increasingly determine the direction of developments.

Figure 10. **Man Machine Interface**



Experts agree that the previously separate field of research into human interaction with IT devices using virtual and augmented reality (VR-AR) will be an integral part of mechanisms for HTI in future. This suits the situation in Germany, especially as the basic technologies for computer graphics are well developed here. Virtual worlds and interactive video technologies are already important components of a great deal of computer work.

Need for Action and Objectives

On the whole, the interaction between the fields of language technology, HTI and virtual and augmented reality must be increased, whereby emphasis should be placed on the competitiveness of the system as a whole. Using sample applications, modular cross-section projects should be developed, in which disciplines should collaborate as much as possible.

In speech and conversation recognition, processes for Internet applications in particular should be made more robust, scalable and domain-independent, using a mix of statistical and knowledge-based analysis processes. To increase the application potential of voice synthesis, we must increase naturalness and adaptation to speaker.

The robustness of HTI solutions must be increased using integral approaches and combining different processes such as multi-modality with input and output, usability engineering, user adaptation and assistance or intelligent dialogue design. To quickly and effectively implement results standardized interfaces in particular are required. There is a great demand for customized usability engineering methods for web-based information systems and efficient error management. Evaluation centres and corresponding evaluation processes are required for all HTI applications.

In the field of virtual and augmented reality, in addition to visual representation, a “rendering of other senses” should be developed in order to increase the bandwidth of communication between humans and computer.

Research Fields

The following R&D fields contain both technical developments on human / technology systems as well as corresponding software developments.

As a challenging cross-application area, a natural speech "Human Virtual Actor" should be developed as a personalized interaction system, which integrates methods of language and dialogue processing, physically simulated animation, autonomous movement as well as language, gestures, facial expressions and "affective computing".

- **Voice processing**
  – Methods should be developed for the "Internet society" which answer domain-independent natural language questions, which automatically extract information and generate suitable summaries as a response. Large audio archives require a targeted language-based contents search of stored audio and video recordings, including summaries that can be adaptable to situations and users.
  – To improve the robustness of speech recognition and synthesis, new models of natural language should be used including engineering disciplines of speech recognition.
  – Speech data collection in Germany should be improved, since it is the basic prerequisite for device development in the industry.
- **Human/Technology Interaction (HTI)**
  – The potential of new modes of interaction should be developed with the full use of human perception and action capabilities as well as for the synergistic cooperation of human intelligence and system-based performance (such as cooperative exploring). In doing so, new forms of interaction should be standardized.
  – Work on anthropomorphous user interfaces (personalized interfaces) should be funded increasingly. This also includes questions of user modelling and the development of user-adaptive systems to adjust and edit the content.
  – To increase the stability of HTI systems, methods for recognizing the user's intentions and improved error management concepts should be developed.
  – Developments in "affective computing" should be integrated.
  – To use HTI systems more effectively, new engineering methods are essential for providing situative information (such as describing work flows).
  – New models, methods and tools for usability engineering of web-based information systems and usability test centres for HTI and VR systems should be funded.
  – Interactive tools and visualization methods for information retrieval.
  – Methods and toolkits for creating and processing interaction objects (automatic conversion to different types of target devices).
  – Interaction with mobile devices in vehicles.
  – Interaction with networked systems.
- **Virtual and Augmented Reality (VR and AR)**
  – In VR environments new sensors that permit a more precise system reaction to user behaviour play an important role. Device interfaces should be developed that are open to new devices and requirements.
  – Information in VR and AR systems increasingly address all of the user's senses and blur the boundaries between users and the system. Universal interfaces should be developed that are not just designed for special applications.
  – Intelligent environments should be developed for future systems in a "virtual continuum", in which users just enter their objectives and which consider different physical and emotional reactions (perceptual computing).
  – Physical-based simulation as a basis for extremely precise visual and animated representations should be further developed.

Important Areas of Application

- Speech technology including the necessary information editing is becoming an essential user interface with the Internet, especially with mobile access. Together with the interaction modes of gestures, facial expressions and haptics, it forms the basis for controlling future IT devices.
- Important applications lie in the new dictation systems for spoken German (improved quality of dictating language, comprehensibility with different interference levels) and intelligent assistant systems for making foreign languages easier to learn.
- The post-PC era with mobile and ubiquitous computing using mobile computers places the highest demands on technical and application-related developments.
- There is an extremely wide range of uses for HTI and VR/AR, from the private area (such as interactive games and movies) to teaching and learning systems, e-business and web-based applications right up to visualizing complex applications and cooperative work in teams. "Affective computing" for teaching programmes and service robots for the elderly are particularly important.

- A broad application field is the sum of applications from a mix of the virtual and the real world (mixed realities).

4.2.4. Intelligent System/Knowledge Processing

Initial Situation

Much has been achieved in the research and application area of intelligent systems over the last ten years. There have been considerable advances in character and speech recognition, in image processing, robotics and adaptive control and planning systems.

The classical algorithmical control concept of robots has until now effectively remained restricted to a formal, coded world and fails with problems of working in a natural, uncoded environment with its high-dimensional and ambiguous features.

Many processes are non-linear. It is difficult to design non-linear systems constructively and only possible in special cases.

The information explosion linked with the use of IT requires new approaches for acquiring and processing knowledge. The determination of non-explicit knowledge must be included in knowledge processing and in knowledge management. It is also necessary to promote self-organization mechanisms in companies.

A wide range of interesting new applications and new industrial branches are emerging in robotics, with the medium and long-term perspectives of service applications. It is foreseeable that the number of service robots will overtake the number of industry robots.

Need for Action and Objectives

The ability to control integrated, intelligent systems is an important prerequisite for numerous products and production processes. The aim should be to conceive and develop systems that can operate in complex dynamic environments. Value should be attached to robustness and scalability. Networked systems must be made controllable.

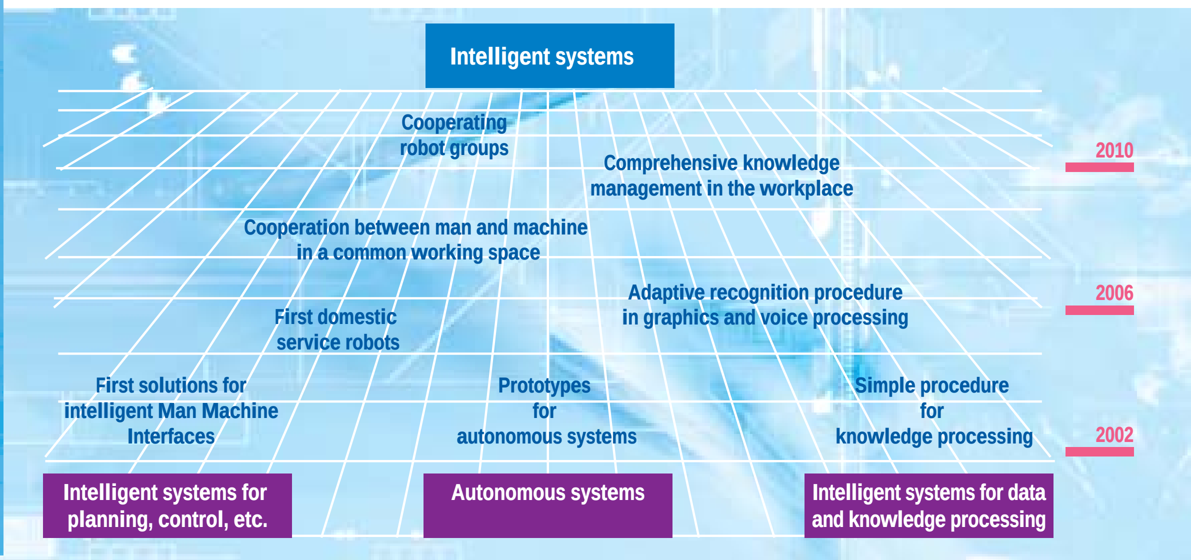
The explosion of knowledge must be managed by AI methods and in particular by methods of information retrieval. Priority must be given to the further integration of sub-symbolic processing with symbolic processing or the way in which humans work with AI methods.

Tasks and problems involving multi-modal human-machine interfaces, cooperating robots, the connection of language to actors have not yet been sufficiently solved.

Regarding service robots and robots that operate in natural environments, fundamental topics of development that are important for all applications should be funded. Furthermore, evaluation mechanisms, benchmarking mechanisms and questions of the comparability of robots are very important.

Agreement on platforms that can be used as a standardized basis for all robot development is necessary in order to reduce the amount of effort required. This move should be supported within a European framework. Modules and components for such platforms should be developed internationally.

Figure 11. Intelligent systems



Research Fields

- **Adaptive intelligent systems**
  - Development of new application systems in robotics by providing universal models and components.
  - Research into introspection, self-modelling and intuitive training in robotics.
  - Further development of image processing in connection with introspection, perception and configurability, as well as analysing and compact coding visual scenes.
  - Set up of evaluation and benchmarking centres for intelligent systems.
- **Integrated systems and processes**
  - Mathematical modelling of non-linear dynamics and optimization.
  - Development of task-dependent similarities, event-based predication, systematic creation of modularity, structure-dependent distribution of learning processes and organization of "system monitors".
  - Robust 3D/2D scene analysis for reading and image processing systems in the field of automation.
- **Systems for knowledge processing**
  - Management of non-explicit knowledge and handling of incomplete or incorrect information.
  - Research into ontologies and semantic information modelling, knowledge management, knowledge-based engineering, distributed developing and planning, constraint technology.
  - Improvements in dialogue and content-based search systems in databases and in the Internet using intelligent technologies.
  - Development, formatting and operation of complex multi-media information structures to automatically extract metadata, format existing information structures and mixed automated, interactive operation of information structures.
  - Knowledge in distributed structures (mobile systems).
  - IT-based community learning.
  - Information retrieval, knowledge discovery.

Application areas

- Process control and system development plays a central role in the field of transport and communication networks, the food industry, the pharmaceutical industry, in medicine, the car industry, the chemical industry, mechanical and plant engineering and in integrated production or logistics systems. Improving their profitability, product quality and reducing the use of raw materials ensures competitive advantages. This opens up many options for intelligent systems.
- Extremely interesting markets are developing for application-specific assistance systems, both in industrial production as well as in the field of domestic appliances and care, and in entertainment and edutainment.
- A particularly important application area is the development of 3D worlds in image processing. Real world situations that represent the third dimension (depth) and screen sequences are still a great challenge for research and development. New applications can be implemented in many areas using results in these research fields.
- New and improved solutions with intelligent components (sensors, actuators, mechatronics etc.) help to decentralize intelligence in products and processes.

Intelligent assistance systems, case-based reasoning in cooperative groups (including maintenance, diagnosis, planning, project management etc.).

4.2.5. Bioanalogous Information Processing

Initial Situation

The outstanding features of biological information processing systems such as the brain, the immune system, the genome, or state-forming insects include their high speed due to parallel processing, their flexibility and their incredible stability when faced with incomplete, disturbed or incorrect sensory data. They have advanced and proven themselves in nature through self-organization by developing complex biological structures.

By projecting these properties onto technical systems in the past years, significant successes have been achieved in the investigation and utilization of biological principles in information processing. Examples are highly parallel fast algorithms for solving complex path-planning or navigation tasks, new efficient algorithms for computer vision and data mining as well as optimizing learning in neuronal networks.

In view of the current explosion of knowledge in the field of genome research and molecular biology, it is worth looking for further biological principles that can be applied to information-processing systems. The increasing flow of data makes this even more essential.

Germany's prospects for assuming a leading role in "bioanalogous information processing" are extremely good, in the development and use of general multi-purpose principles based on the model of the autonomous organization of biological systems.

Need for Action and Objectives

The sustainable further development of bioanalogous information processing in the future requires even closer cooperation between the disciplines of bioinformatics, neuroinformatics, neuroscience, molecular biology, physics and mathematics. From the point of view of computer science, this means a paradigm shift in organizing and controlling networked, targeted processes, and a redefinition of the terms "calculation" and "structure". The core objective is to proceed from the previous, detailed algorithmic procedure derived from discrete mathematics to an even higher level of working in structures based on principles and to make higher complexity manageable for an improved use of resources (neurocomputing, organic computing).

Evolutionary events and neuronal information processing can be used as a basis for biological induction. Qualitative new mathematical approaches must be developed for a formal description of the phenomena that occur here. On the basis of such approaches, progressive biology-inspired IT-theories can be established, which could change computer science fundamentally.

When learning from biology, we should above all focus our research on the way nature solves problems instead of considering individual phenomenon. Emphasis will be placed on the development and application of principles which are versatile and generally useful.

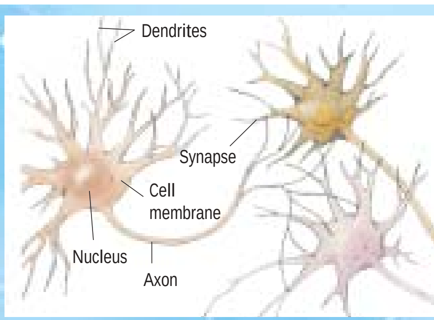
Research Fields

Fundamental interdisciplinary projects from the field of biosciences combined with information processing are being funded, if possible involving the potential users.

Since knowledge about the world of living systems is stored in the structures of evolution, and in view of the fact that the volume of knowledge in the field of genome research and molecular biology has increased explosively, the new programme for bioanalogous information processing should begin with an ideas competition, in which biologists, neuroscientists, computer scientists and representatives of application disciplines propose new principles of information processing which should be taken from biology and adopted into technical systems. The main focal points are:

- **Organic computing as an extended paradigm of technical information processing**
  Expansion of the theory of dynamic, self-organizing and self-adjusting systems for describing complex processes. The task-related structure of problems that is expressed in the system architecture plays a decisive role.
- **Self-organization of complex, technical interaction forms and networked structures**
  – Examination of real, complex networked, cooperating, targeted processes of organization and interaction forms (such as in molecular and neuro-biology) and the use of approaches to evolving hard and software systems.
  – Biology provides a model of high efficiency for extracting, representing and processing information by reducing data by feature integration and synchronized time-place regimes in the data format.
- **Modelling and technical use of the variety of cognitive processes**
  – Implementation of processing precise data right up to vague knowledge and emotional information, linked with anthropomorphous perception and mobility capabilities of robots, to make man's cooperation with and acceptance of assistance systems more secure and natural.
  – Generalization of present models of information representation in neuronal systems above and beyond statistical representations and stable attractor states after the fashion of real biological systems. New types of mathematical and additional formal models of information coding with dynamics of learning in different time scales are required.
- **Strategies of biological data coding as a prerequisite for real-time enabled information technology**
  – Requirement for problem-related structuring of large data sets when there are deficits in knowledge or starting points for an algorithmic procedure.
  – Biological examples (brain as well as genome) for

Figure 12. **Brain - Computer comparison**

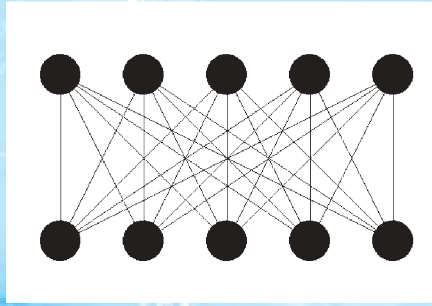


Brain

- **The human brain comprises 10^{10} to 10^{11} neurones**
- **Each neurone is connected to 10^{3} neighbouring neurones**
- **Each axon sends about 10^{3} signals per second**

➔ about 10^{16} – 10^{17} signals/second

- **Power consumption: 60 W**



Computer

ASCII White from IBM

- **< 10^{4} processors (8,192 Power3-II CPUs)**
- **Each processor has 512 shared-memory nodes**

➔ 1.2 * 10^{13} operations/second

- **Power consumption: 3 mega Watt**

Source: DFKI

strategies of information coding, which enable the self-organization of information, flexibility and optimization with variable target functions (evolutionary or learning).

– Quantitative models for creating, processing and storing information in stable networks, such as pulse-coded neurons.

- **Autonomous robots and vehicle systems**
  New biological principles to recognize situations robustly in complex natural scenarios. The question of the robustness of biological systems in unexpected situations has not yet been solved for technical systems.

Application Areas

- Optimization of complex networks of logistics, high-dimensional robotic systems, collective decision processes, adaptive processes in organizations which are robust and resistant to interference and restricted parameter changes.
- The use of new, previously unused biological principles to increase productivity in software development.
- Real-time conversion of high-dimensional numerical information into symbolic information and data mining, for example for industrial information, for assistance systems in process control, for evaluation, filtering, noise reduction in broadband data streams of any origin (satellite data, image interpretation, language, text bodies, World Wide Web, genome, biomedicine).
- Technical assistance systems that adjust to the user's individual cognitive abilities by means of IT solutions from biology, for example by developing bioanalogous recognition methods for new human-technology-interfaces (gestures, facial expressions, eye movements, bioelectrical signals).
- Innovative bioanalogous solutions for deteriorating sensory and cognitive abilities of older people and specific groups of patients.
- Distributive autonomous mobile systems (DAM systems), for example for swarms for monitoring the environment.

4.3. Basic Technologies for Communications Engineering

In 2000, the German telecommunications market achieved a turnover of more than 65 billion Euros, of which 50 billion Euros were derived from telecommunication services, and 15 billion Euros telecommunications technology. In the same year, exports of telecommunications technology increased by 35 % up to 13 billion Euros compared with 1999. The export quota for telecommunications technology is thus over 80 %.

Due to strong growth of Internet traffic, the volume of telephone traffic in highly developed countries will retreat into the background over the next few years, whilst mobile communication will increase considerably. In 2003, more than 80 % of the total transmission volume will be attributed to the Internet.

This has fundamental consequences for network technology. German industry is taking a leading role in comparison with the rest of the world in the classical field of voice communication, as well as in setting up the network. The integration of language and data services in a common network marks a change from classical connection-orientated network structures to network structures which provide a package of services. The Internet will increasingly provide the functionalities of classic language communication networks, absorbing these networks.

In 2000, for the first time, German industry produced more mobile communication technology than fixed network technology. The production of mobile communication technology amounted to 7.5 billion Euros and therefore increased by 37 % in comparison with the previous year. Since GSM (Global System for Mobile Communication) was introduced, mobile communication in Germany and across the world has enjoyed a boom that remains unbroken. Currently almost 1 billion people use mobile communication systems, whereby more than 640 million people in more than 170 countries use GSM networks.

In contrast to communication using fixed networks, mobile communication is currently still restricted to narrow-band applications (speech). The networks are reaching the limits of their capacity as a result of the increased number of participants, restricted availability of suitable frequencies and the predicted increase in mobile data traffic in connection with new applications, such as mobile multimedia communication. Technical developments in the field of mobile networks are therefore urgently required and necessary in order to keep or expand on the existing technological advances and market success.

A further aspect of changes in the network structures are the opportunities for mobile users to access data and information sources. The Internet is becoming possible at any place and any time. Wireless and wired communication networks will grow together from the user's point of view to become one network and provide extensive data services. In future, users will not need to worry about how they access the network. The changes in using and accessing sources of information, as well as the flexible restructuring of the network that will be necessary, place great demands on the development of protocols to manage and organize the network.

Funding of basic technologies for communications engineering as part of the "IT Research 2006" concept concentrates on four areas:

- **Photonic Communication Networks**
  The objective is to adapt the core network, based on optical transmission technology to the increased demands of the Internet over the next few years. The research aims to increase capacity from a transmission rate of up to 50 Terabit per second per optical fibre by 2005. Furthermore, it is important that an intelligent network management is developed for the optical message network which can ensure application services with guaranteed transmission qualities between with core, distribution and access networks.
- **Mobile Broadband Communication Systems**
  The Internet's triumphant progress continues throughout the world. The development of the mobile Internet and its universal availability (any time, any place) plays a key role.
  The challenges of future mobile communication are the universal supply of band widths and the efficient use of all resources. New concepts and architectures are necessary to meet the demands of a volume of traffic that is changing dynamically.
- **Innovative Display Technology**
  In view of the great industrial and political significance of flat screen technologies and the advances in the base technologies that are necessary for them, we must develop innovative display solutions for communication, mobility and production. Tailor-made component solutions for vehicles and communication tech-

nologies using innovative production processes, with high output, seem to be promising for the future.

- **New Components and Materials**

  The objective is to push basic research ahead in the field of new communication technologies so that new materials and new physical effects, such as in quantum physics, can be used to develop innovative components. Furthermore, it is necessary to develop optical memory technologies for the multi-gigabyte area.

  On the one hand, the objective is being pursued comprehensively in order to increase the competitiveness of German manufacturers and service providers. On the other hand, basic research is being carried out in selected fields to enable new products and services in the longer term.

4.3.1. Photonic Communication Networks

Initial Situation

The European market for telecommunication equipment reached 73 billion Euros in 2000: 15 billion Euros in Germany. It will grow each year by approximately 15 %. The European industry holds a leading position in the field of optical communication technology. Data traffic in the Internet is doubling on a yearly basis and optical communication networks must adapt themselves to these new requirements. New network architectures must be tested, transmission capacity must be increased and new, more efficient network components must be developed.

Need for Action and Objectives

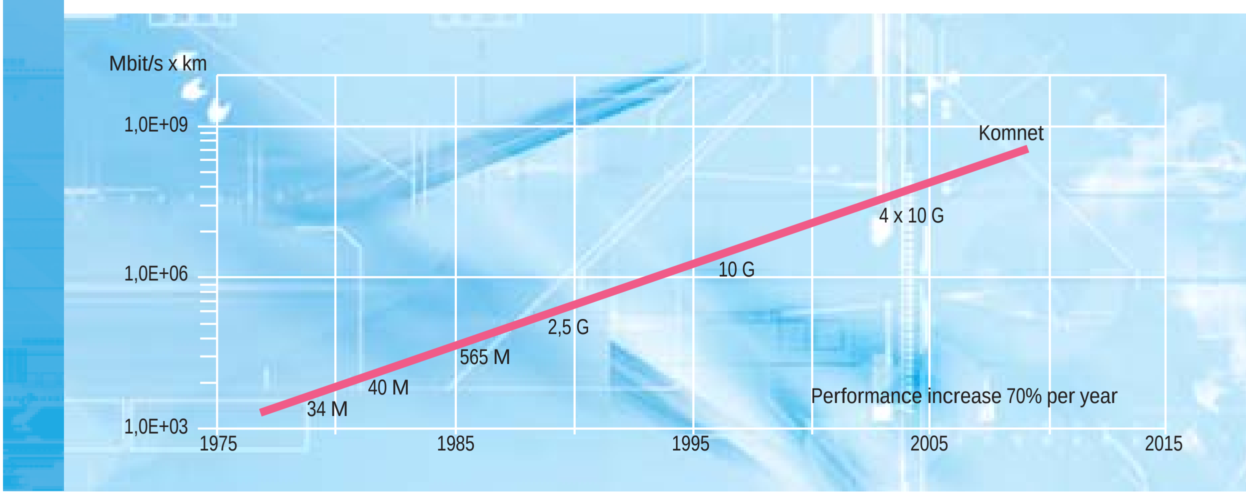
Funding is aimed at establishing close cooperation between German research institutes in the field of communication technology and the suppliers and operators of communication networks, which will lead to innovative ideas being quickly implemented. This also includes European and US companies, which have based their research and development centres, as well as parts of their production, in Germany. The dynamics of development mean that the research projects are conceived in such a way that first results will be available quickly (in approximately 2 years).

Research Subjects

Priority is attached to increasing the performance of optical networks. It is necessary to develop flexible and switchable optical networks, with the same reliability and quality of service as conventional telecommunication networks and under Internet protocols. New planning and simulation software is essential for this. The corresponding network components such as multiplexers and demultiplexers, switches, wavelength converters, amplifiers and lasers have still to be developed.

The volume of data on the Internet will double in size every 6-12 months over the coming years, whereas, according to Moore's Law, the transfer rate of today's electronic Internet routers will only double every 18 months. To overcome this bottleneck, a lot of research is being carried out today throughout the world on optical routers. In the optical router, the high rate Internet packets that are trans-

Figure 13. Transmission capacity of glass fibre



ported via fibre glass networks are processed optically, and not using electronics. Ultra-fast optical signal processing is the key technology for optical routers, and German research is amongst the world leaders in this field. Germany has a high industrial and research potential, which offer an excellent opportunity to assume a leading role in the strategic field of optical routers.

In the field of data networks, a new market segment known as metropolitan area networks, or metro networks, is developing between the remote transmission networks, the connection networks and local networks in individual buildings. These can stretch over medium-sized areas and often have a restricted number of connected nodes. Metro and connection networks should be adjusted to meet the increased capacity demands which are also a prerequisite for broadband network access for companies and private households. A new focus of research, MultiTeraNet, is in the pipeline for these research areas with the four areas:

- **Exploitation of fibre capacity for high speed optical transmission systems**
  The objective is to increase the transport capacity of transmission systems to more than 50 Tbit/s per fibre. The spectral efficiency of optical transmission systems with new modulation and transmission processes is being increased to 0.8 bit/s/Hz and above. Additionally, the use of the complete fibre bandwidth of 1300 nm to 1675 nm is in sight, in particular by using of new types of fibres.
- **Flexible optical networks**
  The objectives are network concepts and architectures with intelligent network nodes and transparent sub-networks; furthermore, intelligent network management and protocols which enable automated command executions as well as evolutionary multi-service and technology solutions. Furthermore, it is also a matter of developing switching processes, with the aim of changing from the current circuit switching to optical packet switching. Concepts such as “optical burst switching”, dynamic wavelength routing and optical packet/label switching are being examined and their prototypes are being tested.
- **Access network technologies, interplay between fixed networks and wireless networks**
  The objectives are optical access networks and other access network technologies with new coding processes for DSL technologies, as well as concepts and protocols for connecting fixed and mobile networks.
- **Key components, technologies and materials**
  The objectives are optical switching nodes, components for optical switch and routing processes, components for WDM systems with a very high number of channels (>1000), components for highest rate TDM systems, components for burst operation as well as components for optical signal processing.

4.3.2. Mobile Broadband Communication Systems

Initial Situation

The current success of mobile communication is based on developing and introducing digital mobile communication systems and standardizing them in a recognized European GSM standard. These efforts towards standardization in the European bodies were preceded by the funding of the basic work in industry and science by the Federal Ministry of Education and Research.

Europe therefore has a leading position in the field of digital mobile communication. Germany also plays a decisive role, and it is important to organize its further development with key initiatives. In doing so, research is of decisive significance as the most important motor for innovation in the rapidly growing mobile communications market.

In the last few years, there have been clear increases in the number of people employed by network operators and service providers in the mobile communication services, from approximately 15,000 in 1996 to around 33,600 in 2000. In 2000 alone, the number of employees rose from 27,800 to 33,600. Furthermore jobs have also been created with system and device producers and with service operators active in this field.

Need for Action and Objectives

New concepts and system architectures are necessary to enable comprehensive broadband provision and the efficient use of all resources, and to meet future challenges. The Federal Ministry of Education and Research is concentrating on developing system solutions, which will lead to proposals for European standards and which, as a result, should develop and shape innovative markets. In turn, this creates and maintains jobs, which is after all the motivation and objective of all funding efforts.

Research Topics

Universal Use of Communication Networks for Future Mobile Communication Generations (HyperNet)

HyperNet supports the development of system concepts which contribute to solving the two dominant problems of future mobile communication, the comprehensive broadband supply and bandwidth efficiency. This moves away from the classical use of mobile communication, which starts from a centrally organized architecture of base stations and participants. It focuses on:

– **Self-organizing mobile networks with multihop capability**
  The "multihop" system concept contributes to clearly reducing the infrastructure expense of base stations and corresponding fixed network access for radio provision. This will be achieved by introducing wireless base stations (such as mobile phones) and integrating them in a self-organized network for wire-less Internet communication. Furthermore, the "multihop" functionality of HiperLAN/2 is to be examined and a standard prepared.

– **Integrated Bandwidth Efficient Software Radio System**
  The "IBMS2" project will show that interference in a mobile communication system can be reduced by switching on a mobile sub-station, thereby increasing total network capacity. To implement this, the network must be self-configurable. Network capacity and efficiency can be increased by means of an adaptive air interface using space and time signal processing. For this it is necessary that the end devices can be software-defined – ideally to suit all available air interfaces.

– **Highest efficiency mobile communication transmission and allocation processes**
  The objective of the "HyEff" project is to considerably increase spectral efficiency and thus the capacity of future mobile communication systems through the flexible and dynamic use of all resources, without considering previous standards. This means that the objective of increased capacity should be achieved using a greater degree of freedom in 4-D communication, consisting of frequency, time, space and code. For this purpose, methods are being examined using non-orthogonal multi-carrier systems, multi-antennae systems, burst transmission and spectrum pooling.

Wireless Communication Based on IP (IP on Air)

The aim is the smooth integration of mobile, wireless and wired communication networks (such as the Internet, mobile communication with various standards, ad-hoc networks), in which efficient, flexible

Figure 14. Future optical communications network (DWDM network)

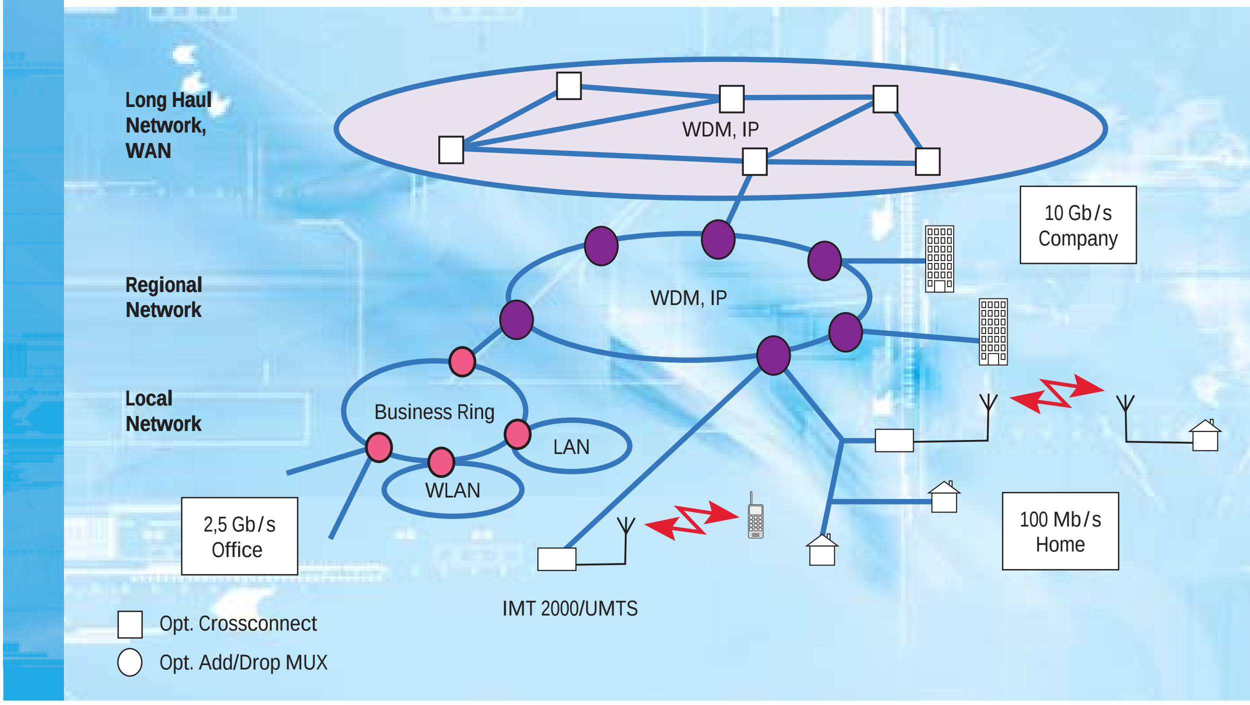
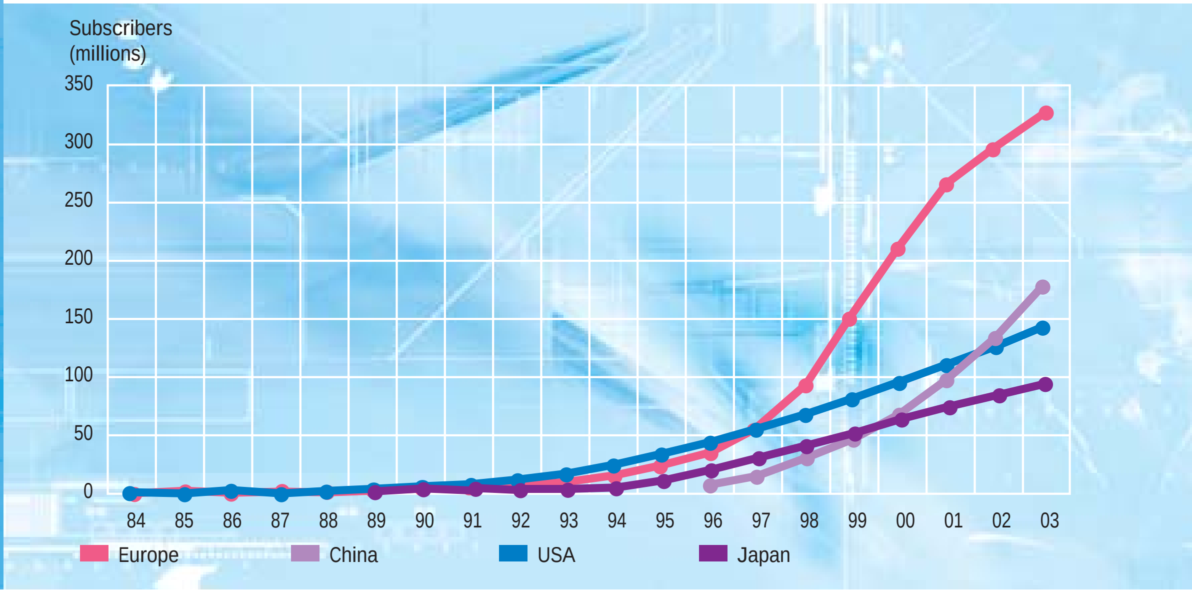


Figure 15. **The four largest mobile phone markets**



and secure communication is possible based on the Internet protocol (IP). Mobile communication over several radio provision areas in a wireless, self-configuring and heterogeneous (multi-standard) environment is considered here a special challenge.

Interest is focused on aspects that deal with managing different radio resources and which make it possible to select the optimal radio interface depending on the application and use. One objective is to provide processes for managing hierarchical multiple access. This poses critical questions with regard to wireless integration, for addressing mobile nodes (IP addresses), for the efficient transport of data as well as for the security of mobile communication.

As far as security is concerned, on the one hand the project examines questions that are closely linked to the confidentiality of personal data of the mobile users. On the other hand, the integration of an IP-based network in the public networks is being examined. Application and service-oriented aspects are discussed in the chapter "New Internet Technologies".

- **Microelectronic Technologies for Mobile Communication (Mobile on Chip)**

The objectives are software-based, universal end devices for mobile communication. The basic idea is a mobile communication system that is transparent for users, which autonomously selects a suitable frequency band and the appropriate standard. This is enabled using end devices based on multiband / multistandard-enabled technologies that are as uniform as possible.

The work focuses on architectural designs for reconfigurable mobile communication systems based on software radio. This then results in the necessary key components for analogue and digital multiband and multistandard frontends (transmitters, receivers, mixers and antennae). The development of key components for high frequencies is focused on low power dissipation for use in mobile communication.

- **Mobile Technologies with Minimal Radiation**

The development of mobile technologies with minimal radiation is an important contribution to further developing mobile communication since they counteract the new electromagnetic sources constantly emerging and the resulting increasing intensities and interferences. The objective of such a technical development is to reduce the spectral power flux density of the emitted radio waves to such an extent that they are as close to natural environmental radiation as possible. We will examine the potential of alternative technologies for reducing electromagnetic load.

4.3.3. Innovative Display Technology

Initial Situation

After microelectronics, display technology is one of the most important basic technologies for the information age. Display technology is increasingly joining forces with microelectronics to form a functional system, which to a large extent determines the properties of the end devices of information and communication technology. The attractiveness of new services is influenced to a large degree by the visual impression, whereby the aspect of mobility is coming increasingly to the fore. The world market for LC displays will grow from US $ 20 to 33 billion over the next few years. The market for OLED displays will reach approximately US $ 20 billion in the year 2010.

Need for Action and Objectives

Germany holds a weak position as a location for the production of flat screens, which are currently produced predominantly for computer systems. We must therefore make Germany competitive for future developments in display technology. Only with a distinctive R&D infrastructure will Germany have a chance to improve its position in the field of displays based on organic light-emitting diodes (OLED) or projection displays, for example. In future Germany's biggest chances are seen in the field of automobile and communication display technology.

Research Topics

- **LCD Technologies on Flexible Substrata**
  Considerable importance for the future is attached to liquid crystal displays on plastic substrata, which are still in the early stages of their development. The development of bistable and multi-stable displays is particularly interesting. These are suitable for mobile applications and low-price applications (price marking, displays in chip cards) for example, since they do not consume any energy at rest.
- **OLED Displays**
  An important feature of displays based on organic light-emitting diodes are their excellent visual and electrical properties (large viewing angle, outstanding imaging of animated pictures due to the high switch speed, low operating voltage, high efficiency). This technology is also considered to have a lot of potential in the field of flexible displays.
- **Projection Systems**
  An alternative to direct view (large) screens is image projection. Both real and virtual representations are possible using small screen light modulators (in transmitted or reflected light, such as transmissive LCD, LCOS, DMD). Projection systems are highly suitable for auto-stereoscopic 3D displays, which will become increasingly important for professional applications.

4.3.4. New Components and Materials

Initial Situation

To a large extent, developments in communication technology are based on the availability of new types of electronic, optical and optoelectronic components, which can be used to implement complex system solutions.

The target-orientated funding of this basic research should be regarded as a prophylactic to ensure Germany's long-term position in the field of micro and optoelectronics and laser technology as basic technologies for communication technology. One cannot always expect industry to become financially involved in this research work from the very beginning.

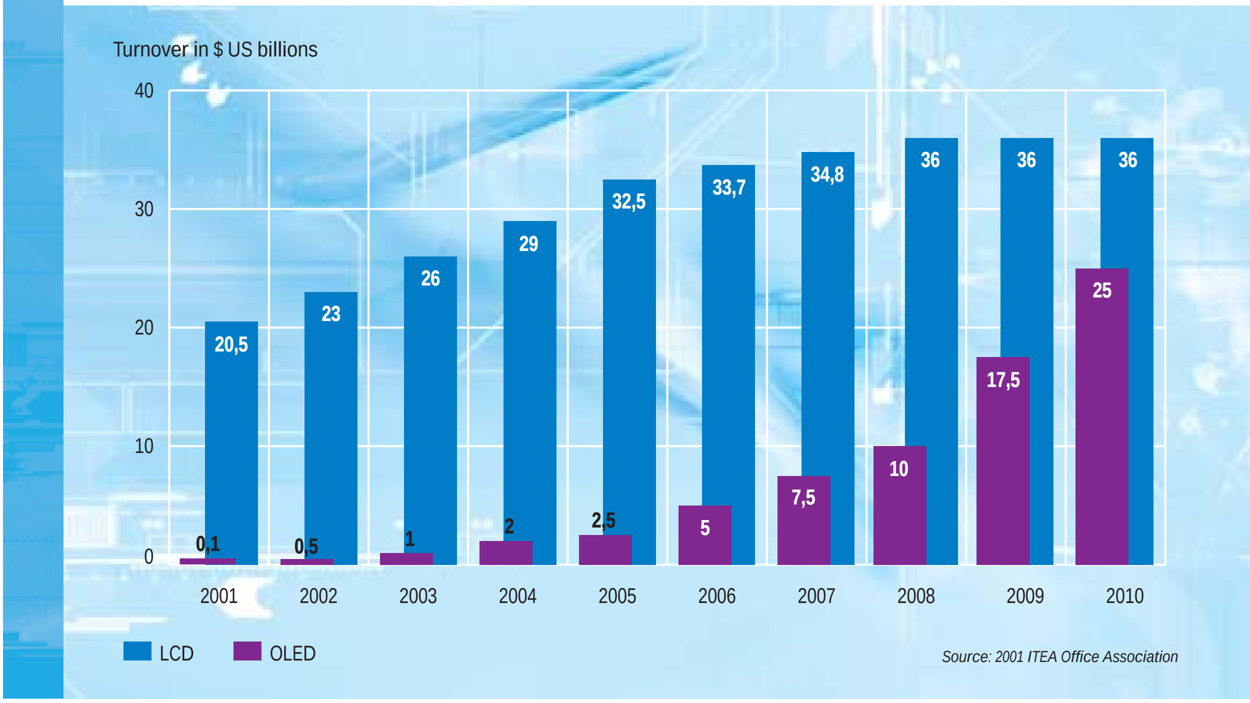
Need for Action and Objectives

New classes of semiconductor compounds are required for many innovative components in communication technology. In classical microelectronics, there is currently a partial transition from silicon to silicon-germanium. In high frequency and power electronics, which are mainly based on semiconductor compounds, gallium-arsenide is partly being replaced by gallium-nitride or indium-phosphide. Switching circuits made of organic materials such as polymers are particularly promising. The uses that will result from this cannot yet be seen individually. In order to be prepared for future developments in solid-state electronics, quantum structure systems are being investigated together with their applications in electric, magnetic and optical components.

Research Topics

- **Indium Phosphide and Semiconductors with Larger Band Gaps**
  Whilst gallium arsenide is still the dominant substrata material for compound semiconductors for manufacturing integrated high frequency switching circuits, indium phosphide is becoming increasingly important for very large data transmission rates as are the so-called "Wide Band Gap" (WBG) semiconductors (silicon carbide and gallium nitride) for high-power applications.
  – Due to increasingly higher demands on data transmission rates (long-term objective 160 Gbit/s), R&D

Figure 16. Growth in turnover of OLED displays



activities for new components and technologies are unavoidable for high-speed electronics. The chosen material here is indium phosphide (InP). Only this semiconductor can achieve the required performance in signal processing and in "high speed electronics". The corresponding research activities therefore concentrate on areas of InP substrata development and component and circuit production based on InP. Scientific and technical development in the field of InP technology was taken up and promoted by the Federal Ministry of Education and Research at an early stage as part of its institutional funding. The measures that are now planned are based on the basic knowledge that resulted from these activities.

– New components are especially required for the considerably increased power demands placed on systems by mobile communication technology. Here the WBG – semiconductors offer enormous potential due to their physical properties (large band gaps). They can be operated at high voltages and very high frequencies; they have large current density and high charge carrier velocities. Whilst at the same time reducing the component dimensions, very high power densities can be achieved so that components based on GaN- or SiC are predestined for robust and extremely powerful amplifiers. (For example in mobile communication basic stations, in satellite and telecommunication).
– The material gallium nitride (GaN) is also required for efficient light sources and lasers, particularly in the field of blue and ultraviolet light. Laser diodes that emit light in the blue spectral area as well as multi-level disk technologies are milestones for the increasing data memory capacity of optical storage disks.
– Research into these material areas covers both substrata development (basic crystal growth) as well as the development of new components.

Polymer Electronics

If in future the Internet is to become the backbone of our information society, we must make everyday objects accessible via the net. This requires reasonably priced electronics, which in the area of consumer goods for example, is integrated in the packaging and can later be disposed of. This type of concept would open up new options for merchandizing and trade. Key materials in this field are polymers, from which electronic components can be produced at extremely low cost. The research is focused on:

– Continuous production processes for integrated polymer circuits on flexible substrata in identification tags. Both printing processes and roll-to-roll processes on a lithographical basis are being researched.
– Polymer display controls on flexible substrata.

- **Photonic Crystals**
  A key technology to further miniaturizing optical components is the use of "photonic crystals". Using specific wavelengths, it is possible to influence the propagation properties of light in materials. In this way, light can be processed on miniaturized modules. The research is concentrating on developing optical components such as multiplexers and demultiplexers, which can be executed with the help of photonic crystals in a more compact form or integrated on a chip.
- **Quantum Structures**
  With advanced miniaturization, components of communication technology have achieved dimensions in which new physical effects come into play within the semiconductor structures. These can be explained with quantum theory. It is a question of developing new principles of circuit design, which use the quantum effects in the nano area. Attempts are being made to use these effects to produce transistors, light emitting diodes as well as lasers, which are in turn key elements of communication technology.

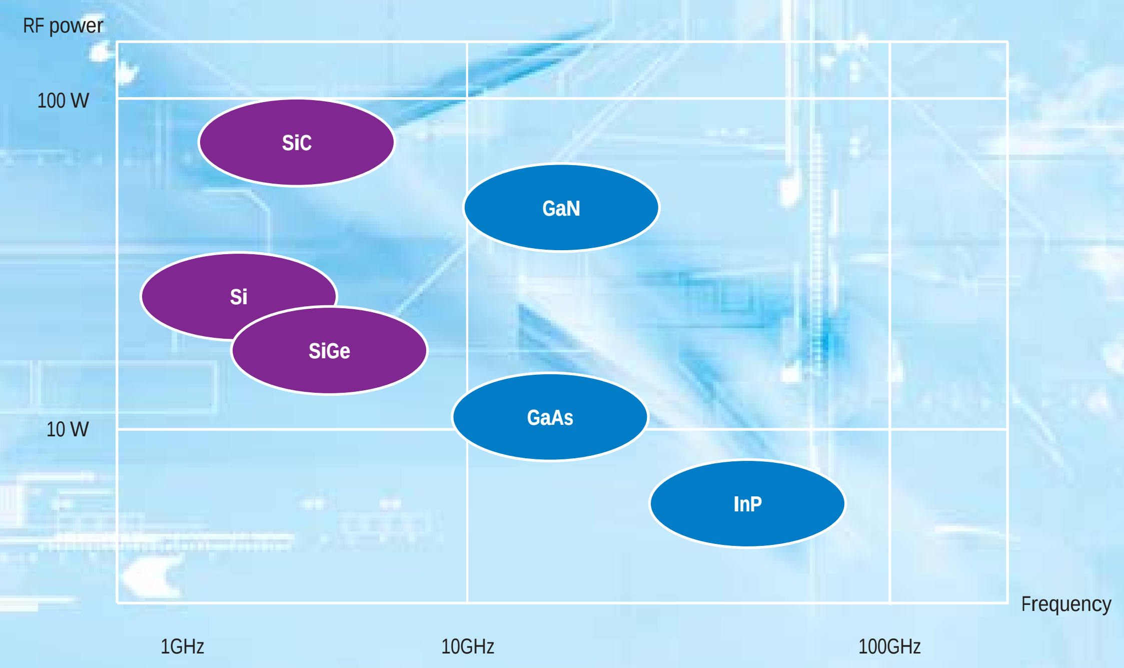
Furthermore, it is also a matter of using electron spin to transmit information. This field of basic research in particular has developed dynamically in the last few years. This can also be seen from the fact that the Nobel Prize for physics has been awarded several times for the development of new components in information technology. The following should be named: Prof. v. Klitzing (Germany, Quantum Hall Effect), Prof. Stoermer (Germany/USA), and finally Prof. Kroemer (USA/Germany), who was distinguished for developing transistors with high electron mobility (HEMT).

4.4. Internet Basics and Services

The Internet has established itself as an almost ubiquitous network with an enormous growth rate. The first services that widely caught on in this medium (usenet, ftp, e-mail and World Wide Web), are today – approximately 30 years after the Internet was "invented" – already changing the way in which we communicate, learn and work.

Germany has made considerable progress in the spread and use of the Internet over the last few years.

Figure 17. Performance characteristics of semi-conductor materials



Source: J.Y. Duboz Phys. Stat. Sol. (a) 176, 5 (1999)

Between the summer of 1997 and that of 2001, the number of Internet users in Germany increased sevenfold from 4 to 28 million. Close to 35 % of Germans use the Internet. According to a survey on behalf of Post AG, 14 million Internet users also make purchases occasionally or regularly via the Internet. This private business (Business to Consumer, "B2C") still plays a subordinate role in Germany – as it does throughout the world. In 2004, three quarters of the world-wide E-commerce revenue will be generated by business between companies (B2B, Business to Business).

Internet technology, based on a family of Internet protocols (IP), is regarded in expert circles today as a starting point for the universal communication networks of the future. This next generation Internet is:

- A communication network which integrates services
- A convergence platform for consolidating different networks, from the telephone network to traditional data networks
- A universal information medium
- A platform for versatile business and entertainment applications.

Today's Internet can in no way meet these demands. In addition to structural changes, considerable research efforts are required in the fields of:

- New Internet technologies
- Tools for obtaining and managing information
- Internet-supported processes.

The following section deals primarily with research into and the development of new Internet applications and services. The funding includes the following three areas:

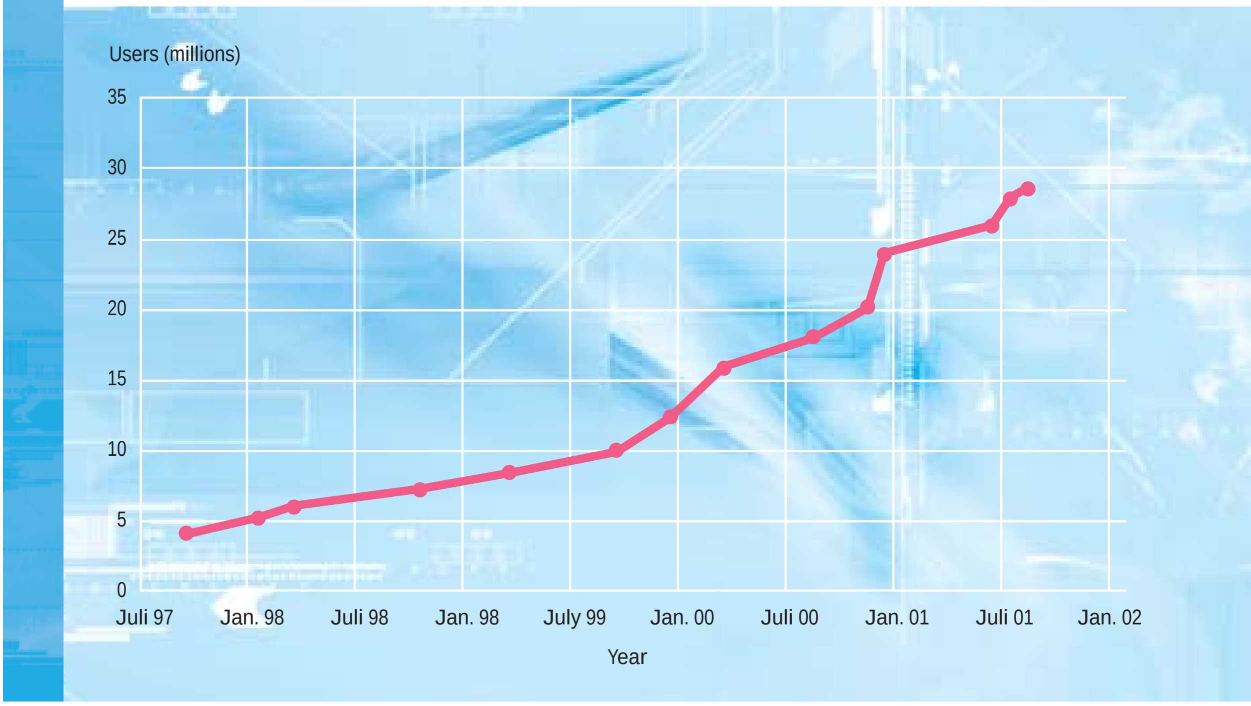
- New Internet technologies: this deals with R&D for Internet-specific technologies and standards
- Knowledge in the Internet: research networks and services for special requirements in the field of research and science, and new methods of efficiently organizing and using information in the Internet
- Research into Internet-supported processes: this deals with scientific methods for measuring, developing and controlling Internet-supported processes in all areas.

4.4.1. New Internet Technologies

Initial Situation

Europe still plays a subordinate role in the further technical development of the Internet at the interface between technology and services. New Internet-specific technologies and standards originate primarily in the USA. US

Figure 18. Number of Internet users in Germany



companies dominate the business of Internet infrastructure. Research in Europe is still a long way from reaching critical mass. In Germany too, there are only a few research groups which are internationally recognized and which work together with industry.

Need for Action and Objectives

So far funding by the Federal Ministry of Education and Research has concentrated on setting up and organizing the corresponding research capabilities in Germany. Meanwhile it has succeeded in setting up a strong network of Internet work groups from universities and external research institutes which tackle larger strategic projects together with industry, and which are also receiving international attention. The main objective is to use Germany's strong position in the field of telecommunications to attain a more favourable competitive position in the next Internet generation.

Research Topics

- **Middleware and Protocols for the Internet**
  The Internet was originally only intended for computer and data communication. Its technology compared with classical telecommunication technology is marked by its simplicity. Data packets of variable length are exchanged between network elements, there are no predetermined paths and the network is largely self-organizing.
  Since all data packets are treated equally, there are no guarantees whatsoever regarding delays or even lost data. The basic principle is called "Best Effort", it is most suitable for simple data traffic where delivery is not time-critical and lost data packets can be caught using mechanisms in the higher protocol layers. Mechanisms for reducing data transmission in overload situations have been developed, but they are not very suitable for applications with a continuous and undisrupted flow of information, such as language and video services, for example.
  Research must therefore work on solutions that meet these increased demands on bandwidth, quality of service (QoS), availability, reliability, security and mobility. The emphasis of the research must lie with the control and operation mechanisms of the network, which must be kept as simple as possible. Initial and subsequent costs that are too high can delay or even prevent industrial use of these concepts and technologies.
  The provision of a network platform with these properties will enable the realization of new, innovative business ideas in the services and application area and therefore considerable economic potential.
- **Mobile Internet**
  Further development of the Internet is marked by the integration of mobile access possibilities and new standards for organization and communication, as well as by increases in bandwidth and speed. Since European companies have a strong position in digital mobile communication, merging the Internet with digital mobile communication ("mobile Internet") can increase the prospects of European Internet technologies. This could benefit both the market opportunities for European industry in the field of Internet equipment as well as in particular the development of innovative Internet applications.

4.4.2. Knowledge in the Internet

Initial Situation

With the expansion of communication networks, there is a growing need to save, process and retrieve knowledge using these networks. In future, the software that is provided on the Internet must no longer just support the search for and retrieval of information, but also assist the handling of the knowledge contain in this information.

Forerunners in this area are in particular research networks and applications in science. About 20 years ago, the Federal Ministry of Education and Research began to push ahead the development and implementation of innovative research networks. With the founding of the DFN and the successful set-up of a German research network, broad and differentiated scientific research into, and with, communication networks has grown up.

Science and research today are hardly conceivable without modern communication networks. This holds true not only for physics or astronomy, but also for engineering and the humanities. The institutes and projects in the DFN's area have supported this by setting up and developing networks, and by developing services and applications. Time and again the impulses for commercial networks and their use have come from science.

The gigabit scientific network means that today one of the most effective communication networks in the world is available to science and research in Germany. Based on this, research can develop and test completely new scenarios for communication, cooperation and scientific use. If preliminary research can be linked with industrial strength in the field of communication technology, Europe will be able to utilize and shape these services and possibly even standards, for mobile Internet for instance, more strongly in future.

Need for Action and Objectives

The prospects of the Internet and similar networks are nowhere near exhausted with today's routine applications – electronic mail or the World Wide Web. Other, more complex processes, such as telecooperation, video conferences via the Internet, or automated negotiations – e.g. based on agent technology – are just at the beginning, since they are still too complex and expensive to be widely used.

Special demands on networks, high levels of user competence and willingness to experiment, and other time and cost structures make it possible for research and scientific establishments to develop and test new network structures and services, which can then win over the general public.

Appropriate solutions require basic research and scientific foundations as well as international efforts and standards in order to become really effective. Initial suggestions and standards – e.g. for describing data contents (XML, Dublin Core, MPEG7 and others) – are available, although to a large extent tools and processes for dealing with knowledge in the Net are still lacking. This is why the Federal Ministry of Education and Research is funding basic research in this field.

Research Areas

- Ensure world-wide high-performing research network in the self-organizion of science; at European level, in particular the further development of GEANT, international connectivity and funding of subsequent technologies
- Mobile agents (e.g. automated software, user-related interfaces, methods for implementing authentication)
- Semantic WEB as well as tools and structures for describing, analysing, filtering, processing, compressing and presenting information in the Internet
- Personalized information and context-sensitive information on the (mobile) Internet
- Further development of intelligent search engines for scientific applications, in particular with the inclusion of broadband applications (visualizing information, information area and corresponding user interfaces),
- Use of directory services, e.g. those for managing information, managing metadata, organizing message services and scheduling processes for communities in the Internet
- Global user roles and authorization administration (in heterogeneous networks),
- Security interfaces for applications in heterogeneous networks and for future mobile (multimedia) Internet applications,
- Processes, middleware and tools for distributed computing and cooperation in the Internet (such as grid).

4.4.3. Research into Internet-Supported Processes

Initial Situation

Following the somewhat over-hasty Internet euphoria over the last years, a new, stronger systematic development of Internet-based applications in science, commerce and society is now beginning. This introduces a new phase in economic-social structural change, marked by the widespread use of network-supported processes.

The outline of this structural change can already be seen today. In the car industry, but also in other industries, provision market places such as Covisint, Supplyon and VW Group Supply, which drastically change cooperation between companies and their suppliers, are becoming established. Volkswagen AG reported in November 2001 around 500,000 transactions within the first year and a 95 % reduction in the duration of these processes.

If we in Germany want to master the opportunities and challenges of this structural change, we should greatly expand on our ability to design and control network-supported processes.
This is also a scientific challenge, since the conception, development and management of competitive Internet-based business processes require appropriate, scientifically sound methods and academic qualifications.

Need for Action and Objectives

The Federal Ministry of Education and Research will fund the setting up of competence centres for “IT Service Management”, involving industry and universities. These competence centres will integrate science, practice and teaching, and contribute towards the more intensive use of the potential of the Internet in Germany and towards being able to actively shape this potential. In addition, the Federal Ministry of Economics and Technology also supports developing and testing innovative E-business and E-government solutions with the aim of moving away from information towards interaction, transaction, and participation. The focus is on connecting production chains, from procurement and production right up to distribution and logistics, as well as designing virtual business relationships, particularly between small and medium-sized companies.

Research Areas

- Theoretical foundation and development of methods (such as mathematical simulations, assessment / pricing procedures, communication of new IT services, knowledge economics, new scientific approaches of political / economic Internet research),
- Formal product models and related subjects (service level agreements, service engineering, product catalogues, model views, metamodels, classification and standardization),
- Control processes for implementing, evaluating and controlling applications, benchmarking, audit frameworks / legal solutions,
- Basic research into marketing processes with Internet applications and services (e.g. Customer Relationship Management in mass markets, category management, communities, signalling, customer relationships/repurchase, personalization),
- Company-wide integration and new operator models (such as ASP, operations management, e-enabling, application/operation hosting).

5 Public IT Research Landscape in Germany

Fraunhofer-Gesellschaft (FhG)

The Fraunhofer-Gesellschaft is the leading body of applied research institutes in Germany. It carries out contract research for industry, service companies and the government. It develops quick and cost-effective solutions to technical and organizational problems for customers in industry and commerce. The Fraunhofer-Gesellschaft currently operates 56 research institutes in locations throughout the Federal Republic. Approximately 11,000 employees, predominantly with scientific or engineering training, handle the yearly research volume worth around 900 million Euros, more than 750 million Euros of which is spent on contract research. Around 60 % of this capacity results from the Fraunhofer-Gesellschaft's careful management of industrial revenue and publicly-financed research projects. Approximately 40 % is provided by the Federal Government and its Länder (states) as basic finance for preliminary research.

Fraunhofer Group for Information and Communication Technology (IaC Group)

Fifteen institutes within the Fraunhofer-Gesellschaft with nine sites in Germany make up the Fraunhofer Group for Information and Communication Technology (IaC Group), whose annual budget is more than 200 million Euros. The IaC Group develops joint strategies and research ideas for application-oriented information and communication technology. It coordinates the transfer of technology and research marketing in interdisciplinary projects and programmes. The Frauenhofer IaC Group and its member institutes provide partners in commerce, science, society and politics with concrete individual solutions from the whole range of IT and mathematical research, as well as with forward-thinking developments, technological evaluation and consulting services.

Under the theme of "Living and Working in a Networked World", the IaC Group follows a programme for application-oriented basic and preliminary research. In the following nine programmes, the institutes work together on important topics in the field of IT and communication technology of the future:

- New generation Internet
- Software engineering and innovative system architectures
- Multimodal communication and new media
- Knowledge and content engineering,
- IT security

- Computing and biology
- Simulation and virtual engineering
- Engineering and enterprise systems
- Innovative applications and IT-based services

These programmes include new technologies for the core and access networks of the coming Internet generation, to support personal mobility as well as the mobility of services and end devices. New systems and methods for content and knowledge management are being devised as are secure and reliable solutions for trading on the Internet, new forms of human and machine communication and net-based cooperation. The objective is to develop an IT solution that focuses on man as the user, and systems that "understand" language, gestures and facial expressions, and can even react to emotions. Computer simulations, visualization and virtual reality are being integrated into digital development environments for the development of industrial products, allowing complete digital products to come within reach of many industries. Interdisciplinary mathematical modelling and innovative algorithms thereby form the foundations. Furthermore, system solutions that support cooperation and processes are also being researched – from engineering to e-business, through to logistics.

Beyond the narrow confines of information technology, research projects are being developed which interface with biology and medicine. IT methods support chemical and microbiological research, for instance with structure analysis that is important for medical and pharmaceutical research into proteins and their functions in the organism, or genome research. Principles of evolution inspire algorithms and system design, such as the development of autonomous robots.

Fraunhofer Microelectronics Consortium (VµE)

In addition to the institutes of the IaC Group, the seven institutes in the Fraunhofer Microelectronics Consortium (VµE) are also concerned with current questions in IT research. Since it was formed in 1996, the consortium with a total of 1,450 employees and a budget of 130 million Euros has successfully coordinated the research strategies of its member institutes.

The Microelectronics Consortium is particularly concerned with developing hardware-based systems as well as their components and technologies. Its direction is increasingly determined through alignment with market requirements for a better quality of life through electronic assistance, and thereby supports the trend of mobile communication to its full extent. The inclusion of the topic of "ubiquitous electronics" in its work for approximately ten years is a logical technical consequence of microelectronics from the user's point of view. Revenue of 60 million Euros confirms the commercial demand for the consortium's work.

Current areas of focus include:

- Energy supply technologies for portable systems and end devices
- Display-based systems (display technologies based on Si and OLED)
- Photonic systems
- Electronic assistance
- Foil technologies for system carriers and components
- High frequency and optical communication systems
- Micromechatronics
- Polymer electronics ("polytronics")
- Multimedia and transmission technology ("MP3")
- Embedded Internet.

In addition to the IaC Group and the Microelectronics Consortium, institutes specializing in production engineering, traffic engineering and logistics or photonics contribute to IT research, often collaborating with the IaC institutes.

For more information, see: www.fraunhofer.de

Fraunhofer Information and Communication Technology Group

AiS	Fraunhofer Institute for Autonomous Intelligent Systems, Sankt Augustin
FIRST	Fraunhofer Institute for Computer Architecture and Software Technology, Berlin
FIT	Fraunhofer Institute for Applied Information Technology, Sankt Augustin
FOKUS	Fraunhofer Institute for Open Communication Systems, Berlin
IAO	Fraunhofer Institute for Industrial Engineering, Stuttgart
IESE	Fraunhofer Institute for Experimental Software Engineering, Kaiserslautern
IGD	Fraunhofer Institute for Computer Graphics Research, Darmstadt und Rostock
IIS-A	Fraunhofer Institute for Integrated Circuits, Applied Electronics Department, Erlangen

IITB Fraunhofer Institute for Information and Data Processing, Karlsruhe
IMK Fraunhofer Institute for Media Communication, Sankt Augustin
IPSI Fraunhofer Institute for Integrated Publication and Information Systems, Darmstadt
ISST Fraunhofer Institute for Software and Systems Engineering, Berlin and Dortmund
ITWM Fraunhofer Institute for Industrial Mathematics, Kaiserslautern
SCAI Fraunhofer Institute for Algorithms and Scientific Computing, Sankt Augustin
SIT Fraunhofer Institute for Secure Telecooperation, Darmstadt
BIOMIP Research Group for Biomolecular Information Processing, Sankt Augustin

Fraunhofer Microelectronics Consortium (VµE)

IAF Fraunhofer Institute for Applied Solid State Physics, Freiburg
IIS-A Fraunhofer Institute for Integrated Circuits, Applied Electronics, Erlangen
IIS-B Fraunhofer Institute for Integrated Circuits, IC Technology department, Erlangen
IMS Fraunhofer Institute for Microelectronic Circuits and Systems, Duisburg, Dresden and Munich
ISiT Fraunhofer Institute for Silicon Technology, Itzehoe
IZM Fraunhofer Institute for Reliability and Micro-integration, Berlin
ESK Fraunhofer Institute for Communication Systems, Munich

Additional IT Research Partners

IML Fraunhofer Institute for Material Flow and Logistics, Dortmund
IPA Fraunhofer Institute for Manufacturing Engineering and Automation, Stuttgart
IPK Fraunhofer Institute for Production Systems and Design Technology, Berlin
IVI Fraunhofer Institute for Transport and Infrastructure Systems, Dresden
HHI Heinrich-Hertz-Institut für Nachrichtentechnik, Berlin

Hermann von Helmholtz Association of German Research Centres

The Helmholtz Association conducts independent research into the long-term objectives of the state and society, including basic research. The Helmholtz Association introduced the conversion phase of its strategic new direction by setting up the registered association “Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren e.V.” on 12th September 2001 and holding the constituted session of its new senate and electing the first president on 11th December 2001.

The largest German scientific organization was reformed with the objective of using its enormous scientific potential in concerted research even more efficiently, in order to provide solutions for large, complex problems and challenges in its fields of research. The Helmholtz Association plans to concentrate its strengths in concerted research, increase competition, expand cooperation and links with science, especially with colleges and universities and commerce and to increase its role in Europe: The HGF wants to become a dynamic power in setting up European research and to provide support in this area. The research centres in Jülich and Karlsruhe are primary contacts in the field of IT at the Helmholtz Association.

Research Centre Jülich

The emphasis on information at the Jülich research centre (www.fz-juelich.de) is used to prepare new technologies for future IT developments. Furthermore, the research also concentrates on the use of supercomputers in the area of scientific computing in research and development.

The research project on materials, processes and components for micro- and nanoelectronics covers processing information in logical components, storing information in Random Access Memories (RAM) and mass memories, and transmitting information at chip and system level as well as over large physical distances. Added to this is the specific area of sensorics as an interface with the outside world. The research subjects result from the challenges that derived from further developments in microelectronics and the early stages of nanoelectronics, as well as from the potential for new types of functions such as inorganic biological interfaces for exchanging information between microelectronics and nerve cells.

The research field interfaces between pure basic research and application-related development. It bears distinctive, interdisciplinary traits, linking solid-state physics, inorganic chemistry, process technology, computer science, diverse areas of analytics as well as theory with each other. In future, this will also include biochemistry and molecular biology.

The IT methods and systems at Jülich are particularly shaped by the high demands of many research projects carried out by the research centre on experimental data entry and processing, as well as the demand for improved electronic communication and new, more efficient mathematical procedures and their implementation in software for modelling and computer simulation. The project is concerned with researching and developing efficient methods and technologies. On the one hand, these make important contributions to the R&D work of the institutes and projects of the Research Centre Jülich as preliminary research, on the other hand they contribute to increasing IT innovation and promoting new generations of scientists and technical experts in Germany.

Over the last few decades, mathematics, computer science, science and technology have become strategic disciplines in scientific computing. They focus on complex systems, that is, on problems that cannot be solved using analytical methods or standard computer resources. Simulation is the technology, the supercomputer is the tool and visualization is the aid. Research and development of new supercomputing concepts, methods and technologies is the objective of the R&D project, which excellently positions institutions within the group of German and international supercomputing centres.

Research Centre Karlsruhe

At the Research Centre Karlsruhe GmbH (FZK) (www.fzk.de), R&D work for developing microsystems has been organised in the microsystem technology (MIKRO) programme since 1992. Around 230 employees from ten institutes are involved in this programme. Work in the MIKRO R&D programme is concentrated on developing manufacturing technologies and materials (the basic technologies are micro structure technologies, material development and system design) and on application fields which on the one hand enable a fast implementation based on market conditions, yet on the other hand also require long-term development work (electronic smell sensors, micro process technology, micro optics as well as protein analytics and microfluidity).

The head of the microsystem technology programme is the contact for cooperation with other research institutes and industry as well as coordinator of the work on microsystem technology, both externally and within the FZK. Contributions to MIKRO come from the following institutes of the Karlsruhe research centre:

- Institute for Microstructure Technology (IMT): Microstructuring according to the LIGA process (UV and deep x-ray lithography including mask technology, galvanics, and casting); micro optics for telecommunication and sensorics; protein analytics and microfluidics. The IMT is certified in accordance with ISO 9001.
- Institute for Materials Research (IMF): functional ceramics; “smart materials” in thin film technology; wear-resistant and bio-compatible coatings; process technology for microsystem compatibly processing of new materials; analysis methods and testing techniques for micro components; simulation and optimizing component behaviour.
- Institute for Instrumental Analysis (IFIA): sensor systems for gases (so-called electronic smell sensors) based on metal oxide and surface acoustic wave sensors; protein analytics.
- Institute for Data Processing and Electronics (IPE): microelectronics; packaging and connection technology for microsystems; development of signal processing concepts.
- Institute for Applied Computer Science (IAI): Computer-supported methods and tools for designing, modelling and testing microsystems; computer-supported micro assembly.
- Institute for Micro Process Technology (IMVT): development of mechanical micro structure technology; development of micro structure apparatus (such as micro reactors) for chemical and thermal process technology which is innovative, safe and ensures the economic handling of resources.
- Institute for Nuclear and Energy Technologies (IKET) as well as the Institute for Reactor Safety (IRS): modelling and experimental validation of computer codes developed to calculate streams in micro channels (Lab-on-chips and micro reactors).
- Institute for Medical Engineering and Biophysics (IMB): Development and application of micro cell containers.
- Institute for Toxicology and Genetics (ITG): protein analytics.

In addition to the institutes, the following organizational units support the transfer of the R&D results:

- Research Centre Karlsruhe Industry Forum Micro Production Technology (FIF): For a annual contribution, the member companies of the FIF receive special access to the research centre's know-how.
- Centre for Raw Materials for Micro Technology (ZWM): This competence centre, which is supported – temporarily – by the Federal Government and the Land, develops innovative and economically attractive solutions for industry in the field of materials.

For more information, see: www.helmholtz.de

Max Planck Society for the Advancement of Science

The institutes of the Max Planck-Society (MPG) carry out scientific, social and humanistic research in the service of the general public with the aim of forming focal points of research excellence in specific research fields in addition to research in universities and other research institutes. A particular concern of the MPG is the promotion of future generations of scientists. Many of the subjects that are processed in the MPG institutes are directly or indirectly relevant for information technology.

In the field of hardware, basis-oriented research, particularly by those institutes that are orientated towards material science, contributes towards the new and further development of materials and processes for manufacturing components and systems of micro- and optoelectronics. The following institutes in particular spend a considerable part of their potential on these subjects, as an element of combined research, but also for purely scientific reasons: MPI for Metal Research, MPI for Solid State Research, MPI for Micro Structure Physics and MPI for Polymer Research. The Max Plank Institutes for Physics, Nuclear Physics, Plasma Physics, Quantum Optics, Polymer Research and for Astrophysics also contribute their scientific research to progress in order to solve specific application problems.

The Max Planck Institute for Computer Science in particular makes basic contributions to the field of software by developments in logical constraint languages and programming tools. Basic knowledge is also developed by the Max Planck Institutes for Mathematics, for Mathematics in Natural Sciences, for Physics of Complex Systems and for Gravitational Physics, as well as by a number of theoretical departments at other Max Planck Institutes. Added to this is research work on elements of neural and cognitive processes, for example at the Max Planck Institutes for Biological Cybernetics, for Experimental Medicine, Neurological Research, Psycholinguistics, Brain Research, Neuropsychological Research, and Biochemistry. On the other hand, only a few research groups carry out development of software that can also be useful for and made accessible to other users.

Essential new initiatives for microsystem technology emerge from the research fields of the scientific and bioscientific Max Planck Institutes. This affects the foundations for new sensor-, measurement and medicine technology in particular.

The humanities institutes of the Max Planck Society are concerned with the social affects and the framework requirements of the new technologies. The law institutes apply themselves to questions of data protection, patent and copyright. The Max Planck Institute for Social Research focuses on sociological evaluative research into the development of telecommunications; the MPI for Psychological Research is concerned amongst other things with the use and effects of computers in schools.

Innovative developments in the field of the provision of scientific information and the electronic preparation and communication of scientific contents are expected from the Heinz Nixdorf Centre for Information Management in the MPG, which began work on 1 September 2001. Within the framework of its general coordination tasks, consultation for setting up suitable infrastructures and development of software tools, the centre plans more in-depth research projects together with individual Max Planck institutes and external partners to enhance electronic scientific documents with semantic structures and to retrieve information for example.

For more information, see: www.mpg.de

German Research Centre for Artificial Intelligence

The German Research Centre for Artificial Intelligence based in Kaiserslautern and Saarbrücken is a private GmbH (limited company) with a non-profit making status. Under the scientific leadership of Prof. Wahlster, the centre has four additional scientific directors at both sites, with professorships at each of the universities. The two universities in Kaiserslautern and in Saarbrücken are associates of the centre. Additional associates include seven companies and a research institution.

The DFKI currently has 140 scientific employees and a budget of around 15 million Euros, of which approximately 2.5 million Euros come from Federal Ministry of Education and Research capital as part of a research project which serves the purpose of basic research at the centre. The centre receives a corresponding range of preliminary research projects from the two Länder of Rhineland-Palatinate and the Saarland. Under conditions of free competition it acquires research projects from the Federal Government, the European Union and commerce, and is a sought after and recognized partner for R&D projects, particularly on the part of the European Commission.

Research at the DFKI focuses on intelligent user interfaces, language technologies, knowledge management, multiagent and deduction systems as well as intelligent visualization and simulation systems. In 2001, Prof. Wahlster received the Federal President's "Future Prize" for leading the "VERBMOBIL" project for recognition and translation of freely-spoken speech.

For more information, see: www.dfki.de

The Leibniz Association

The Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz e.V. – the Leibniz Association – is an association of 78 scientifically, legally and economically independent research institutes and scientific service institutions in Germany, which are jointly financed according to the "blue list" model by the Federal Government and its Länder. It coordinates the common interests of the member establishments, increases cooperation in research and science, promotes future generations of scientists and develops common tools for ensuring the quality and increasing the efficiency of its members. The following institutions are particularly relevant for information and communication technology:

Institute for Crystal Growth (IKZ)
D-12486 Berlin, Max-Born-Strasse 2

Max Born Institute for Non-Linear Optics and Short Pulse Spectroscopy (MBI)
D-12486 Berlin, Max-Born-Strasse 2a

Paul Drude Institute for Solid State Electronics (PDI)
D-10117 Berlin, Hausvogteiplatz 5–7

Ferdinand Braun Institute for Ultra High Frequency Technology (FBH)
D-12489 Berlin, Albert-Einstein-Str. 11

Institut for Semiconductor Physics (IHP)
Frankfurt/Oder GmbH
D-15236 Frankfurt/Oder, Im Technologiepark 25

Weierstrass Institute for Applied Analysis and Stochastics (WIAS)
D-10117 Berlin, Mohrenstrasse 39

For more information, see: www.wgl.de

6 Financial funding for "IT Research 2006"

(Figures in thousands of Euros)

	2002	2003	2004	2005	2006	Summe
IT project sponsorship (research)						
1. Nanoelectronics and systems	77,500	79,500	79,500	79,500	79,500	395,500
2. Software systems	50,000	55,700	55,700	55,700	55,700	272,800
3. Basic technologies for communications engineering	54,500	57,000	57,000	57,000	57,000	282,500
4. Internet basics and services	26,600	31,200	30,900	30,900	30,900	150,500
Communications:						
a. Microsystem technology	55,500	59,000	59,000	59,000	59,000	291,500
b. "UMTS" funds for software systems and Internet	32,400	28,600	0	0	0	61,000
				Total:		**1,453,800**

IT – Sponsorship of institutions for the period 2002 - 2006 (planned and estimated figures)	
1. FhG	810,000
2. HGF	340,000
3. WGL	190,000
4. DFG	140,000
5. MPG	40,000
Total:	**1,520,000**

Total funding from the BMBF for information and communications technology	
1. IT project sponsorship (research)	1.5 bn €
2. IT sponsorship of institutions	1.5 bn €
3. Area of application of project sponsorship in "IT in Education"	0.6 bn €
Total:	**3.6 bn €**

7 BMBF project management organization

a) Project management organizations for information technology (PT-IT) at the Federal Ministry of Education and Research at the German Aerospace Centre (DLR).

Subject area	German Aerospace Centre (DLR)	
	Linder Höhe, D-51147 Köln, Germany	Rutherfordstr. 2, D-12489 Berlin,Germany
Nanoelectronics and systems		Prof. Dr. Werrmann +49 / 30 / 6 70 55-7 20
Softwaresystems		Dr. Wolf +49 / 30 / 6 70 55-7 40
Basic technologies for communications engineering	Mr. Schmidt +49 / 22 03 / 6 01-36 42	
Internet basics and services		Dr. Weigmann +49 / 30 / 6 70 55-7 60

For information, see: www.dlr.de/IT

b) VDI Technology Centre

Subject area	VDI Technology Centre Graf-Recke-Strasse 84, D-40239 Düsseldorf, Germany	
Magnetoelectronics, spintronics	Dr. Dreßen +49 / 2 11 / 62 14-5 80	Dr. Böltau +49 / 2 11 / 61 24-4 65

For information, see: www.vditz.de

c) PProject sponsors for information technology (PT-IT) at the Federal Ministry of Economics and Technology at the DLR

Subject area	German centre for aerospace Linder Höhe, D-51147 Cologne, Germany
Multimedia, foundation of new companies, pilot applications and best practise, tele-cooperation, security and user-friendliness through technology	Mr. Wältring +49 / 22 03 / 6 01–36 71

For information, see: www.pt-multimedia.de

General information on funding by the Federal Ministry of Education and Research can be obtained from the BMBF Funding Information Office:

Forschungszentrum Jülich GmbH
– PTJ –
Wallstr. 17–22, D-10179 Berlin
Tel.: 0 18 88 - 57 27 11, Fax: 0 18 88 - 57 27 10
E-mail: beo1101.beo@fz- juelich.de
For information see: www.fz-juelich.de/ptj/bmbf_auskunft_home.html

8 Glossary of Terms Used

- **Ad hoc network**
  (Radio) network that manages itself without a fixed infrastructure.
- **Adaptive software systems**
  Software system that adapts itself independently to the prevailing context conditions.
- **Affective computing**
  New IT research area; looks into the role of human emotions in taking in information, when thinking and so on, as well as the computer's strategy for communicating with humans; particularly important for the research area of interaction between humans and technology.
- **Agents**
  In the "network", those programmes that can perform tasks autonomously and are able to learn are called agents.
- **Application**
  Programme / service for solving specific tasks and creating documents, e.g. word processing or spreadsheet programmes, telephone, search engines.
- **ASIC**
  Abbreviation for Application Specific Integrated Circuit
- **ASP**
  Application Service Provider.
- **Aspect-orientated software development**
  New programming methodology with the aim of creating software in an improved logical structure.
- **Auto-stereoscopic 3-D display**
  Displays that generate a three-dimensional image without any additional aid (such as glasses).
- **B2B**
  Business to Business – describes electronic business relationships between companies
- **B2C**
  Business to Consumer – describes electronic business relationships between companies and consumers –.
- **Backend processes**
  Wafer test, bonding and packaging the chip, right up to the end test of the saleable component part (often also known as components and packaging technology).
- **Bandwidth**
  Spectrum (frequency) that is required to transfer data over a medium (air interface, cable or glass fibre).
- **Bandwidth efficiency**
  Efficiency with which the existing bandwidth can be used for data transmission; specified in Bit/s/Hz (Bit per second per Hertz).
- **Best effort**
  The best data connection under the given network conditions. It is generally used to express that the partners involved in Internet communication are in no way responsible for the network itself, and that they therefore cannot accept responsibility for the results of their communication (for example, regarding the quality of transmission). The opposite of this are "Service Level Agreements", whereby the persons involved are obliged to meet specific, objective quality criteria ("quality of service").
- **Burst switching**
  Special switching method in optical data communication, whereby a number of data packets are switched at once.
- **CASE**
  Abbreviation of "Computer Aided Software Engineering".
- **Category management**
  Organization of offers on the market related to the customer's situation (and not related to product categories).
- **CDMA process**
  Code Division Multiple Access; special signal coding process that is used with UMTS, amongst others.
- **Chip**
  Component part that contains the integrated circuit. Examples are DRAM, microprocessors or ASIC.
- **Chip complexity**
  Connection of several different functions (such as sensorics, processing electronics, memories, transmitters), circuit types (analogue, digital) or systems (electronic, optical, electromechanical) to a chip, usually connected by a large number of transistors.

Chip design, circuit design
Structured conversion of electric and logical specifications of the required IC or circuit system in production documents, such as mask sets, which contain the geometric structures of the integrated circuit. These are transferred to the wafer by lithography and additional technological steps.

CMOS technology
Standard circuit technology for integrated circuits (complementary metal oxide semiconductor). The vast majority of silicon integrated circuits are currently produced in CMOS technology.

Communities
Virtual communities in the Internet based on similar interests.

Community learning
Target group-specific training.

Constraint technology
(Artificial intelligence) methods for logical programming based on outline requirements for the problem.

Cooperative research
Research that is carried out in cooperation with companies and public R&D institutes.

Core networks
Central part of the communication network, in which language and data are transmitted across wide areas at top speed.

Customer relationship management
Maintenance and organization of customer relationships; in the context of the Internet, this usually describes systems that organize company data in such a way that emphasis is always placed on information and relationships with the customer.

Data mining
Examination of (very) large datasets and recognition of information interdependencies.

Data packet
Within the framework of a data network, a data packet is a defined formation of characters, which are treated as a unit by transmission services with data packet switching.

Data rate
The transfer capacity of communication systems, which is generally specified in Bit/s (Bit per second) or in Mbit/s (megabit per second).

Design gap
Gap between the complexity of circuits, which could be feasibly manufactured and the type of complexity that can actually still be controlled in the circuit design.

Design productivity
Number of all logic gates or other circuit functions, which are converted into working chips by each developer in a year.

Designability
The ability to convert manufacturing circuits that can potentially be produced in an adequate circuit design.

DFN
German Research Network (Deutsches Forschungsnetz) – the computer-controlled information and communication system for science, research and education in Germany, which is operated by the DFN Association (www.dfn.de).

Directory
FOn the Internet, this usually means directories of Internet addresses, on the basis of which information can be “routed” to its destination.

DLP
Digital Light Processing; describes the process by which the light from a projection lamp is shone onto a DMD chip, from where it is projected onto a screen.

DMD
Digital Micromirror Devices; core of DLP technology; chip with more than 500,000 moving micromirrors.

DRAM
Dynamic Random Access Memory, chip with working memory (read-write memory).

DSL
Digital Subscriber Line; broadband data transfer using standard copper wiring.

Dublin Core
An open, international process resulting in the compilation of fifteen fundamental elements, which are used to describe digital and non-digital (physical) information sources so that they can be later retrieved as the result of a targeted search.

Electron spin, Spin
Elementary property of an electron, which is the basis of all magnetic effects.

Electronic Design Automation (EDA)
Computer-supported, largely automatic design of complex circuits or whole systems, from the creation of a specification right up to the result that can be mass-produced.

- **E-mail**
  Electronic mail (electronic post), the easiest basic function of computer networks, the most widely used service on the Internet.
- **Embedded systems**
  A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function. In some cases, embedded systems are part of a larger system or product, as is the case of an anti-lock braking system in a car.
- **EMVU**
  Electro-magnetic environmental compatibility.
- **E-services**
  Electronic services. Services over a network (usually the Internet), such as ASP.
- **Front end processes**
  Semiconductor production of structures, ranging from integrated component parts on the wafer right up to wafer processing.
- **ftp**
  File transfer protocol; as well as the transmission protocol, it also describes the Internet service that is implemented with this protocol. It enables data/files to be transferred between different computers or rather, between special "file" servers over the network.
- **Generative programming**
  Creation of programmes and parts of programmes from given specifications.
- **GRID computing**
  Transparent use of productive hard and software resources that are not networked locally.
- **GRID**
  "Grid"; nowadays this usually describes the idea of several computers working together in a cross-organization network (such as the Internet).
- **GSM**
  The Global System for Mobile Communication is today's world-wide standard for digital mobile phone networks, on which all German mobile networks are based. The data transmission rate is 9.6 Kbit/s.
- **Haptics**
  Study of the sense of touch.
- **Heterogeneous networks**
  Intersection of networks with the same type of function, but which are implemented and structured differently.
- **HiPerLAN/2**
  High Performance Local Area Network; radio transmission standard in a local area network (LAN) in a frequency band above 5GHz with up to 25Mbit/s net data rate.
- **IC**
  Integrated circuit.
- **Information retrieval**
  Retrieval of information, above all with vague queries and uncertain knowledge.
- **Integration level**
  Number of the functional elements on a chip, such as transistors; the Pentium P6 chip consists, for example, of approx. 10 million transistors, the Athlon K7 processor even has around 22 million transistors.
- **Intellectual properties**
  Standards, circuit designs, descriptions of electronic function blocks, software and design tools, which users can reuse in their own circuit designs, or which can be offered for use by third parties. Intellectual Properties can be protected by protection rights (such as patents).
- **Internet**
  Sum of all computer networks that are joined together throughout the world, which communicate with each other in accordance with a standardized procedure (including IP protocol).
- **Interoperable software**
  The ability of software systems originating from different manufacturers to communicate with each other.
- **IP**
  Network protocol that adds address information to data packets, with which the data packets can be delivered ("routed") independently, they can be checked for completeness their receipt can be controlled. One of the protocols on which the Internet is based.
- **IPv6**
  Internet Protocol Version 6 enhances the Internet address area from 32 Bit to 128 Bit and the protocol functionality. The protocol has not yet been implemented.
- **ITRS roadmap**
  The association of the US semiconductor industry (Silicon Industries Association, SIA) creates a 15-year prognosis every 2 to 3 years, the ITRS roadmap (International Technology Roadmap for Semiconductors) for developing all essential technical, technological and economic microelectronic data..

- **Knowledge Based Engineering**
  Engineering of knowledge-based systems.
- **Knowledge discovery**
  Methods for analysing data with the aim of finding or visualizing hidden interdependencies.
- **Knowledge economics**
  Science that deals with rules that result from dealing with knowledge in groups of humans.
- **LC display**
  Liquid Crystal Display; technical principle for implementing flat screens.
- **LCOS**
  Liquid Crystal on Silicon; reflective micro displays based on silicon.
- **LED**
  Light emitting Diode..
- **Lithography**
  Process in semiconductor technology for transmitting structure details from the switch design to the chip. This usually uses the principle of the optical, minimized projection of several "slides" (exposure templates that contain the chip image) onto the wafer. Since the minimum number of structure measurements that can be reached is determined primarily by lithography, it adopts the role of pacemaker in increasing the performance of ICs and at the same time decreasing structure size.
- **Magneto-electronics**
  Electronics that uses ferromagnetic component parts to enhance chip functionality.
- **Meta data**
  Data about data, contextual information that describes, for example, the format of data or their affiliation to specific subject areas.
- **Metro network (Metropolitan Area Network; MAN)**
  Telecommunications network, which covers the local area and regions.
- **Microprocessor**
  "Electronic brain", chip with a highly complex calculation unit.
- **Middleware**
  Middleware is a group of general-purpose programmes that are located between the system platform (hardware + operating system) and the applications, and which support application data traffic. This type of programme is also known as "services".
- **MPEG 7**
  International standard that represents the content of audio and video sequences, images and graphics in an efficient and expedient display, thereby ensuring that you can search for information. The standard was set by the Moving Pictures Experts Group, hence the name MPEG.
- **Multiband**
  Concerning multiple frequency bands.
- **Multimodal**
  Concerning several senses or interaction modes.
- **Multiplex procedures**
  Combination of several signal streams for transmission in one transmission path.
- **Multistandard**
  Concerning different transmission standards.
- **Nanoelectronics**
  Microelectronics with structures that define the function of less than 100 nanometres.
- **Nanometre**
  10^{-9} metre, the millionth part of a millimetre.
- **OLED display**
  Displays from Organic Light Emitting Diodes (organic LEDs).
- **Ontology**
  Modelling of a domain (basic terms, facts, relationships between the two). Ontology ensures that domain knowledge is correctly converted into semantics.
- **Organic computing**
  Solution for complex overall processes above the detailed algorithmical levels.
- **Packaging**
  The sum of a large variety of technologies for "packaging that is suitable for chips", as well as realizing (electrical and other) interfaces of integrated circuits with the outside world.
- **Personalization**
  Selection and display of data that is specially adapted to a user, based on the information that the user stored.
- **Photonic crystals**
  Crystals with special optical properties that are required for the specific processing of optical signals.
- **Power electronics**
  Branch of microelectronics in which the active components mainly have circuit functions and are used either to control different types of actors (such as in vehicle electronics), or to form and control larger streams or higher power.

- **Quality of Service**
  Combination of different criteria, which describe the quality of a service in the network with respect to speed and reliability.
- **Rendering**
  Computer graphic: image process from an internal 3-D computer model to a 2D screen for monitors and print-out.
- **Requirements Engineering**
  Requirements analysis for software systems.
- **Scalability**
  Property of a technical system to adapt itself to the required task. Example: a parallel computer with double the number of processors works at approximately twice the speed. The term is also used for applications.
- **Security**
  Access security of IT systems.
- **Self-organized software systems**
  Software systems that are able to arrange, structure and execute active and independent processes.
- **Semantic web**
  Technology that supports access to unstructured, heterogeneous and distributed information on the Internet.
- **Service**
  In a network such as the Internet, a service is an application that is available to all of the computers that are connected to the network. On the Internet there are many different types of services, such as the "World Wide Web", e-mail, newsgroups etc.
- **Signalling**
  Signals product properties that are not recognizable before purchasing the product; this is a central feature in particular with services on the Internet.
- **Silicon wafer**
  Silicon crystal in the form of a perfectly circular disk with, for example, 200 or 300 mm diameter and a thickness between 500 and 800 micrometers. Initial product for chip manufacture, to which the individual structure details of the future switch are transferred using lithography.
- **Silicon, Si**
  Important semi-conductor material; in the very pure form that is required for microelectronics, it is extracted over different intermediate levels from quartz sand (silicon dioxide).
- **SME**
  Small and medium enterprise.
- **Software radio**
  Software-controlled telecommunications device, which can be adapted according to requirements to the current radio infrastructure.
- **Spectrum pooling**
  Common, serial use of a frequency band by different users (mobile phone operators, military, and so on).
- **Spintronics**
  Area of research with the aim of using electron spins to enhance chip functionality.
- **System-on-Chip (SOC)**
  Term for implementing whole, highly complex systems on a single chip (instead of switching several chips).
- **Tacit knowledge**
  Knowledge that cannot be understood using formalized knowledge models.
- **TDMA process**
  With Time Division Multiple Access, the individual participants send their data packets at the same frequency, but in so-called timeslots one after each other, according to a specific frequency scheme.
- **Ubiquitous computing**
  Global computing that is not linked to a particular place.
- **UMTS**
  The Universal Mobile Telecommunications System is the standardized third generation mobile phone system in Europe and Japan. Like CDMA-2000 (the striven for third generation system in the USA), UMTS uses the CDMA process as the modulation technology. Data rates of up to 384 kbit/s are typical.
- **Usability engineering**
  Systematic approach for easily creating software – here for example user-centric software creation.
- **Usenet**
  Independently managed network that is linked to the Internet via interfaces.
- **VR/AR**
  Abbreviation for Virtual Reality/Augmented Reality.
- **WBG semiconductor**
  Wide Band Gap semiconductors are semiconductors with a wide band gap. Examples are Gallium nitrate (GaN) or silicon carbide (SiC).

- **WDM**
  Wavelength Division Multiplex; simultaneous transfer of several (light) signals with different frequencies over a medium (such as glass fibre).
- **World Wide Web**
  Abbreviation: www or w3 – a computer-controlled information system that is organized in a client/server architecture, which, typically using several www servers, provides information, data, images, screen sequences, audio sequences and so on that are stored in hypertext format and can be called by www clients to be displayed, stored, printed or forwarded locally.
- **XML**
  Extensible Markup Language – meta language for creating documents in the World Wide Web. XML can create a separate, formal language and map the structure of any document type. The syntax itself is more rigid with XML than with “HTML”.

- **world wide web**

  Abgek. www oder w3 – ein in Client/Server-Architektur organisiertes rechnergestütztes Informationssystem, über das verteilt, typischerweise über mehrere www-Server, im Hypertext-Format gespeicherte Informationen, Daten, Bilder, Bildfolgen, Tonfolgen etc. bereitgestellt und von www-Clients zur lokalen Präsentation, Speicherung, Ausdruck oder Weiterleitung abgerufen werden können.

- **XML**

  Extensible Markup Language – Metasprache zur Erstellung von Dokumenten im World Wide Web. Mit XML lässt sich eine eigene formale Sprache erzeugen und die Struktur eines beliebigen Dokumententyps abbilden. Die syntaktischen Vorgaben selbst sind bei XML strenger als bei „HTML“.

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