Centre for Telematics and Information Technology

ANNUAL REPORT

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PREFACE

The Centre for Telematics and Information Technology (CTIT) has concluded its fourth year of operation. It was a year in which initiatives, started previously, took further shape and came to fruition.

The university's policy to strengthen telematics research, has been targeted at five key research areas: user environments, architecture of telematics systems and applications, telematics applications systems, networks, and systems management. CTIT appointed four senior researchers to strenghten these areas. As a result we were able to play a substantial role in the establishment of the national Telematics Institute in Twente, physically close to CTIT. The Telematics Institute is a mixed private-public initiative funded by government, a number of companies and four research institutes (CTIT itself, CWI, University of Delft and TNO). Projects started in late 1997 with a strong participation of CTIT, in particular through the MESH and Testbed projects. In the coming years we expect a considerable build-up of the CTIT research activities in the Telematics Institute.

A new initiative was taken: the establishment within CTIT of an Advanced Networking Technology Center. This is a laboratory with state-of-the-art network and measurement equipment which will be used for experimental networking research. The laboratory is supported by a number of companies, e.g., through donations of equipment. The intent is for CTIT to become an expertise center on networking technology for industry.

The Telematics Graduate School was established to foresee in the educational aspects of the Ph.D. programme. A succesful bid for recognition of the graduate school by the Royal Dutch Academy of Sciences was made. All research activities of Ph.D. candidates of the Telematics Graduate School will be carried out within CTIT.
CTIT also gave an impulse to two further initiatives in the realm of education: the development of a telematics engineering degree programme and an international Master of Science programme. Both are seen as long term solutions to alleviate the severe shortage of telematics experts.

In quantitative terms CTIT has grown considerably with respect to 1996. The number of externally funded projects grew from 14 to 18 in 1997, the associated funding increased by a factor of 2.5 and the number of staff and researchers employed by CTIT grew in 1997 from 23 to 42.

We can look back at a successful year with a lot of growth. Achieving synergy between the disciplines present in the CTIT still remains a major concern and a challenge. As we have learned before, it requires a sustained effort from all involved parties to get the benefits. We expect that the participation of CTIT in the Telematics Institute will be a strong incentive to achieve this.

This Annual Report presents an overview for the year 1997 of:

- new developments in telematics research at the CTIT (Section 1)
- the research programme (Section 2)
- the research projects (Section 3)
- the CTIT organisation (Section 4)
- the CTIT finances (Section 5)
- the external visibility (Section 6)

There is a companion CTIT publication, entitled "CTIT Projects and Scientific Results 1998", which gives a complete and detailed report on the projects and the research results achieved in 1997. This report is available from September 1998.

We would like to thank Board of Directors, the CTIT researchers, Scientific Council members and support staff. Their dedication was crucial for reaching the ambitious goals that CTIT has set for itself.

Prof. dr. ir. I.G. Niemegeers
Scientific Director

The CTIT in 1997

1 Telematics Research at the CTIT

The Centre for Telematics and Information Technology (CTIT), a research institute of the University of Twente, is in its fourth year of operation. The CTIT research focuses on the design of complex telematics and information technology systems. It comprizes not only research on the technical apects of these systems, but also on the complex issues of how to successfully introduce and use these systems in organizations, businesses and private life. Six departments of the University of Twente (technical and non-technical disciplines) are involved in the institute.

Telematics is one of the spearheads of research at the University of Twente. In 1996, the university granted within the framework of its incentive policy an extra budget of 1 Mdfl per year to the CTIT, for a period of five years. The purpose of this incentive was to strengthen the CTIT's research programme, in order to be in a good position to join a national initiative for leading technological institutes. In 1997, the university's incentive proved to be a major step in achieving this goal: the CTIT was able to play a substantial role (in collaboration with the Telematics Research Centre and other Dutch academic institutes) in the definition of plans for this leading technological institute. This finally lead to the establishment by the Dutch government of the LTI on telematics research: the '*Telematics Institute*' started operating on October, 1, 1997. A considerable part of the CTIT's research will be performed within the framework of this institute.

1.1 1997: A Quick Overview

The year 1997 can be characterized as a year in which initiatives, started in previous years, took further shape. The University's incentive policy to strengthen telematics research, has been targeted at five key research areas:

- Architecture of Telematics Systems and Applications

- User Environments
- Telematics Applications Systems
- Communication Networks
- Operational Aspects and Management of Telematics Systems

The CTIT attracted senior researchers on four of these areas. It has also invested in three part-time senior researcher positions: one within the area of Photonic Networks, one within the area of Speech and Language Engineering, and since December 1, 1997, one within the area of Tele-Education and Training.

In 1997, the research programme of the CTIT has been finalized, and major contributions have been made to initiatives for a separate telematics undergraduate curriculum at the University of Twente, as well as a Masters of Science programme on telematics, destined for foreign students. Also, a lot of effort was spent on contributions to the business plan, research programme and research projects of the Telematics Institute.

CTIT Research Programme

In 1997, the definition of the CTIT research programme has been completed. This programme has a scope of five years, to be annually updated. It provides a framework for all multidisciplinary research activities within the institute. An outline of the programme is given in Section 2.

Research Projects

The CTIT was successful in the acquisition of new projects. The number of externally funded projects increased in 1997 to 18 at the end of the year, some more will start early 1998. The income from external funding has grown by a factor 2.5 with respect to 1996 (2.586 Kdfl versus 1.065 Kdfl). Sixty percent of the budget of the autonomous part of the institute is now funded externally. This has led to an increase of personnel from twenty-three to forty-two within the autonomous part of the institute.

1.2 Leading Technological Institutes

In 1995 the Minister of Economic Affairs issued a report "Kennis in Beweging"[1] in which he disclosed his views on increasing and improving the economic growth and competitiveness of the Netherlands by the establishment of five Leading Technological Institutes in areas closely linked to Dutch industrial interests. These institutes would be funded by three parties: the government (about 11 Mdfl per institute per year), industry and the participating research institutes.

Within the area of telematics, an initiative for a Leading Technological Institute (LTI) was started by the Telematics Research Centre (TRC). The TRC succeeded in building a strong consortium of companies and research institutes. The plans of this Consortium successfully passed the selection, resulting in a positive decision by the Dutch Governement on April 14, 1997. The ’Telematics Institute’ started operating in October 1997.

The Telematics Institute is a unique collaboration between major Dutch companies and research institutes within the area of telematics. The involved industrial partners are: ABP/USZO, Arcadis Heidemij, CAP Gemini, CMG, ECT, Ericsson, IBM, ING, KPN, Lucent Technologies, NOB, NS, Océ, Origin, Rabofacet, Syllogic, and VNU. The participating knowledge institutes are, beside the University of Twente (CTIT), the Technical University of Delft, CWI and TNO-MET. The scientific staff of the TRC has been transferred to the central organization of the Telematics Institute; therefore the TRC ceased to exist. Prof. Chris A. Vissers has been appointed director of this institute.

The University of Twente has committed a contribution of 1Mdfl per year to the Telematics Institute. For the CTIT, participation in the Telematics Institute is of major importance. New opportunities for collaboration in a national and international context will appear, and substantial sources of funding for

1. "Kennis in Beweging: over kennis en kunde in de Nederlandse economie", Report Ministry of Economic Affairs (24R58), 1 June 1995.

telematics research can be accessed. In fact, participation in the Telematics Institute is a unique opportunity for the CTIT to better fulfil its mission and to firmly establish the CTIT as the centre of academic expertise in the field of telematics in the Netherlands.

1.2.1 Research within the Telematics Institute

1.2.1.1 Research 'philosophy'

The research within the Telematics Institute consists of a mix of basic research, which is of a generic nature, generally of long-term duration with a strategic character, and market-driven research, which is closely linked to the needs of industry, mostly of short-term duration. The philosophy is, that effective knowledge transfer from universities to companies (which is one of the objectives of the Telematics Institute) requires a substantial amount of market driven research carried out jointly with industry. The institute strives to achieve a balance between basic research and market drive research.

1.2.1.2 Research programme and research projects

The research programme of the Telematics Institute has been determined by its Programme Council in the fall of 1997. The underlying research topics were put forward by the participating industrial companies. Projects will encompass a considerable industrial component, clearly based on concrete research questions raised by industry. About twenty proposals are in preparation, and around May 1998, the first projects started.

The MESH and Testbed projects (in which the CTIT already collaborated with the TRC) have been brought in into the Telematics Institute; the CTIT therefore has already a substantial contribution to the newly established institute.

1.2.2 The role of the CTIT within the Telematics institute

The CTIT (as other academic partners) has direct influence on the research programme of the Telematics Institute since the Director of the CTIT is a member of its Programme Council. This allows us to harmonize our research programme with that of the Telematics Institute.

1.3 Telematics Graduate School

At the end of 1997, the Telematics Graduate School (TGS) was established. The Graduate School is closely related to the CTIT: its research is situated at the heart of it, i.e., it is aimed at telematics research in a multidisciplinary context. As such, the research programme of TGS is based on that of the CTIT. In order to prevent double structures, the organizational structure is similar to that of the CTIT, and the director of the CTIT, prof. Ignas Niemegeers, is director of TGS as well. Only where needed, new structures are introduced (e.g., an Educational Council). However, CTIT and TGS are not completely equivalent: some research groups of the CTIT are involved in other national graduate schools: IPA (software algorithms), SIKS (knowledge-based systems), BETA (business engineering and technology application), MRI (mathematics) and COBRA (communication technology / opto-electronics). Within the context of research conducted in the Netherlands, TGS has a clear and unique identity: the multidisciplinarity of its research distinguishes it from other graduate schools, that are more discipline-oriented. In May 1998, TGS acquired official recognition by the Dutch Academy of Sciences.

Although initially TGS is based on research groups of the University of Twente, it is open to participation of relevant disciplines from other universities. In particular, steps are being taken to extend the school with the telecommunications research group of the Technical University of Delft. Organizational changes at the TU Delft have prevented their formal participation to TGS at this moment, but joint research activities are being established in the context of the Telematics Institute. Full partnership of TU Delft is expected in the course of 1998. Also, junior researchers of the Telematics Institute can enroll as Ph.D. students in TGS, since the collaboration between the University of Twente and the Telematics Institute has been settled in a Collaboration Agreement.

1.4 Advanced Network and Technology Centre

The CTIT created an expertise centre: ANTC (Advanced Network and Technology Centre) on advanced networks and applications (ATM technology, measurements, and management).

The objective of the ANTC is to advance the dissemination of knowledge, available at the university, as well as to inspire the research through new (practice-based) questions. To this end, the CTIT collaborates with suppliers of equipment and potential users. ANTC provides demonstration facilities and will provide courses, expertise on relevant scientific research, applications and future developments. In 1997, the ANTC acquired equipment from several vendors, such as ATM switches, beta-test software and hardware (routeservers and ethernet bridges), and management software, in order to carry out experiments

1.5 Future developments

CTIT has introduced a "Distinguished Visitors Programme", through which leading scientists within the field of telematics will be invited to visit the CTIT on a temporary basis, in order to give an impulse to specific research areas. The "Distinguished Visitors Programme" is especially meant to strengthen research areas that are at present inadequately represented within the CTIT.

2 Research Programme

URL: http://www.ctit.utwente.nl/Docs/research/index.html

In 1997, in view of the participation in the Telematics Institute, the definition of the CTIT research programme has been completed; it has been adopted by the Scientific Council in November 1997. The research programme offers a structure for projects within the CTIT, such as ACTS and ESPRIT projects, individual Ph.D. projects and other externally funded projects.

The research programme serves as the long-term strategic reference for all research activities within the CTIT; it describes the research issues that will be addressed the next five years and provides the basis for:

- the coordination of research projects.
- the CTIT organization, such as for instance the appointment of area leaders and the constitution of the Scientific Council.
- the evaluation of the research, as may be performed by the CTIT board, the VSNU and / or other organizations.
- the external presentation of the research, which takes place through, for instance, the CTIT Annual Reports and the CTIT web server. The research programme will also be used to structure the UT's 'Onderzoek Informatie Systeem' (OIS) and 'WebDoc' system. Research results will thus be published according to this new structure.

The research programme has a scope of five years, parallel to the commitments of the participating departments. It will be updated annually.

2.1 Structure of the research programme

The Research Programme is structured into research areas and clusters of research areas. The choice of areas is motivated by the external (societal and economic) relevance of the areas, thus reflecting the external orientation of the CTIT research. As a consequence, research of individual groups can be programmed under more than one area. Area clustering reflects the CTIT's view on telematics: some areas are concerned with the primary goal of telematics research, i.e., designing telematics systems or telematics system user environments; other areas are concerned with the design methods and techniques for this; and yet other areas are concerned with the enabling technologies.

The following figure gives the structure of the research programme:

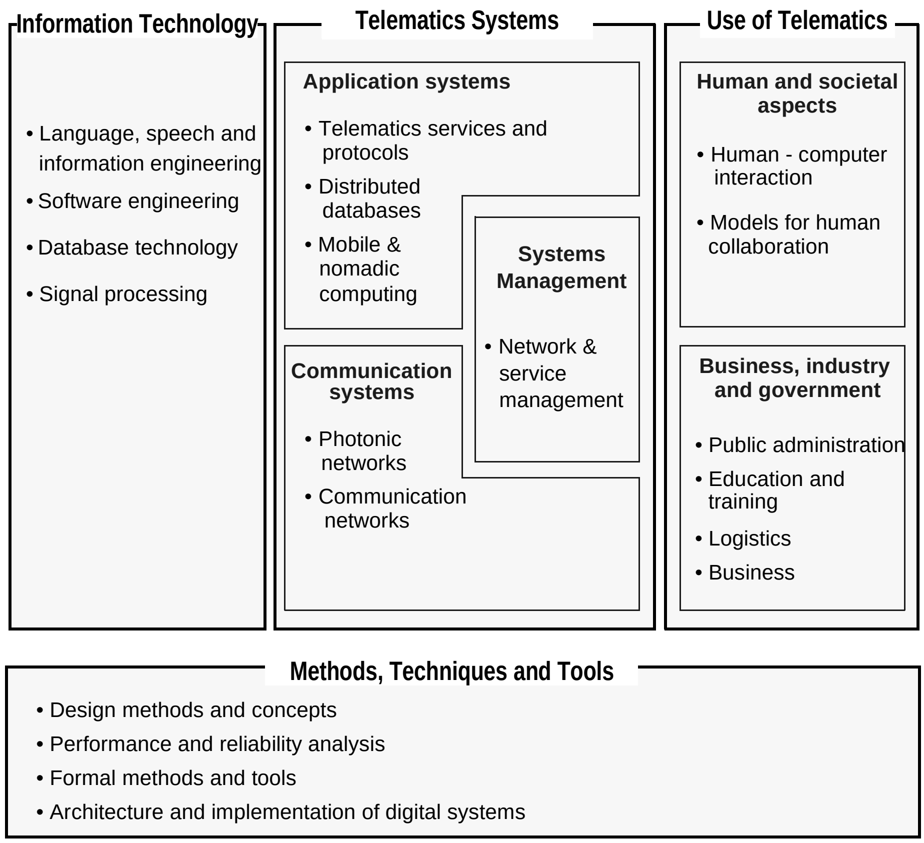

Figure 1: Structure of the CTIT Research Programme

2.2 Description of the Research Areas

2.2.1 Information Technology

This cluster is concerned with the development of technologies that enable the engineering of telematics systems and user environments. The cluster consists of the following areas:

- I1: Language, speech and information engineering.
- I2: Software engineering.

- I3: Database technology.
- I4: Signal processing.

2.2.1.1 Area I1: Language, speech and information engineering

Applications enabled by the technology corresponding to LSI engineering are conceivable and/or currently developed for domains where there is a need for information content processing, for easy access to information sources, and for man-machine communication. Electronic information content has become a key element in everyday life. The need for utilizing information content is still increasing. The challenge to provide improved information services via telephone, Internet and CD, requires a thorough understanding of the basic carrier of information: natural language.

Natural language can have many different realizations. It comes as speech and as text. Automating the process of written and spoken language understanding requires the availability of various technologies, including text processing, speech processing, and techniques for the handling of context dependent aspects of language, such as knowledge engineering, and expertise on handling meta-information. By focusing on these technologies the area addresses the needs following from the ICT functionality required by service providers, professional content providers and document production departments. The area makes the linguistic knowledge available that supports support document-intensive processes in distributed enterprises and that helps consolidating distributed knowledge into collaborative document spaces, and it provides tools for the use, reuse and commercial exploitation of digital information among the general public.

2.2.1.2 Area I2: Software engineering

Telematics systems are among the most complex software systems of today. Software companies have to deal with very high software testing and maintenance costs. Designing robust, adaptable, reusable and maintainable software systems is considered as one of the crucial challenges for cost-effective realization of telematics systems. This area aims at bridging the gap between advanced methods for software engineering and the effective design and implementation of telematics systems. The research focuses on object oriented methods and techniques supported by tools. Applying this to the field of telematics is a novel and promising area for which the need is apparent.

The research is based on an analysis of the current situation with respect to the development, implementation and use of telematics systems, and the role software engineering plays in it.

2.2.1.3 Area T2 and I3: Distributed databases & Database technology

The interest in multimedia applications is growing tremendously. At the same time one starts to realize that multimedia objects are essentially different from traditional, administrative type of objects. Currently, it is quite easy to store and to transmit multimedia objects. However, it is more difficult to find multimedia objects based on a content search, or, to address another issue, to get the right performance while processing and transmitting large multimedia objects, like videos.

The research in this area focuses on the following topics:

- *authoring:* extension of authoring tools, developed in a hypertext environment, to cover also multimedia documents;
- *indexing:* capturing and understanding of text and speech;
- *figure understanding:* figure understanding and figure generation, as a preparation of image understanding (long-term goal);
- *multimedia searching:* integration of existing database techniques with new, dedicated techniques;
- *architecture and performance:* practical architectures, mechanisms and algorithms for real-time performance.

2.2.1.4 Area I4: Signal processing

The focus of the research is on applications of signal processing for (a.o.) telematic systems. On purpose the scope is wide and comprises the full design trajectory: from the research and development of signal processing algorithms, the real-time implementation on DSPs or programmable hardware including embedded systems, design and realization of hardware PCBs, to the design and realization of real-time signal processing ASICs. In many cases the functionality added to an application can be characterized as computational intelligence (adaptive signal processing, neural networks, fuzzy reasoning etc.). Topics include: acoustic and line echo canceling, adaptive equalization in mobile communications, spatial equalization in DECT systems, mobile communication (speech and data) for public safety (TETRA), speech processing and compression, video processing and compression, processing for binaural hearing, audio and video processing for multi-media applications (reproduction and display improvement), and processing for DAB.

2.2.2 Telematics Systems

This cluster is concerned with the design of telematics system infrastructures and consists of the following subclusters:

- Application systems, which addresses the (infra-) structures for access to, use of, and interworking between applications. Three areas are defined:
  - T1: Telematics services and protocols
  - T2: Distributed databases (see description under 2.1.1).
  - T3: Mobile and nomadic computing.
- Communication systems, which addresses the infrastructures for information exchange. Two areas are defined:
  - T4: Photonic networks.
  - T5: Communication networks.
- System management, which addresses management of services, networks and network elements. A single area is defined:
  - T6: Network & service management.

2.2.2.1 Area T1: Telematics services and protocols

The area Telematics services and protocols aims at the development of advanced telematics services and protocols. Telematics services directly support the actual tasks of the end-users of telematics systems; the protocols (often referred to as application protocols) that provide telematics services operate over a communication infrastructure. This area therefore bridges the gap between communication networks and telematics applications (in market and societal sectors). Important qualitative characteristics to be pursued in this area are ‘openness’, ‘portability’ and ‘transparency’ (w.r.t. distribution aspects). The research is directly linked to the development of implementable standards for telecommunications/telematics services and distributed computing services in multi-vendor environments.

The research topics in this area are grouped into three sub-areas:

- *application protocol engineering:* this research is concerned with concepts, methods and techniques that can be used in the application protocol design process;
- *multimedia telematics services:* this research is concerned with application protocols that address the integration of multiple media in a single telematics service;
- *QoS (Quality of Service) in telematics services:* this research is concerned with the matching of application QoS requirements with network QoS capabilities.

2.2.2.2 Area T3: Mobile and nomadic computing

Mobile Computing has evolved as a consequence of miniaturization and ever decreasing power consumption of components. The technology used in mobile telephony can be combined with those for hand-held and notebook computers to produce powerful devices that can be used in a wide variety of applications. Important usage areas are: sharing information with the work place while on the road, multimedia person-to-person communication, electronic shopping, electronic contract exchange, navigation. Achieving this requires research in the areas of overall systems architecture, power-management architecture, security architecture, and communication architecture.

Mobile computing is an active research area with a great deal of activity being directed towards hardware power management and communication, as well as towards new applications. Relatively little effort is being spent on the operating system support for mobile computing and the relationship between resource provision and consumption. Examples of resources that are frequently scarce in mobile environments are battery capacity, network bandwidth and CPU cycles. Resource-aware applications, in collaboration with the operating system, can save significant resources, leading to longer operational life between battery charges and lower communication cost.

2.2.2.3 Area T4: Photonic networks

The progress in expanding the capacity of point-to-point fibre-optic transport links is still impressive. Since the beginning of the ’80s there is an average increase in bitrate-length product of more than 70% per year. Laboratory trials have shown 100 Gbit/s over 6300 km; transoceanic systems at 5 Gbit/s are commercially installed. At the moment, the maximum transported bitrate stands at 2.6 Tbit/s, being 132 wavelengths at 20 Gbit/s each.

However, the penetration of optical fibre in the lower network levels is still premature. Techniques to realise multipoint optical networks purely on the physical level are receiving much attention, but the co-working of the physical layer with the network-management-and-control layers is barely studied. Furthermore, the costs of optical techniques in their present form are still prohibitive for wide-spread application in the lower network levels. E.g., Fibre-to-the-Home seems to be further away than ever. On the other hand, there is a clear increase in the capacity requirements per end user, cf. the booming of Internet and multimedia services. This area focuses on broadband (all-)optical multipoint networking (especially at the lower network levels like MAN/LAN/residential access), exploiting the unique characteristics of the fibre (low attenuation, huge bandwidth) in a multi-dimensional way (switching and routing in the wavelength, time and space dimension). A specific topic is the disclosure of the wavelength domain for additional networking flexibility in combination with innovative (hybrid network) management and control concepts.

2.2.2.4 Area T5: Communication networks

The communication networks area has, as its main study, network control in all of its aspects. What we mean by network control is just this: A set of concepts algorithms, protocols, formats, and messages, all of which are used to provide, in real time, the services of the network, and which control the network itself and the communication between end-users that the network provides. This is dedicated to the control of lines, switches, buffers, frequencies, wavelengths, bandwidth, error rates, CPU cycles, in short, all the physical resources that the network comprises.

The explosion in the past decade of many different networking technologies has made this study even more interesting albeit more complex. There are many different ways of classifying networks and many different reasons for building a network. All of these different kinds of networks have similar problems to solve. These problems include, but are not limited to: setting up paths or connections or virtual circuits or routing tables which determine how information gets from its source to its destination(s); allocating network resources for the communication between two or more endpoints; guaranteeing the level or grade of quality of service for the communication between endpoints; preventing, detecting, and removing congestion in the network; detecting failures in the network and reacting to them, perhaps by rearranging routes or routing tables for example; dynamically adjusting the network resource allocations and perhaps even the configuration based on the current state of the network.

2.2.2.5 Area T6: Network and service management

Systems management is concerned with the initialization, monitoring and modification of the operation of communication networks, network applications and telematics services. Until recently, systems management has been performed in an ad-hoc and enterprise specific manner. This is not adaquate anymore for management of future telematics systems, which can be characterized by fast growing numbers of users, frequent configuration changes and multi-vendor equipment, and which demand management solutions that are scalable, flexible and open.

This area focuses on management solutions which are open (multi-vendor) and easy to adapt. The research is not restricted to the management of networks and network elements, but also covers the management of provided services, collaboration between multiple management domains, and customer control over their network view. New approaches based on WWW and CORBA technologies will be investigated. Specific research topics are: design and implementation of network management platforms and protocols, distribution of management functionality, accounting, management of transport networks, and management of network applications.

2.2.3 Use of Telematics

This cluster is concerned with the environment of the telematics system user and consists of the following subclusters:

- Human and societal aspects, which addresses the human behaviour in interactions with telematics systems, and the embedding of telematics systems in society. Two areas are defined:
  - U1: Human-computer interfaces.
  - U2: Models for human collaboration.
- Business, industry and government, which addresses the organisation and needs of specific user environments that (plan to) embed telematics systems. Four areas are defined:
  - U3: Public administration.
  - U4: Education and training.
  - U5: Logistics.
  - U6: Business

2.2.3.1 Area U1: Human computer interaction

Human-computer interaction (HCI) is the study of how people design, implement, and use interactive computer systems and how computers affect individuals, organizations and society.

Interfaces of the future will use multiple modalities for input and output (speech and other sounds, gestures, handwriting, animation and video) and have intelligent components (agents) to adapt the interface to the different wishes and needs of the various users. Making the interface between people and computers more humane does not only imply adding human perceptual features to machines. For example, one may ask questions how HCI does bear on dynamic changes in human perception, affect natural human communication and acts to control human cognitive adaptation. Therefore HCI research appeals to researchers across disciplines: computer science, cognitive ergonomics and, more general, researchers interested in socio-cultural implications of developments in the interaction between ICT and human cognitive processes. On an even more general level of the interaction between men and machine is the issue of the impact, positive or negative, of developments in ICT. Technology assessment can be used to obtain predictions and to anticipate on these predictions on impact. A topic of particular interest is the relation between approaches to ICT development and issues (socio-political, ecological, and psychological) which relate to improving and ensuring the quality of life. The provision of technology access in ICT is another important issue that arises. In order to improve accessibility it is useful to distinguish between different user groups and to study why certain user groups have no access to the information society and what can be done to improve this.

2.2.3.2 Area U2: Models for human collaboration

Collaboratories in effect are infrastructures of methods, tools, techniques, and information resources. Scientists (and others involved) apply their proven R&D methods in a joint fashion and thus build up a common storehouse of experiences, knowledge, and tool frameworks. Collaboratories gain considerable momentum and power by situating them in ‘virtual worlds', for example virtual reality worlds for molecule physics or environmental science that can jointly be created, explored, modified, and especially extended.

Collaboratories typify interdisciplinary approaches to R&D and will not only be applicable for R&D purposes as colloboratory worlds are excellent ‘teaching- and training worlds'. Furthermore, the application potential of collaboratories is not limited to the university. We may expect that the collaboratory concept will prove to be very attractive for office computing and for (virtual) enterprises, as the majority of groupware applications (like Lotus Notes) involve company computing and electronic commerce. Groupware can be seen as a forerunner of the more involving collaboratory concept. As collaboratories stress the computing and communication power of networks and are perceived by the NSF as a major development in (distributed) university computing for the coming decades, it is no surprise that the Internet 2 framework and preferred application domains heavily stress this type of application.

2.2.3.3 Area U3: Public administration

The heart of public administration is governance: the steering of society by the government. Three aspects of steering can be distinguished: decision-making, organization and accountability. Decision-making implies making judgements and a process on which these judgements are founded. For decision-making the content of the information as well as the quality of the information are important. On the one hand ICT may improve the effectiveness and efficiency of existing processes of information supply. On the other hand ICT influences the content as well as the form of decision-making processes through changes in the availability and division of information.

Organization is the complex pattern of communication and relations in a group of people. The internal communication within the government as well as the external communication between the government and its citizens goes on through information flows. The content and the form of these information flows are determined to a large degree by available ICT. Developments in ICT influence internal as well as external communication.

Accountability on the way the government steers society, especially concerning the quality of the actions of the government, is essential in a constitutional democracy. Accountability of one body to another body is a special type of information supply. Specific demands are posed to this information supply and special guarantees are needed. Developments in ICT shine a new light on questions of accountability. There are new possibilities for politicians to control the administration. There are also new possibilities for designing relations of accountability in the area of vertical and horizontal decentralization.

2.2.3.4 Area U4: Education and training

This area comprises the instrumental support of processes that result in learning, communication and information acquisition. The support is being realized via media, in particular media based on ICT. This leads to educational instrumentation in the form of electronic educational material and educational environments. The characteristics of these media are the subject of research. The knowledge and skills needed to perform this research cross traditional disciplinary boundaries.

The integration and penetration of computers and media in daily live, and therefore also in education and training, is enormous. There is, however, a sharp distiction between the ever changing visionary prospects and the advantages that can be achieved and measured. Abundant practical and conceptual problems are still to be solved. The potential of new technological developments need to be aligned with and adapted to the real needs and characteristics of its users. This is an important and rapidly increasing task. To perform this task it is necessary to understand how and where technological developments, and in particular the possibilities and value of there application in education and training, can be realized. In this respect there is an apparent need for an adequate design and evaluation methodology for distributed learning environments and accompanying tools. The approach taken in this research area contributes to this. This research area also strives to link up to ICT developments and to assess their value for society. A balance has to be found between the technology push by industry and an adequate and justified technology pull by the users.

2.2.3.5 Area U5: Logistics

Research in this area is strongly motivated by the need for industrial organisations to improve their performance through:

- decreasing engineering and manufacturing lead times (time-based competition)
- improving product quality and process reliability
- improving product and process flexibility (high variety, short lead times)
- improving process efficiency.

A primary goal of the research is to combine the use of quantitive, analytic models (Operations Research) and ICT to develop decision support systems (including intelligent algorithms) to enhance both design and planning problems in industrial companies. At the same time, the industrial context has stimulated the development of important new models, algorithms and DSS frameworks and as such has a highly fruitful impact on the further scientific development of the field. Research in this area includes topics such as the design, planning and control of manufacturing systems, supply chain management, the design, planning and control of material handling systems in production, storage and distribution of parts, products and tools and finally maintenance management. In addition, applications in a non-manufacturing context are studied.

2.2.3.6 Area U6: Business

Globalization of markets and the increasing complexity of business organizations and processes (and the accompanying focus on core competencies) now force organizations to co-operate world-wide. Telematics and ICT is a powerful enabler (in fact, a prerequisite) of this process, however, simply introducing technology is not sufficient to foster co-operation. Co-operation is a multidimensional problem, since co-operation depends on the specific configuration of processes, people, technology and organization, and involves both structural and cultural aspects.

Understanding and expertise from several disciplines (including organizational science, computer science and social science) is needed in order to design effective and efficient organizations and to optimize co-operation. Furthermore we must know how organizations really operate in order to be able to translate performance requirements into satisfactory or (ideally) optimal organizational designs. Knowledge about how organizations really work in practice is available at the organizational level, but hardly at all on the level of groups and tasks. In this area we focus on acquiring this knowledge in a bottom-up fashion by means of longitudinal case studies conducted across a range of national and international industries.

2.2.4 Methods, Techniques and Tools

This cluster is concerned with the development of methods, techniques and tools that support the design of telematics systems and user environments. The cluster consists of the following areas:

- M1: Design methods and concepts
- M2: Performance and reliability analysis
- M3: Formal methods.
- M4: Software tools.
- M5: Architecture and implementation of digital systems

2.2.4.1 Area M1: Design methods and concepts

The distributed systems of interest for telematics (business processes and telematics systems) have intrinsically complex functional requirements. This implies that their development process is intricate, such that it can only succeed if abstractions of these systems are applied in their development, according to precise design guidelines (methods and techniques). Adherence to standards may also be required especially for telematics systems, since it makes it possible for different manufacturers to produce these systems. This implies that abstractions and guidelines used in the development of standards also have to be internationally agreed in case the systems are subject to standardization.

Specific issues in this area can be grouped as follows:

- *design milestones:* a design milestone is a projected result at a specific point in the design process. Design milestones can be used to structure a design metholodogy;
- *architectural models:* collection of architectural concepts and their combination rules, which can be applied to elaborate a specific design milestone;
- *design refinement:* the operational definition of a manipulation of a design, meant to bring it closer to its realization;
- *implementation process:* mapping of abstract constructs onto implementation structures.

2.2.4.2 Area M2: Performance and reliability analysis

The deployment of modern telecommunication networks, such as broadband integrated service networks (B-ISDN), mobile and wireless communication systems, poses numerous issues that need to be investigated. Efficient use of network resources should be achieved while providing the quality of service (QoS) required by the end-user applications.

The objectives of the research in this area are:

- To support the design of telematics applications and the underlying communication networks and infrastructures;
- To develop new performance evaluation methodologies;
- To build tools for the evaluation of performance and dependability of communication networks and telematics systems.

2.2.4.3 *Area M3: Formal methods and tools*

There is an increasing need for reliable software, which is especially critical in areas such as communication protocols, distributed systems and real-time systems. Reliability can only be achieved through the use of rigorous design techniques. This has motivated a large amount of research on design and implementation methods, and tools that support both the design and implementation phase.

The goal is to design and realise notations, methods and provide the foundations for tools that are used to develop and validate system specifications, and to transform these specifications into efficient implementations. As such this area is very closely linked with that of software tools with which it has many common activities. Examples of models and theories that provide the formal underpinning for this work are transition systems, process algebras, Petri nets, extended state machines, I/O-automata, event structures, and temporal and other modal logics. Important specification formalisms and semi-formal notations that are pertinent to the work in this area are LOTOS, SDL, Estelle and TTCN.

Software tools

There is an increasing need for reliable software, which is especially critical in areas such as communication protocols, distributed systems and real-time systems. Reliability can only be achieved through the use of rigorous design techniques. This has motivated a large amount of research on design and implementation methods, and tools that support both the design and implementation phase.

The goals in this area are to design and realize tools that are used to develop and test specifications, and to transform these specifications into efficient implementations. Examples of such tools are editors, analysers, debuggers, simulators, transformers, compilers, interpreters, formatters, pretty printers, program generators, and test generation, implementation and execution systems. An integrated collection of such tools is called a software-development environment.

2.2.4.4 Area M4: Architecture and Implementation of Digital systems

Design methods for high-level architectural synthesis are of crucial importance for the manufacturers of telecommunication equipment. The complexity of the design is increasing continuously, due to the ever increasing technological possibilities. Although a lot of tools are available for low-level synthesis, the tools available for high-level synthesis are far from complete. In fact, only for digital signal processing applications real high-level tools are available. The distinction between the development of hardware and software for embedded systems is disappearing. Currently, large digital signal processors are already equiped with operating system kernels. Hardware-software co-design has become a hot item. However, the interface between hardware and software in a design process is hardly understood. It is therefore of utmost importance for the European telecommunication industry that the theoretical and practical knowledge of the highest levels of the design process (high-level architectural synthesis) is improved.

This area focuses on design methodology and fault tolerance. Design methodology aims at the development of a fundamental approach to high-level digital system design and in particular at developing a transformational design methodology for digital system architecture. Fault tolerance aims at methods to develop systems which maintain their functionality in the presence of malfunctioning hardware. In this research, special attention is given to the reliability and security of storage systems in the presence of malicious faults.

3 Overview of 1997 Research

The research programme forms a framework and reference point for the CTIT projects. Projects vary widely and generally address research issues, identified in one or more research areas described in the programme.

In 1997, many CTIT projects were in their second year of operation:

funding organization	**project name**
European Union	
ACTS	- INSIGNIA (AC068) - TOBASCO (AC028)
ESPRIT	- WIDE - MobyDick (EP20422)
Telematics Applications Programme	- Twenty-One (IE21080)
National projects	
Senter	- Optically Packet and Circuit-switched Networks
Telematics Research Centre	- Testbed (Business Process Re-design)
University of Twente	
	- IDYLLE (Tele-learning) - 3 Ph.D. projects

In this year, the CTIT was successful in the acquisition of projects:

funding organization	**project name**
European Union	
ACTS	- PRISMA (AC349), start on April, 1, 1998
Telematics Applications Programme	- Pop-Eye (LE4234)
National projects	
Senter	- MESH, a continuation of the PLATINUM project - Extension to the Optically Packet and Circuit-switched Networks project
HPCN	- IMPACT, funded by the Dutch Foundation for research on High Performance Computing and Networking.
SURFnet	- Management of ATM Networks - SURFnet Infrastructure *(both continuations of previous projects)* - SURFnet Tele-education pilot (part of MESH) - SURFnet Multimedia in Web-based Courses using Networks
SION (Dutch Foundation of Informatics Research)	- PhD-project on Accounting Management, under its programme 'Electronic Super-Highway' (start: 1 January 1998)

STW (Dutch Foundation of Technical Sciences)	- FLAMINGO (start in April 1998)
Ministry of Home Affairs	- Civic Center 2000

In 1997, some projects were concluded, e.g., the *Moby-Dick* project, and the project *Societal effects of scientific research relating to the "Telematica-stad Twente"* (this research has a continuation within the 'Civic Center 2000' project).

All projects together have led to an annual turnover in 1997 of 1.545 Mdfl direct funding and of 2.586 Mdfl external funding (of which 1.213 Kdfl was still in the procedure of payment at the time of drawing up the annual account) in the autonomous part of the institute. In 1998, compared to 1997, the direct funding will decrease, since the budget of one of the centrally funded projects has been fully paid out in previous years, whereas the project itself continues in 1998. The external funding is expected to increase to at least 3.5 Mdfl, due to participation in the Telematics Institute. Figure 1 illustrates the funding history and projections for 1998.

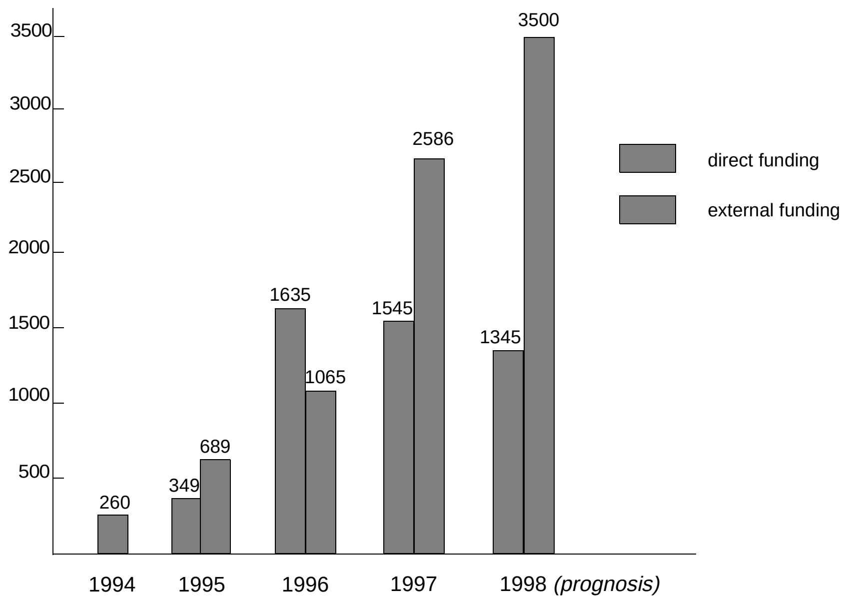

Figure 1: Annual turnover CTIT 1994 - 1998 (in Kdfl)

The acquisition of projects led to an ongoing growth in the number of employees (scientific staff and support), from twenty-five at the beginning of 1997 to forty-two at the end of the year. This number is expected to increase further in 1998, since vacant positions in projects have to be filled in, and new projects within the framework of the Telematics Institute are about to start. In view of the economic growth in general in the Netherlands and consequently the growth of employment in the information an communication technology sector, attracting qualified people will be a major concern in 1998.

A detailed progress report on all CTIT projects is given in a seperate edition of the Annual Report: "CTIT Projects and Scientific Results 1998" (to appear: September 1998). The (mainly internal) projects within the federative part will be accounted for in internal reports of the participating departments. Next year, all research results will be published according to the new structure of the CTIT research programme.

4 CTIT Organization

4.1 Board and Management

The CTIT is directed by a Board, consisting of four external members: *Prof. Dr. H.C. P.J. Kühn* (Chairman, University of Stuttgart, F.R.G.), *Prof. Dr. E.J. Neuhold* (GMD-IPSI, Darmstadt, F.R.G.), *Prof. ir. M. Antal* (director of Eurescom, Heidelberg, F.R.G.) and *Prof. ing. W. Zegveld* (Rijswijk, NL). The Board supervises the research policy, the institute’s finances and the performed research, and assesses the five-yearly general research programme of the CTIT.

The Scientific Director, *Prof.dr. ir. I.G.M.M. Niemegeers*, assisted by an Executive Committee and a Management Team, is charged with the day-to-day management of the institute and determines the institute’s strategy.

4.2 Organizational Structure

Six faculties of the University of Twente now participate in the CTIT: Computer Science, Electrical Engineering, Educational Sciences and Technology, Applied Mathematics, Business and Management Sciences, Public Administration. At the beginning of 1998, the Cognitive Ergonomics group of the faculty of Philosophy and Social Sciences, which is involved in the CTIT, was moved to the faculty of Educational Sciences and Technology; therefore, the participation of the faculty of Philosophy and Social Sciences ended.

Participating faculties have committed for a period of five years scientific personnel and supporting staff to the CTIT, to carry out its research programme. Scientists from these departments, together with scientists employed by the CTIT itself, collaborate in CTIT research projects. Research groups are represented by their leader in the Scientific Council, an advisory body for research policy.

4.3 Research Staff

The institute consists of so-called "federative" and "autonomous" parts. The federative part consists of the commitments of the participating departments (research staff and related budgets remain under the control of the departments, but are formally assigned to the institute; the director of the CTIT is authorized to *manage* this research manpower). The autonomous part comprises the personnel appointed by the CTIT itself, as well as budgets acquired from incentives and external funding.The institute's manpower for 1997 is shown in Table 1. The units are fte's (full time equivalents, i.e., manyears).

department	total fte's
Computer Science	70.0
Electrical Engineering	9.38
Applied Mathematics	3.05
Educational Sciences	2.22
Business & Management Sciences	0.9
Public Administration	1.0
subtotal	86.55
CTIT-autonomous	28.8
total	115.35

Table 1: Contribution in manpower (fte's) per department in 1997

4.3.1 CTIT personnel

The number of people employed by the CTIT increased further in 1997. Contracts for personnel in projects are generally concluded on a temporary basis (between 2 and 4 years), with the exception of the management staff. The total number of personnel employed per 1-1-1997 was 23, per 31-12-1997 it amounted to 42 persons. In 1997, four employees left the CTIT and twenty-three new ones were appointed. The management staff has been extended mid-1997 with the appointment of three senior researchers, a fourth senior researcher has been appointed per 1 March 1998. The CTIT also invests in three part-time senior researcher positions, one within the area of Photonic Networks, one within the area of Speech and Language Engineering, and one within the area of Tele-Education and Training.

It turns out to be increasingly difficult to attract junior research staff, in view of competition with industry. Companies are able to offer higher salaries and more permanent contracts. The CTIT now more and more attracts foreign research staff (i.e., from Eastern Europe, Latin America, Africa).

4.3.2 Exchange of researchers

Within the BELSIGN project (Human Capital and Mobility), Miss M.A. Anton Gil from the University of Cantabria, Spain, visited the CTIT from June - September 1997. Another exchange of researchers within the BELSIGN network is planned for 1998.

4.3.3 Starting entrepreneurs

Within the University of Twente's programme to stimulate young entrepreneurs in starting up a new business (the so-called TOP programme), two of these companies were linked to the CTIT:

- *"3D Interfaces"*, providing Human Computer Interaction consultancy for commercial and business applications, founded by a former CTIT scientific staff member, Dr. A.N. Ladhani, in October 1996.
- A business on database technology by H.C. Theisens, who acquired a grant per February 1997.

4.4 Scientific Council

The Scientific Council of the CTIT is an advisory body to the scientific director of the CTIT on matters of research strategy. It formulates new ideas on future programmes, also with respect to the participation in the Telematics Institute, and it acts as a scientific reviewing board for programmes and projects. The Council meets in general once per six weeks.

In 1997, in view of the participation in the Telematics Institute (TI), most effort was spent on developing the CTIT research programme, contributions to the TI's research programme and consecutive TI projects.

5 Institute's finances

The institute's budget in 1997 consisted for the main part of the capitalization of the commitments of the participating departments of the Institute. This 'federative' budget remains under the formal control of these departments. In addition to this budget, the CTIT has its own 'autonomous' budget. The total budget of 1997 is shown in Table 2. The units are Kdfl.

Department	1 st (direct) funding	2 nd (indirect) funding	3 rd (external) funding	total
Computer Science	7.985	691	1.200	9.876
Electrical Engineering	3.325	0	385	3.710
Applied Mathematics	443			443
Educational Sciences	238			238
Technology & Management	180			180
Public Administration	190			190
Philosophy and Social Science	138			138
Total federative part	12.499	691	1.585	14.775
Autonomous part	1.545		2.738[a]	4.283
Total CTIT	14.044	691	4.323	19.058

Table 2: The CTIT budget in 1997 (in Kdfl)

a. 2.586 Kdfl concern the revenues of external projects, of which an amount of 1.213 Kdfl is in the procedure of payment; 152 dfl concern other revenues

The estmated budget for 1998 is shown in Table 3:

direct funding	external funding	total autonomous budget	total federative budget	total budget 1998
1.345	3.500 [a]	4.845	14.576	19.421

Table 3: The CTIT budget 1998 (in Kdfl)

a. including estimation of the participation in the Telematics Institute

Figure 1 represents the growth of the budget in the period 1994-1998 (in Kdfl):

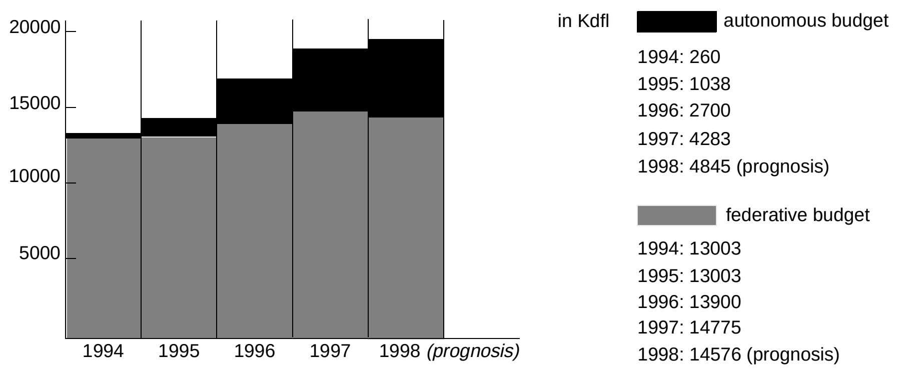

Figure 1: CTIT budget 1994-1998

5.1 Autonomous budget

The financial state of the CTIT in 1997 was as follows:

Centre for Telematics and Information Technology

Specification (in Kdfl)			
expenditures		budgets	
Personnel		**Central Budgets**	
salaries	1.552	budget changes	27
social security	486	Allocations	1.514
expenses other departments	(12)		
indirect personnel costs	112		
Total Personnel	**2.139**	**Total Central Budgets**	**1.541**
Total Housing	**10**		
Equipment		**Third Parties**	
depreciation equipment	19	External contracts	
purchasing equipment	165	2nd (indirect) funding	
		3rd (external) funding	2.586
		Mutation 'Work carried out'	
		2nd (indirect) funding	1
		3rd (external) funding	(1.213)[a]
		Total External Contracts	**1.374**
		Other revenues	11
Total Equipment	**183**	**Total Third Parties**	**1.385**
Materials		**Internal revenues**	
collections	0	other departments	19
materials	4		
administrative means	39		
Total Materials	**43**	**Total Internal Revenues**	**19**
Other Expenditures		**Special revenues and expenses**	**125**
equipment rental costs	0		
communication facilities	22		
computer processing costs	0		
travel costs	164		
(external) contract work	42		
memberships	2		
advisory costs	19		
managerial costs	28		
services dept. CS	220		
Total Other Expenditures	**496**		
Total Result	**198**		
TOTAL EXPENDITURES	**3.069**	**TOTAL BUDGETS**	**3.069**

a. this amount was still in the procedure of payment, when drawing up the annual account 1997; work has been carried out in 1997

The following budgets have been allocated by the University of Twente to the CTIT: 200 Kdfl central allocation, 245 Kdfl allocation for three PhD projects, 250 Kdfl for the IDYLLE (= Tele-Education) project, and 750 Kdfl for strengthening the CTIT within the University's incentives policy. The

Telematics Systems & Services (TSS) group of the departments of Computer Science and Electrical Engineering contributed with 50 Kdfl to the salary costs of the management staff (their total contribution amounts to 470 Kdfl for the period 1994-2001), and 125 Kdfl interest was received.

Compared to the estimated budget for 1997, as stated in our Annual Report 1996, the total compensation from external projects increased with more than 700 Kdfl. However, an amount of 1213 Kdfl was still in the procedure of payment at the time of drawing up the annual account; this amount will thus be accounted for in 1998. The increase is due to the fact that more projects were accepted for funding than first expected. Also the start of the Telematics Institute could not yet be foreseen at the beginning of 1997; activities to start up this institute (e.g., contributions to the research programme, writing of project proposals) have been refunded by the Telematics Institute.

In 1997, a Service Level Agreement (SLA) has been concluded with the department of Computer Science, in which the payment for services to the CTIT by the technical and administrative staff of Computer Science have been settled, as well as costs for housing, the use of the computer network, and library. In 1997, a total amount of 220 Kdfl has been paid for these services.

Travel and meeting costs include the costs for workshops that have been organized throughout the year (the Annual CTIT Workshop, two Idylle Workshops, MESH Workshops). Equipment costs concern mainly the purchase of two advanced video boards for the MESH project, special analyzing equipment for the Optically Networks project, personal computers for newly appointed CTIT personnel, and a Color Printer for general use.

Results

There is a positive result, amounting to 198 Kdfl. These results will be transferred to the general reservations of the CTIT. The general reservations of the CTIT amount at the end of 1997 upto 2.380 Kdfl. In fact, these reservations are fully committed to salary expenditures in the period 1998-2002 (employment contracts do not run parallel with the allocation of budgets): 575 Kdfl for the salary costs of Ph.D. students and regular staff from the budget for innovative research and the Idylle project, 1.340 Kdfl as reservation for the salaries of the senior research staff and management/administrative staff, and 355 Kdfl for extensions of contracts of 3 Ph.D. students. Finally, a budget of 110 Kdfl is reserved for the "Distinguished Visitors Programme.

6 External visibility

6.1 CTIT Publications

CTIT has since its start its own publications series: a "CTIT Ph.D.-Thesis Series" and a "CTIT Technical Reports Series". In 1997 seven Ph.D.-Theses were published and thirty-seven Technical Reports. A list of these publications will be incorporated in a separate edition of this Annual Report: "CTIT Projects and Scientific Results 1998" (to appear September 1998). It is expected that these numbers will show a growing tendency in the coming years.

6.2 Workshops

CTIT Workshop

The Annual CTIT Workshop was held on September, 26, 1997 at the University's premises. Presentations were given on CTIT research, coupled to presentations on related research topics by experts from outside the university.

IDYLLE Workshops

On January 31, 1997, the IDYLLE project organized its second workshop. The project and all its subprojects were presented. IDYLLE organizes workshops once per half year, one with an internal and one with a national scope. This second workshop had a national scope, with presentations from well-known national experts. A second national workshop is scheduled on March 6, 1998.

6.3 The CTIT Web Server

The CTIT Web-server received a new outlook in 1997. At the server information is available on the institute itself, its research programme and projects, staff, main events, publications, with links to the information of all participating groups and interesting external sites. Most of the projects have their own project website, which is kept up-to-date by the project members themselves.

Web-information is regarded a crucial medium for the public relations of the institute. The web-site will be continuously updated and extended with information that is relevant to the outside world.

Members CTIT Scientific Council

J.M. Akkermans (Computer Science)

M. Aksit (Computer Science)

P.M.G. Apers (Computer Science)

A.C. van Bochove (Electrical Engineering)

H. Brinksma (Computer Science)

Ph.F. Chimento (CTIT)

U. Faigle (Applied Mathematics)

L. Ferreira Pires (Computer Science)

B.L. de Goede (Computer Science/Electrical Engineering)

S.M. Heemstra de Groot (Electrical Engineering)

O.E. Herrmann (Electrical Engineering)

H. Johansson (Eurescom, Heidelberg).

F.M.G. de Jong (Computer Science/CTIT)

A.M.J. Koonen (Electrical Engineering/CTIT)

Th. Krol (Computer Science)

J.C. Looise (Technology and Management)

E.F. Michiels (Electrical Engineering)

J.C.M.M. Moonen (Educational Sciences)

S.J. Mullender (Computer Science)

D. Nauta (Philosophy and Social Sciences)

I.G.M.M. Niemegeers (Computer Science - Chairman)

A. Nijholt (Computer Science)

H. Pot (student)

A. Pras (CTIT)

J. Schot (Telematics Research Centre)

M.J. van Sinderen (CTIT)

J.H.A. de Smit (Applied Mathematics)

C.H. Slump (Electrical Engineering)

H. Thielmann (GMD-Darmstadt)

G.C. van der Veer (Philosophy and Social Sciences)

P.E. van der Vet (Computer Science)

Participating Groups

Department of Computer Science:

- Telematics Systems and Services (TSS - interdepartmental group with the Department of Electrical Engineering)
- Formal Methods and Tools
- Databases for Object-oriented and Logical Languages
- Knowledge-based Systems
- Methods and Architectures for Information and Communication Sysstems Software Engineering
- Parlevink (Speech and Language Engineering)
- Laboratory for Systems Research (Huygens)
- Laboratory for Architecture and Implementation of Digital Systems

Department of Electrical Engineering

- Telematics Systems and Services (TSS - interdepartmental group with the Department of Electrical Engineering)
- Telecommunications Engineering
- Laboratory for Network Theory

Department of Applied Mathematics

- Stochastic and Operations Research group

Department of Educational Sciences

- Educational Instrumentation

Department of Philosophy and Social Sciences

- Cognitive Ergonomics

Department of Business and Management Sciences

- School of Management Studies

Department of Public Administration

- Management and Finance