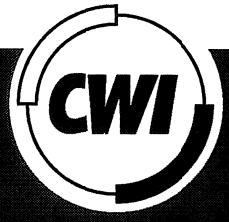

Centrum voor Wiskunde en Informatica

ANNUAL REPORT '95

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ANNUAL REPORT '95

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Photo: Sjoerd Mullender

CWI is the National Research Institute for Mathematics and Computer Science. CWI is part of the Stichting Mathematisch Centrum (SMC), the Dutch foundation for promotion of mathematics and computer science and their applications. SMC is sponsored by the Netherlands Organization for Scientific Research (NWO). CWI is a member of ERCIM, the European Research Consortium for Informatics and Mathematics.

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CONTENTS

This Annual Report is complementary to the Jaarverslag SMC (in Dutch), which concentrates on SMC's National Activities in Mathematics.
This year no Research Highlights were included, because these were already extensively covered in the Jubilee book *Images of SMC Research 1996.*

A complete overview of CWI's research activities, as well as SMC's Financial and Social Reports (in Dutch), are also available.
This Annual Report and all the other reports can be ordered at
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OVERVIEW

In the present decade, CWI has started a significant process of change, scientifically and as an organization. Based on the 1992 policy document *Towards New Equilibria: MOBILE*, CWI chose to pursue a few clear lines in its research:

- optimal use and expansion of the *synergy* between mathematics and computer science in the institute; and more generally:
- increased attention for *multidisciplinary* projects;
- more *flexibility* in the research topics, focussing on *themes* rather than disciplines;
- with respect to the choice of research themes, a close linking-up with *societal demands*, while retaining the *innovative* character;
- strengthening of *knowledge transfer*, for example by cooperation with the *trade & industry* sector;
- ongoing intensification of cooperation with *academia*;
- further reinforcement of the *international position* of CWI research (EU, ERCIM).

This policy is in accordance with recent trends in national and international policy. These principles already adopted by CWI for sometime, also appeared in several recent publications, at the (inter)national level as well as in connection with a specific research area or with CWI. These included the reports *Wiskunde in Beweging* (Mathematics on the Move) by the Exploratory Committee on Mathematics (1992) and *High Performance Computing and Networking* by a commission chaired by P.J. Zandbergen (1993), as well as the EU publication *Fourth Framework Programme* (1994). Following these publications, the report year saw a rich harvest of documents highly relevant to CWI's future course. On the national level, the following policy documents appeared: *Kennis in Beweging* (Knowledge on the Move) – a joint publication of the ministries of Economic Affairs and of Education, Culture and Science – and *Kennis Verrijkt* (Knowledge Enriched) by NWO, the *Advies inzake de Para-Universitaire Instituten* (Advice on Para-Academic Institutes) by the Government's Advisory Council on Science & Technology AWT, the advice of an international Visiting Committee concerning CWI's *research in mathematics*, and a report by the advisory bureau Andersson, Elffers & Felix, that initiated a *restructuring of SMC/CWI*, to be carried out in the forthcoming year. Below it will be elucidated how CWI in the report year lived up to the principles mentioned before.

Synergy

The theme High Performance Computing & Networking (HPCN) provides a good example of synergy between mathematics and computer science. Recognizing its importance, the ministry of Economic Affairs decided to finance a national HPCN programme amounting to 35 million Hfl. Almost forty research proposals were submitted. In 1995 six proposals were approved, in four of which CWI plays a prominent role:

- Environmental Modelling
- HPCN in Financial Services
- Visualization
- Computational Fluid Dynamics – NICE

The projects' names already indicate the breadth of applications covered here.

Another example of synergy is the processing and analysis of images. CWI participates in NWO's Priority Programme Computer Intensive Methods in Stochastics (1993–1998). A concrete application of this research in image analysis concerns the stochastic modelling of lungs, carried out in cooperation with the Daniël den Hoed Hospital in Rotterdam and Delft University of Technology.

Traffic problems, in real life as well as in computer systems, have been the subject of CWI research already for several years. Here mathematics and computer science go hand in hand, for example in applications of queueing theory to the performance of computer and communication networks. In particular, in 1995 CWI started new research into the performance of broadband ISDN networks.

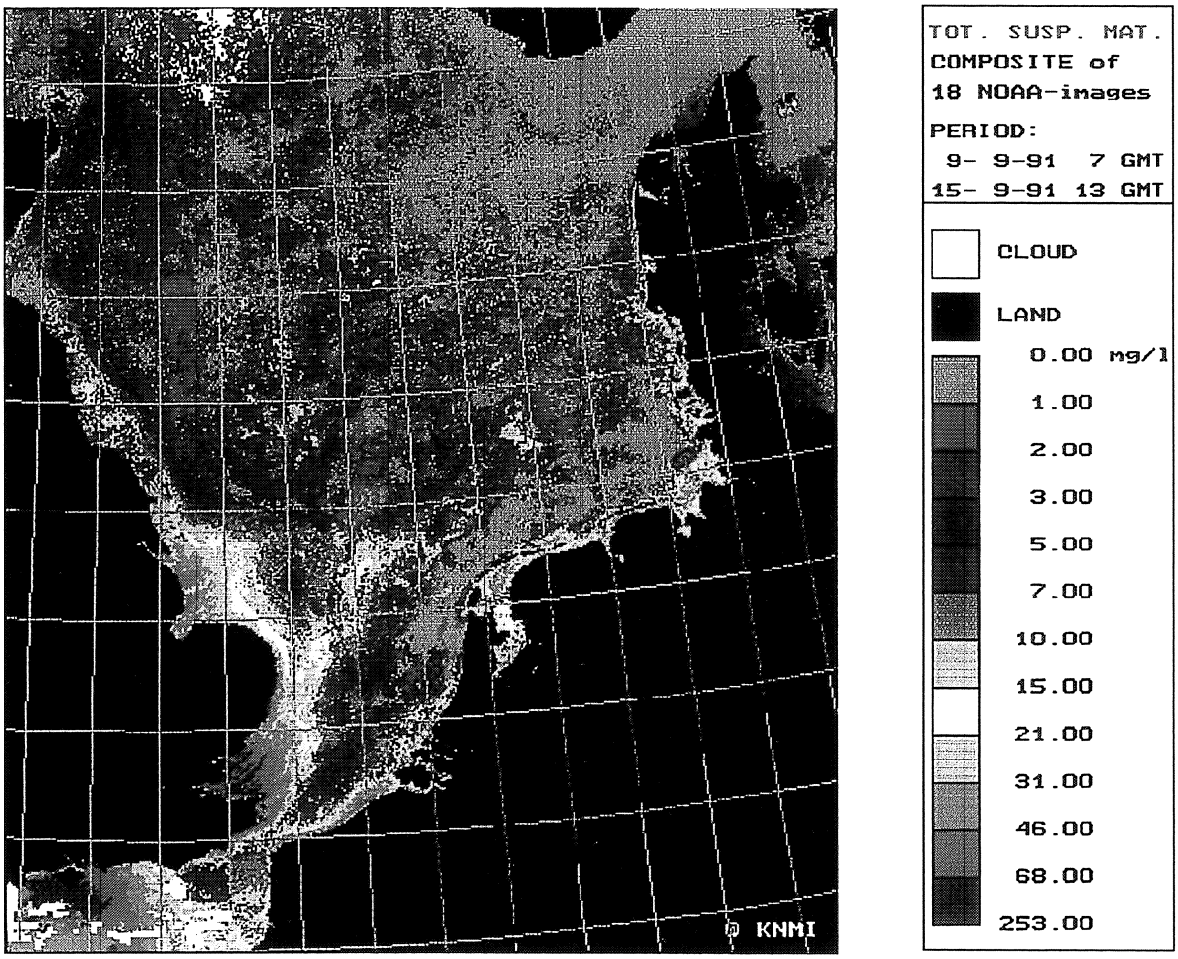
Combinatorial optimization is a relatively new branch of mathematics, which is unconceivable without the use of the computer. In its turn, the computer has essentially influenced this research area, in which aspects of discrete mathematics, operations re-

search and complexity theory come together. CWI's research group in this field has gained a strong reputation over the years in optimally combining fundamental research with practical applications. Examples include the determination of optimal driving routes (the package CAR – Computer Aided Routing – in the 1980s) and the design of a new railroad timetable (CADANS). The latter research, commissioned by and in cooperation with NS/Railned, started in 1994 and continued in 1995.

The last example of synergy concerns research and services in the field of dynamical systems, an area in full swing, with the computer playing a crucial role in its development. The Dynamical Systems Laboratory at CWI, funded by the NWO Priority Programme Non-linear Systems, combines research and services at the national level. Yu. Kuznetsov, CWI's staff member in charge, had his book *Elements of applied bifurcation theory* published by Springer Verlag in 1995. The Laboratory's activities were continued for another two years.

Multidisciplinarity

Synergy between mathematics and computer science is a special case of multidisciplinary collaboration. CWI research is increasingly characterized by such collaboration projects with partners who bring in their domain knowledge. A very convincing example is Mathematics and the Environment, a research theme started in 1992, in which knowledge of physical, chemical and biological processes is as indispensable as that of (applied) mathematics. In the framework of this long-term project, CWI cooperates with national institutions as the National Institute of Public Health and Environmental Protection (RIVM), the Royal Dutch Meteorological Institute (KNMI),



CWI's environmental research includes the study of pollution and sediment transport in shallow seas, as part of the European MAST II project NOWESP (North West European Shelf Programme).

the Institute for Marine and Atmospheric Research of the University of Utrecht (IMAU), and the Agricultural Research Unit (DLO). The research concerns, among other things, the dispersion of pollution in the atmosphere and in ground water and surface water, and the spread of infectious diseases in animal populations. In 1995 CWI started a research project on flow and transport in porous media.

A second multidisciplinary project *pur sang* is Scientific Visualization. Here knowledge of computer science, e.g., computer graphics, is applied to explore large, disordered scientific data collections by means of visualization. Recent applications concerned energy research (with the National Energy Centre ECN as a partner), exploration of the atmosphere of Venus (Free University VU, astronomy department) and the mathematical modelling of complex chemical industrial processes.

Flexibility

Going along with the external dynamics of society and the internal dynamics of the disciplines mathematics and computer science, CWI's research programme is in a perpetual state of change. A regularly recurring phenomenon – actually already dating back from CWI's early years – is that a research theme, having run its course at CWI, is continued and eventually expanded at a Dutch university or in the form of a spin-off company. In the past this happened with the fields of mathematical statistics, operations research, and discrete mathematics. The most recent example is the termination in 1995 of CWI's research in biomathematics (project leader O. Diekmann took up a full professorship in Utrecht), which was initiated over twenty years ago by H.A. Lauwerier. At the same time C.J. van Duijn, coming from Delft University of Technology, initiated at CWI a new project, in which fundamental research into nonlinear partial differential equations is applied to, e.g., transport phenomena in porous media.

Research in cryptography was reorganized towards the end of the year. The existing group was dissolved, but its research continued as a part of other groups, viz., Algorithms and Complexity, and Interoperable Multimedia Systems. Here attention focusses on secure protocols. Continued involvement in cryptography is also shown by CWI's participation in the ESPRIT project SEMPER (Secure Electronic Market Place for Europe). This project may be viewed as a sequel to the CAFE project, which was successfully concluded in 1995.

The termination of research into *symbolic computation* as a major effort marked the end of an eight years period, which saw, among other things, the establishment of the foundation CAN (Computer Algebra Nederland) in 1989 and the research institute RIACA (Research Institute for the Applications of Computer Algebra) in 1993.

Finally, the research branch of the Computer Systems and Telematics department, focussed on multimedia applications, was transferred to the Algorithmics & Architecture department. The group will remain under the supervision of D.C.A. Bulterman, who was succeeded as CST's department head by F. Kuiper.

Focussing on themes

In particular during the last few years, CWI has adopted a deliberate policy of organizing its research around a limited number of themes, to which in general several research groups contribute. Following this policy, in 1995 concrete preparations were made for a realignment along a few core themes. CWI's research theme Mathematics and the Environment, started already in 1992, may be seen as the protype of such a thematic approach. The *Data Mining* project, started a few years later, rapidly developed into such a theme. The uncovering of hidden information in large data sets requires knowledge of, e.g., databases, algorithmics and statistics. In this field CWI coordinates the ESPRIT project KESO (Knowledge Extraction for Statistical Offices), which started in 1995 with participation of one of CWI's recent spin-off companies, Data Distilleries.

The theme *Traffic Flows* is another good example of a research effort where several fields contribute, viz., queueing theory, control theory, combinatorial optimization, and algorithmics. In this theme real life situations, e.g., on motorways, as well as flows in computer networks are addressed.

Societal needs

Although as a matter of fact CWI, during its entire existence of almost fifty years, never exhibited an ivory tower mentality, this decade the institute reinforced its awareness of the importance of problems posed by society. This is borne out in several carefully selected research activities, in which the relevance for society is a major driving force. In the report year, some of the ongoing projects in this category were:

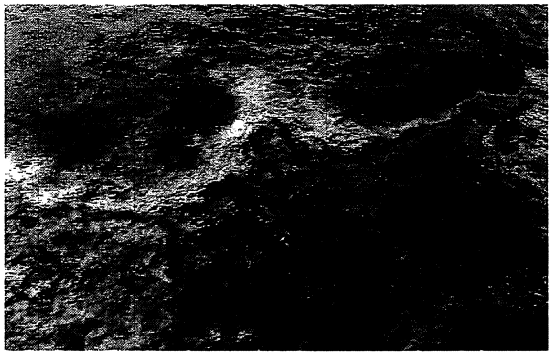
- data mining on behalf of insurance companies (risk profiles) and banks;
- software renovation in the financial sector;

- specification and verification of embedded software, e.g., in protocols (Philips) and power plants;
- spatial statistics applied to the estimation of oil spills in the North Sea;
- image compression, all-important to telecommunication, by means of, e.g., wavelets;
- a new research programme Wavelets, financed by the NWO Technology Foundation STW, with applications in seismology (KNMI) and geophysics (Shell);
- combinatorial research into optimal railroad timetables and circulation of rolling-stock, on behalf of Dutch Rail;
- research into traffic flow control, for example on motorway networks (ministry of Public Works);
- application of neural nets techniques in a statistical analysis of sales patterns;
- assignment of platforms to autobuses in a bus station (Nederland-Haarlem);
- stochastic modelling of, e.g., lungs (Daniël den Hoed Hospital Rotterdam) and geological structures (Shell);
- models for large-scale numerical computations in Computational Fluid Dynamics, including air flows around flying objects (Dutch aerospace industry) and high frequency oil flows in shock absorbers (KONI);
- large-scale numerical models to predict pollution in the atmosphere (KNMI) and of ground water and surface water (RIVM);
- biomathematical research into the spread of infectious diseases among the seal population in the Dutch Shallows (ID-DLO Texel);
- research into the design of interactive books (STW), jointly with publishers (Wolters Kluwer, Elsevier);
- improvement of the ergonomy of World Wide Web presentations by designing better user interfaces;
- security of electronic payments (European projects CAFE and SEMPER, with several European companies involved).

Knowledge transfer

Knowledge transfer proceeds along various lines and is by and large a continuous process. Apart from the broad traditional framework of publications in professional journals, lectures at conferences, etc., some activities deserve special attention here.

Since 1992 CWI organizes annually a special day *CWI in Bedrijf* (CWI in the Market-place), with lectures and demonstrations on its current research, targeted at interested parties including the trade & industry and government sectors. The 1995 theme, *Interaction in R & D*, aimed at a more intense exchange of ideas, knowledge, and problem formulations between trade & industry and the knowledge infrastructure in The Netherlands. Interest for this event still increases, from 60 participants in 1992 to 150 in 1995.



CWI has applied spatial bootstrapping to estimate oil pollution in the North Sea.

The lecture series *Questions from IT-practice*, started in 1994, continued in 1995. In these lectures, representatives of companies, banks, etc., present problems encountered in their practice, for which as yet no solution has been found and CWI may contribute to finding one.

Annually CWI (jointly) organizes several conferences, workshops, etc. Two major events in 1995 were *KdV'95* in Amsterdam, dedicated to the formulation one century ago of the now famous Korteweg-De Vries equation, and *Eurographics'95* in Maastricht, the annual conference of the European computer graphics community (CWI also organized this conference in 1986).

CWI has always considered the mobility of researchers of major importance, already long before the European Commission declared this to be a core issue. Mobility of CWI staff is realized in several ways, including the training of graduate students, appointment of researchers at universities, and secondment of staff members elsewhere and, in turn, researchers from companies and institutions at CWI.

Eighteen graduate students completed their Ph.D. thesis in 1995; ten of them worked at universities in projects coming under the SMC National Activities in Mathematics, eight were employed at CWI. Two group leaders took up a full-time professorship: O. Diekmann (Modelling and Analysis) at the University of Utrecht, and F.W. Vaandrager (Concur-

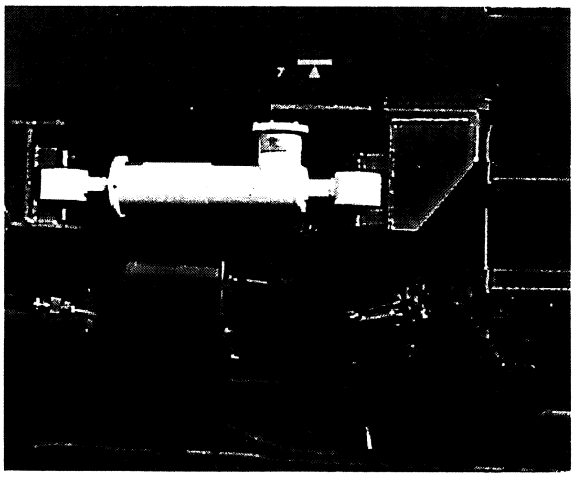
rency and Realtime Systems) at the Catholic University of Nijmegen. Altogether 71 researchers were seconded at CWI.

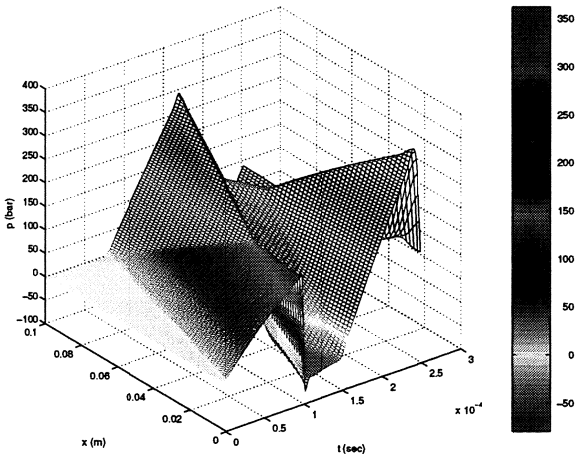
CWI pursues an active policy in the starting up of spin-off companies by its staff members. The most important arguments to support such actions are: it creates high-level employment; knowledge generated at CWI finds direct application; a spin-off is a possible partner bearing responsibility for the part of the trajectory from idea to application which is not a part of CWI's mission (for example, implementation and marketing). The report year saw the birth of two CWI spin-offs: *General Design*, aiming at the design of user interfaces, in particular in connection with World Wide Web, and *Data Distilleries*, which applies data mining techniques in practice.

In line with the creation of spin-offs is the disposal of activities once they have reached the stage that they do not match very well anymore CWI's research profile or have to give way to new research. In this vein, CWI's biomathematics research was terminated in 1995 after a fruitful period of twenty years. Furthermore, following an earlier transfer of most of CWI's activities in symbolic computation to the CAN foundation and the research institute RIACA, where both institutions still had rather close ties with CWI, in 1995 CAN became self-sufficient and RIACA was transferred to Eindhoven University of Technology. Finally, services rendered so far – free of charge – by CWI to Dutch (academic) network users, were placed with a new foundation, NLnet.

Cooperation

Approaching the turn of the century, cooperation in research has really become so self-evident that bringing up the matter would suggest that one still has to get accustomed to the idea. As CWI is concerned, nothing is further from the truth. CWI has always carried out its research in a wide spectrum of collaborative frameworks. As the spectrum is still broadening, some attention is due here. Traditionally, contacts with academia always were very intensive. At present some dozens of professors in mathematics and computer science at Dutch universities have their roots in CWI. In addition, several staff members fulfill a part-time professorship. Ever since the creation of the *Onderzoekscholen* (graduate schools) CWI has aimed at formal cooperation agreements. Presently such agreements have been concluded with the Thomas Stieltjes Institute for Mathematics (Leiden), the Euler Institute for Discrete Mathematics and Applications EIDMA (Eindhoven), the Dutch graduate school in Logic (Amsterdam), and the Institute for Programming Technology and Algorithmics IPA





In order to reduce noise nuisance caused by shock absorbers in trains such as TGV, CWI studied jointly with KONI high frequency oil flows. (Photo courtesy KONI.)

(Eindhoven). Furthermore, CWI carries out many research projects financed by the NWO foundation SION for computer science and by SMC for mathematics (the National Activities in Mathematics, to be placed in a new NWO foundation SWON early in 1996). Here cooperation with academia is inherent in the project application mechanism. Finally, secondment of university staff to CWI becomes a more and more common phenomenon.

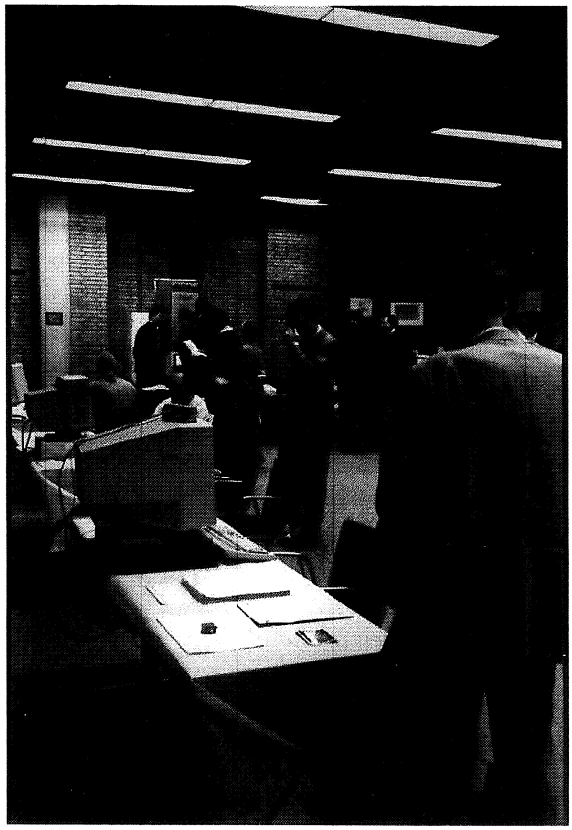
CWI's cooperation with industry proceeds by and large along lines similar to its cooperation with academia. However, there is still a notable difference in approach between industry and research institutions as CWI. As a matter of fact, this holds more or less for the whole of Europe. Recently CWI has been intensively involved in bridging the gap and reached encouraging results. Participation in projects of the NWO Technology Foundation STW ensures industrial interest and concrete involvement. CWI pursues collaborative projects in several sectors of trade & industry. Many of these contacts were established already quite some time ago (Philips, Shell, etc.), others resulted from CWI's ongoing acquisition efforts, which were given special attention in particular in the nineties. CWI's research in cooperation with Dutch Rail, originated from a contact laid at the first of the annual *CWI in Bedrijf* (CWI in the Market-place) days in 1992, is a good case in point.

The Large Technological Institutes, such as the National Aerospace Laboratory, Delft Hydraulics and the National Energy Centre, occupy a special position in CWI's industrial relations network. Strategic alliances with these institutes enable CWI to operate far more successfully on the trajectory idea – application, since these are better equipped to prepare research results for concrete applications.

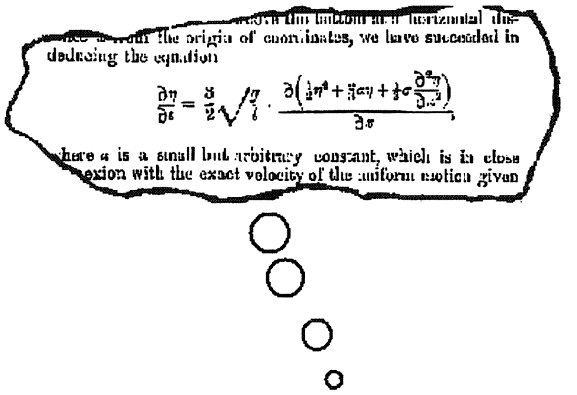
Finally, the national HPCN programme, run by the ministry of Economic Affairs, provides a new platform for cooperation at national level. As mentioned already above, CWI participates in four out of six projects approved so far. In these projects concrete involvement of trade & industry is emphatically prescribed.

Internationalization

On the international scene CWI has succeeded in further extending its name, established in the eighties, as a high-quality, reliable research partner. Contrary to the expectation, expressed by some, that it would become increasingly difficult for CWI to maintain its level of participation in European research programmes such as ESPRIT, there is until now no sign of a substantial decline. On the contrary, in 1995 the European Commission allotted several projects in which CWI plays a prominent role: MERCURY (Performance Management of Commercial Parallel Systems), CHAMELEON (Multimedia), STEM (Telematics and Environment), SEMPER (Electronic Markets), and KESO (Data Mining). CWI also profits from participation in projects initiated by the European consortium ERCIM, for example the Digital Libraries Initiative, which was boosted in 1995 and is considered highly important in Brussels. Finally, the attempts to establish in The Netherlands a European institute (EURANDOM) for fundamental and applied research in statistics, probability and (non-deterministic) operations research, are worth mentioning. CWI has stepped forward as a candidate to set up this institute, in cooperation with both Amsterdam universities (UvA and VU), close to its present premises.



CWI's annual knowledge transfer and acquisition event 'CWI in Bedrijf'.



The Dutch mathematician D.J. Korteweg formulated, in cooperation with his graduate student G. de Vries, in 1895 the non-linear equation which now bears their names. A symposium at CWI highlighted the centennial.

Infrastructure

An institute as CWI, performing frontier research related to present and future societal needs, can not properly operate without the professional support by many not directly involved in research. In particular the computer infrastructure is a crucial factor. CWI considers itself fortunate that in 1995 the government allotted an amount of six million Hfl to reinforce CWI's computing facilities in support of its research. The bulk of the money is used for the installation of an ATM fibre glass network, enabling fast data transfer in other than the traditional forms (e.g., images). A second major operation, carried out during the report year, was the total renewal of CWI's office outfit. The personnel in charge succeeded in finishing this very exerting job for the main part in 1995.

SMC's 50th anniversary

Part of the work carried out in a particular year is related to preparations for the future. In the case of CWI, the fiftieth anniversary of the foundation SMC in 1996 cast its shadows ahead and a lot of energy was put in composing and partly already realizing the jubilee programme. It was decided to organize two scientific meetings: one for mathematics, and one for computer science. Next, a policy-oriented symposium for policy makers and deciders in academia, government and trade & industry (the formal anniversary celebration), a festive evening with Donald Knuth and Benoit Mandelbrot as speakers, and a problem-solving national competition (the problem is derived from commissioned research on optimal circulation of railway rolling-stock, carried out by CWI on behalf of Dutch Rail). Also CWI's annual summer course for mathematics teachers will receive special attention. This course was given without interruption from 1946 on, except in 1954, when the International Congress of Mathematicians took place in Amsterdam. Last, but not least, the jubilee book *Images of SMC Research 1996*, in which the current research carried out at CWI and in the framework of SMC's National Activities in Mathematics is highlighted, was prepared for printing. The book appeared early 1996.

Overlooking all activities described we may conclude that: CWI is fully alive and can look forward with confidence to the turn of the century and beyond.

G. van Oortmerssen, General Director

ORGANIZATION

CWI (Centre for Mathematics and Computer Science) is the research institute of the Foundation Mathematical Centre (SMC), which was founded on 11th February 1946. SMC is funded mainly by the Netherlands Organization for Scientific Research (NWO).

The organizational structure of SMC and CWI is shown on the opposite page. CWI's mission is two-fold:

- to perform frontier research in mathematics and computer science;
- to transfer new knowledge in these fields to society in general, and trade and industry in particular.

CWI's research is carried out in six scientific departments. There is considerable inter-departmental collaboration, for example in the ongoing multidisciplinary programmes *Mathematics & the Environment* and *Multimedia*. Researchers at CWI are supported by state-of-the-art computer facilities and a well equipped library of national importance and, hence, ideally prepared to handle the dynamic and interdisciplinary demands of present day research.

Besides being responsible for CWI, SMC also finances research projects in mathematics at Dutch Universities (National Activities in Mathematics). These activities comprise a total of almost sixty projects. CWI can obtain project funding from this source as well and cooperates in various projects with university researchers.

SMC is administered by a Board of Trustees. The Dutch mathematics community is represented in the Board by three members, appointed on recommendation of the section Mathematics of the Royal Netherlands Academy of Arts and Sciences. Another three members are appointed in consultation with the Netherlands Computer Science Research Foundation (SION). This reflects the importance of the relationship between CWI and SION (CWI participates in many research projects sponsored by SION, and SION advises SMC about CWI's research programme in computer science).

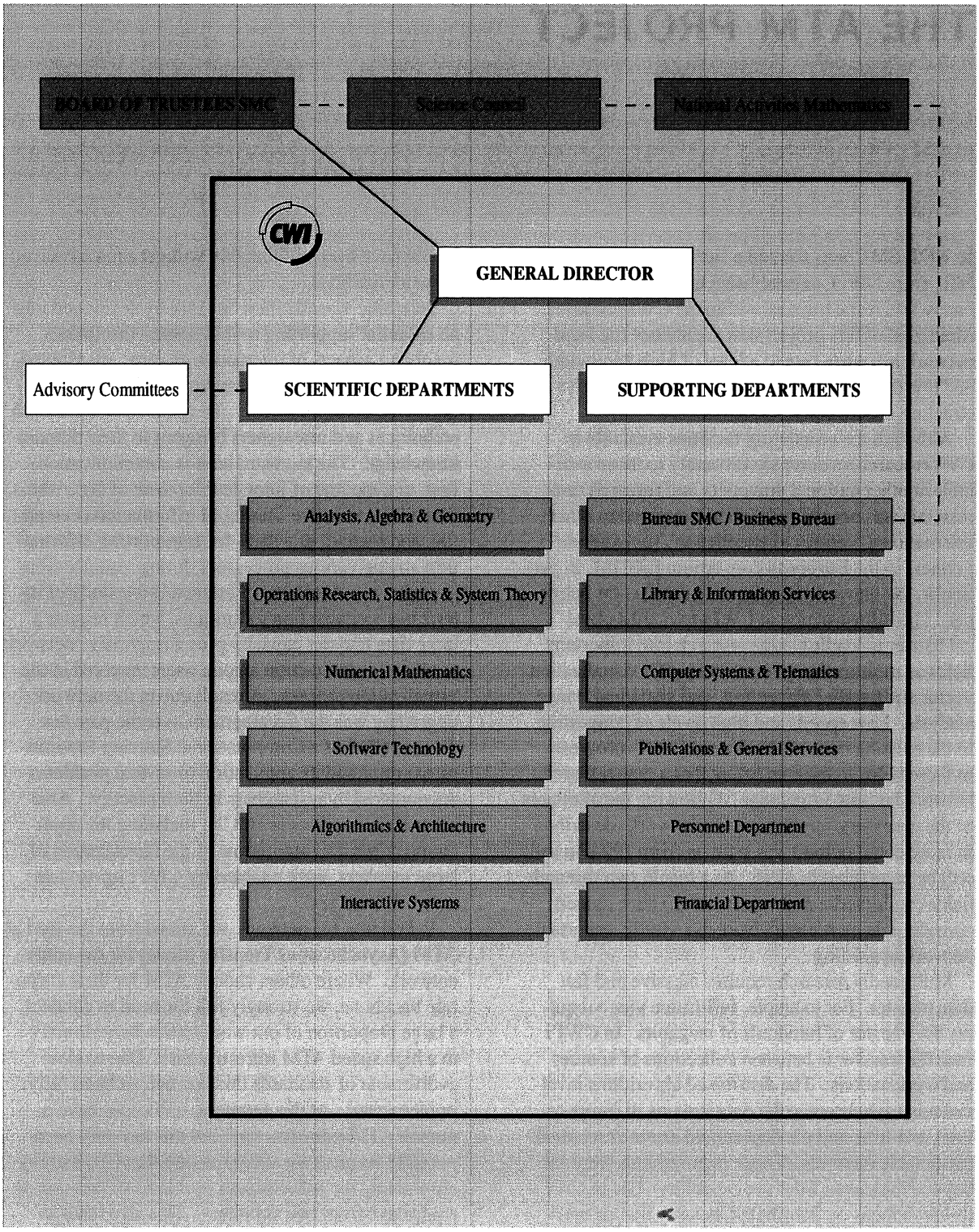
Actual management of SMC and CWI is delegated to the General Director, who is supported by a scientific management committee, consisting of the heads of CWI's scientific departments.

A Science Council advises the Board of Trustees on matters of research policy and organization involving both the National Activities in Mathematics and CWI. The Science Council consists of five researchers from universities, including one from CWI. A number of Advisory Committees make recommendations to CWI's scientific departments on implementing research plans.

In the fall of 1995, it was decided to change SMC's organizational structure significantly. The decision was based on several considerations including those expressed in reports by a Visiting Committee, chaired by professor J.C. Willems (University of Groningen), which evaluated CWI's research into mathematics, and by the advisory bureau Andersson, Elffers & Felix, which investigated the relationship between SMC/CWI and the Netherlands Computer Science Research Foundation (SION).
The changes concern:

- the placing of SMC's National Activities in Mathematics in a separate foundation (SWON), to be governed by the present SMC Science Council;
- the regrouping of CWI's research by replacing the present discipline-oriented departments by subject-oriented research groups.

The aim is to realize these changes during the coming year.



Organizational chart: the Stichting Mathematisch Centrum SMC and its research institute CWI.

THE ATM PROJECT

In 1992, SMC was granted a subsidy totalling 6 Mfl. from NWO, to establish a hierarchical, high-bandwidth infrastructure within the CWI premises. Main goal of this project was to enhance the local network infrastructure to a level of high bandwidth and low delay, and to upgrade our computer infrastructure accordingly.

Although the computing facilities available to CWI researchers compare favorably to those available at other national university and research centres, this was not the case when compared to other international 'centres of excellence', for example partners in the European consortium ERCIM. In particular, the networking infrastructure was far below par. The infrastructure at CWI provided a physical barrier to leading-edge research into important fields as multimedia systems, scientific visualization, vector and parallel algorithms, and statistical image analysis. Low speeds and high levels of congestion in the existing network hampered CWI's progress in these fields to such an extent that a new research network became imperative. Following the allotment of the necessary funding, such a network (described in more detail below) was built up from 1994 on and will be completed in 1996. As a result, two research fields (multimedia and visualization) have gained considerable momentum from this vitally important network upgrading.

Multimedia research requires massive and fast data transfer. For example, full-frame video requires the transfer of hundreds of megabits. In CWI's case the transfer is between collections of sources and workstations. The distributed algorithms involved must synchronize the data streams in (more or less) real-time and the data should arrive at relatively predictable intervals. These requirements went far beyond the extant Ethernet capability. Given CWI's research focus on distributed, heterogeneous multimedia systems, a network supporting concurrent high-throughput, low-latency data transfer at a rate in excess of 100 Mbits/sec was considered essential. The development and utilization of CWI's multimedia editor CMIFed in the subsequent years, for example in the new ESPRIT project CHAMELEON, would have been unthinkable without such advanced network facilities.

Scientific visualization has rapidly developed into an essential supporting tool in several disciplines, involving aspects of interactive systems, distributed data collection, data processing and analysis. It requires the combined skills of experts in visualization techniques and researchers bringing in their domain knowledge. The keyword here is communication: first, as a method of joint development of algorithms, in which interactive sharing of information is essential, and second, as a basis for transporting information among various processors during visualization experiments. One area of interest is the study of interactive visualization techniques, which require a large data transfer capacity plus a responsive network to allow for interaction among users involved in the visualization process. A result due to the network upgrading was the development over the past few years at CWI of a Computational Steering Environment editor and its application to several problems encountered by researchers in their practice. Also several applications in HPCN, including the application of parallel algorithms to the factorization of large numbers, were enabled by CWI's up-to-date network facilities.

In building the network, we aimed from the start at ATM (Asynchronous Transfer Mode) for the entire network. Where others choose ATM for their corporate backbone, we strongly felt the need to connect a large proportion of our workstation base directly to a high speed ATM infrastructure. Due to slow evolvement of standards this has not yet been fully implemented. At this moment, CWI does have a mature ATM infrastructure, but this has only been possible because we adhere to one supplier, thereby eliminating the still eminent problems of connecting equipment from two suppliers. This also leads to the problems when using ATM beyond the CWI lan, especially within the SURFnet4 project.

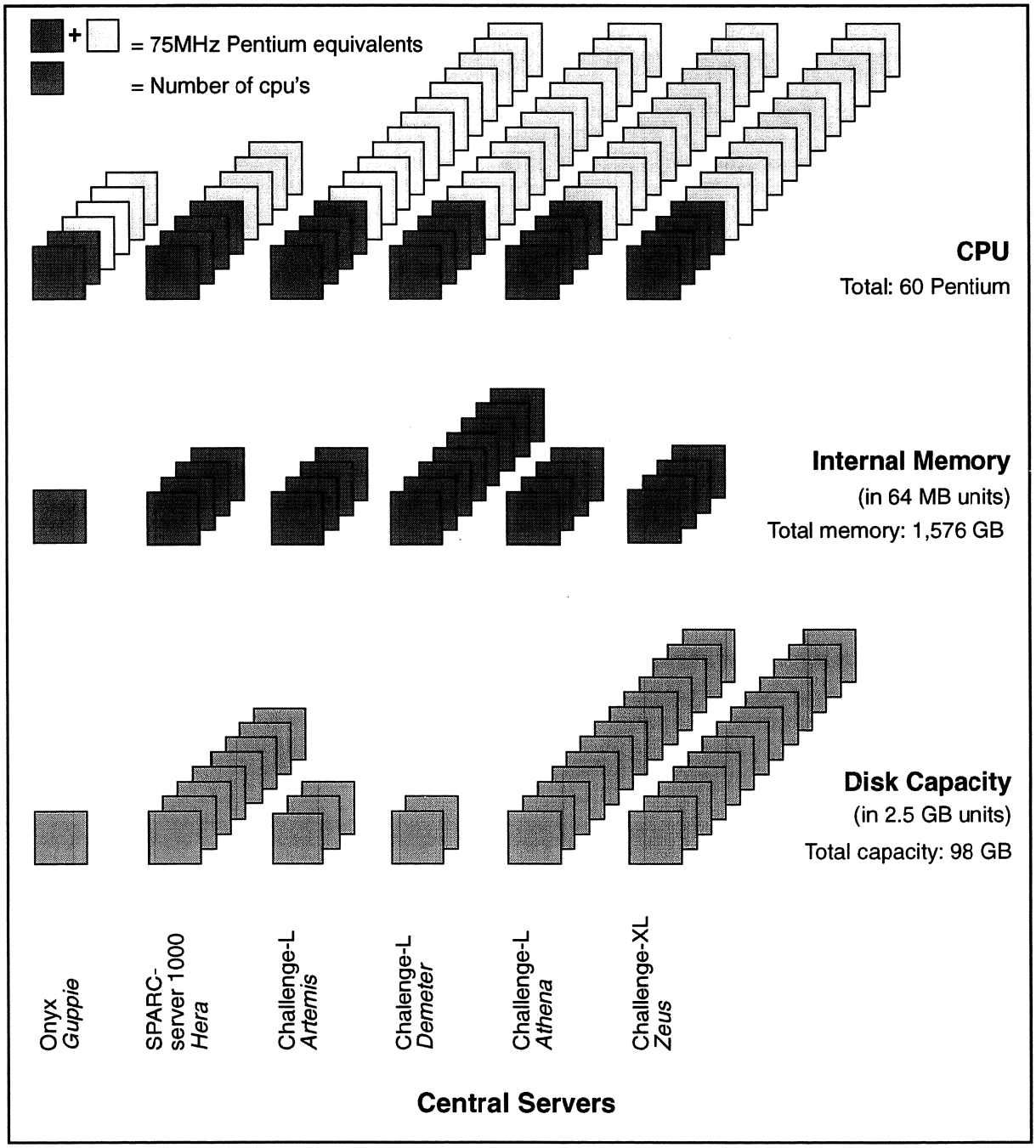
Next to a principle decision for ATM other investments have been made. Basic to all is the establishment of our 'Fibre to the Desktop' project. When this will be finished in the summer of 1996, every

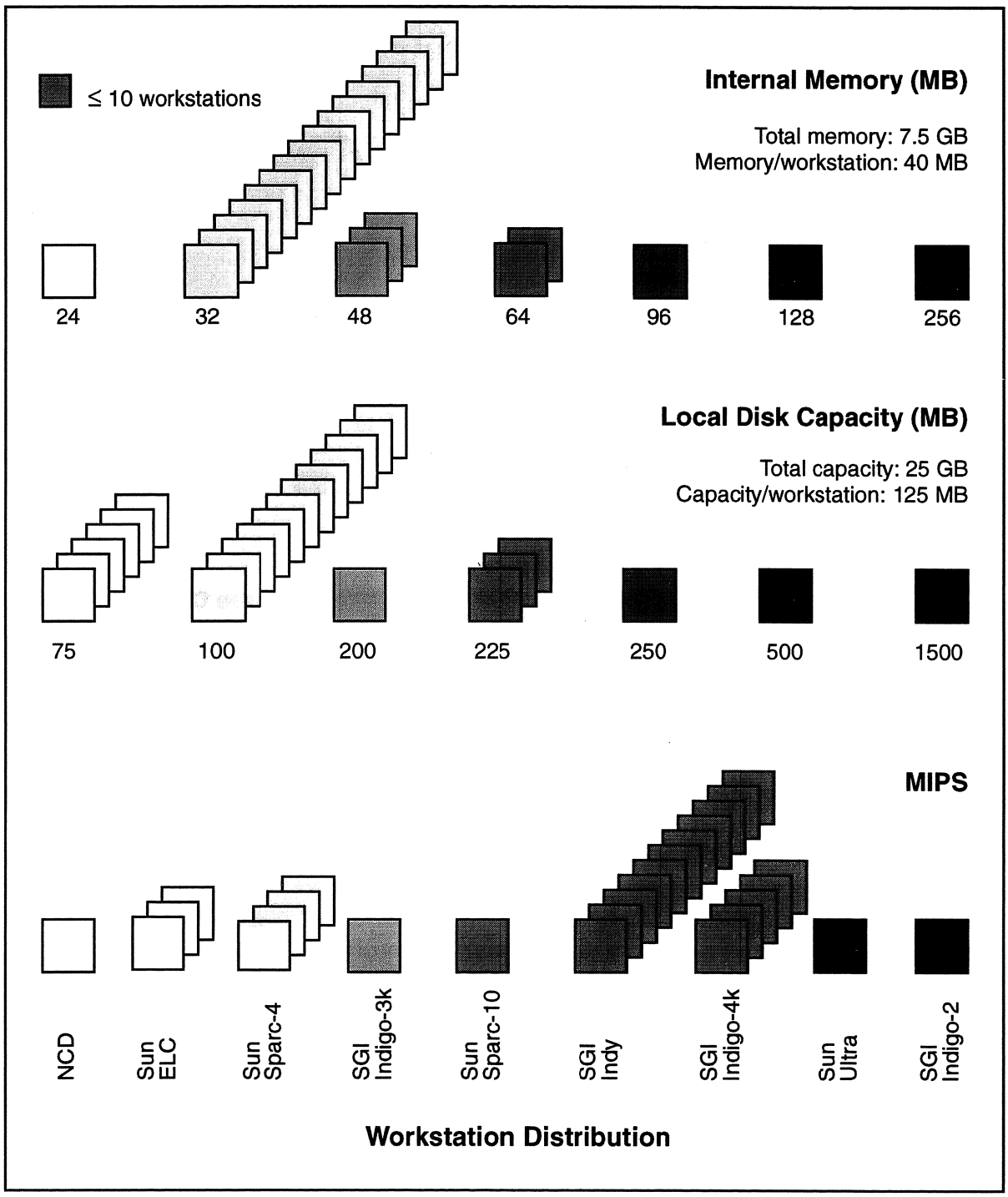
researcher will have two possible fibre connections available. This leaves room to grow for other protocols. With this new infrastructure in place, we are able to connect most of our research workstations.

With our new ATM-based infrastructure, we feel we are ready for the next generation of networked computing. Our goal is to provide our researchers with all required network facilities enabling them to pursue innovative research in the fields mentioned above. We hope to reach this by further improving facilities, including a wider spread of ATM-homed workstations within the institute and true standardised ATM connections with the outside world.

Interactive visualization of scientific data is an important application enabled by CWI's ATM fibre glass network.

COMPUTING EQUIPMENT RESOURCES




≤ 10 workstations
Internal Memory (MB)
Total memory: 7.5 GB
Memory/workstation: 40 MB
24
32
48
64
96
128
256
Local Disk Capacity (MB)
Total capacity: 25 GB
Capacity/workstation: 125 MB
75
100
200
225
250
500
1500
MIPS
NCD
Sun ELC
Sun Sparc-4
SGI Indigo-3k
Sun Sparc-10
SGI Indy
SGI Indigo-4k
Sun Ultra
SGI Indigo-2
Workstation Distribution

FINANCES, PH.D. THESES

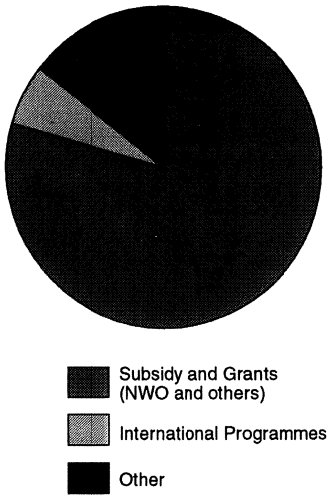
FINANCES 1995

In 1995, SMC spent Dfl. 28.45 million, of which about Dfl. 3.08 million was allocated to university based research and Dfl. 25.37 million to CWI. The expenses were covered by a subsidy from NWO (Dfl. 23.28 million), other subsidies and grants (Dfl. 0.38 million), and from the international programmes (mainly EC programmes, e.g. ESPRIT, BRITE, SCIENCE and HCM) (Dfl. 1.68 million). Finally, an amount of Dfl. 3.78 million was obtained as revenues out of third-party-services and other sources.

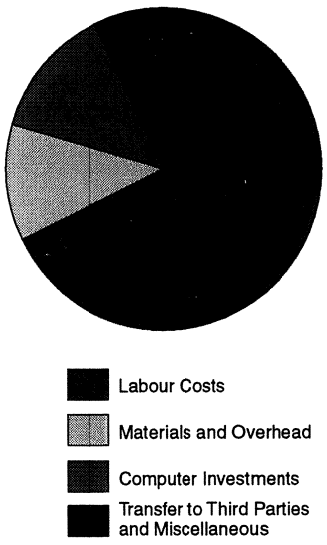
During 1995 CWI also hosted 72 researchers in externally financed positions. These are not included in the adjacent financial summary.

	university based	CWI	SMC
	* Dfl. 1000		
INCOME			
subsidy and grants			
- NWO	3439	19841	23280
- other	177	199	376
international programmes	-	1679	1679
other revenues	1	3786	3787
total income	3617	25505	29122
EXPENSES			
labour costs	2213	17128	19341
materials and overhead	251	2977	3228
computer investments	-	3397	3397
transfer to third parties	616	1769	2385
miscellaneous	-	100	100
total expenses	3080	25371	28451

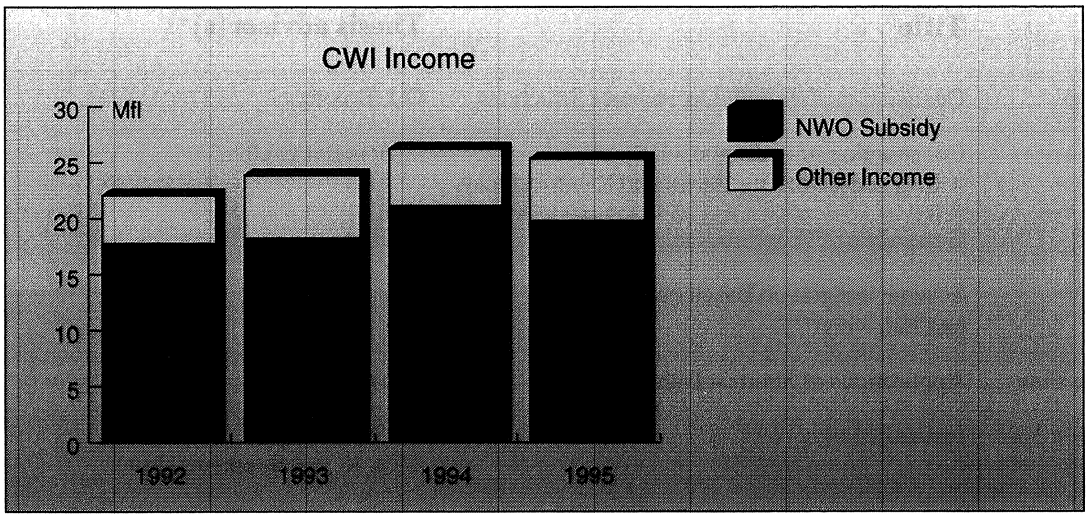
Income CWI

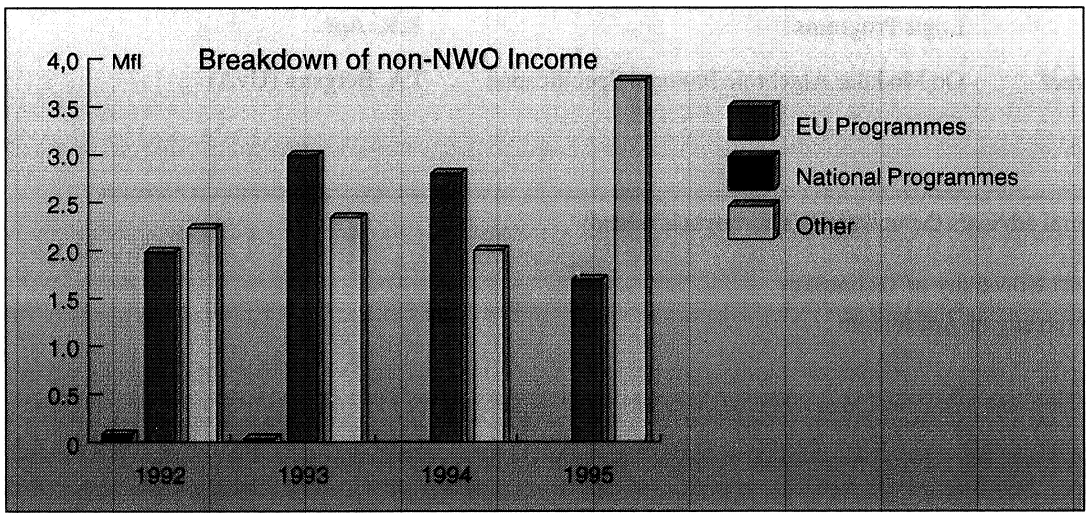


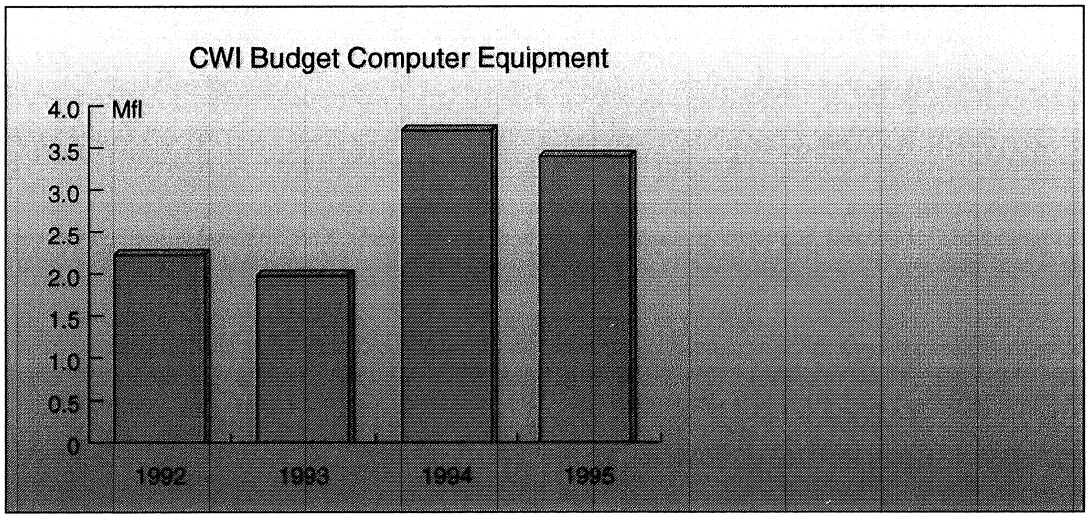
Expenses CWI



FINANCES 1992 – 1995







CWI Ph.D. THESES

Author	Title	Thesis advisor(s)+)
M.B. Combé	Queueing models with Dependence Structures	O.J. Boxma
R.H.P. Janssen	Construction of Orthogonal Polynomials Associated with Time Series and Random Fields	C. Scheffer (TUD)
F. Tip	Generation of Program Analysis Tools	P. Klint
C. Thieme	Scheme Integration Based on Structure and Behaviour	M.L. Kersten
J. Coelho de Pina	Applications of Shortest Path Methods	A. Schrijver
W.P.M. Meyer Viol	Instantial Logic	D.J.N. van Eijck J.F.A.K. van Benthem (UvA)
S. Etalle	Transformation and Analysis of (Constraint) Logic Programs	K.R. Apt
J.J. Brunekreef	On Modular Algebraic Protocol Specification	J.A. Bergstra (UvA)

+) For external advisors the university's acronym is added:

TUD = Delft University of Technology
UvA = University of Amsterdam

CWI RESEARCH PROGRAMMES

Algebra, Analysis & Geometry

Algebra, combinatorics, and information technology

Topics in algebra, combinatorics and pure and applied mathematical problems that come out of electronic publishing, interactive books, and information finding, with emphasis on the latter.
Projects:

- Hopf algebras and quantum groups
- Algebraic combinatorics
- Computer assisted mathematics and interactive books
- Chart and web of mathematics

Group leader: M. Hazewinkel

Modelling and analysis

Theoretical and applied analysis for the modelling and analysis of natural phenomena, ranging over epidemics and bifurcation analysis, seismic signals, flows through porous media, transport phenomena and a variety of processes relative to our environment.
Projects:

- Population dynamics and epidemiology
- Dynamical systems
- Asymptotics
- Wavelets
- Nonlinear partial differential equations and applications

Group leader: C.J. van Duijn

Operations Research, Statistics & System Theory

Combinatorial optimization and algorithmics

Fundamental and applied research, with an orientation towards mathematics (discrete mathematics, geometry, number theory), operations research (linear and integer programming, optimization, sequencing, scheduling), computer science (complexity theory, computational geometry) and applications (VLSI-layout, robotics, pattern recognition, transportation routing and scheduling).
Projects:

- Design and analysis of algorithms
- Polyhedral methods and polynomial-time algorithms
- Multicommodity flows and VSLI-layout
- Applications

Group leader: A. Schrijver

Analysis and control of information flows in networks

Fundamental and application-oriented research concerning the behaviour of complex stochastic systems: mathematical analysis of queueing models; performance analysis of computer and communication networks; integration of queueing and reliability theory in order to assess the behaviour of systems subject to breakdown, replacement and repair; stochastic phenomena in lattice-type networks, including applications in mathematical physics and communications.
Projects:

- Analysis of mathematical queueing models
- Stochastic processes on networks
- Reliability and availability of networks
- Performance analysis and control of computer and communication networks

Group leader: O.J. Boxma

System and control theory

In the field of realization, modelling and system identification: the construction of state space representations of dynamic systems from measurements; and in the field of control: the derivation of control laws that achieve the control objectives of stability, cost minimization, robustness, and adaptation. Current emphasis on realization of positive linear systems, stochastic realization, system identification with information theoretic criteria, modelling and control of discrete event systems and of hybrid systems, robust control theory, and realization theory for linear systems.
Projects:

- Control, realization, and system identification
- System theory
- Control of distributed computer systems

- Hierarchical and decentralized control of discrete event systems
- Control of discrete event systems
- System identification of compartmental systems
- Modelling of hybrid systems
- Control of hybrid systems

Image analysis and spatial stochastics

Theory and applications of mathematical and statistical problems arising in the analysis of digital images and spatial stochastic processes, with emphasis on stochastic and geometric methods for stochastic models and dynamical systems.
Projects:

- Stochastic geometry
- Bootstrap resampling
- Time series and random fields
- Mathematical morphology and discrete image transforms
- Ergodic theory of spatial processes

Group leader: M.S. Keane

Numerical Mathematics

Discretization of evolution problems

Parallel solvers for large-scale (stiff) ODE systems, with applications from circuit analysis and control engineering; transport problems derived from environmental applications, focussing on models describing atmospheric air pollution and pollution in surface water; and high performance computing research, intertwined with the work on parallel ODE solvers and transport problems.
Projects:

- Equations of fluid mechanics and related topics
- Three-dimensional flux modelling in shallow water
- Parallel initial-value-problem algorithms
- Algorithms for atmospheric flow problems

Group leaders: P.J. van der Houwen, J.G. Verwer

Boundary-value problems, multigrid and defect correction

Design, development and analysis of numerical methods for the efficient solution of boundary value problems, in particular multilevel-type methods such as multigrid, domain decomposition, nested adaptive grids, sparse grids for 2D and 3D problems, and their application to industrial problems. Further, the defect correction principle – the basis for multigrid methods – is exploited more generally for the accurate and efficient solution of boundary value problems.
Projects:

- Defect correction and adaptive techniques
- Computational fluid dynamics
- Singular perturbation problems
- Parameter identification in ordinary differential equations

Group leader: P.W. Hemker

Large-scale computing

High performance scientific computing, focussed on the optimization and comparison of mathematical and numerical algorithms on massively parallel processors, on parallel vector processors and on clusters of workstations; the development and use of tools for enhancing portability of parallel software, and for performance evaluation of parallel hardware.
Projects:

- Parallel numerical algorithms
- Computational number theory

Group leader: H.J.J. te Riele

Software Technology

Computational models

Semantics: mathematical modelling of a wide range of programming notions from contemporary computer languages, in particular (concurrent) object-oriented programming, and foundational studies of the techniques applied here (domain theory and transition systems).
Multiple computing agents: study of decision problems and constrained optimization, based on computing agents in the form of neural networks and genetic algorithms (biologically inspired computation models often used for classification and optimization).
Projects:

- Higher order and object-oriented processes
- EUROFOCS – comparative domain theory
- Foundations and applications of semantics
- Decision problems
- Constrained optimization

Group leader: J.W. de Bakker

Concurrency and real-time systems

Development and application of formal methods and tools for the specification and verification of reactive discrete event systems, both to control the complexity of such systems and to achieve the desired degree of correctness.

In particular: embedded systems, safety critical systems, and protocols used in telecommunications.
Projects:
- Expressiveness of languages for concurrency
- Checking verifications of concurrent systems with type theory tools
- Specification, testing and verification of software for technical applications
- Tools for program verification
- Specification and analysis of embedded software
- Transfer

Group leader: F.W. Vaandrager

Extensible programming environments

Generation of incremental programming environments from algebraic language definitions. More specifically, the group is extending, maintaining, and promoting the ASF+SDF system for the interactive development of programming and application languages.
Projects:
- Generation of interactive programming environments
- Generic tools for program analysis and optimization
- Parallel rewriting on SP1
- Industrial contacts

Group leader: P. Klint

Algebraic and syntactic methods

Term rewriting systems and their application in algebraic specifications and functional programming, in particular the design of suitable formats for higher-order and term graph rewriting and the establishment of their main structural properties, such as confluence and termination. The emphasis is on syntactic rather than semantic methods.
Projects:
- Expressiveness of languages for concurrency
- Higher-order rewriting
- Equational term graph rewriting
- Theorem proving, term rewriting, and symbolic computation
- Supportive research in term rewriting

Group leader: J.W. Klop

Algorithmics & Architecture

Algorithms and complexity

Algorithmic and theoretical issues at the front line of computer science, shifting gradually from complexity theory and parallel algorithms towards machine learning, quantum computing and cryptography.
Projects:
- Multiple agents learning
- Quantum coherent computing
- Parallel and distributed computing
- Secure protocols

Group leader: P.M.B. Vitányi

Interoperable multimedia systems

Development of formalisms and tools that support the concept of interoperability, including mechanisms that support abstract modelling, authoring, and runtime implementation of multimedia applications at the systems and user levels. Studies of applications focus on presentation on heterogeneous environments and requirement for long life-cycles. Core problems include the development of document activity specification that can be used as the basis for transportable applications, the development of protocol rules for adaptive communication of multimedia data, and distributed resource allocation algorithms.
Projects:
- Interactive books
- Multimedia authoring environments
- Distributed multimedia applications
- Specification of secure protocols

Group leaders: D.C.A. Bulterman, L.G.L.T. Meertens

Databases

Architectures for advanced database management systems to be used in strategic applications. Driving force is the development of theory, algorithms, and software prototypes for data mining applications, underpinned with studies into data modelling and performance assessment of database systems.
Projects:
- Parallel database architectures
- Data mining
- Performance assessment and capacity management
- Active databases
- Databases at the information superhighway

Group leader: M.L. Kersten

Interactive Systems

Computer graphics

Image synthesis and reconstruction, focussing on user requirements for fast response to maximize user control of applications, with special attention on adaptive wavelet-based coding techniques. Development of a Computational Steering Environment (CSE), in which users can easily define interfaces to and visualizations of their simulations.

Projects:

- ADMIRE – an object model for adaptive rendering
- Multiresolution image coding
- Scientific visualization – from data visualization to interactive exploration
- High performance visualization
- 3D computational steering

Group leader: A.A.M. Kuijk

Interaction and parallelism

Development of conceptual models and practical languages for coordination of interactions among a potentially large number of co-operative concurrent processes that make up a single application. The focus is on conceptual models and languages for coordination, multiple computing agents, visual programming and program visualization, user interfaces to complex systems, meta-computing in distributed heterogeneous environments, and constraint systems.
Projects:

- MANIFOLD language and system
- Visual parallel programming
- Meta-computing and parallel applications
- Constraint solving

Group leader: F. Arbab

Interaction and multimedia

The creation of basic facilities for media integration, in particular the design of an application-specific concrete set of integrated multimedia products which represent information perceived as units. Work in the ESPRIT project MADE will provide the basis for multimedia object creation and authoring, and introduce advanced, novel object-oriented techniques for this purpose. The created methodology will be contributed to an international effort, coordinated by CWI, to develop an international standard for multimedia programming.
Projects:

- Multimedia fundamentals
- Multimedia systems
- Multimedia applications

Group leader: P.J.W. ten Hagen

Logic programming and computational linguistics

The use of mathematical logic in modelling concepts from artificial intelligence and computational linguistics, in connection with issues in knowledge representation, alternative programming styles, common sense reasoning and semantics of various linguistic constructs. Secondly, the use of computational models developed by computer scientists in connection with logic programming, formal aspects of Prolog and its extensions, non-monotonic reasoning, modelling of concurrent programming and programming with constraints, and on natural language processing, in particular on parsing, information processing updating, and concept building.
Projects:

- Logic programming and non-monotonic reasoning
- Constraint logic programming
- Parallel logic programs
- Incremental parser generation and disambiguation in context
- A framework for computational semantics
- Dynamic logic, artificial intelligence and information processing
- Concept building from key phrases in scientific documents

Group leaders: K.R. Apt, D.J.N. van Eijck

INTERNATIONAL AND NATIONAL PROGRAMMES

This chapter summarizes the major national and international projects in which CWI participates.

The following data are given for each project:
- title,
- period,
- cooperation with other institutes,
- special role of CWI (if any),
- CWI project leader(s).

European Programmes

ESPRIT

COMPARE (5399): Compiler Generation for Parallel Machines
January 1991 – April 1995
Ace BV, STERIA, GMD, INRIA, Harlequin Ltd, Univ. Saarland
P. Klint

MADE (6307): Multimedia Application Development Environment
May 1992 – December 1995
Bull SA, SNI, Iselqui, British Aerospace, INESC, Gipsi SA, ESI, Barclays Bank, NR, FhG-IAO, INRIA
P.J.W. ten Hagen

SEMAGRAPH II (6345): The Semantics and Pragmatics of Extended Term Graph Rewriting
October 1992 – October 1995
Univ. East Anglia, ECRC GmbH, Univ. Rennes, Univ. Nijmegen, Imperial College
J.W. Klop

CONFER (6454): Concurrency and Functions: Evaluation and Reduction
September 1992 – September 1995
INRIA Rocquencourt, ECRC GmbH, Univ. Edinburgh, CNRS-ENS, Imperial College, INRIA Sophia Antipolis, Univ. Pisa, SICS
J.W. Klop

COMPULOG II (6810): Formal Aspects of Prolog and Logic Programming
August 1992 – August 1995
Univ. Leuven, ECRC GmbH, RWTH Aachen, Univ. Saarland, Univ. Pisa, Univ. Rome (La Sapienza), Univ. Rome (TorVergata), UNINOVA Lisbon, Univ. Uppsala, Imperial College, Universities of Bristol, Edinburgh and Aix-Marseille II
Coordinator: K.R. Apt

CAFE (7023): Conditional Access for Europe
December 1992 – December 1995
DigiCash, PTT, Cardware, Gemplus, SEPT, Ingenico, SINTEF-Delab, Institut für Sozialforschung Frankfurt, Institut für Informatik Hildesheim, Siemens, Universities of Leuven and Aarhus
Coordinator: R. Hirschfeld

PYTHAGORAS (7091): Performance Quality Assessment of Advanced Database Systems
May 1992 – November 1995
ICL, Bull SA, Heriot-Watt Univ., CCIP, Infosys, IFATEC
Coordinator: M.L. Kersten

CONCUR 2 (7166): Calculi and Algebras of Concurrency: Extensions, Tools and Applications
September 1992 – September 1995
Universities of Eindhoven, Aalborg, Edinburgh, Sussex and Oxford, INRIA, SICS, INPG, Sharp, Chalmers Univ., ECRC
F.W. Vaandrager

QMIPS (7269): Quantitative Modelling In Parallel Systems
October 1992 – October 1995
Univ. René Descartes LAA, Univ. Erlangen-Nürnberg, Univ. Torino, Imperial College, Univ. Newcastle, INRIA Sophia Antipolis
O.J. Boxma

NeuroCOLT (8556): Neural and Computational Learning
January 1994 – January 1997
Royal Holloway and Bedford New College, Univ.

Mons, Rheinisch-Westfälische Tech. Hochschule, Univ. Pompeu Fabra, Techn. Univ. Graz, London School of Economics, Helsingin Yuopisto, Lab. de l'Informatique du Parallelisme, Univ. Milan
P.M.B. Vitányi

MERCURY (20089): Performance Management of Commercial Parallel Database Systems
January 1996 – December 1998
ICL, IFATEC, ING, Heriot-Watt Univ.
M.L. Kersten

KESO (20596): Knowledge Extraction for Statistical Offices
January 1996 – December 1998
National Statistical Offices of Finland, Greece (via FORTH), and The Netherlands, Infratest Burke (D), Data Distilleries (NL), GMD (D), University of Helsinki
Project manager: A.P.J.M. Siebes

CHAMELEON (20597): An Authoring Environment for Adaptive Multimedia Documents
November 1995 – November 1998
CLRC (UK), Epsilon SA (GR), Cartermill International (UK), Comunicacion Interactiva (SP), Egnatia Epirus Foundation (GR), Cycnos Systèmes Ouverts (F)
D.C.A. Bulterman

DELOS (21057): ERCIM Digital Library
March 1996 – March 1999
Elsevier, Univ. Michigan, all ERCIM Institutes
F.A. Roos

BRITE/EURAM

AERO II (AER2-CT92-0040): Solution adaptive Navier-Stokes solvers using multidimensional upwind schemes and multigrid acceleration
January 1993 – January 1996
Von Karman Institute for Fluid Dynamics, Free Univ. Brussels, Politecnico di Bari, Technical Univ. Denmark, Royal Institute of Technology, Dornier Deutsche Aerospace, Fokker Aircraft B.V., Aerospatiale, British Aerospace, Dassault Aviation
P.W. Hemker

DRIVE

DYNA (V2036): A Dynamic traffic model for real-time applications
January 1992 – January 1995
Hague Consulting Group, CSST, Univ. Naples, Elasis, RWS, Univ. Lancaster, Univ. Libre Bruxelles, Univ. Delft
J.H. van Schuppen

MAST Marine Science and Technology

NOWESP (MAS2-CT93-0067): North-West European Shelf Programme
September 1993 – September 1996
RWS, Institut für Meereskunde, Univ. Leuven, NIOZ, Proudman Oceanographic Laboratory Bridston, Sir Allister Hardy Foundation for Ocean Science, Institute of Marine Research, Inst. für Ostseeforschung, Delft Hydraulics, BSH, IfBM, IFREMER, MUMM, Univ. Delft, Trinity College, Universities of Bordeaux and Liverpool
P.J. van der Houwen

MMARIE: Application of High Performance Computing Techniques for the Modelling of Marine Eco Systems
February 1995 – February 1998
Univ. Leuven, Delft Hydraulics, Univ. Southampton, IFREMER, CRS Cagliari, Univ. Hamburg, Univ. Liège, Univ. Delft, RIKZ, CETIIS, Univ. Bradford, Hydraulic Research Wallingford, Proudman Oceanographic Laboratory Bridston, UP de Catalunya.
P.J. van der Houwen

RACE/ACTS

BOOST (2076): Broadband Object-Oriented Service Technology
January 1992 – January 1995
MARI Computer Systems Ltd, IPSYS Software Plc, Bull S.A., Sociiti Frangais de Genie Logiciel S.A., GIE Emeraude, Detecon Technisches Zentrum, Intrasoft S.A., Telefonica, Intecs Sistemi Spa, Standard Elektrik Lorenz AG, Alcatel SEL, Centro de Estudos de Telecomunicagoes, Univ. College of Wales, Universities of Athens and Aveiro
F.W. Vaandrager

SEMPER (AC026): Secure Electronic Marketplace for Europe
September 1995 – September 1998
Cryptomathic (DK), DigiCash (NL), Eurocom Expertise (GR), Europay International (B), FOGRA Forschungsgesellschaft Druck (D), GMD (D), IBM European Networking Center (D), Intracom (GR),

KPN Research (NL), Otto-Versand (D), r3 security engineering (CH), SEPT (F), Univ. of Freiburg and Hildesheim (D)
D.C.A. Bulterman

TELEMATICS

STEM (EN1014): Sustainable Telematics for Environmental Management
January 1996 – January 1997
Univ. Edinburgh, Assynt Crofters Trust, Software AG España, CEAM, Univ. Karlsruhe, Implex Environmental Systems
L. Hardman

FRACAS (LRE 62-051): A Framework for Computational Semantics
January 1994 – April 1996
Univ. Edinburgh, Univ. Saarland, Univ. Stuttgart
D.J.N. van Eijck

RIDDLE (1038): Rapid Information Display and Dissemination in a Library Environment
February 1993 – February 1995
Longman Cartermill Ltd, Rutherford Appleton Laboratory
F.A. Roos

DACCORD (TR1017): Development and Application of Coordinated Control of Corridors
January 1996 – January 1999
Hague Consulting, TU Delft, Univ. Lancaster, TNO, RWS, Univ. Naples, CSST, Autostrade Italia, INRTS, Ile de France, Ville de Paris, Univ. Crete, TCU
J.H. van Schuppen

VALUE

POWER (CTT-646): Performance Oriented Workbench Experiment on Real Information Systems in the Energy Field
1994–1995
IFATEC
M.L. Kersten

CAFE Exposure (CS-657): Promotional Activities related to the ESPRIT 7023 project CAFE
1994–1995
Cardware
Coordinator: R. Hirschfeld

SCIENCE/HCM

MASK (CT92-0776): Mathematical Structures in Semantics for Concurrency
September 1, 1992 – September 1, 1995
Univ. Pisa, CNRS/INRIA, Universities of Udine, Mannheim and Koblenz
Coordinator: J.J.M.M. Rutten/J.W. de Bakker

System Identification: Modeling, Realization and Parameter Estimation for Problems of Engineering, Economics and Environmental Science
July 1992 – June 1995
Univ. Groningen, Technical Univ. Wien, Univ. Leuven, INRIA, Univ. Rennes I, Univ. Cambridge, LADSEB-CNR, Linköping Univ. CWI participates through the Systems & Control Theory Network of Univ. Groningen, seat of the coordinator
J.H. van Schuppen

EXPRESS: Expressivenes of languages for concurrency (CT93-0406)
1994–1997
Univ. Utrecht, SICS, Univ. Genova, Univ. Rome (La Sapienza), Univ. Hildesheim, Univ. Amsterdam, INRIA, GMD, Univ. Sussex, Univ. Nijmegen
Coordinator: F.W. Vaandrager

Statistical inference for stochastic processes (CT92-0078)
1993–1996
Universities of Paris VI, Berlin, Aarhus and Freiburg, INRIA
K.O. Dzhaparidze

EUROFOCS: European institute in the logical foundations of computer science (CT93-0081)
1994–1996
Univ. Edinburgh, INRIA, Universities of Pisa and Cambridge, ENS
J.W. de Bakker

The equations of fluid mechanics and related topics (CT93-0407)
1994–1996
CMAP, Univ. Paris VI, IX, XIII, Univ. Pisa, Univ. Ferrara, Univ. Nantes, IST (Lisbon), Universities of Trento, Pavia, Grenoble, Coimbra, London and Valladolid
J.G. Verwer

Algebraic combinatorics (CT93-0400)
1993–1996

Univ. Magdeburg, KTH Stockholm, Univ. Perugia, Univ. Cagliari, Univ. Bielefeld, Univ. Strasbourg, Univ. Bayreuth, Univ. Vienna, Univ. Paris VI, Univ. College of Wales, Universities of Copenhagen, Erlangen and Bordeaux I, Konrad Zuse Inst.
M.A.A. van Leeuwen

DONET: Discrete optimization and applications (CT93-0090)
1993–1996
Univ. Joseph Fourier, ZOR Bonn, Univ. Oxford
A. Schrijver

DIMANET: Discrete Mathematics Network (CT94-0429)
1994–1996
Universities of Bielefeld, Bologna, Cambridge, Montan, Lisbon, Madeira, Milan, Oxford, Paris 1, and Umea, Konrad Zuse Zentrum, Danmarks Tekniske Univ., Techn. Hochschule Darmstadt, Ecole Polytechnique Lausanne, Queen Mary and Westfield College, ENS Lyon, CNRS, Kungliga Tekniska Hogskolan
A. Schrijver

ERCIM computer graphics network (CT93-0085)
1993–1996
P.J.W. ten Hagen

ERCIM advanced databases technology network
1994–1997
M.L. Kersten

DIA: Digital Identification and Authentication (CT94-0691)
1995–1997
ENS, Univ. Salerno, Univ. Saarland, Univ. Aarhus
Coordinator: R. Hirschfeld

INTAS

ERCIM-FSU Cooperative Network in Informatics and Applied Mathematics
1994–1995
M. Hazewinkel

Network Mathematical Methods for Stochastic Discrete Event Systems
1994–1995
O.J. Boxma

National Programmes

SION (Netherlands Foundation for Computer Science)

Nonwellfounded sets and semantics of programming languages
1991–1995
J.J.M.M. Rutten

Extensions of orthogonal rewrite systems – syntactic properties
1992–1995
J.W. Klop

Computational Learning Theory
1992–1996
P.M.B. Vitányi

Declarative and procedural aspects of non-standard logics
1992–1996
K. Apt

MathViews – Functional and architectural aspects of mathematical objects in an Integrated System
1992–1996
A.M. Cohen

From ideas to reality – Implementing cryptography
1994–1998
R. Hirschfeld

WINST: Themes for collaboration in mathematics and computer science
1994–1998
Universities of Nijmegen and Eindhoven
J.W. Klop, M. Hazewinkel

Design theory for autonomous databases
1993–1997
A.P.J.M. Siebes

Incremental parser generation and disambiguation in context
1993–1997
Univ. Amsterdam
D.J.N. van Eijck

MDL Neurocomputing
1994–1998
P.M.B. Vitányi

Equational term graph rewriting
1994–1998
J.W. Klop

Generic tools for program analysis and optimization
1994–1998
P. Klint

Checking verification of concurrent systems with type theory tools
1994–1998
Univ. Utrecht
J.F. Groote

Constraints in object-oriented interactive graphics
1994–1998
Univ. Eindhoven
P.J.W. ten Hagen

Higher-order and object-oriented processes (HOOP)
1994–1999
Universities of Eindhoven and Leiden
J.W. de Bakker

MAGNUM, Database technology for multimedia information systems
1994–1998
Universities of Twente and Amsterdam
M.L. Kersten

Constraint-based graphics
1994–1996
Univ. Eindhoven
F. Arbab

Cryptography, learning and randomness
1994–1996
Univ. Amsterdam
P. Vitányi, R. Hirschfeld

Classifying algorithms for propositional logic
1994–1998
Univ. Delft
J.F. Groote

Scientific Visualization – from data visualization to interactive exploration
1995–1997
Univ. Delft, Free Univ. Amsterdam
J.J. van Wijk

NFI (National Facility Computer Science)

Performance analysis and control of distributed computer systems
1990–1995
O.J. Boxma/J.H. van Schuppen

Structural and semantic parallels in natural languages and programming languages
1991–1995
Univ. Amsterdam, OTS, Univ. Utrecht
D.J.N. van Eijck

ALADDIN – Algorithmic Aspects of Parallel and Distributed Computing
1992–1996
Univ. Utrecht
P.M.B. Vitányi

Distributed Algorithms
1993–1995
P.M.B. Vitányi

Intelligent CAD systems (MANIFOLD)
1986–1996
Univ. Eindhoven
F. Arbab

Special NWO projects

AIDA: Algorithms in algebra
1993–1996
Universities of Eindhoven, Groningen and Twente
M. Hazewinkel

Nonlinear systems
1993–1996
Universities of Groningen, Delft, Utrecht, Wageningen and Leiden, KSLA
C.J. van Duijn

Computationally intensive methods in stochastics
1993–1996
Universities of Leiden, Amsterdam, Rotterdam, Utrecht and Nijmegen
M.S. Keane

Computational number theory
1993–1996
University of Leiden
H.J.J. te Riele

STW (Foundation for the Technical Sciences)

Parameter identification and model analysis for nonlinear dynamic systems

1993–1997
P.W. Hemker

Parallel codes for circuit analysis and control engineering
1993–1997
Univ. Amsterdam
P.J. van der Houwen

ACELA – Architecture of a Computer Environment for Lie Algebras
1993–1996
Univ. Eindhoven
L.G.L.T. Meertens

Wavelets
1996–1999
Univ. Delft
N.M. Temme

NCF

CIRK: Mathematical modelling of global transport and chemistry of trace constituents in the atmosphere
1994–1997
Univ. Utrecht, KNMI
J.G. Verwer

Magnetohydrodynamics
1995–1996
Univ. Utrecht, FOM Rijnhuizen
H.J.J. te Riele

ICES HPCN Programme

HPCN for Environmental Applications
1996–1999
Univ. Delft, Delft Hydraulics, TNO
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IMPACT – HPCN for Financial Services
1996–2000
ING, Univ. Amsterdam, Univ. Twente, Getronics, Univ. Delft, CAP Volmac, Data Distilleries, BIT by BIT
M.L. Kersten

High Performance Visualization
1996–1998
ACE, CAP Volmac, Arcobel, TNO
R. van Liere

NICE – Computational Fluid Dynamics
1996–1999
TNO, Univ. Twente, MARIN, Delft Hydraulics, Univ. Groningen, Univ. Delft, NLR
P.J.W. ten Hagen

ELSIM – Electrotechnical Simulations
1996–1999
Univ. Utrecht, Philips, Universities of Leiden and Groningen
P.J. van der Houwen

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Analysis, Algebra and Geometry

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Algorithmics and Architecture

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H.J. Sips	(TUD)