Business plan
High Tech Systems

A new focus on Education, Research and Innovation

in Intelligent Mechatronic Systems

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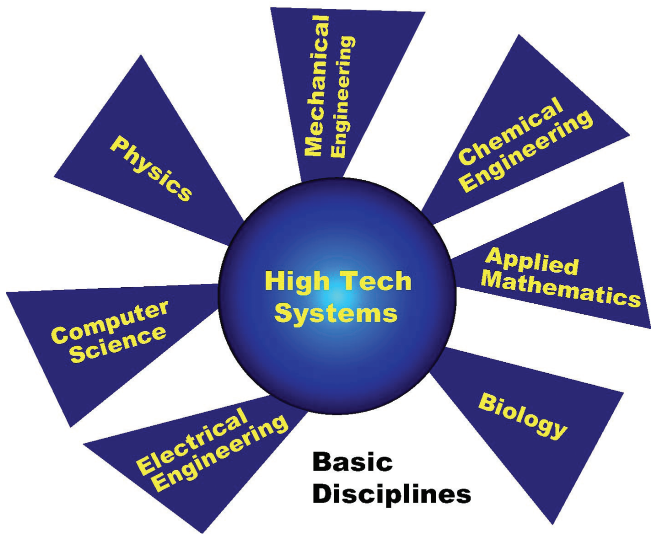
Part A
Centre of Competence

High Tech Systems
CoCo HTS

1 Introduction

High Tech Systems and Materials forms one of the four clusters that are identified by the 'Innovatieplatform' as areas in which the Netherlands is leading in terms of economy and knowledge. This is confirmed by many activities which industrial partners are undertaking like the High-Tech Systems Platform composed of ASML, FEI, Philips Medical Systems, Stork, Thales and Vanderlande Industries.
The area is broad and aims at various niches in the market and forms a strong combination of industrial activity (e.g. medical systems, automotive, gas-turbines, etc.) and knowledge (e.g. micro-systems, embedded systems, mechatronics etc.). Likewise, research and knowledge on design and product development are essential.
Although a precise definition of High Tech Systems seems difficult, an essential feature of HTS is that it involves multiple basic disciplines. Typically, although the importance of the cluster HTS is widely acknowledged, HTS is not a separate department at one of the technical universities, see Fig. 1 for a schematic positioning of HTS with respect to basic disciplines. Multi-disciplinarity, synergy and collaboration are therefore key ingredients for HTS.

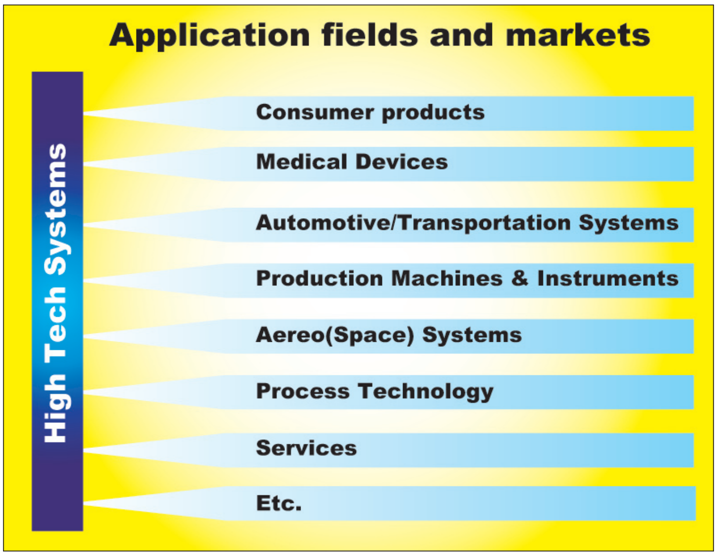
Figure 1.
Basic disciplines related to HTS



The application-field of the cluster High Tech Systems is very large, both in size and diversity. An incomplete but illustrative list is given in Fig. 2. The industrial activity in these fields is quite large and is often characterized by the combination of different disciplines in multi-disciplinary technology development. For the Netherlands, the production industry is and will be successful thanks to the qualitatively high-level products, often aiming at niche-markets. In order to keep a forefront position in this regard, education, research and innovation in High Tech Systems is essential.

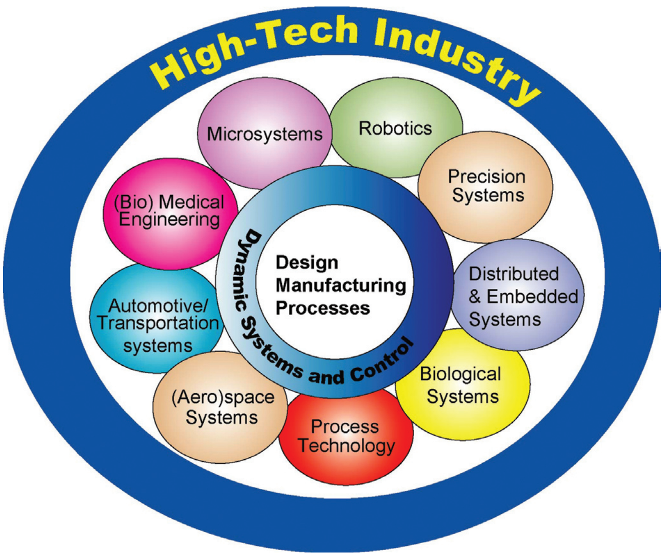
1 Introduction

Figure 2.
Main future markets and applications of High Tech Systems.



The understanding and research on High Tech Systems requires knowledge from different areas. Although one can argue that all departments at a technical university are somehow essential for High Tech Systems, we provide here a Center of Competence on High Tech Systems of the 3TU-IST. A schematic overview of the key technology fields that are involved in the CoCo HTS is given in Fig. 3. Note that at each of the three technical universities the listed technology fields are part of a –traditional- department; often one technology field can be found at different departments.

Figure 3.
Key technology fields and positioning of HTS



1 Introduction

The fact that the CoCo HTS is broad and deals with multiple basic disciplines, makes that it is absolutely required to have a common framework as to interact with each other. As an illustration, mechatronics as a technology field traditionally is built upon electrical and mechanical engineering, two basic disciplines at each of the three technical universities. Nowadays, also other disciplines, such as computer science and physics, are involved in intelligent mechatronic systems. For the integration of different disciplines in the CoCo High Tech Systems, and particularly for intelligent mechatronic systems, the field of Systems and Control is highly instrumental, since it allows the structural embedding of modeling tools from different disciplines. The field of systems and control is an enabling technology that provides the means to operate engineering systems to maintain desirable/optimal performance by automatically adapting to changes in the environment (see Appendix 1 for a further explanation of the role of systems and control).
The field is notably present at the three technical universities, is united in the national research school DISC with strong 3TU contribution, and a 3TU joint Master of Science on Systems and Control has been initiated.

2 Participating Chairs per Institution

A list of participating Chairs is given in appendix 2.

3 (Top) Research Schools, Institutes, TTI's etc. with group participation ≥ 50%

Figure 4 represents the relevant 3TU institutes and research schools for the HTS Center of Competence. The CoCo involves two current TTI/PPS initiatives: "Institute for Precision Systems" and "Bio-adaptive Systems Institute for Care". Central Research School is the KNAW accredited "Dutch Institute of Systems and Control" (DISC), that has a longstanding position in national/3TU training of PhD students (since 1987).

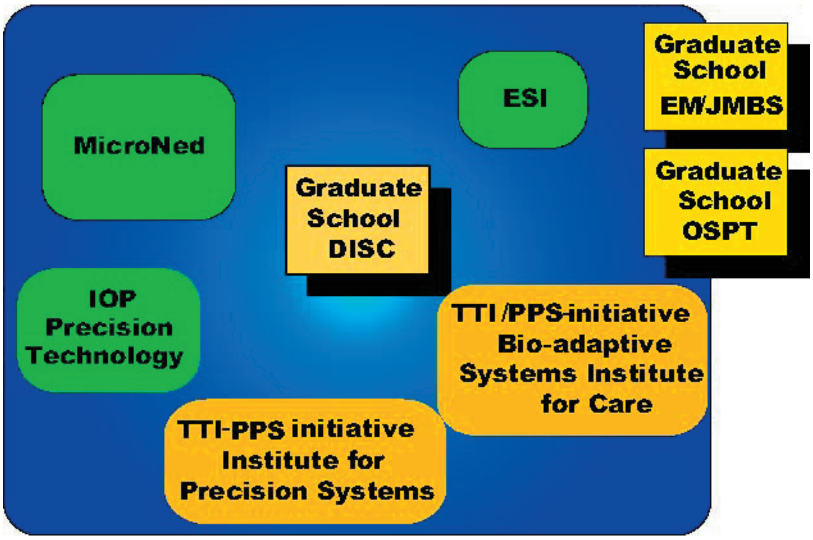


Figure 4. Scheme of existing 3TU structures within the scope of the CoCo.

Abbreviations in figure:
Graduate Schools:
- DISC, Dutch Institute for Systems and Control
- EM, Engineering Mechanics
- JMBS, J.M. Burgerscentrum, onderzoekschool voor stromingsleer
- OSPT, Onderzoekschool procestechnologie.

Consortia and Institutes
- MicroNed, Consortium on Micro-Technology (Bsik subsidieprogramma)
- ESI, Embedded Systems Institute
- IOP, Innovatiegerichte Onderzoeksprogramma's (subsidieprogramma)
- TTI, Technologische Top Instituten
- PPS, Publiek-Private Samenwerking

In this CoCo, focus and mass is created through the collection of several existing 3TU institutes and structured university/industry collaborations, in combination with an internationally recognized 3TU graduate school (DISC), and supported by several local institutes and centers, among which

TUD: Delft Centre for Mechatronics and Micro-systems, including Delft Institute for Microelectronics and Submicrontechnology (DIMES), Delft Centre for Systems and Control; Transport Research Centre Delft.

TU/e: Embedded Systems Institute (ESI), Centre for Fluid Mechanics, Solid Mechanics and Control (FSMC).

UT: Institute for Mechanics, Processes and Control (IMPACT), Institute for Microsystem- and Nanotechnology (MESA+).

For a complete overview we refer to Appendix 2.

Part B
Centre of Excellence

Intelligent Mechatronic Systems
CoE - IMS

4 Introduction

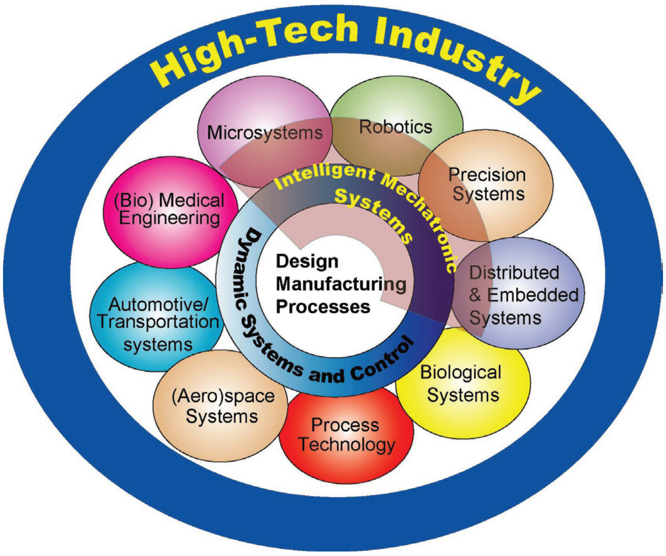


Figure 5.
Positioning and focus of the Center of Excellence within the Center of Competence HTS.

Within the field of High-Tech Systems, a Center of Excellence (CoE) is constructued that will focus on Intelligent Mechatronic Systems as indicated graphically in figure 5. The adjective "Intelligent" intends to stress the innovative nature and approach making wide use of advanced tools from physics, engineering, manufacturing, computer science, control etc.
Intelligent mechatronic systems is an area with high innovative potentials, driven by major industrial activities in several sectors, where a strong position in the world market is supported by an excellent knowledge position within the universities. Technology development in Mechatronics in the Netherlands has an outstanding international reputation. Most notably, the strength of this field in the Netherlands is its inherent multidisciplinarity, both in research as well as in industry. Complex components of high tech machines or systems require a continuous search for further development of the interaction and combination of the forementioned areas. Furthermore in this area industrial and university partners are already organized in several private-public cooperative initiatives as e.g. the Holst Centrum, MicroNed, High-Tech Systems Platform, and Mechatronica Valley Twente.
Intelligent mechatronic systems forms a key driver for the Dutch industry to remain at the forefront of important application fields and markets as are indicated in figure 2.

The CoE Inteligent Mechatronic Systems will also support the existing knowledge capital to strengthen the current market positions and to possibly open new frontiers and new markets. A typical success story is ASML, which since its birth in 1985, in twenty years has reached 54% of the current international market share in lithographic machines.
The existing expertise and the proposed investments for the CoE address the main technological fields which are relevant for Intelligent Mechatronic Systems and can be summarized in the following areas (see Fig.5):

- Robotics
- Precision Systems
- Micro-systems
- Distributed and Embedded Systems

The above areas are intimately correlated and will help to achieve excellence in the support of the mechatronics knowledge capital and realization of many technological dreams: e.g. any (industrial) robotic system needs an embedded control system, demands on micro-systems go hand in hand with precision design, etc., but the subdivision places emphasis on important aspects of intelligent mechatronic systems. As indicated in Figure 5 the integration of the different areas is enabled by means of the field of dynamic systems and control.

More particular challenges in the four programmes are:

Robotics
Development of humanoid robots / intelligent machines for the execution of servicing as well as industrial tasks, in high-level autonomous operation, with capabilities to effectively communicate with and adapt to its environment, and to operate and coordinate in teams.
This includes the integration of technology; applications of multitudes of sensors, machine/robot vision, haptics (force sensing and feedback), adaptive/learning systems, and the control of interacting/cooperating systems.
The 3TU partners in this program act as the joint university partner in the PPS-initiative "Bio-adaptive Systems Institute for Care".

Precision Systems
Design of high-end mechatronic systems with extreme performance demands, with use of innovative design, actuating, sensing and control principles, in order to achieve high-speed and high-accuracy (in nanometer range) precision systems for production, manufacturing and instruments.
The 3TU partners in this program act as the joint university partner in the PPS-initiative "Institute for Precision Systems".

Micro-systems
Miniaturization of mechatronic systems, including the required sensing and actuation technology is dependent on the integration of mechanical production/design with silicon- and other microsystems-technology. Realization of high-accuracy miniature devices including manufacturing/fabrication, micro-assembly, micro-machining, micro-system design, and incorporation of micro-system-based sensing and actuation functions in intelligent mechatronic systems.
The 3TU partners in this program are actively involved in the current BSIK programme MicroNed, and have invested in institutes for application of micro-systemtechnology, as DIMES (TUD) and MESA+ (UT).

Distributed and Embedded Systems
Intelligent mechatronic systems are a conglomerate of a hierarchy of subsystems whose actions have to be suitably coordinated for optimal overall performance. This includes high tech systems with high numbers of distributed sensors and actuators, with both continuous and discrete dynamics, and with systems and control technology that is able to handle this high level of complexity. It involves coordinated distributed control, hybrid control, and implementation issues where both systems and control theory as well as informatics (software engineering) play a crucial role. Application domains range from complex mechatronic systems in the high tech systems industry, to automotive systems and transportation networks.

5 Participating Chairs per Institution

Delft University of Technology

Professor	Chair	VSNU scores
Prof.dr.ir. M.H.G. Verhaegen	Systems and Control Engineering	2000: 4 5 5 4 *
Prof.dr. C.W. Scherer	Systems and Control Technology	2000: 5 4 4 5 *
Prof.dr.ir. P.M.J. Van den Hof	Model Based Measurement and Control	2000: 5 4 4 5 *
Prof.dr. F.C.T. van der Helm	Bio-mechatronics	2000: 5 4 5 5 *
Prof.dr. J.van Eijk	Advanced Mechatronics	n.a.
Prof.dr. P.M. Sarro	Microsystems/MEMS Technology	2000: 4 4 5 4 *

Eindhoven University of Technology

Professor	Chair	VSNU scores
Prof.dr.ir. M. Steinbuch	Control Systems Technology	n.a.
Prof.dr.ir. P.P.J. van den Bosch	Measurement and Control	2000: 4 4 4 4
Prof.dr.ir. A.J.A.Vandenput	Electro-mechanics and Power Electronics	2000: 4 3 5 4
Prof.dr. H. Nijmeijer	Dynamics and Control	n.a.

University of Twente

Professor	Chair	VSNU scores
Prof.dr. M.C. Elwenspoek	Transducers Science and Technology	2000: 4 4 5 5
Prof.dr.ing. M. Wessling	Membrane Technology	2002: 5 2 4 5
Prof.ir. H.M.J.R. Soemers	Mechatronic Design	n.a.
Prof.dr.ir. S. Stramigioli	Advanced Robotics	n.a.

n.a.: persons where not evaluated yet in any VSNU visitation.

6 Sub-themes of the 'Sleutelgebieden' covered by the CoE

High Tech Systems is part of the "Sleutelgebied" High Tech Systems and Materials.

7 Sub-themes of the FP7 covered by the CoE

The theme of the CoE has several relations with current European KP7 themes.

- Health: Technologies for human health; Non-invasive or minimally invasive approaches.
- ICT: Cognitive and learning systems; bio-inspired artificial and autonomous systems; machine learning; robotic systems; applications research for health, improving autonomy of patients.
- ICT: Integrated micro-nano systems. Pushing the limits of miniaturization, integration, variety and density; increasing performance and manufacturability at lower cost;
- ICT: Intelligent ICT-based transportation systems and vehicles enabling people and goods to move safely, comfortably and efficiently. Integration of technology: intelligent infrastructures.
- ICT: Embedded systems, computing and control.
- Transport: Surface transport: development of transport networks, infrastructures and systems; ensuring sustainable urban mobility.

European Technology Platforms:

- Embedded Computing Systems
- Manufuture (Platform on Future Manufacturing Processes)
- EUROP (Robotics)

8 Names of 3 top-groups from the EC working on the same theme

Three foreign research groups active in Mechatronics in Europe and having an excellent international reputation are:

1. DLR Institute of Robotics and Mechatronics, Germany, (http://www.dlr.de/rm/en/)
   Consortium of Technology Institute, University of Munich, and automotive and aerospace industry.

2. Grenoble-LAG, France (http://www.lag.ensieg.inpg.fr)
   Consortium of University, Technology Institutes (INRIA, CEA, CNET, ESRF), and industry.

3. KUL, Leuven. Belgium. (www.kuleuven.ac.be)
   Consortium of University, Technology Institute IMEC, Industry.

9 People to be newly employed and their fields of expertise outside the 3TU

For the realization of the research challenges as formulated in the description of the CoE, the following new positions are required:

Newly created positions:

- Robotics
  - Three tenure track positions in mobile robotics, haptics, and robot vision (TUD/UT)

- Precision systems
  - One chair/research group in Precision Mechatronics Design (TUe)

- Micro-systems
  - One chair in Out-of-clean-room Fabrication of Micro-devices (UT).
  - One tenure track position in Microsystems Distributed Sensing and Control (TUD)

- Distributed and embedded systems
  - One chair/research group in Hybrid Systems for Embedded Control (TUe)
  - One chair in Hybrid Control and Intelligent Transportation (TUD)
  - One chair in Mathematical Systems and Control Theory (UT)

Positioning of newly created academic positions

Delft University of Technology
In the area of Intelligent Mechatronic Systems, TUD has a recently established and renewed departmental structure within the faculty 3mE (Mechanical, Maritime and Materials Engineering) which is embedded within the Delft Centre for Mechatronics and Microsystems. The new investments in U(H)D positions will be positioned in the existing departments: Precision Manufacturing Engineering, Bio-Medical Engineering, Delft Center for Systems and Control, while the new chair in Hybrid and Distributed Control will be positioned on the interface between DCSC and the group Transportation Technology (3mE).

Eindhoven University of Technology
The newly created chair in Precision Mechatronic Design within Mechanical Engineering reenforces the mechatronics activities at the TU/e.
The newly created chair on Hybrid Systems for Embedded Control, within Electrical Engineering, aims at the reenforcement of the activities at the TU/e regarding embedded systems, and it is expected to form a valuable bridge towards the activities at the Embedded Systems Institute (ESI). Both chairs form together a key development for intelligent mechatronic design. It is foreseen that the chairs will strongly cooperate.

University of Twente
The chair in Mathematical Systems and Control Theory (EWI) is a unique full-time mathematical system theory chair within 3TU. The related activities in TU/e (Hautus) and TUD (Olsder) have been (or are being planned to be) discontinued. Focussing on this substantial activity in UT is of crucial importance for the system theoretical support of the field of high tech systems in the scope of the 3TU's.
The chair in Fabrication of Micro-Devices complements existing micro-systems activities currently present within MESA+.
The tenure track position in robotics is embedded in the chair on advanced robotics (EWI).

A more detailed formulation of research focus per item, as well as relations with current activities and research groups is collected in Appendix 3.

10 Translation of a socially relevant question in a technological dream

Societal Relevance

"Humanoid robots supporting future society"

Some of the biggest problems our society is facing are aging of the population, support of elderly and medical care. Besides that, there exist many time-consuming or dangerous tasks requiring human intervention like in rescue operations, many tedious or laborious jobs or in more futuristic situations like the planned mission to Mars where humans can profit from the assistance of humanoids for special delicate operations or emergencies.
Humanoids can move in environments without any specific environment adaptation, act as humans, but without the restrictions that humans have due to limited daily time employment, limited precision, working condition limitations and so on. The advantage represented by Humanoids for the society is comparable to the ground-braking introduction of industrial robots for industries in the 80' but now with unforeseen versatility, precision and in any human environment with the same levels of safety and interaction possibilities.
The CoE foresees as a long term dream a group of humanoids acting with higher precision than humans, with extensive interactive and sensorial capabilities and energy efficiency which greatly outperforms any existing effort in this field.
During the road to the achievement of this technological dream, many technologies will result in different cross fertilization possibilities for HTS.
Hereafter the four technological fields included in the theme Intelligent Mechatronic Systems of the CoE will be put in perspective with respect to this dream:

Microsystems: "Resembling nature by Miniaturization"
The realization of many parts of a humanoid like tactile sensing, intelligent vision devices, skin, smell, thermal perception etc., cannot be obtained otherwise than by miniaturization.

Robotics: "Understanding and Tackling Motion and Interaction"
The humanoids will have to mechanically interact with the external world and with each other, will have to walk, turn, stop, grasp objects and do meaningful tasks. These problems will be tackled using robotics theory and technologies.

Precision Systems: "Better than humans"
The humanoids the CoE is aiming for are far beyond humanoids available at the moment. The mechanics, control, micro-technology and sensory system allow precisions of motion which will be able to address for example extreme micro-surgical operations as well as high precision low scale assembly.

Distributed and Embedded Systems: "Computational Complexity and Reactive Behavior"
Many computing devices will be necessary addressing local control problems in various parts of the system by embedded technology. On the other hand, all these controllers will have to cooperate and interact to make the whole system behave properly. Last but not least, the coordination of a group of collaborating humanoids to achieve a common goal, requires deep knowledge of distributed and embedded control.

11 R&D-agenda related to this point who is doing what per location

An R&D agenda has been formulated on the basis of 4 programmes:
- Robotics
- Precision Systems
- Micro-systems
- Distributed and Embedded Systems.

They are indicated in more detail in Appendix 3.
The four programmes are closely related and are considered to be performed in close interaction.
Focus and mass is created – per location - in the following fields:

Delft University of Technology
- Dynamic systems and control
- (Bio)robotics
- Mechatronics and micro-systems (incl. DIMES)

Eindhoven University of Technology
- Precision mechatronics and control
- Embedded systems
- Automotive systems

University of Twente
- Mathematical system and control theory
- Micro-systems and fabrication (incl. MESA+)
- Robotics

12 Realization of a common Master education with specialisation per location (see R&D agenda)

Master program

The currently planned and developed 3TU MSc programme Systems and Control can serve as a program that addresses the generic tools and underlying common language that is relevant for the integration of the core activities within this CoE. Preparations for the start of this programme are on schedule; it is planned to start in September 2007.
Obviously this programme can not cover all disciplines within the field of High Tech Systems.
There is room for more 3TU MSc programs in this field, like e.g. Solids and Fluids.
In this new picture, the status of the UT MSc programme Mechatronics may need further reconsideration.

The existing PhD programme of DISC can serve as a basis and the model for the PhD program of the CoE. It builds upon the to-be-established MSc program and has a long-standing international reputation since its start in 1987.
Extension of the scope of this PhD program towards the surrounding technology domains can be realized by utilizing (a combination of) the following possible tools:

- Broadening the scope of the current DISC PhD program
- Utilizing PhD programs of the 3TU research schools EM/JMBS (Fluid and Solid Mechanics), OSPT.
- Creating an additional 3TU PhD program in robotics/mechatronics/manufacturing.

13 List of existing big facilities (≥ 1 mln.) per location within the 3TU

Infrastructure

All three universities have moderately sized shared laboratory facilities that support the local research activities in this field. Major sized laboratories for micro-technology are situated in Delft (DIMES) and Twente (MESA).

No major investments in laboratory facilities are foreseen.

14 New infrastructure, to be financed from the CoE-budget: accents per location

Infrastructure

For the purpose of prototyping and realization of real high-tech demonstrators investments are planned for UT in the micro and macro characterization and prototyping. As shown in the budget, a Micro System Analyzer is budgeted which will allow to characterize out of surface motion of MEMS and MOEMS devices. This will allow dynamic measurements which are at the moment not possible, but necessary to understand and eventually adapt complicated micro designs.
On the macro side, investments are planned for quick prototyping of mechanical and electrical parts for robotics applications which will be directly invested for the ``humanoid dream” together with future, to be found, extra funding.
In TUD additional laboratory costs are budgetted for instrumentation and for production of prototype micro- and mechatronic systems.

Action points

15 (planned) where the advantages of the cooperation are evident: sharing/concentration points infrastructure (see 14), concentration points research (see 11 and 12)

Advantages of a 3TU-cooperation

See also nrs. 11 and 12.

Next generation products in intelligent mechatronic systems, will require a further step away from the classical contributions from mechanical and electrical engineering. Complexity increase in terms of number of subsystems, interaction, sensing and actuation of several sorts, as well as the advanced design issues that are involved, together with more intensive use of developments in physics, requires technology development programs that go beyond the scope of one single department and even one single university.

Opportunity for using the organization and program of the current national/3TU graduate school in systems and control (DISC), for setting up an extended graduate school in intelligent mechatronic systems. This will provide PhD students with an excellent 3TU course programme that goes beyond the local capabilities per university, and thus will enhance the quality of research in this domain. This benefit of 3TU/national graduate schools has been experienced by the DISC community for almost 20 years now, and has contributed considerably to the international visibility and recognition of this community.

The R&D agenda of the CoE focusses on four programmes, while for most of them there already exist collaborative TTI/PPS programmes with industry. In this sense research groups have been positioning themselves already on a 3TU level to create focus and mass in technology fields for which extensive collaboration with industrial partners has high economic potentials. The TTI/PPS programmes typically provide additional funding for –temporary- researchers to be embedded in the several university groups. This CoE will, with its investments in structural (tenured) positions, increase the capabilities for research groups to participate in these TTI/PPS’s, thereby contributing more substantially to the development of high potential technology.

Concentration points for research per location, are summarized under item nr. 11.

16 Plan for scan of possible innovation possibilities of the research results

Valorisation

The 3TU CoE High Tech Systems can be characterized as a the unique platform within the 3TUs developing enabling technology towards multiple application fields. Specific focus will be intelligent mechatronics, which can be characterized as the development and design of motion systems by the combination of mechanical, electrical and computer science. Specifically the application fields of micro-systems, robotics, precision systems, and distributed and embedded systems will be addressed. Intelligent mechatronics is empowered by analysis and research tools from the dynamic systems and control field, which forms the universal language between the various application areas.

The design and manufacturing of prototypes will be done within the previously mentioned technology fields. The bringing to the market of technological developments can be characterized with two paths.

1. The addressed application fields have their own organizations and relations with the corresponding industry. The Center of Excellence supplies enabling technology to these application fields. The valorization of the developed technology is channeled through these existing application fields. The inherent valorization program within bsik MicroNed is available, as guided by STW and Senter/Novem.
2. The CoE High Tech Systems has its own relations with industry. This will be extended, where possible, through the very recent new initiatives towards establishing new programs and technology institutes like the IOP Precision Technology, the Institute for Precision Systems, The Dutch Manufacturing Institute, the Bio-adaptive Institute for Care, etc.. Cooperation will be sought with - and input given to - the existing initiative of the "3TU Innovation Lab" in this respect.

To set up a structural relation between the CoE and relevant industrial partners two particular actions are planned:

- Creation of an industrial advisory board
- Organization of a yearly 3TU High Tech Systems symposium focussing on the interplay between university research and industrial technology.

An overview of applications and the most important industry sectors within the domain of intelligent mechatronic systems is added in Appendix 4.

17 Necessary budget for 9+14, detailed in the 5 years [amounts in k euro]

Budget

Item	Schaal	2006	2007	2008	2009	2010	Totals
Delft University of Technology							
2 U(H)D Robotics and Intelligent Machines	11,12	135	215	297	302	308	**1256**
1 U(H)D Distibuted sensing/control microsystems	11	135	138	141	144	146	**704**
1 HL Hybrid Control / Intelligent Transportation	16	181	185	189	193	197	**945**
Start-up budgets / infrastructure		75	75	75	72	70	**367**
Totals		**526**	**613**	**702**	**711**	**721**	**3273**
Eindhoven University of Technology							
HL Hybrid Systems for Embedded Control (HSEC)	16	181	185	189	193	197	**945**
1 UD HSEC	10	124	127	130	132	135	**649**
HL Precision Mechatronics Design (PMD)	16	181	185	189	193	197	**945**
1 UD PMD	11	135	138	141	144	146	**704**
Totals		**621**	**635**	**649**	**662**	**676**	**3243**
University of Twente							
HL Fabrication Technology (FT)	16	181	185	189	193	197	**945**
HL System Theory	16	181	185	189	193	197	**945**
1 UD Robotics	10	124	127	130	132	135	**649**
MSA-400 Micro System Analyzer		280	0	0	0	0	**280**
Prototyping CNC Milling Machine		100	0	0	0	0	**100**
PCB prototyping machine		40	0	0	0	0	**40**
Laboratory infrastructure / Humanoid Material		50	50	50	50	50	**250**
Totals		**956**	**547**	**558**	**569**	**580**	**3209**
Graduate School							
International lecturer program		30	30	30	30	30	150
extension Ph.D. program to technology fields		25	25	25	25	25	125
Totals		**55**	**55**	**55**	**55**	**55**	**275**
Totals		**2158**	**1849**	**1963**	**1997**	**2032**	**10000**

To extend the activities of the graduate school DISC, budget is reserved for the introduction of an international lecturer program, where per year 2 world leading scientist are invited for a one month visit, including the teaching of a short course (3ECTS) in the 3TU graduate program.

For extension of the current DISC educational program to the wider area of the technology fields incorporated in this CoE, a budget of 25 k euro per year is reserved. This concerns in particular teaching facilities and secretarial support.

18 Budget for 16 [STW]

Budget

For the organization of an industrial advisory board, and the yearly organization of a 3TU High Tech Systems Innovation Symposium that brings together university research and industrial technology, a yearly budget is requested of 15k euro.

Appendix

Dynamic Systems and Control

In the area of High Tech Systems an important role is played by Dynamic Systems and Control as a domain independent discipline. Being a hidden technology it is often poorly understood.
The following characterizations are interpreted from R. M. Murray (Ed.), "Control in an Information Rich World: Report of the Panel on Future Directions in Control, Dynamics and Systems," SIAM, 2003. See also http://www.cds.caltech.edu/~murray/cdspanel/report/cdspanel-15aug02.pdf

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- The field of systems and control is an enabling technology that provides the means to operate engineering systems to maintain desirable/optimal performance by automatically adapting to changes in the environment. It is precisely this aspect of control as a means of ensuring robustness to uncertainty that explains why feedback control systems are all around us in the modern technological world.

- A common feature is that system level requirements far exceed the achievable reliability of individual components. This is precisely where control (in its most general sense) plays a central role: by applying smart operation to a system, in terms of sensing and actuation, its overall performance is far more accurate than the performance of the invidual components. As a result, control plays a key role in the design and realization of high tech systems that are robust to changes and disturbances in its environment.

- Contributions to the field of control come from many disciplines, including pure and applied mathematics, aerospace, chemical, mechanical and electrical engineering, operations research and economics, and the physical and biological sciences. The interaction with these different fields is an important part of the history and strength of the field.

- The system's approach to modern control theory links four important concepts that are central to both engineered and natural systems:

1. dynamics
2. modeling
3. interconnection
4. uncertainty

The system's approach has generated effective and generic tools for modeling interconnections of multi-domain (physical/chemical/mechanical) dynamical systems in one and the same framework, analysis of its stability and performance, and ensuring robustness with respect to uncertainties.

In this same report the role and position of DISC is referred to:
"One other mechanism, popular in Europe but not yet established in the United States, is the creation of regional control alliances that build critical mass by linking together multiple universities in a geographic region. This mechanism is used very effectively, for example, in the Netherlands through the Dutch Institute of Systems and Control (DISC)."

Participating chairs in CoCo HTS

Delft University of Technology

Delft Centre for Mechatronics and Microsystems

Faculty 3mE – Delft Center for Systems and Control

Professor	Chair
Prof.dr.ir. P.M.J. Van den Hof	Model Based Measurement and Control
Prof.dr.ir. M.H.G. Verhaegen	Systems and Control Engineering
Prof.ir. O.H. Bosgra (0.2)	Systems and Control Engineering
Prof.dr. C.W. Scherer (AvL)	Systems and Control Technology
Prof.dr. R. Babuska (AvL)	Systems & Control

Faculty 3mE – Biomechanical Engineering

Professor	Chair
Prof.dr. F.C.T. van der Helm	Bio-Mechatronics
Prof.dr.ir. P.A. Wieringa	Man- machine systems
Prof.dr. J. Dankelman (AvL)	Medical Engineering
Prof.dr. T. Tomiyama	Life cycle engineering

Faculty 3mE – Precision and Microsystems Engineering

Professor	Chair
Prof.dr.ir. F. van Keulen	Structural Optimization and Computational Mechanics
Prof.dr.ir. D.J. Rixen	Engineering Dynamics
Prof.dr.ir. J. van Eijk (0.3)	Advanced Mechatronics
Prof.dr.ir. L.J. Ernst	Strength of materials
Vacancy	Precision Manufacturing and Assembly (PMA)
Vacancy	Mechatronics Design

Faculty EWI – DIMES (Delft Institute for Microelectronics and Submicrontechnology)

Professor	Chair
Prof.dr. P.J. French	Electronic Instrumentation
Prof.dr. P.M. Sarro	Microsystems/MEMS Technology

Additional groups DISC (Dutch Institute of Systems and Control)

Faculty EWI – Delft Institute of Applied Mathematics

Professor	Chair
Prof.dr. G.J. Olsder	Mathematical Systems Theory
Prof.dr.ir. A.W. Heemink	Mathematical Physics

Faculty Aerospace Engineering

Professor	Chair
Prof.dr.ir. J.A. Mulder	Control and Simulation

Participating chairs in CoCo HTS

Delft University of Technology

Delft Centre for Sustainable Industrial Processes

Faculty 3mE – Department Process and Energy

Professor	Chair
Prof.dr.ir. P.J. Jansens	Separation Technology
Prof.dr.ir. J. Westerweel	Aero and Hydrodynamics

Faculty TNW – Department of Chemical Engineering

Professor	Chair
Prof.ir. J. Grievink/vacancy	Process Systems Engin. / Process & Product Engin.
Prof.dr. J.A. Moulijn	Reactor and Catalysis Engineering

Faculty TNW – Department of Multi-scale Physics

Professor	Chair
Prof.dr.ir. H.E.A. van den Akker	Physical Transportation Phenomena
Prof.dr.ir. C.R. Kleijn (AvL)	Micro-reactors
Prof.dr. R.F. Mudde (AvL)	Multiphase flow

Delft Centre for Life Science and Technology

Faculty TNW – Department Biotechnology

Professor	Chair
Prof.dr.ir. S. Heijnen	Bioprocess Technology

Faculty TNW – Department Imaging Science and Technology

Professor	Chair
Prof.dr. I.T. Young	Quantitative Imaging
Prof.dr.ir. L.J. van Vliet (AvL)	Quantitative Imaging

Faculty EWI – Information and Communication Theory

Professor	Chair
Prof.dr.ir. M.J.T. Reinders	Bioinformatics

Participating chairs in CoCo HTS

Delft University of Technology

Transport Research Centre Delft

Faculty CITG – Transport and Planning

Professor	Chair
Prof.dr.ir. H.J. van Zuylen	Dynamic Traffic Management

Faculty 3mE – Marine and Transport Technology

Professor	Chair
Prof.dr.ir. G. Lodewijks	Transport and Logistic Technology

Miscellaneous

Faculty CITG – Geotechnology

Professor	Chair
Prof.dr.ir. J.D. Jansen	Reservoir Engineering Systems and Control

Participating chairs in CoCo HTS

Eindhoven University of Technology

Faculteit Electrotechniek

Professor	Chair
prof.dr.ir.P.P.J.van den Bosch	Measurement and Control
prof.dr.ir.A.J.A.Vandenput	Electromechanics and Power Electronics
prof.dr.H.Corporaal	Embedded Systems Architecture
prof.dr.ir.J.W.M.Bergmans	Signal Processing Systems

Faculteit Werktuigbouwkunde

Professor	Chair
prof.dr.ir. M.Steinbuch	Control Systems Technology
prof.dr.ir. J.E.Rooda	Systems Engineering
prof.dr. A.Dietzel	Micro-& Nano-Scale Engineering
prof.dr. H.Nijmeijer	Dynamics and Control

Faculteit Scheikundige Technologie

Professor	Chair
prof.dr.ir. J.Schouten	Chemical Reactor Engineering

Faculteit Technologie Management

Professor	Chair
prof.dr. A.G.de Kok	Operations Management

Faculteit Wiskunde en Informatica

Professor	Chair
Prof.dr. O.Boxma	Stochastic Operations Research
Prof.dr. J.Baeten	Formal Methods

Faculteit Technische Natuurkunde

Professor	Chair
Prof.dr.ir.M.W.J.Prins	Molecular Biosensors for Medical Diagnostics

Participating chairs in CoCo HTS

University of Twente

Members of MESA

Professor	Chair
Dr. J.G.E Gardeniers	Micro-reactors
Prof.dr.ir. J.Schmitz	Semiconductor Components
Dr.ir. L. Abelman (substitute)	Magnetic Medias
Dr.ir. H.J.M. ter Brake	Low Temperature Division
Prof.dr. M. Pollnau	Integrated Optical Micro-Systems
Dr.ir. R.B.M. Schasfoort	Bio on the Chip

Members of IMPACT

Professor	Chair
Prof.dr.ir. A. de Boer	Noise and Acoustics
Prof.dr.ir. J.B. Jonker	Mechanical Automation
Prof.dr.ir. D.J. Schipper	Tribology
Prof.dr.ir. F.J.A.M. van Houten	Ontwerp, Productie en Management
Prof.ir. H.M.J.R. Soemers	Mechatronic Design
Prof.dr.ir. J.W.M. Noordermeer	Rubber Technology
Dr. J.W. Polderman (substitute)	System Theory
Prof.dr.ir. J. van Amerongen	Control Engineering
Prof.dr.ing. M. Wessling	Membrane Technologies
Prof.dr.ir. M.C. Elwenspoek	Transducers Science and Technology
Prof.dr.ir. R. Akkerman	Ontwerp, Productie en Management
Prof.dr.ir. S. Stramigioli	Advanced Robotics
Prof.dr. F.G. Mugele	Physics of Complex Fluids
Prof.dr. D. Lohse	Physics of Fluids
Prof.dr. ir. J. Huétink	Technische Mechanica
Prof.dr.ir. H.W.M. Hoeijmakers	Engineering Fluid Dynamics
Prof.dr.ir. L. Lefferts	Catalytic Materials and Processes
Prof.dr.ir. J.A.M. Kuipers	Fundamentals of Chemical Reaction Engineering
Prof.dr.ir. G.F. Versteeg	Development and Design of Industrial Processes
Prof.dr.ir. J.J.W. van der Vegt	Numerical Analysis and Computational Mechanics

Members of BMTI

Professor	Chair
Prof.dr.ir. P.H. Velting	Biomedical Signals and Systems
Dr.ir. H.F.J.M. Koopman	Biomedical Mechanical Engineering

Members of CTIT

Professor	Chair
Prof.dr.ir. C.H. Slump	Signals and Systems

CoE Research Programs

1 Robotics

Challenge
To develop humanoid robots / intelligent machines for the execution of servicing as well as industrial tasks, in high-level autonomous operation, with capabilities to effectively communicate with and adapt to its environment, and to operate and coordinate in teams.
This includes the integration of technology; applications of multitudes of sensors, machine/robot vision, haptics (force sensing and feedback), adaptive/learning systems, and the control of interacting/cooperating systems.

Current activities and strengths
Bio-robotics and development of humanoid robotic systems in TUD/3mE/BME (van der Helm), including their link towards medical systems and minimal invasive surgery (Dankelman). Approach of the TUD-team has been published in Science.
Additional strengths in TUD include vision systems (Young, van Vliet), sensors (French) and (learning) control (Verhaegen, Babuska).
Design and control of humanoid robots is also undertaken in UT/EWI, with an emphasis on modeling and control of multi-body systems through advanced analytical methods (Stramigioli).
Advanced (nonlinear) motion control and master slave control of robotic systems are focal points at the TU/e, and more recently newer activities on micro-robotics have emerged (Dietzel).

Involved CoCo-members
Stramigioli (UT), van der Helm (TUD), Dankelman (TUD), Babuska (TUD), Young (TUD), v. Eijk (TUD), French (TUD), Steinbuch (TU/e), Verhaegen (TUD), Nijmeijer (TU/e), Soemers (UT), van Vliet (TUD), Dietzel (TU/e), Veltink (UT), van Keulen (TUD), van den Bosch (TU/e), Koopman (UT), Tomiyama (TUD), Bergmans (TU/e).

New investments
Reinforcement of a 3TU robotic research programme through integration of bio-robotics, (learning) control, force feedback (haptics), mobile robotics, sensor technology and vision.
The current programme in TUD/3mE is being reinforced and broadened with 2 tenure track U(H)D positions to develop the aspects of haptics feedback, sensing, vision in the loop, mechatronic design en (learning) control of robotic and interacting systems.
One tenure track position is planned in UT/EWI which will focus on autonomous mobile robotics and smart design of robotics systems.
On the material side, at the UT investments will be done for fast prototyping of robotics systems to support the applications of the robotic and mechatronic cluster.

Benefits 3TU-cooperation:
Broadening, intensifying and coordination of the current research activities is necessary to contribute to the development of technology for industrial/medical applications. The program requires too many different disciplines to be executed in one location.
The 3TU partners in this program act as the joint university partner in the PPS-initiative “Bio-adaptive Systems Institute for Care”. In the field of biped locomotion toward the realization of energy efficient humanoids, the collaboration between the UT and TUD can effectively bring the IST-3TU to a world leadership in this technology: even if good collaborations are already present, the CoE will give a structural form to this strength.

2 Precision Systems

Challenge
Design of high-end mechatronic systems with extreme performance demands, with use of innovative design, actuating, sensing and control principles, in order to achieve high-speed and high-accuracy (in nanometer range) precision systems for production, manufacturing and instruments.

Current activities and strengths
Part-time mechatronics chairs in TUD and UT, and a vacant full-time chair in TUD. In TU/e mechatronics activities are included in the Control Systems Technology group and the Dynamics and Control Group(Wb).

Involved CoCo-members
Soemers (UT), v. Eijk (TUD), vacant chair Mechatronic Design (TUD), Steinbuch (TU/e), Nijmeijer (TU/e), Scherer (TUD), Verhaegen (TUD), Van den Hof (TUD), Vandenput (TU/e), vacant chair Precision Manufacturing and Assembly (TUD).

New investments
- A new research group Precision Mechatronics Design is installed in TU/e-Wb. Precision design of accurate mechanical devices, robotic and embedded systems are essential in the new chair.

Benefits 3TU-cooperation
Design and integrating aspects of precision mechatronic systems are that central to every mechanical engineering program and department, that a chair in mechatronic design is necessary to be included in every Wb-faculty. This requires investment of a new chair/section in TUe/Wb in which a particular emphasis is incorporated with respect to activities in embedded mechatronics, related to the activities in Embedded Systems within TU/e.
The 3TU partners in this program act as the joint university partner in the PPS-initiative “Institute for Precision Systems”.

3 Micro-systems

Challenge
Realization of high-accuracy miniature devices including manufacturing/fabrication, micro-assembly, micro-machining, micro-system design, and incorporation of micro-system-based sensing and actuation functions in intelligent mechatronic systems.

Current activities and strengths
In TUD design, modeling, optimization and production of micro-systems; symbiosis of micro-systems and mechatronics, sensor technology, precision manufacturing and medical applications, in the scope of the Delft Centre for Mechatronics and Microsystems, including DIMES.
In UT design and fabrication of micro-systems, sensors, actuators and functional microstructures. Fabrication technology based on photolithography; silicon micro-machining (Elwenspoek). Fabrication of polymeric, ceramic and metallic (porous) microstructures, surface modification of microstructures for controlled wetting and molecular recognition (Wessling); cooperation with MESA+.
At the TU/e a Master track Micro-Nano Technology started in 2003 and in 2004 a full chair on Micro-engineering (Dietzel) was appointed.

Involved CoCo-members
Elwenspoek (UT), van Keulen (TUD), Sarro (TUD), van Eijk (TUD), Dietzel (TU/e), French (TUD), Wessling (UT), Prins (TU/e), Schouten (TU/e), Nijmeijer (TU/e), van der Helm (TUD), vacant chair Precision Manufacturing and Assembly (TUD).

New investments
- One new chair/section on Out-of-Clean-Room Fabrication of Micro-devices in UT/CTW.
- One U(H)D positions in TUD/3mE on Microsystems Distributed Sensing and Control.

To support the UT-chair and the already present chairs involved in the CoE, a white light microscope with fibrometer measurements is budgeted in order to measure vertical motions and dynamic response not measurable otherwise with the present devices.

Benefits 3TU-cooperation
Miniaturization is becoming more and more important in high tech systems. In each of the technical universities there are fastly growing research activities in the area of micro-systems and the new investments that are planned generate a faster step towards the newest developments in this area. Clearly, the CoE HTS forms an excellent and timely means for bringing the Netherlands also at the forefront of the engineering-side of micro-systems. The 3 TU partners are already involved in activities organized by MicroNed, and will in the future jointly act towards new initiatives towards the establishment of a new TTI/PPS in this field.

4 Distributed and Embedded Systems

Challenge
Modern dynamic engineering systems are a conglomerate of a hierarchy of subsystems whose actions have to be suitable coordinated for optimal performance of the whole. This includes high tech systems with high numbers of distributed sensors and actuators, with both continuous and discrete dynamics, and with systems and control technology that is able to handle this high level of complexity. It involves coordinated distributed control, hybrid control, and implementation issues where both systems and control theory as well as informatics (software engineering) play a crucial role. Application domains range from complex mechatronic systems in the high tech systems industry, to automotive systems and transportation networks.

Current activities and strengths
Activities on embedded systems and hybrid control in TU/e partly in relation to the Embedded Systems Institute (ESI). In TUD the current activities focus on hybrid systems and control with particular application in transportation networks, in relation with the TUD Transport Research Centre Delft.

Involved CoCo-members: van den Bosch (TU/e), Verhaegen (TUD), Scherer (TUD), v. Eijk (TUD), Steinbuch (TU/e), de Kok (TU/e), Nijmeijer (TU/e), Baeten (TU/e), Boxma (TU/e), Rooda (TU/e), Corporaal (TU/e), Lodewijks (TUD), van Zuylen (TUD), Bergmans (TU/e).

New investments
- One new chair/section (1 HL, 1UD) in Hybrid Systems for Embedded Control in Tue/El. Network and automotive applications are key in the activities of the new chair.
- One new chair in TUD/3mE on Hybrid and Distributed Control, with particular application to Transportation Networks.
- One new chair in Mathematical System and Control Theory in UT/EWI. This chair is within the generic supporting field of dynamic systems and control.

Benefits 3TU-cooperation
Embedded and distributed systems is rapidly becoming one of the most demanding sub-technologies within Intelligent Mechatronic Systems. The enormous capabilities of computers in combination with high tech machines and tools, make the structuring, architecture and control extremely challenging. For this reason, it is extremely important that under the CoE HTS simultaneous investments at each of the 3 TU's are made as to strengthen the role of this area. The Netherlands is having a leading role in this area, both from an industrial perspective as well as from a research perspective, but in order to keep such position also within the engineering disciplines, the investments are essential. Clearly, the CoE HTS will, together with the new investments, jointly participate in initiatives on distributed and embedded systems (ESI, Philips High Tech Campus, etc.).

Application Fields and Related Industry

Technology Fields	Applications and Industry				
	Medical	**Consumer Products**	**Defence / Space**	**Make-Industry**	**Intelligent Transportation Systems**
Robotics Applications	MIS, Surgery and Diagnostic Devices, Smart Prothesis, Haptics & Telemanipulation, Bio-sensors, Delivery devices,	Storage Devices, Entertainment Robotics	Radars, Mobile Robotics, Aerospace structures, Rescue robots	Litographic tools, Smart mounts, Pick and Place, Micro-robotics for micro-assembly	Tracking systems, Traffic sensors, Adaptive cruise control, X-by-wire
Robotics Industry	Philips, Siemens, Intuitive, FCS, Medspray, Zebra Bioscience, Spec-trum, IBIS Tech-nologies,Storz, Ethicon, Olympus.	Philips	Thales, Stork-SP, Eurocarbon, ESA/ESTEC, Dutch Space, Xens, Maxon, Demcon	ASML, Philips, IMS, FEI, SKF, Neopost, Besi, Flextronics, Assembleon, Demcon	Phileas, Nissan, Inalfa, TNO, SKF, Groeneveld, Bosch, Frog
Precision Systems Applications	MIS, Diagnostics, Endoscopy, Biopsy	Vision, systems on foil lab on chip	Satellite measurement systems, GAIA, LISA, Darwin	Wafer scanners, EUV, Inkjet Technology, Optical storage systems	Sensors
Precision Systems Industry	TeStrake, Medtronic, Philips Medical, Academic Hospitals, Panalytical, Bronkhorst	CCM, Philips	ESA, Dutch Space, Stork, Demcon, Astron	ASML, Philips, Nyquist, Oce, ASM, Mitutoya, OTB, CCM, Assembleon, NMI, IBS Pre-cision Systems, Frencken, Demcon, IMS, Urenco	Siemens, Philips
Microsystems Applications	MIS, Implantable microsensors, Dosage systems, Biocompatible coatings, pipets, X-ray imaging detectors, Active catheters, Elastomer actuators	Probe storage, Imaging Devices, Data storage	Microrobots, RF MEMS	Femto-second lesers, Deep RIE, mask aligners, maskless lithography, wafer-scale post-processing	Automotive sensors and devices
Microsystems Industry	Philips, Medtronic, Ssens, Aquamarijn, Cordis	Siemens, Philips, Bosch, TI, IBM, Samsung	Thales	ASML, Philips, IBM, IMS	SKF, TNO, Bosch
Distributed and embedded systems Applications	MRI scanners, pacemakers,	Television, high end electronic systems	Fault detection, Coordinated Flight, Intelligent sensors	Wafer steppers, Printers, Optical storage systems	Automated highway systems, Autonomous vehicles, AGV's, Traffic control Satellites
Distributed and embedded systems Industry	Philips Medical	Philips, Siemens	(Aero)space, ESA , Dutch Space, Thales	ASML, Oce, Philips Aptech, Imtech,	Frog, TNO, Siemens, DHV, Vialis, Peek Traffic, LogicaCMG, AVV, Vanderlande cars