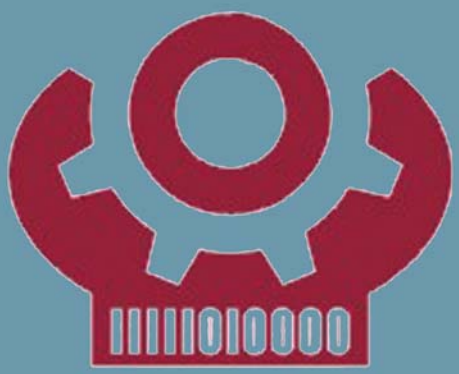
PUBLICATIONS OF THE ACADEMY OF FINLAND 13/03

Research Programme on the Future Mechanical Engineering 2000-2003

EVALUATION REPORT



ACADEMY OF FINLAND

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Research Programme on the Future Mechanical Engineering 2000–2003
EVALUATION REPORT

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The Academy's object is to finance high-quality scientific research, act as a science and science policy expert and work to strengthen the position of science and research. The Academy's operations cover all scientific disciplines.

The main focus of the Academy's development activities is on improving professional research career opportunities, providing preconditions for high-profile research environments and utilising international opportunities in all fields of research, research funding, and science policy.

The Academy has a number of funding instruments for various purposes.

The Academy's annual research funding amounts to about 185 million euros, which represents some 13 per cent of total R&D spending of the Finnish government.

Each year Academy-funded projects account for some 3,000 researcher-years at universities and research institutes.

The wide range of high-level basic research funded by the Academy generates new knowledge. The Academy of Finland operates within the administrative sector of the Ministry of Education and is funded through the state budget.

For more information on the Academy of Finland go to www.aka.fi/eng.

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Preface

The Research Programme on Future Mechanical Engineering (TUKEVA) was launched by the Academy of Finland in 2000 to strengthen existing research and researcher training, and to open new lines of basic research in the area of mechanical engineering. The programme covered a wide range of engineering research and was very multi-technological by nature. The total volume of public funding for the years 2000-2003 was 4.25 million euros. A total of 13 projects of the submitted 67 applications were approved into the programme. In addition, two projects funded by the National Technology Agency Tekes were also included into the programme. Foreign and domestic experts were extensively used in reviewing the applications.

The Academy of Finland appointed an international evaluation panel in February 2003 to review the programme as a whole. The panel was also to assess to which degree the TUKEVA programme has reached the objectives originally set for it. The members of the evaluation panel were Senior Lecturer Steve Culley (University of Bath), Professor Monika Ivantysynova (Technische Universität Hamburg-Harburg), and Vice President Technology, Professor Juhani Pylkkänen (Valtra Inc., Chair).

The evaluation panel was asked to consider the following items when evaluating the TUKEVA research programme:

- Implementation of the programme
- Scientific level and results of the programme
- Collaboration of organisations and researchers
- Applicability of the results
- Recommendations

The evaluation was executed during two days in Helsinki by interviewing members of the programme steering group as well as project leaders and team members from four projects, by studying in advance the final report of the programme and self-assessments of the project teams. The discussions and presentations were conducted in an extremely open atmosphere with great enthusiasm.

This publication includes the report of the evaluation panel. Documentation of the programme and projects is available at http://www.hermia.fi/tukeva.

Helsinki, 26 September 2003

Juhani Pylkkänen
Monika Ivantysynova
Steve Culley

1 TUKEVA Programme

1.1 Background

The Finnish mechanical engineering industry enjoys a strong and leading market in certain special areas of industry worldwide. As an export-oriented industry it has a key role in the Finnish economy. The gross value of the mechanical industry in 2002 was 18 billion euros with an export of 9.4 billion euros. Exports of the mechanical engineering and metal products industry account for 76 per cent compared to the total exports of electronics and electrical industry. The investment in R&D is less than one quarter of the corresponding figures in electronics and electrical industry. Innovation in mechanical engineering industry, together with its competitiveness and profitability, can be significantly improved by investing in basic and applied research. There is also a need for more young PhDs in Finnish mechanical engineering industry.

The first steps leading to the TUKEVA research programme were taken with the establishment of a working group on future research needs in August 1998. The working group hosted an exploratory workshop in March 1999 in order to learn about the views of foreign experts as well as of representatives of Finnish industry and research. On 1 June 1999, the Board of the Academy of Finland approved the proposal by the Research Council for Natural Sciences and Engineering to launch a three-year research programme on Future Mechanical Engineering in 2000.

1.2 Organisation

At its meeting on 1 June 1999, the Academy of Finland Board appointed a steering group to make preparations for the TUKEVA research programme. The chair of the steering group was Professor Mauri Määttänen from Helsinki University of Technology (Research Council for Natural Sciences and Engineering of the Academy of Finland). Among the twelve members of the steering group were four representatives from industry. In addition, the Research Council for Health, the Research Council for Biosciences and Environment and the Research Council for Culture and Society were also involved in the steering group. The programme was opened for proposals in autumn 1999. Research proposals for funding were applied for by individual research teams and by consortia of several teams. Selection of projects was made in two phases. For the first phase applicants were asked to submit a short plan with calculation for required funding. For this first selection phase, a total of 67 plans of intent were submitted by 13 consortia and 54 individual research teams. The steering group selected six consortia and 14 individual projects for the second phase. In the final selection, four projects by consortia and nine projects by individual research teams were approved. The Finnish Work Environment Fund joined the TUKEVA programme in funding two subprojects and the National Technology Agency Tekes joined in co-funding one project and by funding two additional projects. The final selection was done based on scientific review by an international evaluation panel. The composition of the steering group changed slightly over time. Professor Riitta Keiski took over the chair of the steering group after the launching

of the programme. The programme director acting as coordinator for the TUKEVA programme has been Dr Kalle Hakalehto from Tampere Technology Centre Ltd. The coordinator started his work 1 November 1999 and will end 31 December 2003. In January 2002, an intermediate seminar was held where the status and results of all projects were presented.

1.3 Programme funding

The total funding for TUKEVA amounted to 4.25 million euros, of which 3.53 million euros were provided by the Academy of Finland. Further funding bodies were the National Technology Agency Tekes with 0.58 million euros and the Finnish Work Environment Fund (TSR) that supported the programme with 0.14 million euros.

The research work done within TUKEVA has been strongly supported by the existing laboratory facilities of individual research teams. The three-year funding of the projects started from 1 June 2000 and is available until 31 December 2003.

1.4 Research objectives and goals

TUKEVA was the first research programme in the field of mechanical engineering launched by the Academy of Finland. The aim of the TUKEVA programme was to strengthen existing research efforts and to open new lines of high-quality basic research, which support ongoing and future R&D work of Finnish industry. The specific objectives were:

- to establish closer links of collaboration between theoretical and applied research
- to strengthen the research culture seeking to extract new product innovations
- to increase the number of doctoral students in mechanical engineering and manufacturing technology
- to promote national and international networking among individual researchers and research units

The key areas specified by the programme memorandum were: *machine design, manufacturing technology and use*. The details are shown below.

Design

Key areas of research in machine design included:

- environmentally friendly design
- concurrent design
- reduction of vibration and noise
- electronics, opto-electronics and information technology applications
- new materials and structures
- man-machine interface and user-oriented design

Manufacture

Key areas of research in manufacturing technology included:
- new manufacturing methods and materials
- machining, forming and cutting
- computational methods in manufacturing technology
- simulation, optimisation and control of networked production
- autonomous, learning production equipment and systems
- quality control methods and reliability of production systems
- working methods, environment and safety
- reducing environmental impacts

Use

Key areas of research with respect to use included:
- safety of machines and equipment and controlling adverse health effects
- man-machine interaction and interface requirements
- intelligent monitoring of machines, diagnostics and prognostics
- intensified use of machine systems and overall reliability
- reducing environmental impacts
- taking into account the requirements of the arctic environment

2 Evaluation Procedure

The evaluators met in the evaluation panel at the Academy of Finland in Helsinki on 25-26 September 2003.

The evaluators were asked to pay attention to the five main criteria in their evaluation:

1. Implementation of the TUKEVA programme
2. Scientific level and results of the programme
3. Collaboration of organisations and researchers
4. Applicability of the results
5. Recommendations

The documents provided to the evaluators included:

- Programme Memorandum
- Proceedings of the intermediate seminar, 3 January 2002
- Final Report of the TUKEVA programme
- Self-evaluation forms of the projects
- Coordination report
- "Knowledge, Innovation and Internationalisation", review by the Science and Technology Policy Council of Finland, Helsinki 2003

During the meeting the evaluators met representatives of the TUKEVA steering group. The panel also received presentations from four of the projects and discussed the projects and the process with the participants. This was an invaluable element of the overall evaluation process, and the panel gained understanding and valuable insights from these sessions.

3 Evaluation of the Programme

3.1 Implementation of the programme

The programme was able to cover approximately 75 per cent of the topics highlighted in the programme memorandum in the areas of *machine design, manufacturing technologies and use.* The projects participating in the programme are listed in Appendix 2. It was also possible to include a number of additional topics. This is an indication of a well-coordinated initial programme.

The programme had a good balance between fundamental research, working with industry, cross-disciplinary activity, generating infrastructure and promoting postgraduate degree activity. It was also possible to include a number of research institutes.

The importance of the background infrastructure was evident from the presentations, though less so from the reports. Around six per cent of the TUKEVA funds were allocated to equipment, leaving, however, to the projects the final decision on the use of funding. The really successful projects seemed to be the ones where basic or innovative research was undertaken on the back of an existing team, equipment or project, or where existing researchers were brought together as part of the TUKEVA process.

3.2 Scientific level and results

It is concluded that a number of the projects were world-class and that half of the projects were at a very good national level, although the context of the research had not been fully described in the final reports (see Recommendations). In a number of cases the TUKEVA funding had facilitated the establishment of potentially valuable long-term facilities and in other areas had supported innovative world-class developments. There was a very good balance between theory and experiments and between challenge and risk.

A number of new methods and integrated multi-domain-system approaches for computer-aided design were developed; these methods are extremely useful for the virtual prototyping of machines and systems. The models and technologies developed in the project "User interface of robotics …" and "Simulation of multiphase flows …" are of a high scientific level. The results of both projects have been widely published and the robotics project was awarded a prize at an international robotics conference.

The publications are as listed below in Table 1. This is commendable and of a very good level in relation to the timescale of the projects. It shows the impact that the programme has had in developing the academic base in mechanical engineering. It is to be expected now that systems are in place, problems have been overcome etc. that further publications will flow. The panel was disappointed that a couple of the projects appeared to have no publications. The programme had resulted in two

patents listed in the project report and two more where patents were in the process of evaluation.

Table 1. Summary of published output of the TUKEVA programme.

Journal articles	35
Conference papers	110
Other publications	18

The details of the trained output are shown in Appendix 1 and show seven doctoral dissertations for 2003, 13 in the pipeline for 2004, and 12 for 2005. This is a significant achievement of the TUKEVA programme, and it could be argued that the programme has effectively doubled the number of dissertations in mechanical engineering in Finland (see Table 2).

At the evaluation panel a number of young researchers presented and discussed their work. They were all, without exception, of a very high calibre.

Table 2. Mechanical engineering doctoral degrees completed in Finland in 2002.

Doctoral degrees in 2002	All disciplines	Mechanical Engineering
HUT, TUT, LUT, Uni of Oulu	280	12

The TUKEVA programme embodied the concept of a predetermined and predefined research programme which had two major targets listed in its objectives; namely basic scientific research and the development of researchers with the additional emphasis of innovation. It clearly had the effect of stimulating innovation as described above, for besides the new generic knowledge created, a number of patented ideas have also been generated.

3.3 Collaboration of organisations and researchers

Overall, the projects are not linked together in the TUKEVA programme and they have functioned predominantly as individual projects. However, the consortium projects have been of benefit as they have enabled/encouraged a number of disparate but linkable research work to be brought together with considerable benefit, e.g. in the project “Extreme values of piston engine”.

As discussed in Recommendations it may/should be possible to group together topics and research teams in the future. Once natural groupings have been established or required, the researchers should be able to and should be expected to coordinate themselves.

It was clear that within projects there was good collaboration. There were examples of mechanical engineers working with electrical engineers and system or simulation engineers working with structural engineers. Also several of the projects were working with other partners, from industry and research institutes, many of whom had

received their funds from other sources, such as Tekes. There were some significant management overheads with these activities.

However, there appeared to be very little collaboration between the projects, even those where there was some synergy and discussion might have yielded benefit. Thus the idea of loosely grouping or categorising projects would seem of benefit (see Recommendations).

There was good collaboration with industry, especially in the projects "New suspension structures and damping systems in off-road vehicles", "Extreme values of the piston engine", "User interface of robotic machines based on perception and cognition", "Novel ceramic technologies in realization of miniature actuators and motors", "Simulation of multiphase flows for industrial processes", "Advanced surface coatings by high power lasers" and "Fatigue strength modelling of laser welded joints" respectively.

The international collaboration varied considerably from excellent to non-existent and in fact some projects had limited their publications to Finnish or Nordic conferences.

3.4 Applicability of the results

The panel analysed the projects in some detail. It considers that in approximately half of the projects there were innovations, techniques, algorithms, devices and methods that could and really should be implemented within the next one to three years. The panel was impressed by the project "Novel ceramic technologies in the realisation of miniature actuators and motors" in that the critical manufacturing and design elements had been researched very effectively. This project has the potential to open up a number of new applications and fields, for example in medical engineering. There is also the opportunity for new business and spin-offs.

4 Recommendations

The panel commends the Academy of Finland for initiating the TUKEVA programme and considers that it has made an invaluable contribution to research in mechanical engineering. The panel makes the following recommendations to support the ongoing process.

Timescales

The panel considers that it would be of considerable benefit to extend the timescale of the programmes. It would seem sensible that as part of the evaluation process a number of projects (not all) should be extended. It may be possible to also group together some of the activities and bring in other researchers into these groupings, to aid this process of building critical mass in certain areas. The panel is pleased to hear that the Academy has extended the normal timescale for new programmes to four years and hopes that some form of grouping may be encouraged (see below).

Grouping

The TUKEVA programme effectively consisted of some 15 projects undertaken in consortia and as individual projects. The panel considers that greater leverage would be obtained by grouping the strong topics and dropping or refocusing other topics. This would have an effect of creating communities of expertise that would strengthen the next phases of any research activity. As an example it may be possible to link the excellent work in "Simulation of multi-phase flows…" with the very challenging project on "Extreme values of the piston engine".

It is suggested that a new focussed programme on mechanical engineering covering four or five strategic areas/topics, based on the work that has emerged, is pursued. The topics that suggest themselves are mobile vehicles, surface engineering and materials, and mini-robotics.

Context

It is essential that the research being presented is put in the context of key research being undertaken nationally, within the reset of Europe and internationally. This should be a requirement of any request for funding and the final report.

Final Report

There was considerable variation in the quality and coverage of the final reports, in fact one group had only bothered to submit a previously published paper, and two reports arrived in the morning of the evaluation panel.

It is thus recommended that of proforma or strict guidelines are presented for content. This might limit the report to three pages covering: Abstract*, Introduction, Need for work, National and international context, Aims and objectives, Research

methodology, Activities undertaken, Research issues/challenges, Operational problems, Deliverables, Expenditure, Collaborations, Conclusions, Future work. Publications could be listed in an Appendix and the researchers would be requested to submit their best/most important publication. In a consortium each grouping in the consortium would be requested to submit a paper.
**Abstract including title, researchers, affiliations, dates of milestones, funding plus 75 words is surprisingly useful and can be used in booklets and websites for quick reference.*

Evaluation

The Academy should give strong consideration to the formal evaluation of final reports as is undertaken in a number of European countries, perhaps with the use of external evaluators from both academia and industry. This evaluation may be used as part of the assessment for future funding or may be used to allocate some final amount of funding (say 10%) held back for the purpose.

APPENDIX 1. Doctoral dissertations

Doctoral dissertations contributed by TUKEVA programme.

Title of the project	Year 2003	Year 2004 (estimation)	Year 2005 (estimation)	Total (estimation)
New suspension structures and damping systems in off-road vehicles (consortium)	2		1	3
Extreme values of piston engine (consortium)	1	1	3	5
The effect of parameter uncertainty on the reliability of virtual testing of fluid power systems (consortium)		1	1	2
Intelligent laser surface engineering (consortium)		1	1	2
User interface of robotic machines based on perception and cognition	1	1		2
Analysis and control of vibrations in electrically driven machine systems	1	1	2	4
Condition monitoring of high temperature power plant components using metal embedded fibre optic bragg-gratings		1		1
Novel ceramic technologies in realization of miniature actuators and motors		1	2	3
Coherence microscope in industrial manufacture, robotics and imaging			1	1
Axially moving materials and composites		1	1	2
Simulation of multiphase flows in industrial processes	1	1		2
The modelling and optimisation of dynamic production networks based on the evolutionary principles observed in animate organisms	1	1		2
Fatigue strength modelling of laser welded joints		1		1
Advanced surface coatings by high power lasers (funded by Tekes)		2		2
Fussy classification and neural networks in particle recognition (funded by Tekes)				
	7	13	12	32

Number of completed doctoral degrees in technological sciences in Finland.

Year 2000	Year 2001	Year 2002
161	205	204

APPENDIX 2.
List of projects and participants

Consortia research projects

New Suspension Structures and Damping Systems in Off-Road Vehicles
(includes a subproject funded by the Finnish Work Environment Fund)
Helsinki University of Technology, Laboratory of Automotive Engineering
University of Oulu, Laboratory of Machine Design
VTT Electronics

Extreme Values of Piston Engine
Helsinki University of Technology, Laboratory of Internal Combustion Engine
Tampere University of Technology, Institute of Hydraulics and Automation
Tampere University of Technology, Institute of Materials Science

The Effect of Parameter Uncertainty on the Reliability of Virtual Testing of Fluid Power Systems
Tampere University of Technology, Institute of Hydraulics and Automation
Helsinki University of Technology, Department of Mechanical Engineering

Intelligent Laser Surface Engineering
Lappeenranta University of Technology, Laboratory of Laser Processing
VTT Industrial Systems
Tampere University of Technology, Institute of Production Engineering

Individual research projects

User Interface of Robotic Machines Based on Perception and Cognition
(includes a subproject funded by the Finnish Work Environment Fund)
Helsinki University of Technology, Department of Automation and Systems Technology

Analysis and Control of Vibrations in Electrically Driven Machine Systems
Lappeenranta University of Technology, Department of Mechanical Engineering

Condition Monitoring of High Temperature Power Plant Components Using Metal Embedded Fibre Optic Bragg-gratings
VTT Industrial Systems

Novel Ceramic Technologies in Realization of Miniature Actuators and Motors
(funded also by Tekes)
University of Oulu, Laboratories of Microelectronics and Materials Engineering

Coherence Microscope in Industrial Manufacture, Robotics and Imaging
University of Helsinki, Laboratory for Electronics and Industrial Physics

Axially Moving Materials and Composites
University of Oulu, Department of Mechanical Engineering

Simulation of Multiphase Flows in Industrial Processes
University of Jyväskylä, Department of Physics

The Modelling and Optimisation of Dynamic Production Networks Based on the Evolutionary Principles Observed in Animate Organisms
Tampere University of Technology, Institute of Production Engineering

Fatigue Strength Modelling of Laser Welded Joints
Helsinki University of Technology, Ship Laboratory

Advanced Surface Coatings by High Power Lasers
(funded by Tekes)
Tampere University of Technology, Institute of Materials Science

Fussy Classification and Neural Networks in Particle Recognition
(funded by Tekes)
VTT Industrial Systems

The Research Programme on Future Mechanical Engineering (TUKEVA) was launched by the Academy of Finland in 2000 to strengthen existing research and researcher training and to open new lines of basic research in the field of mechanical engineering. The programme covered a wide range of engineering research and was multi-technological by nature. A total of 15 projects were approved into the programme.

An international evaluation panel reviewed the programme as a whole. The panel considers that the programme has greatly contributed to research in mechanical engineering. A num ber of projects were world-class and half of the projects were at a very good national level. The panel also gives several recommendations for further development of the field.

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