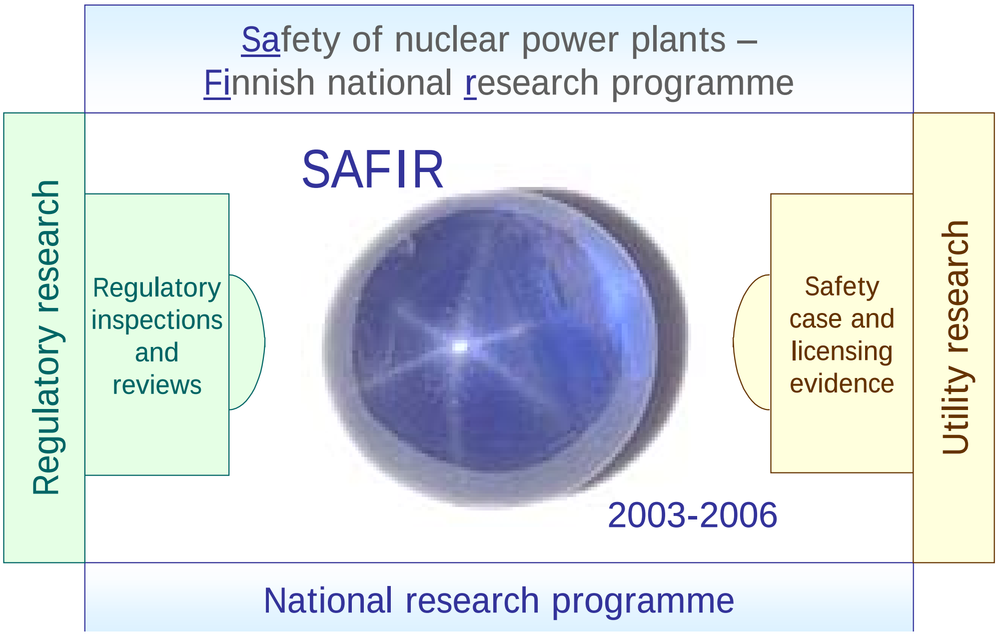

SAFIR, THE FINNISH RESEARCH PROGRAMME ON NUCLEAR POWER PLANT SAFETY, ANNUAL PLAN 2006

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Summary

SAFIR 2003–2006 is the Finnish public research programme on nuclear power plant safety, launched and administrated by the Ministry of Trade and Industry (KTM).

The steering group of SAFIR was nominated by KTM. VTT acts as the coordination unit of SAFIR. The projects for the SAFIR programme for the year 2006 have been selected on the basis of an open call for proposals. The main funding sources of the programme in 2006 are the State Nuclear Waste Management Fund (VYR) with 2.7 M€ and Technical Research Centre of Finland (VTT) with 1.5 M€. KTM, VTT, Radiation and Nuclear Safety Authority (STUK), the power companies Teollisuuden Voima Oy (TVO) and Fortum Oyj (Fortum) along with National Technology Agency (Tekes) and Helsinki and Lappeenranta Universities of Technology (HUT and LUT) are represented in the steering group of the programme.

SAFIR research programme consist currently of 22 research projects in the six research areas. Two projects are foreseen to operate under the ‘umbrella’ of SAFIR without VYR-funding. The volume of the projects in 2006 varies from some person months up to several person years, and the planned total duration from one to four years within the scope of the current programme. In 2006 the planned volume of the programme is 38 person years and 5.4 million €.

The research areas and focus of the programme have been defined in the framework proposal for the content and organisation of SAFIR. These six key research areas are reactor fuel and core, reactor circuit and structural safety, containment and process safety functions, automation, control room and IT, organisations and safety management and risk-informed safety management.

The execution of the programme is based on this annual plan 2006 prepared by the programme staff in consultation with the main funding partners of the programme and accepted by the steering group.

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PREFACE

SAFIR, Safety of Nuclear Power Plants – Finnish National Research Programme, 2003–2006, is the newest link in the chain of Finnish national research programmes in nuclear. The Ministry of Trade and Industry (KTM) in Finland has already launched the planning of the successive national research programme on reactor safety for the period 2007–2010. This planning will take place in a separate project utilising the experience gained in the SAFIR programme.

Organisation of public nuclear energy research as national research programmes was started in 1989 by KTM. Since then national programmes have been carried out in the fields of operational aspects of safety (YKÄ 1990–1994, RETU 1995–1998), structural safety (RATU 1990–1994, RATU2 1995–1998), and in FINNUS 1999–2002 that combined the operational aspects and nuclear safety.

Nuclear waste management research has been carried out in parallel programmes (JYT 1989–1993, JYT2 1994–1996, JYT2001 1997–2001, KYT 2002–2005) and currently in the KYT2010 (2006–2010) programme. Fusion research has been carried out in FFUSION (1993–2002) programme and is continuing in the FUSION2 (2003–2006) programme. In addition to public research programmes there has been research funded by Finnish utilities and the National Technology Agency (Tekes) such as the Advanced Light Water Reactor programme (ALWR) 1998–2003 and a project on plant life management (XVO) 1999–2003.

KTM decided to continue the national research efforts on fission reactor safety in a single programme after completion of FINNUS. The national advisory committee on nuclear energy, commissioned by KTM, gave the mandate of planning the new programme to the FINNUS steering group that nominated the SAFIR planning group to make the proposal for the content and organisation of the new research programme [1].

The programme is administrated by the steering group that has been nominated by KTM. The steering group of SAFIR consists of representatives from Radiation and Nuclear Safety Authority (STUK), KTM, Technical Research Centre of Finland (VTT), Teollisuuden Voima Oy (TVO), Fortum Oyj (Fortum), Tekes, Helsinki University of Technology (HUT) and Lappeenranta University of Technology (LUT).

At the beginning of 2004 there was a major change in the funding structure of the programme in comparison with the year 2003 due to a change in the Finnish legislation on nuclear energy. The funding by KTM, STUK, Fortum and TVO was replaced by funding from a separate fund of the State Nuclear Waste Management Fund (VYR). This VYR-funding is collected from the Finnish utilities Fortum and TVO with respect of their MWth shares in Finnish NPPs.

The main funding sources of the programme in 2006 are VYR with 2.7 M€ and VTT with 1.5 M€. The projects for the SAFIR programme for the year 2006 have been selected on the basis of an open call for proposals. VTT acts as the co-ordination unit.

The SAFIR programme has been divided into six research areas: 1: Reactor fuel and core, 2: Reactor circuit and structural safety, 3: Containment and process safety functions, 4: Automation, control room and information technology, 5: Organisations and safety management, and 6: Risk-informed safety management. The programme consists currently of 22 research projects. The volume of the projects varies from some person months up to several person years, and the planned total duration from one to four years. In 2006 the volume of the programme is planned to be 38 person years and 5.4 million €.

The final year of SAFIR programme will include an internal poll on the programme in February, an international evaluation of the programme in March, strategy seminar for planning of the new programme in April and final seminar and reporting at the end of the programme.

This report has been prepared by the programme leader and project co-ordinator in cooperation with the project leaders and members of the programme staff.

CONTENTS

1 INTRODUCTION

The starting point of a public nuclear safety research programme is that it provides the necessary conditions for retaining the knowledge needed to ensure the continuance of safe and economic use of nuclear power, to develop new know-how and to participate in international cooperation.

The SAFIR programme has been carried out and will also be carried out in 2006 according to the framework plan [1] made for the period 2003–2006. However, the framework plan has been based on safety challenges identified for a longer time span as well, as indicated in Figure 1.1. The safety challenges set by the existing plants and the new plant unit, as well as the ensuing research needs do, however, converge to a great extent.

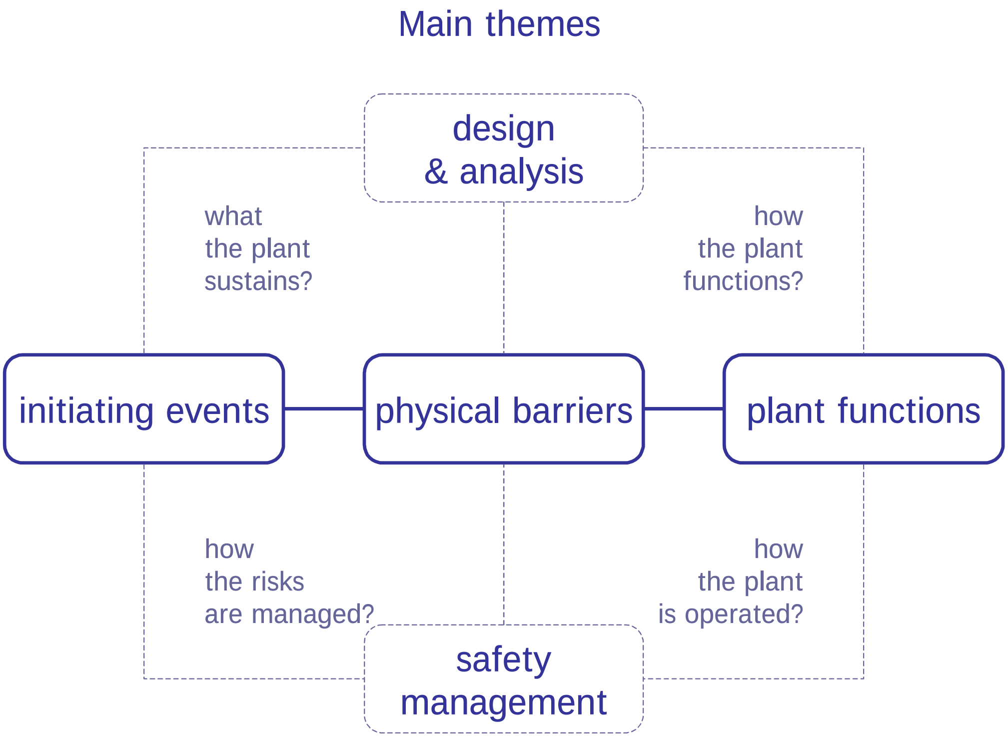

Figure 1.1. Main themes of nuclear plant safety [1].

The construction of the new power plant unit has already increased the need for experts in Finland. At the same time, the retirement of the existing experts is continuing. These factors together will call for more education and training, in which research activities play a key role.

The framework plan [1] defines the important research needs related to the safety challenges, such as the ageing of the existing plants, technical reforms in the various areas of technology and organisational changes. The research into these needs is the programme's main techno-scientific task. In addition, the programme has to ensure the maintenance of know-how in those areas where no significant changes occur but in which dynamic research activities are the absolute precondition for safe use of nuclear power.

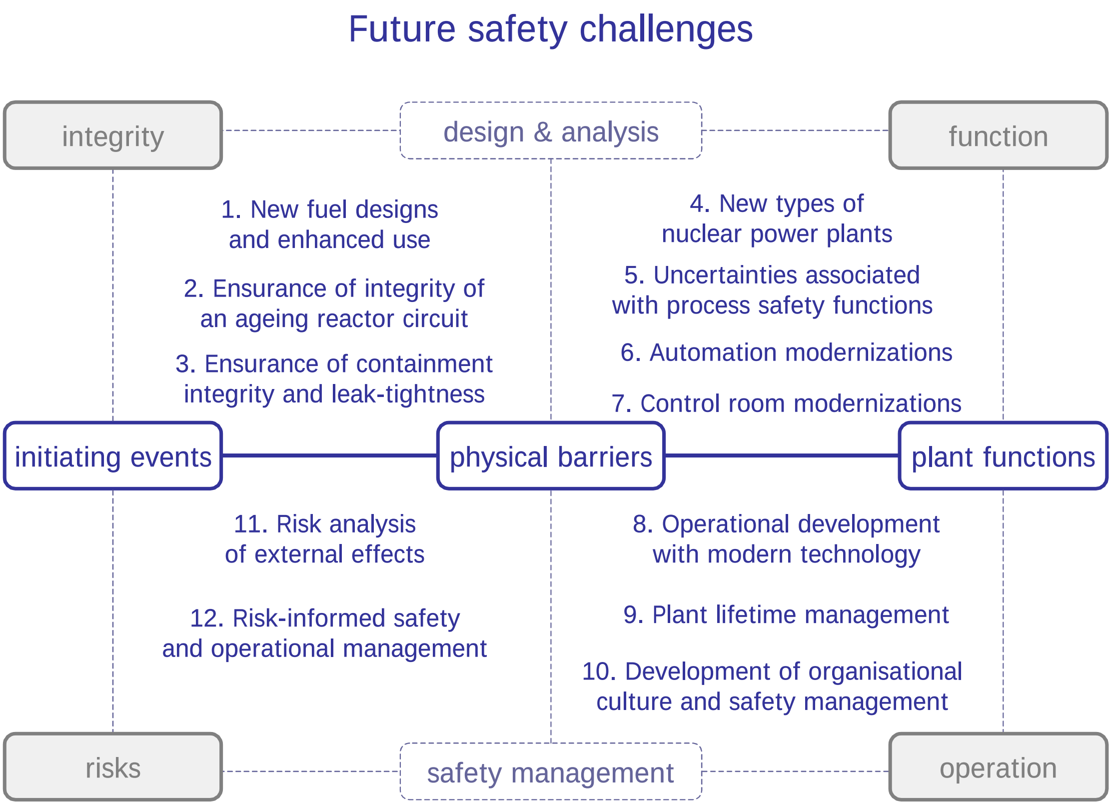

Figure 1.2. Future safety challenges to be addressed at in the SAFIR programme [1].

Although SAFIR builds strongly on the FINNUS [2,3] and on all the other preceding national research programmes on nuclear safety, new areas and flexibility is sought, too, within the limits of available funding. Thus, rapid specified projects, projects running throughout the entire research programme and development work of a very long duration all suit into the SAFIR programme in a flexible manner.

In addition to conducting the actual research according to the yearly plans, SAFIR will function as an efficient conveyor of information to all organisations operating in the nuclear energy sector and as an open discussion forum for participation in international projects, allocation of resources and in planning of new projects.

2 MAIN GOALS AND RESULTS

The SAFIR programme has been divided into six research areas:

1. Reactor fuel and core

2. Reactor circuit and structural safety

3. Containment and process safety functions, which is currently supervised by reference groups in

   3a. Thermal hydraulics

   3b. Containment

4. Automation, control room and information technology

5. Organisations and safety management

6. Risk-informed safety management

Figure 2.1 illustrates the division of the twelve major future safety challenges into these six research areas of SAFIR. Figure 2.1 indicates also the fact that many of the safety challenges extent over the various research areas.

Figure 2.1. Division of the twelve major future safety challenges into the six research areas of SAFIR [1].

There are 22 research projects and the administration project going on during the year 2006 in the programme. The titles of the projects and their division into the six research areas have been illustrated in Table 2.1. The extent of the projects vary from a few man months into several man years. Most of the projects have been planned to continue throughout the entire four-year span of the SAFIR programme [4, 5]. Detailed research plans of the projects have been included in Appendix 1 and corresponding tables on expenses and financing in Appendix 2. The personnel in the steering group, in the seven reference groups and in the 22 research projects have been listed in Appendix 3.

Due to the fact that 2006 is the last year of the current research programme, many of the projects with 3-4 years of total duration will concentrate of fulfilling the research goals set at the beginning of the project and summarising the results in a compact format for the end users.

Table 2.1. The research projects of SAFIR in 2006.

Group	Project name	Acronym	Funding k€	Volume, person months
1.	Enhanced methods for reactor analysis	EMERALD	583	46,7
	High Burnup Updates in Fuel Behaviour Modelling	KORU	293	25,5
2.				
	Integrity and life time of reactor circuits	INTELI	1149	73,4
	LWR oxide model for improved understanding of activity build-up and corrosion phenomena	LWROXI	92	8,2
	Concrete Technological Studies Related to the Construction, Inspection and Reparation of the Nuclear Power Plant Structures	CONTECH	126,5	9,2
3a.				
	Coupled Termohydraulics and Structural Mechanics	MULTIPHYSICS	98	11
	Development of APROS Containment Model	TIFANY	116,8	10,5
	Thermal hydraulic analysis of nuclear reactors	THEA	259	21
	Archiving experiment data	KOETAR	40	4
	Condensation pool experiments	POOLEX	292	22
	Participation in development of European calculation environment	ECE	50	7
3b.				
	Wall response to soft impact	WARSI	170,5	10,5
	Impact tests	IMPACT	220	16

	Severe accidents and nuclear containment integrity	CAPHORN	320,25	21
	Behaviour of fission products in air-atmosphere	FIKA	315	27,5
4.				
	Interaction approach to development of control rooms	IDEC	217	17,5
	Software qualification – error types and error management in software life-cycle	QETES	74,94	4,5
5.				
	Organisational culture and management of change	CULMA	184	15
	Disseminating tacit knowledge in organizations	TIMANTTI	52	7
6.				
	Potential of fire spread	POTFIS	208	13
	Principles and practices of risk-informed safety management	PPRISMA	224,9	15,8
	Assessment smart device software	ASDES	80	6
0.	SAFIR Administration and information (1.1.2006-31.3.2007 including VAT 22%)	SAHA	194,73	10
	Total		**5 360,622**	**402,3**

2.1 REACTOR CORE AND FUEL

The area covers reactor physics, reactor dynamics and fuel behaviour analysis. The research is done solely with the help of calculational tools, partly with sophisticated tools developed at VTT and partly using tools developed elsewhere. The area has living contact to the experimental work via international connections, such as the OECD Halden Reactor Project. In 2006 there are two projects in this area, the Enhanced methods for reactor analysis (EMERALD) dealing with reactor physics and dynamics and High-burnup upgrades in fuel behaviour modelling (KORU) dealing with the fuel research. In both projects, education of the new generation has an essential role.

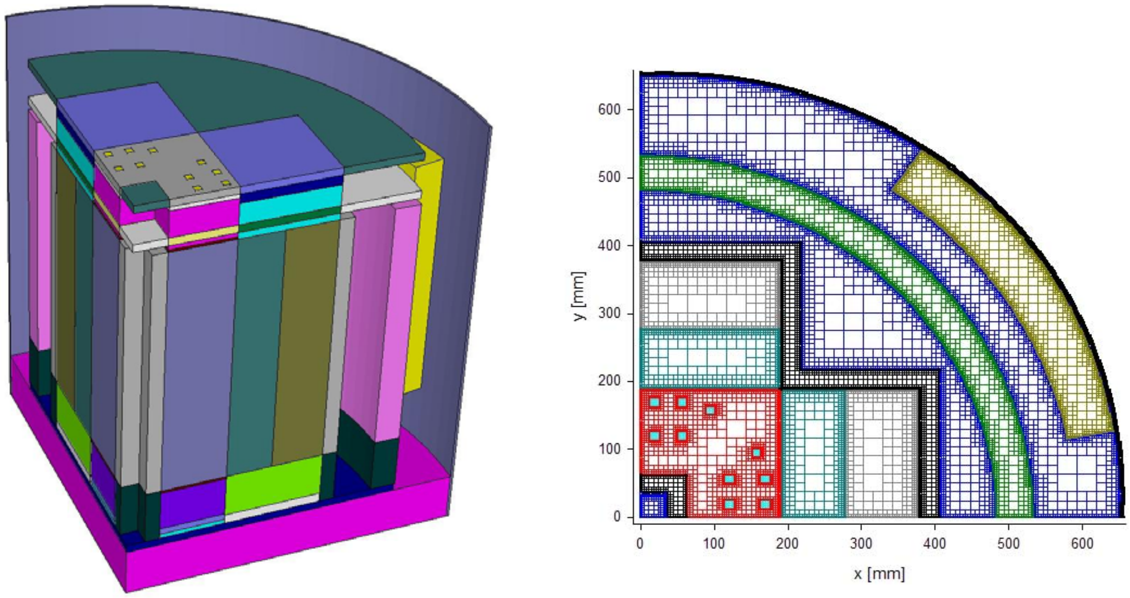

Figure 2.1. Modelling of the VENUS-2 reactor for benchmark calculations in the EMERALD project in 2005.

2.1.1 Enhanced methods for reactor analysis (EMERALD)

The main objective is to accomplish a really unified, complete, up-to-date, easy-to-use and flexible entirety consisting of both programs acquired from elsewhere and programs that are the results of own development. The code system has to cover the whole range of calculations, from handling of basic nuclear data, i.e. cross section libraries, over fuel and core analyses in normal operating conditions to transient and accident studies using coherent models and methods. It should be possible to follow the whole life cycle of the nuclear fuel from a reactor physics point of view until its final disposal. The same or similar models can often be used in both the static and in the dynamic calculations. Special attention will be paid to the documentation of the research.

Additionally, it is of special importance in today´s situation, when the use of nuclear power is increased at the same time as the present generation of nuclear experts are gradually retiring from work, to maintain competence and train new personnel. Cooperation with the technical and other universities is necessary to make new students interested in this branch of science and thus ensure that the nuclear plants in Finland will be in the hands of competent people in the future, too. The tasks of the project provide also excellent possibilities for university students to perform work for their academic degrees.

The project has continued during the four years of the SAFIR program with new or updated goals that have been specified on a year-by-year basis.

2.1.2 High-burnup upgrades in fuel behaviour modelling (KORU)

The modelling in fuel behaviour codes in use at VTT will be upgraded to meet the requirements from evolving fuel design and operational data – notably higher burnup goals – and from revised guidelines for applying the licensing procedures. Emphasis will in postulated accident conditions, ongoing international experiments, and parallel model development and validation. For steady-state conditions, the well-established codes also need partial renovation in descriptions of fission product swelling and release, and detailed mechanical response. Effective probabilistic methods will be favoured even in fuel accident behaviour codes. Education and training of experts is another big challenge in this project.

2.2 REACTOR CIRCUIT AND STRUCTURAL SAFETY

The area covers studies on the integrity and life time of the entire reactor circuit and studies of containment building construction, inspection, ageing and repairing. The reactor circuit studies are all included in one very large project, Integrity and life time of reactor circuits (INTELI), oxide modelling in one project (LWROXI) and the containment is studied in Concrete technological studies related to the construction, inspection and reparation of the nuclear power plant structures (CONTECH) project, which also includes the former separate small CONSAFE-project. In this area, the work done outside SAFIR, both in Finland and in several EU-projects will be reported in the reference group.

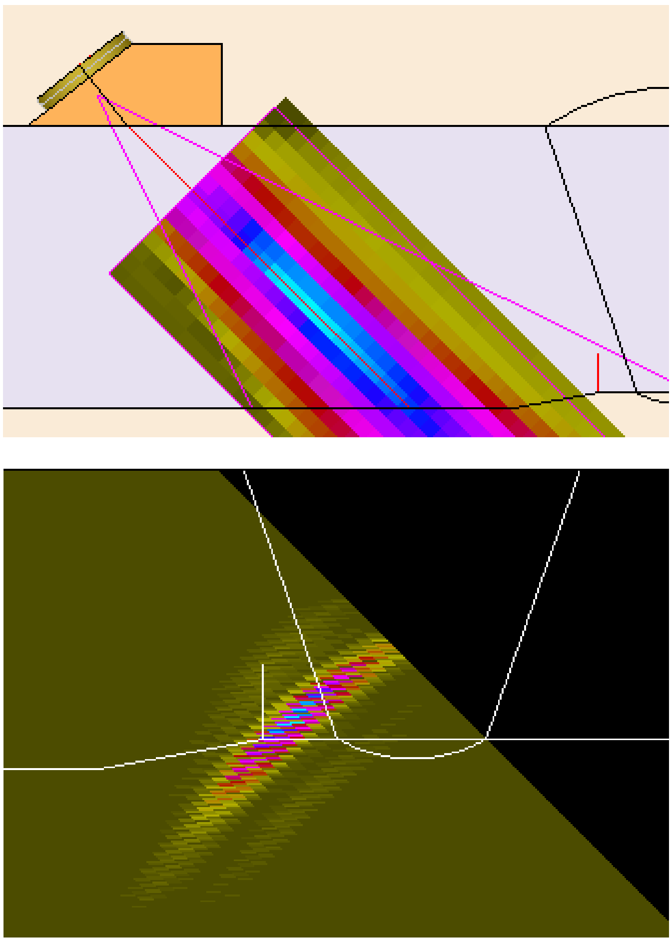

Figure 2.2. Computer simulation of ultrasonic testing. Scan with computed field (above) and indication pattern with amplitude coding (below). INTELI project 2005.

2.2.1 Integrity and life time of reactor circuits (INTELI)

The main objective of the project is to assure the structural integrity of the main components of the reactor circuit of the nuclear power plant and to study the typical ageing mechanisms affecting the integrity of main components during the life-time of the reactor. The main components included in the scope of the project are:

- Reactor pressure vessel with nozzles and internals
- Piping of reactor circuit
- Other components (steam generators, pumps, valves, pressurizer, heat-exchangers)

The overall objectives of the research work related to these components are following:

To understand and model the ageing mechanisms of the reactor pressure vessel including safe-end nozzles and internals. The target is predicting the development of the ageing and estimate the effects of ageing and the need for corrective actions and possible repairs.

To develop improved methodology for the assessment of the embrittelement of reactor pressure vessel. To verify the transferability of the material data based on the Master Curve to the structural analysis of real components.

To improve the reliability of nondestructive evaluation methods used to detect, characterise and monitor defects in different areas of RPV.

To develop reliable methods for the assessment of bimetallic welds of nozzles and their loading conditions. Especially, the assessment methods of residual stresses and thermal loads will be improved.

For the reliable and quick analysis of defects and damages new methodologies and tools will be developed based on multitechnical analysis software and expert networks.

To develop methods for the measurement and prediction of material properties of reactor internals during service. The key-elements of this work will be the modelling of failure mechanisms, identification of loads affecting the structures and the technology related to the application of miniature test samples.

To apply risk-informed methods to the life-time management of piping. Risk-informed methods will be used to optimise the inspection practises applied to piping.

To continue development of methods for analysing fluid-structure interactions. The POOLEX experiments performed at Lappeenranta University where steam is blown into a water pool are analysed as test cases.

To develop and take in use new, more realistic material models basing on more accurate material data and improved understanding of phenomena affecting the material. Material models and realistic modelling of residual stresses and loads are necessary for the numerical simulation of the behaviour of piping.

To increase the theoretical understanding and to develop practical methods for optimisation of water chemistry of nuclear power plant piping. Especially, the work is focussed on the alternative secondary side water chemistry of existing and new nuclear power plants.

2.2.2 LWR oxide model for improved understanding of activity build-up and corrosion phenomena (LWROXI)

This work is performed in co-operation with ALARA Engineering (Sweden), who has long experience of BWR type water chemistries in Sweden and Finland.

The goals of the proposed project are to develop a predictive model for activity build-up in nuclear power plants and to increase the understanding and develop a phenomenological model of the oxide film build-up and break-down, controlling the stress corrosion cracking.

The model is based on first principles, i.e. fundamental physico-chemical mechanisms. In order to ensure adequate modelling, uncertain or non-determined fundamental parameters are set or adjusted within the range of reasonable values by evaluating well-defined or well-controlled in-plant observations or laboratory experiments.

To achieve these goals, a new generation of the VTT model for oxide films is developed and integrated with the existing ALARA radiolysis/activity incorporation model in order to produce a model approach that is more deterministic, has an increased predictive ability and is smarter and/or more adaptive, i.e. able to take into account the effect of a variety of environments on the oxide films in a fully quantitative way.

2.2.3 Concrete technological studies related to the construction, inspection and reparation of the nuclear power plant structures (CONTECH)

This project is a part of long-term co-operation in concrete technological studies in Finland. The goal of the project is to acquire knowledge on the structural and durability behaviour of both pre-stressed and non-pre-stressed concrete structures. The results will be applied on the design of structures, development of inspection and reparation methods, controlling of ageing behaviour and getting prepared for and controlling of accidents.

The project includes also participation in the OECD NEA Task Group on Concrete Ageing and making description and implementation plan for the Safety Management System of Concrete Structures in Nuclear Power Plants.

2.3 CONTAINMENT AND PROCESS SAFETY FUNCTIONS

The area covers simulation of nuclear power plant processes, calculational and thermal hydraulics using both CFD-tools and APROS-code, experimental thermal hydraulics at Lappeenranta University of Technology (LUT) and severe accidents studies, where both experimental and calculational work is included. Altogether 10 projects have been included into this area. Due to practical reasons the area has been divided under two reference groups, the *Thermal hydraulic group* dealing with thermal hydraulic calculation methods and experiments and *Containment group* dealing with severe accident projects. In this field, training of new personnel as well as information on international research programmes has a vital role, too.

2.3a Thermal hydraulics

Thermal hydraulic group covers the following projects: The integration of thermal-hydraulics (CFD) and structural analysis (FEA) computer codes in liquid and solid mechanics (MULTIPHYSICS), Development of APROS containment model (TIFANY), Thermal Hydraulic Analysis of Nuclear Reactors (THEA), Archiving experiment data (KOETAR), Condensation pool experiments (POOLEX) and Participation in development of European calculation environment (ECE).

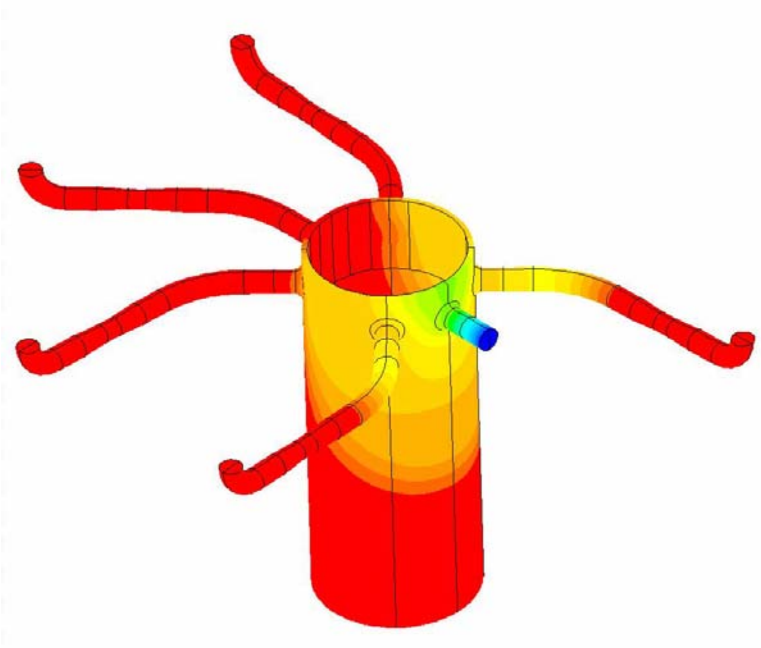

Figure 2.3. Calculation of the pressure wave propagation to the reactor of the NPP in the Large Break Loss of Coolant Accident (LBLOCA) using Computational Fluid Dynamics (CFD) codes in MULTIPHYSICS project in 2005.

2.3.1 The integration of thermal-hydraulics (CFD) and structural analyses (FEA) computer codes in liquid and solid mechanics (MULTIPHYSICS)

The objective of the project is to improve the numerical modeling capabilities of physical systems including fluid-structure-interaction (FSI). The FSI is a relevant phenomenon in many economically and technically important industrial applications. The practical objective of the project is to develop a useful method for coupling of the computational fluid dynamics (CFD) and the finite element stress and strain analysis (FEA) codes. The developed method is used for applications in which the pressure field is transferred from CFD to FEA code and the resulting structure deformations are returned from FEA to CFD. The codes used for development and simulations are for CFD calculations STAR-CD and FLUENT and for FEA ABAQUS code is used. Coupling can be made using some general codes, but the code producers are also developing code specific solutions. In addition to CFD-FEA linking the possibilities to use 1-D system codes with CFD for boundary condition calculations in multiphase cases will be studied.

2.3.2 Validation of APROS containment model (TIFANY)

The main objective of the TIFANY project is to validate the APROS containment model. The aim is to confirm that APROS containment model is capable to calculate the selected experiments correctly or at least as well as the competing programs.

In TIFANY project also some improvements will be made to the containment model and in the thermal hydraulic model of APROS. These improvements include model modifications that probably will be found necessary during the validation work and are required in order to carry out effectively the validation cases. Some of the already planned improvements ease the containment modeling and extend the validity of some models to other plant types as VVER-440.

2.3.3 Thermal hydraulic analysis of nuclear reactors (THEA)

The objectives of THEA project are to support experimental work in Lappeenranta University of Technology, to develop new or improved methods for thermal hydraulic analysis, especially for calculating multidimensional two-phase flows, and to increase the knowledge and understanding of reactor thermal hydraulics.

In 2006 PKL benchmark calculation with APROS will be continued. APROS model of ROSA LSTF test facility will be created and one experiment of OECD test program will be calculated. Helium distribution in MISTRA experiment will be simulated with CFD code and APROS containment model. The results will be compared with dedicated containment code TONUS.

To test NURESIM thermal-hydraulic tool NEPTUNE by simulating a steam blow-down experiment performed at Lappeenranta University of Technology. The work started in 2005 will be continued.

The Finnish participation into international thermal hydraulic research programmes OECD/GAMA, OECD/PSB-VVER and USNRC/CAMP, OECD/PKL and OECD/ROSA as well as Scandinavian thermal hydraulic network Northnet takes place via this project.

2.3.4 Archiving experiment data (KOETAR)

The objective of the KOETAR project is to save, check, and archive data and documents of the thermal-hydraulic experiments performed with different facilities at Lappeenranta University of Technology during the past 30 years. Data and documents are on several media from CD disks to printed papers. Some of the data and documents are even on media that are not compatible anymore with the hardware and software in use today.

The work will be done following the priority classification updated in SAFIR research program in 2003. The checked data and documents will be archived in the STRESA database (http://www.et.lut.fi/yty/stresa) maintained by the Nuclear Safety Research Unit at Lappeenranta University of Technology and in CD and/or DVD disks.

2.3.5 Condensation pool experiments (POOLEX)

The main goal of the project is to increase the understanding of different phenomena in the condensation pool during steam injection. These phenomena could be connected to bubble dynamics (bubble growth, upward acceleration, detachment, break up), pool swell, pressure oscillations, condensation rate and vibrations of the vent pipe. To achieve this understanding these phenomena has to be measured with sophisticated, high frequency instrumentation and/or captured on film with high-speed cameras or corresponding equipment. For example, to estimate the loads on the pool structures by condensation pressure oscillations the frequency and the amplitude of the oscillations has to be known. Furthermore, strains of the pool wall at exactly defined locations have to be measured for the verification of the structural analysis. The final result of the project will be a database, which can be used for testing and developing calculation methods used for nuclear safety analysis.

2.3.6 Participation in Development of European Calculation Environment (ECE)

The goal of the ECE project is to take part in the development and validation process of the new Common European Standard Software Platform for modeling, recording, and recovering computer data for the simulations of next-generation nuclear reactors. A key activity of the project is also to maintain good relations and increase contact intensity to the European nuclear research community. The participation ensures the access to use the new platform and new simulation tools. The project gives a possibility to increase educational competence and to acquire readiness to use new two-phase flow simulation tools.

Concrete objectives of ECE are as follows:

- To select, evaluate and convert suitable steam blowdown experiment data from the condensation pool test series of the SAFIR/POOLEX project.

- To use these selected experiment results for development and validation of new simulation tools.

The experiment results must be investigated thoroughly to ensure the suitability, quality and accuracy of the results for validation purposes. The data will then be converted and new conversion tools developed. The new simulation tools will be installed and tested to the SALOME platform for the validation purposes of the CFD modeling. The SALOME is an open source platform for numerical simulation integration and supported by Linux operating system.

2.3b Containment

The Containment group includes the following projects: Wall response to soft impact (WARSI), Impact Tests (IMPACT), Cavity phenomena and hydrogen burn (CAPHORN) and Behaviour of fission products in air-atmosphere (FIKA).

Figure 2.4. Example of a still figure obtained from high-speed camera in the IMPACT project tests in 2005.

2.3.7 Wall response to soft impact (WARSI)

The main aim of the project is to develop and take in use methods for predicting response of reinforced concrete structures subjected to impacts of deformable projectiles that may contain combustible liquid, such as jet fuel. Also release and spreading of liquid from fragmented missiles will be dealt with. This project also assists the IMPACT project in planning the tests besides assessing and analysing the test results.

2.3.8 Impact tests (IMPACT)

A general objective of this project is to obtain experimental information on the physical phenomena involved in a condition where an airplane impacts against a nuclear facility. Three specific aims of the project include firstly new data on the time-varying pressures that arise during such an impact. Secondly, it is believed that high hydrodynamic shock pressures can arise while the fuel tanks impact against a fixed structure. Data on this phenomenon are requested. Thirdly, data on the shedding of the debris and spreading of liquid (fuel) from the disintegrated tanks caused by the impact are also requested. Fourth, response of reinforced concrete wall (deflection, penetration) to aircraft-like impact loads will also be tested.

As the Institute for Radiological Protection and Nuclear Safety (IRSN) joins the project in the end of 2005, the specific objectives described above were specified in further detail.

2.3.9 Cavity phenomena and hydrogen burn (CAPHORN)

The key goal of the CAPHORN-project is to investigate physical phenomena that occur in the reactor cavities, i.e. core-concrete interaction and debris coolability. The second target issue is enhanced maintenance of competence in the area of analytical assessment of hydrogen combustions. Thirdly, the plant models of OL1 and OL2 as well as LO1 and LO2 for new MELCOR release 1.8.6 will be updated and e.g. two selected accident scenarios will be analysed and reported. The work will partly serve also the education of new experts for plant analysis. And last, the follow-up and participation of major international research projects in the area of severe accidents will be carried out as part of the project. The project is planned to run for one year within SAFIR programme.

2.3.10 Behaviour of fission products in air-atmosphere (FIKA)

In this project the ruthenium behaviour in an air ingress accident, especially during plant maintenance operations, will be experimentally studied. The objective is to investigate the effect of steam partial pressure, temperature, flow rate and aerosol seed particles on ruthenium transport and speciation in the primary circuit. In this project also the catalytic effect of RuO2 on RuO4 and/or RuO3OH decomposition, which has been claimed to have taken place in previous studies, will be assessed.

Results from the ruthenium transport and speciation experiments will be discussed in the frame of SARNET and NKS networks. ENEA and IRSN will participate in the interpretation of VTT's ruthenium experiments. The results will be linked with ruthenium release experiments carried out by EDF, CEA and KFKI AEKI as well as studies of ruthenium behaviour in the containment, which are conducted by IRSN and possibly also Chalmers Technical University.

Phebus FP is a large scale facility, where phenomena taking place in a severe nuclear accident have been experimentally studied in realistic conditions. In this project the work done at the Phebus FP program is followed up. In year 2006 VTT will review aerosol transport section of the Phebus FPT-2 final report. Especially significant is to interpret the role of revaporisation on the transport of volatile fission products as in FPT-2 experiment it was the first time directly measured. VTT will also participate in an international experts group on the potential future uses of the Phebus facility in nuclear safety research.

International Source Term Programme (ISTP) is a cooperative research programme on severe accidents based on separate-effect experiments. The results from these experiments will allow improving models used for source term evaluation studies. VTT participates in the design of the facilities and the experiments.

In Artist experimental program fission product retention in the structures of a steam generator is studied in tube rupture scenarios. The project provides a unique database to support safety assessments and analytical models. VTT participates in the program by conducting aerosol deposition and resuspension experiment in an internal tube flow and by modelling particle resuspension form surfaces.

2.4 AUTOMATION, CONTROL ROOM AND INFORMATION TECHNOLOGY

The area includes currently two research projects: Interaction approach to development of control rooms (IDEC)and Software qualification – error types and error management in software life-cycle (QETES). This area has a close connection to the ASDES project and one subproject of the PPRISMA in the area of Risk-informed safety management. Additionally, the work done beyond SAFIR in Finland in the projects related to the renewal of existing control rooms and in connection of the new unit as well as work in some international projects will be discussed and reported in the reference group.

Figure 2.5. Experimental control room of Fortum Nuclear Services have been used in the IDEC project.

2.4.1 Interaction approach to development of control rooms (IDEC)

The project aims at formulating a scientifically founded method for the evaluation of human-system interfaces of complex industrial systems. In the project the structure of a method, including a set of indicators and evaluation criteria will be created. Both concern the interface and the design process used to create it. In defining the indicators and criteria for a good control room interface we consider what good practices of process control are. An appropriate interface should impose good practices by referring to relevant information. This attribute of an interface we refer to as systems usability. The evaluation framework under development in IDEC project is called Contextual Assessment of Systems Usability (CASU). CASU methodology and the related criteria are developed in connection with NPP control room design cases.

So far in the project, an evaluation framework, indicators and criteria have been created for the evaluation of human-system interfaces from a comprehensive point of view. The basis of the method lies in the existing standards and literature about the evaluation and design of the usability of complex systems. A traditional usability concept has been extended in several respects and a new concept of “systems usability” developed. The theoretical justification of the CASU method has been accomplished in conceptual benchmarking exercises. During

2005 the method has been tested against the earlier collected base-line data, and further testing of the method will take place 2006 via its application in validation & verification tasks and in specific design cases.

IDEC project cooperates with and is partly funded by Halden Reactor project, and cooperates with University of Toronto and Electricité de France. IDEC work is also considered in a new COST action MAUSE which deals with new usability methods.

2.4.2 Software qualification – error types and error management in software life-cycle (QETES)

Software qualification is one of the main challenges in implementation and renewal of I&C systems in Nuclear Power Plants. Users need more knowledge about different error types of application documents for establishing the means how to prevent, tolerate, removal and forecast errors in different phases of software life-cycle. The objective of the research is to create recommendations for inspections of documents and other application artefacts of the software intensive I&C systems. The focus in this research will be in documents which means, for instance, that all test plans and results are documented and from those documents someone can find whether tests are sufficiently performed. The recommendations is in order to base on the following two means of evaluation under regulators and standards instructions (for instance, YVL 5.5, IEC 60880, and IEC 62138):

- to determine error types of application software documents
- to clarify effectiveness of error management methods for determined error types.

In order to clarify the effectiveness of the error management methods in qualification a new approach for classifying software errors is used. Errors are divided according to linguistic concepts to syntactic, semantic and pragmatic errors. This classification will lead the way to a new possibility to assess qualification material, that is, designs, tests, analyses, and operating experiences (YVL 5.5).

2.5 ORGANISATIONS AND SAFETY MANAGEMENT

Currently the work in SAFIR in this area is performed in the project Organisational culture and management of change (CULMA) and Disseminating tacit knowledge and expertise in organisations (TIMANTTI). In this area the two projects work in close co-operation.

Figure 2.6. CULMA projects researchers in TVO plant revision in 2004.

2.5.1 Organisational culture and management of change (CULMA)

The main objective of the research project is to increase the understanding of the effects of organizational factors on nuclear safety. The project aims to produce knowledge of the effects of organisational culture, organisational changes and the different ways of organising work on the safety of nuclear power production. The practical goal is to develop methods and models with which to take organizational factors into account e.g. in change situations and development initiatives so that all of the criteria for an effective organisation (safety, productivity and health) are adequately considered. The project is carried out in case studies in close cooperation with the power plants.

2.5.2 Disseminating tacit knowledge and expertise in organisations (TIMANTTI)

The general objectives of the TIMANTTI-project are to enhance, develop and facilitate the sharing of tacit, experience based knowledge between experienced experts and their less experienced followers and to develop methods for tacit knowledge sharing in the NPP context. The specific objective for the year 2006 is to create new understanding concerning the role of tacit knowledge in three selected cases each of which have a distinctive context and interest in sharing knowledge between experienced experts and novices. During the project the nature and content of experience based knowledge in selected case units will be modelled. The special challenges in sharing experience based knowledge in different contexts will be identified and methods for experience based knowledge sharing will be investigated, developed and implemented. The possibilities for sharing tacit, experience based knowledge in the formal training process and control room trainee period are researched. In 2006, both practically and scientifically important findings will be made about sharing of experience based knowledge at the Finnish nuclear power companies. New knowledge concerning the advantages, challenges and limitations of the piloted methods for sharing tacit knowledge will be produced

2.6 RISK-INFORMED SAFETY MANAGEMENT

The research area includes currently three projects Potential of Fire Spread (POTFIS) and Principles and Practices of Risk-Informed Safety Management (PPRISMA) and Assessment smart device software (ASDES). The area has a close connection to the area of Automation, control rooms and information technology via the ASDES and PPRISMA projects. In this area, too, the work done beyond the scope of SAFIR both in Finland and in international projects will be discussed and reported in the reference group.

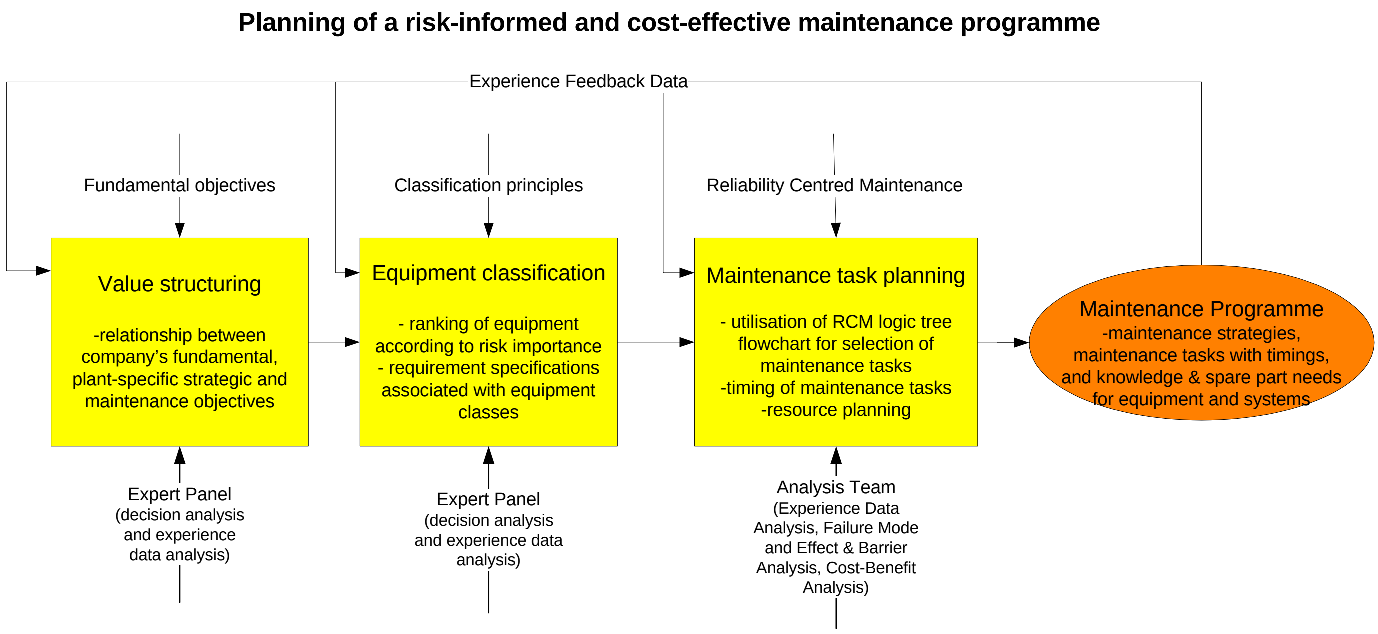

Figure 2.7. Planning of a risk-informed and cost-effective maintenance programme was one of the research themes of the PPRISMA project in 2005.

2.6.1 Potential of fire spread (POTFIS)

According to goals of SAFIR, PSA-models should be developed as complete as possible, and include external effects such as floods and fires. Fires alone present a very demanding research problem; there a dynamic approach is essential and needed. The central goal for fire research is continuing the avenue opened during FINNUS to develop deterministic and stochastic submodels to the same level as other branches of PSA. The major strategic problem during SAFIR is the ability to predict potential of fire spread in given scenarios. To be able to utilize already available knowledge and tools in practise several parallel development lines are needed: (a) input data and its reliability for fire-PSA, (b) ignition and flame spread models of fires, (c) reliability models of active fire protection, (d) assessment of operative fire protection, and (e) special fire themes related to passive systems.

Concentrating on the physical phenomena in real PSA knowledge is needed from widely different fields as depicted schematically in Figure 1 below. For data base for ignitions statistical data collected worldwide are needed together with a grouping of rooms types important to nuclear safety. Data on screening most safety relevant rooms are needed from existing PSAs from utilities. Quantitative fire risk calculation is carried out for this type using tools developed during previous years. A rather simple case will be selected from a real plant for application, where emphasis is on the application method starting from inputs from existing PSA, going through all needed practical steps, and ending with feedback to update PSA by the gained new information.

Exploring of the most significant rooms from view point of fire risk in the present Finnish NPPs indicated that lack of tools to predict fire spread on solids, especially on cables, is the biggest missing link of the models to close the problem. As a result of progress during the previous years we proposed new test rigs to measure the needed experimental parameters. These rigs are under construction outside the project. Tests of their performance as well as upscaled experiments will be carried out. Proposals of new algorithms are made and implemented as part of FDS numerical simulation tool.

A modelling of fire extinguishing and fire detection systems unavailability will be carried out by collecting results obtained in our earlier work. Fire department performance has been modelled by VTT outside this program, and valuable results have been obtained for operations taking place outside the target building, as well as on extinguishment. For movements of firemen inside the target building, no data are available. In large buildings like NPPs success in actions inside the building dominates when total performance is evaluated. The applicability of research on fire department performance on NPPs will be investigated and operative fire fighting performance pilot study will be done.

OECD PRISME project has been proposed to start in 2006 to provide code validation data for fire and smoke propagation from a source room to neighbouring room(s). Fire simulations will be carried out in POTFIS related to but outside PRISME aiming to guidance for design of experiments and to validate developed models.

2.6.2 Principles and practices of risk-informed safety management (PPRISMA)

Risk-informed safety management means use of information from probabilistic safety assessment (PSA) to support decision making in various contexts. Generally, the project deals with the whole scope of risk-informed methods and application areas related to safety of nuclear power plants. The main objectives are

- to develop risk-informed decision making methods that integrates results from risk and reliability analyses with other expertise in the problem domain

- to develop assessment methods for nuclear power plants operation and maintenance in order to enhance risk-informed ways of planning of activities and acting in safety-critical situations

- to develop methodologies in the problem areas of PSA

- to advance skills in nuclear risk analysis, assure the competence transfer to the new generation and to participate in international co-operation.

2.6.3 Assesement smart device software (ASDES)

The assurance of smart devices for use in critical applications requires the safety assessment of their software. The overall objective of this project is to develop an approach to the assessment of such smart device software that takes into consideration:

- the particular issues of assessing COTS and the design and accessibility of smart devices

- regulatory context of the nuclear industry in Finland (e.g. YVL guides 2.0, 2.1, 2.7, 2.8, 5.5)

- current practices of software assurance developed in Finland and more widely in the UK and European projects.

The project aims at developing a generic safety case approach for smart devices. The approach will take into account specific characteristics of the architecture of smart devices, of their development processes and their nuclear applications. It will be generic enough to be applicable to a wide range of smart device applications. In addition to this, the project aims at defining approaches to compensate for missing or insufficient evidence, common in industrial COTS products in general, and smart devices in particular.

The project is envisaged in a number of phases. The first phase will be to appraise existing Finnish and other research and practices to define a framework for assessment. Follow on work will be proposed to apply the framework to an actual smart device. The results of the work will be discussed and disseminated more widely with the stakeholders throughout the project.

3 FINANCIAL AND STATISTICAL INFORMATION

The planned total cost of the programme in 2006 is € 5.36 million. The major funding partners are VYR with € 2.75 million, VTT with € 1.54 million, Fortum with € 0.14 million, TEKES with € 0.11 million, NKS with € 0.14 million, EU with € 0.18 million and other partners with € 0.48 million. The volume, funding and costs of SAFIR in 2006 have been illustrated in Table 3.1. The total extent of the programme in 2006 will be 38 man years. In addition to the projects with VYR-funding, two projects with Tekes and utility funding are reported and followed up within SAFIR programme. The personnel costs are the major share of yearly expenses, as illustrated in Figure 3.2.

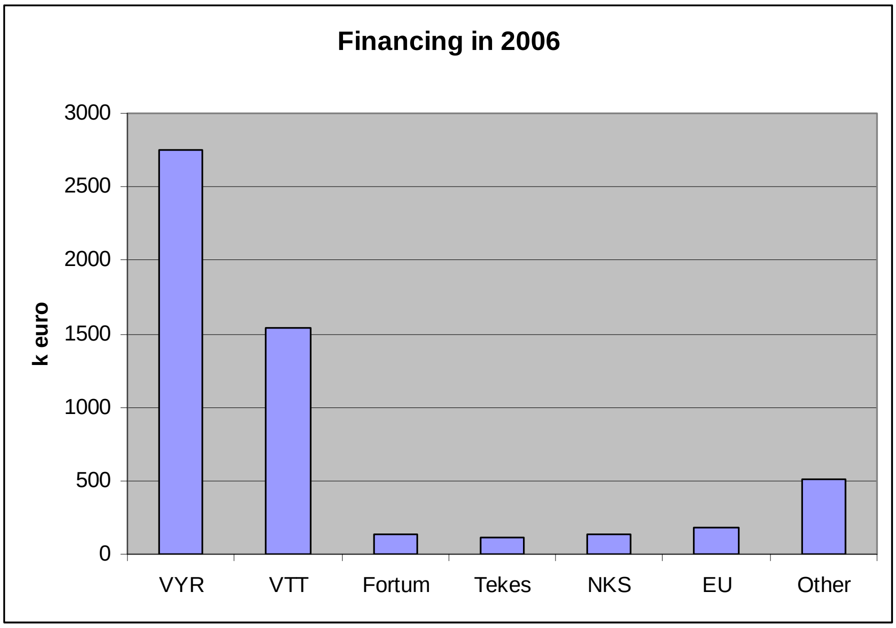

Figure 3.1. Financing of the SAFIR programme in 2006.

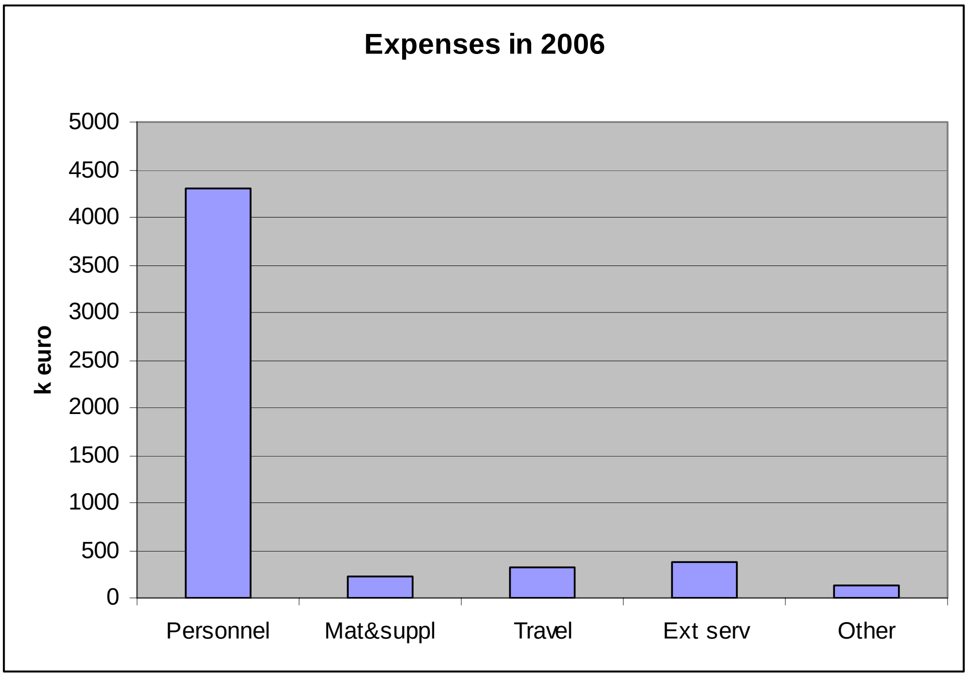

Figure 3.2. Expenses of the SAFIR programme in 2006.

SAFIR 2006 Research Projects and Administration

01.06.2006
E.K. Puska

		Expenses						VYR %	Financing						
	Volume pers month	Personnel keuro	Mat&supp keuro	Travel keuro	Ext serv keuro	Other keuro	Total 2006 keuro	*VYR % of total*	**VYR keuro**	Fortum keuro	TVO keuro	NKS keuro	EU keuro	VTT keuro	Other keuro
VTT Enhanced Methods for Reactor Analysis (EMERALD)	46,7	550	0	20	5	8	**583**	**32,247**	**188**					395	
VTT High-Burnup Upgrades in Fuel Behaviour Modelling (KORU)	25,5	269	0	19	0	5	**293**	**54,26621**	**159**					90	44
VTT Industrial Systems Integrity and life time of reactor circuits (INTELI)	73,4	835	114	90	93	17	**1149**	**46,91036**	**539**			54	130	386	40
VTT LWR oxide model for improved understanding of activity build-up and corrosion phenomena(LWROXI)	8,2	62	0	15	15	0	**92**	**43,47826**	**40**						** 52
VTT Concrete Technological Studies Related to the Construction, Inspection an Reparation of the Nuclear Power Plant Structures (CONTECH)	9,2	115,2	2,9	5,3	3,1	0	**126,5**	**15,81028**	**20**					7,5	99
Fortum Nuclear Services The integration of thermal hydraulics (CFD) and structural analyses….(MULTIPHYSICS)	11	96,3	0	1,5	0,2	0	**98**	**0**	* **0**	49					49
Fortum Nuclear Services Development of APROS containment model (TIFANY)	10,5	116,4	0,4	0	0	0	**116,8**	**0**	* **0**	28,8	30				58
VTT Thermal hydraulic analysis of nuclear reactors (THEA)	21	204	0	25	25	5	**259**	**37,06564**	**96**	8	0	0	22	133	
Lappeenranta University of Technology Archiving experiment data (KOETAR)	4	38	1	1	0	0	**40**	**75**	**30**					10	
Lappeenranta University of Technology Condensation pool experiments (POOLEX)	22	173	4	5	110	0	**292**	**90,75342**	**265**			27			
Lappeenranta University of Technology Participation in development of European calculation environment (ECE)	7	45	2	3	0	0	**50**	**50**	**25**				25		
VTT WAll Response to Soft Impact (WARSI)	10,5	131	2	4	32	1,5	**170,5**	**73,60704**	**125,5**					45	
VTT Impact tests (IMPACT)	16	156	28	15	15	6	**220**	**40,90909**	**90**					30	100
VTT Cavity phenomena and hydrogen burn (CAPHORN)	21	241,25	30	24	0	25	**320,25**	**61,20219**	**196**					124,25	

VTT Behaviour of fission-products in air-atmosphere (FIKA)	27,5	254	40	21	0	0	**315**	**31,74603**	**100**	35		40		80	60
VTT Interaction approach to development of control rooms (IDEC)	17,5	210	1	5	0	1	**217**	**50,69124**	**110**					47	60
VTT Software qualification - error types and error management in software life cycle (QETES)	4,5	69,94	0	5	0	0	**74,94**	**73,31198**	**54,94**	20					
VTT Organisational culture and management of change (CULMA)	15	168	2	12	2	0	**184**	**54,34783**	**100**			14		70	0
Helsinki University of Technology Disseminating tacit knowledge in organizations (TIMANTTI)	7	44,4	0,7	5,9	1	0	**52**	**96,15385**	**50**						2
VTT Potential of fire spread (POTFIS)	13	140	4	14	14	36	**208**	**80,76923**	**168**					40	
VTT Principles and practices of risk-informed safety management (PPRISMA)	15,8	203	1	20,9	0	0	**224,9**	**54,46865**	**122,5**					81	21,4
VTT Assessment Smart Device Software (ASDES)	6	41	0	4	35	0	**80**	**100**	**80**						
VTT															
Administration and information of the research	10	136,616	0	5	18	35,11552	**194,7315**	**100**	***194,7315***						
programme (SAHA) ***															
Total	**402,3**	**4299,106**	**233**	**320,6**	**368,3**	**139,6155**	**5360,622**	**51,36851**	**2753,672**	**140,8**	**30**	**135**	**177**	**1538,75**	**585,4**

* Information updated according to funding from Tekes for MULTIPHYSICS and TIFANY.
**In LWROXI Funding from SSI 20 k€ and from Swedish utilities 32 k€ applied.
*** Period 1.1.2006-31.3.2007 with VAT 22 % included

Figures 3.3 and 3.4 illustrate the distribution of funding and person years between the six research areas of SAFIR, respectively. The most "nuclear-specific" research areas 1: reactor fuel & core, 2: Reactor circuit and structural safety and 3:Containment and process safety functions, that has been divided into 3a: Thermal hydraulics and 3b: Containment, have the largest shares, whereas the three remaining areas with more connections and applications beyond the nuclear field, namely 4: Automation, control room and information technology, 5: Organisations and safety management and 6: Risk-informed safety management total into 21 % of the entire programme funding.

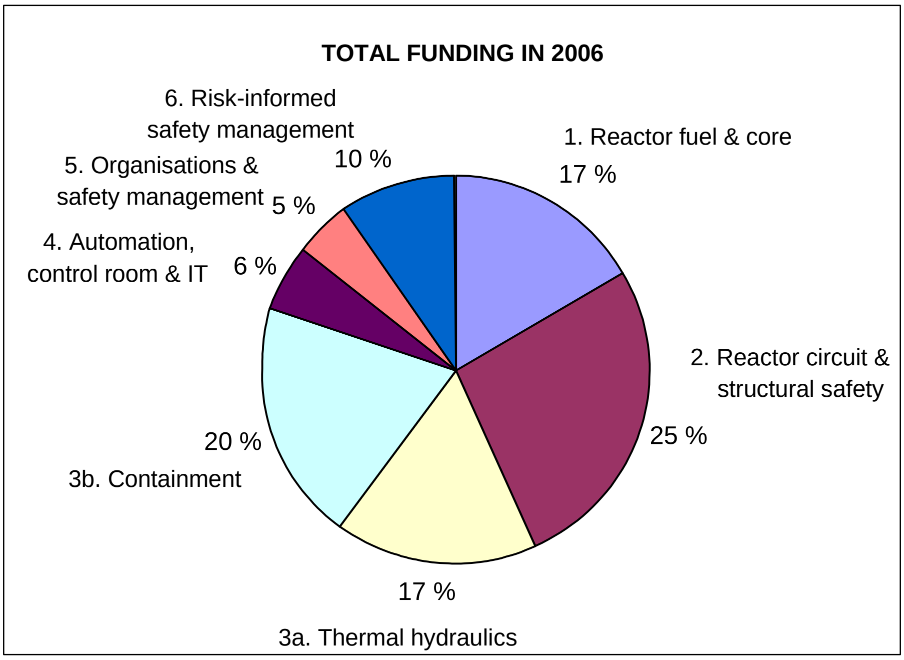

Figure 3.3. Distribution of financing in SAFIR research areas in 2006.

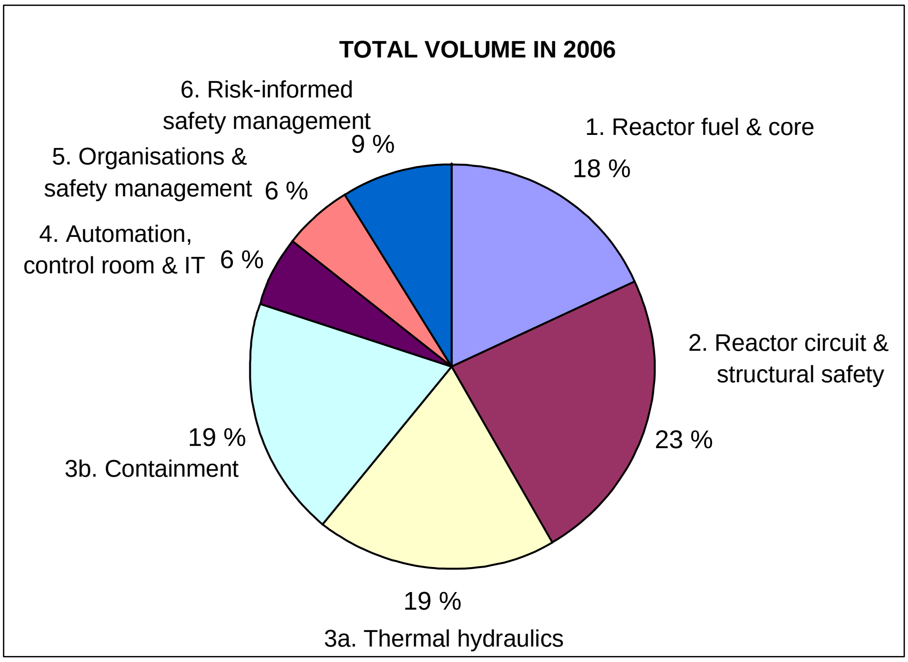

Figure 3.4. Distribution of person years in SAFIR research areas in 2006.

The trends in funding and person years in the various research areas of SAFIR have been illustrated in Figures 3.5 and 3.6. The Figures indicate both the increase of the total volume of the programme from 4.1 million € in 2003 to 5.4 million € in 2006 and the increase of funding and volume in the research areas 1–3.

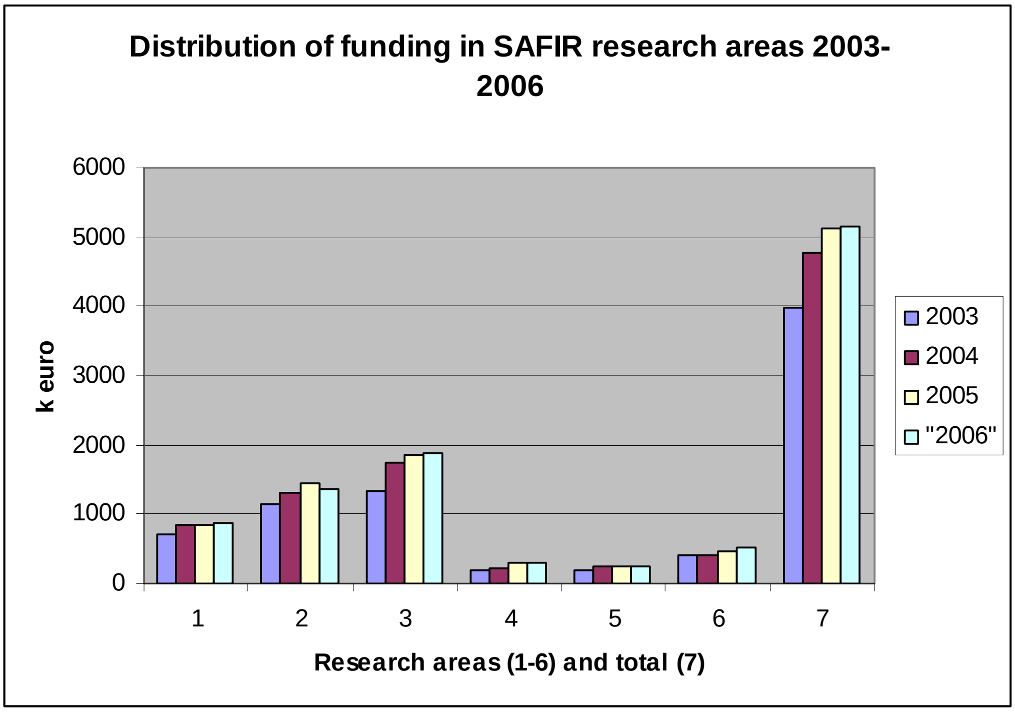

Figure 3.5 Development of funding in SAFIR research areas (1–6) and in total (7) in 2003–2006. Realised numbers for 2003–2005 and plan 2006.

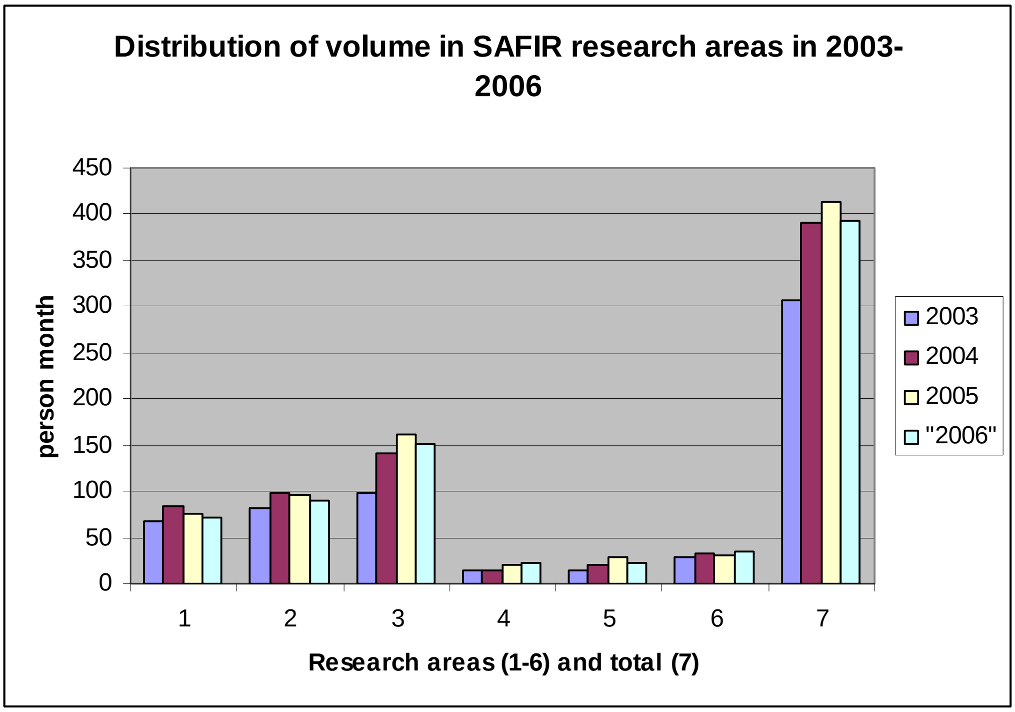

Figure 3.6. Development of person volume in SAFIR research areas (1–6) and in total (7) in 2003–2006. Realised numbers for 2003–2005 and plan 2006.

4 ORGANISATION AND INFORMATION

The programme management bodies, the steering group and the seven reference groups, will meet on regular basis 3–4 times annually. The ad hoc groups that have a vital role in some areas with many projects will carry on their operation and new groups may be formed by the project managers. The ad hoc groups will meet upon the needs of the specific project. All these groups will be regularly informed using standard progress reports. The list of persons involved in the steering and reference groups, as well as programme staff and their main duties are presented in Appendix 3. Figure 4.1 illustrates the current administration structure of SAFIR with the seven reference groups, that have the principal responsibility of scientific guidance and surveillance of the various research projects together with the various ad hoc groups. The steering group administrates the entire research programme.

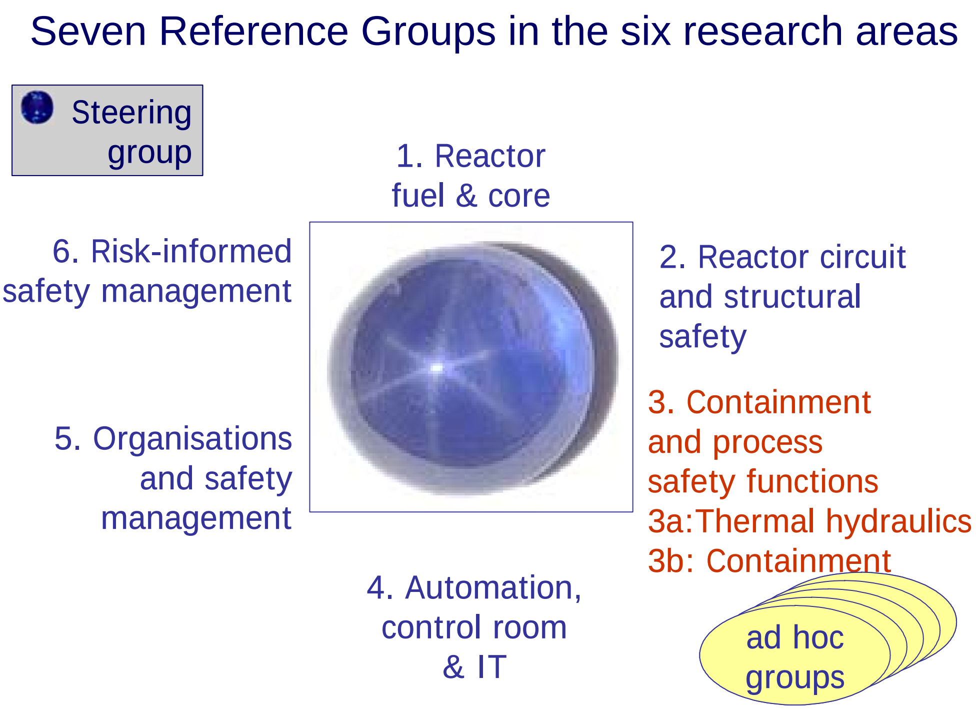

Figure 4.1 SAFIR structure with steering group, seven reference groups and ad hoc groups.

The information on the research performed in SAFIR will be communicated formally via the quarterly progress reports yearly, the annual report of the programme and the www-pages of the programme. Additional information will be given in seminars organised in the various research areas. The detailed scientific results will be published as articles in scientific journals, conference papers, and separate reports.

In addition to conducting the actual research according to the yearly plans, SAFIR will function as an efficient conveyor of information to all organisations operating in the nuclear energy sector and as an open discussion forum for participation in international projects, allocation of resources and in planning of new projects.

The final year of SAFIR programme will include an internal poll on the programme directed to some 120 persons involved in SAFIR (steering group, reference groups, project managers). The poll is carried out in February and will be utilized in planning of the next research programme. An international evaluation of the programme will take place in March. A strategy seminar for planning of the new programme will take place in April. Final seminar with presentations and seminar publications will be arranged at the end of the programme, presumably in January 2007.

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APPENDIX 1

Project research plans for 2006

Expenses and financing of the projects in 2006

The steering group, the reference groups and the scientific staff of the projects and their tasks in 2006