Evaluation of the Finnish Nuclear Safety Research Programme “SAFIR2014”
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Executive Summary

Chapter 7 Section 53a of the Finnish Nuclear Energy Act establishes arrangements to ensure that there is sufficient Finnish nuclear expertise to address any new factors affecting the safe operation of nuclear facilities and the safety of Finland and its people. This responsibility falls to the Finnish Ministry of Employment and the Economy (MEE).

To fulfil this responsibility, MEE establishes four year nuclear research programmes. At the end of each four year SAFIR programme, MEE arranges for an independent evaluation to be completed to check the consistency, comprehensiveness, and other aspects to demonstrate satisfactory achievement of the objectives of such programmes. In doing so it also seeks advice on formulating the next SAFIR programme.

This report provides the results of such an evaluation of the SAFIR2014 programme by an international panel of experts. The experts are: Mike Weightman (retired head of the UK nuclear regulator and HM Chief Inspector of Nuclear Installations, Royal Academy of Engineering Visiting Professor Cambridge University), Tony Roulstone (Lecturer and Director of the Cambridge University Masters Course on Nuclear Energy); Derek Lacey (ex Deputy Chief Inspector of Nuclear Installations in the UK, with particular responsibilities for nuclear policy and research).

The panel were asked to answer the following questions:

a. How well does it meet the goals laid down in the Nuclear Energy Act paragraph 53a?

b. Is the programme effective in respect of funding, applicability of the results and the presence on international scientific forums?

c. How well does the expertise cover the nuclear safety research field to meet the goals set down in the Nuclear Energy Act and is the entire programme balanced to all different fields?

d. Does it raise sufficient new experts?

e. Have the 2010 evaluation results been implemented successfully into the SAFIR2014 programme?

Additionally, the panel was asked to identify any main challenges and recommendations for the SAFIR programme.

The panel addressed these questions by reviewing documentation provided by the SAFIR2014 Programme Director and by a series of interviews with senior people and researchers associated with the programme.

The main conclusions are:

- SAFIR2014 is an extensive high quality programme with much high quality nuclear related research conducted under its banner;
the basis and development of the SAFIR2014 programme is an example to other nations;

it is generally effective in promoting new nuclear experts and maintaining the related basic infrastructure capability;

there is good co-operation among the users and it promotes positive interactions and behaviors between the regulator and the industry without impinging on the independence of the regulator;

evaluation of SAFIR2014 has confirmed that Finland continues to have a cadre of highly enthusiastic high quality nuclear researchers;

it is noted that the operating environment is fast changing especially with proposals for further new nuclear power capacity in Finland and the evolution of standards, technology, etc;

while there is a degree of cross-working among the various technical areas and projects, given the increasing complexity of nuclear safety related issues the need for such co-operation is growing;

project proposals are developed from a bottom up approach with a strategic steer through the SAFIR2014 Framework Plan and Steering Group. A greater balance towards achieving defined strategic objectives would be beneficial;

SAFIR programmes account for about half of the nuclear power safety research in Finland. Additionally, there is a large programme of research work undertaken on nuclear waste management. Given the objective of SAFIR2014, then there is scope for greater cross programme co-operation and co-ordination across these boundaries;

while the administration arrangements for the programme are excellent, there are future challenges.

And the panel makes the following main recommendations:

SAFIR’s role should include oversight of all nuclear safety expertise and facilities required to fulfil the obligations of the Nuclear Energy Act and include in such a wider oversight role other nuclear related disciplines;

the SAFIR programme should be managed on a theme basis rather than through a research area basis;

a review should be undertaken of the funding for the maintenance, operational, development, etc of all relevant nuclear safety related research infrastructure such that it can be established on a sustainable basis;
• the budget for SAFIR should be reviewed in line with the issues identified in the Report of the Committee on Nuclear Energy Competences in Finland, other challenges and any enhancement of its role as suggested in this evaluation report;

• Finland should host international conferences related to the SAFIR programme and thereby demonstrate further the high quality of its nuclear research;

• consideration be given to identifying additional ways to fulfil the requirements of 53a of the Nuclear Energy Act, such as funding academic posts in some areas;

• the recommendations of previous evaluations should be reviewed and reported on as part of the reporting of the SAFIR steering committee;

• to further enhance the excellent administration of the programme, particularly to meet future challenges, consideration should be given to:

  – making more use of self evaluation of the programme as feedback;

  – reviewing the flexibility of the programme to better respond to the impact of the fast changing operating environment;

  – providing a greater strategic steer;

  – seeking way to minimise the administration demands on researchers while ensuring proper reporting, oversight and governance;

  – identifying the need for Finnish expertise in nuclear technologies used elsewhere;

  – ensuring that the comprehensive Report of the Committee for Nuclear Energy Competence in Finland, published in 2012, is fully taken into account in future SAFIR programmes;

  – arranging a peer review of future draft SAFIR Framework Plans to provide more effective feedback at the start of such programmes thereby maximising an appropriate strategic basis and direction.

The panel makes more detailed recommendations for specific research areas to further enhance the work, and provides advice on the main challenges.
Acknowledgements

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1 Introduction

1.1 Basis of the SAFIR2014 Program

It is expected that a country with a nuclear power programme has sufficient nuclear education and research to independently understand and address issues concerning such use of nuclear energy. It should also have sufficient capability to be able to participate in international cooperation. Such activities will be of use to and may be funded by the industry, regulator or ministries. However, these may not be sufficient to provide the total need for nuclear experts in Finland. The underlying education and research needs planning and managing such that the research programmes deliver the Government’s objectives in having sufficient nuclear expertise to address safety related issues.

Chapter 7a, Section 53a of the Finnish Nuclear Energy Act (the Act) sets out as the objective to ensure the continued availability of expertise to address any new factors affecting the safe operation of nuclear facilities. It provides for the collection of fees from nuclear licensees, and from organisations who have been granted a Government decision-in-principle, to fund activities to achieve this objective. In this way it makes a very significant contribution to Finland’s nuclear education and research activities.

The Finnish Ministry of Employment and the Economy (MEE) are charged with fulfilling this obligation utilising the fees collected under the act. These together with contributions made independently by key organisations in the area of nuclear energy amount to around 10 m euros per year. They do so through four-year nuclear research programmes, the latest one being the SAFIR2014 programme that covers the years 2011 to 2014. It is this programme that is the subject of this evaluation.

The mission of the SAFIR2014 programme, derived from the Finnish Nuclear Energy Act is:

“to develop and maintain experimental research capability, as well as the safety assessment and nuclear safety expertise of Finnish nuclear power plants, in order that, should new matters related to nuclear safety arise, their significance can be assessed without delay.”

1.2 Background

SAFIR2014 is the third such programme. The previous ones covered the years 2007 to 2010 (SAFIR2010) and 2003 to 2006 (SAFIR2006). Previous to these SAFIR programmes there have been Finnish national nuclear safety research programmes since the 1980’s.

In the SAFIR2014 programme period there have been several licencing and other regulatory procedures undertaken for new and existing nuclear power plants. These, and present proposals for further development of the Finnish nuclear industry, emphasis the need for an expanded infrastructure for nuclear expertise and hence for the SAFIR2014 programme.
Additionally, during the period of the SAFIR2014 programme, and going on from now, many of the nuclear experts who have been involved in the construction or operation of the Finnish nuclear power plants have or will retire. They embody a unique set of experiences and knowledge. Transferring this knowledge to a younger generation is vital, and well targeted research projects can assist in this important process.

1.3 Scope

While the prime objective of the SAFIR2014 program is to ensure adequate Finnish nuclear expertise to address new issues, it also is intended to assist in generally enabling the ability of Finland to address current and foreseen safety issues. However, it is not aimed at solving specific safety issues on any particular nuclear reactor. That is the responsibility of the industry or the regulator – the Radiation and Nuclear Safety Authority (STUK). Nevertheless, it is intended that SAFIR2014 assists in retaining and expanding knowledge in all technical disciplines related to nuclear safety. In doing so it provides a very valuable training framework for a new generation of nuclear safety experts.

The SAFIR2014 programme uses a range of activities to achieve its objectives such as: the development of suitable analytical tools including modelling codes; experiments in Finnish research facilities; generation of nuclear safety related databases; and participation in international networks and working groups. These include those of the OECD’s Nuclear Energy Agency (NEA), the European Union (EU) Frameworks Programmes, the International Atomic Energy Agency (IAEA), and other bilateral and multilateral programmes.

The scope of the SAFIR2014 is consequently broad and administratively was broken down into nine research groups, viz:

1. Man, Organisation and Society
2. Automation and Control Room
3. Fuel Research and Reactor Analysis
4. Thermal Hydraulics
5. Severe Accidents
6. Structural Safety of Reactor Circuits
7. Construction Safety
8. Probabilistic Risk Analysis

1.4 Administration of the Programme

A three level structure was adopted to oversee and manage the programme. At the top a steering group, appointed by MEE and chaired by a senior manager from STUK, makes final decisions on the structure, content, annual plan and annual report. It also supervises the quality of the results of the programme. The organisations represented are:
At the second level are technical Reference Groups with a similar representation. These align with the nine research areas covering the scope of the programme. They are responsible for the strategic plan of projects in the field of research covered by their topic area and their delivery to time, quality and costs. The Reference Groups discuss links between the research projects in their area and other research, national and international.

Project execution is undertaken at a third level via projects executed in line with the particular management system for the research organisation executing the project. However, a project manager is identified for each project responsible, on behalf of the research organisation involved, for delivery of the project according to the plan and budget.

From time to time, a cross-discipline Ad Hoc Group is formed to oversee a project that cuts across several Reference Group topic areas or to provide a coordination function across technical areas.

A Programme Director and administrative organisation for the day-to-day running of SAFIR2014 was appointed from the Technical Research Centre of Finland (VTT).

### 1.5 Evaluation Objectives

The MEE established an evaluation panel of three nuclear experts (Mike Weightman, Royal Academy of Engineering Visiting Professor Cambridge University; Tony Roulstone, Lecturer and Director of the Cambridge University Masters Course on Nuclear Energy; and, Derek Lacey, Nuclear Consultant) to address the following main questions about SAFIR2014:

f. How well does it meet the goals laid down in the Nuclear Energy Act paragraph 53a?

g. Is the programme effective in respect of funding, applicability of the results and the presence on international scientific forums?

h. How well does the expertise cover the nuclear safety research field to meet the goals set down in the Nuclear Energy Act and is the entire programme balanced to all different fields?
i. Does it raise sufficient new experts?

j. Have the 2010 evaluation results been implemented successfully into the SAFIR2014 programme?

Additionally, the panel was asked to identify any main challenges and recommendations for the SAFIR programme.

### 1.6 Method of Evaluation

The evaluation was conducted in three stages:

1. Assessment of relevant documentation provided as listed in Appendix A.
2. Face to face discussions in Helsinki, over the week 2nd to 7th March 2014, with Steering Group Members, Chairs of Reference Groups, Project Managers and other key players. Appendix B provides a list.
3. Review and consideration of the evidence gathered during 1 and 2.

The documentation initially provided was generally comprehensive and covered the entire scope of the programme. One document, Report of the Committee for Nuclear Energy Competence (March 2012) was handed over during the visit to Helsinki, as was other information about the administration of the programme. The evaluation panel members each had specific areas of interest. Tony Roulstone concentrated on Fuel Research/Reactor Analysis, Thermal Hydraulics and Severe Accidents, and Derek Lacey on Structural Safety of Reactor Circuits, Construction Safety and Fire Research. Mike Weightman covered the rest of the technical areas.

Mike Weightman conducted the week of discussions in Helsinki on behalf of the panel. This stage was very well organised with good presentations and very open discussions, all being responsive to questions and probing. Mike Weightman provided an initial view at the end of the week on the findings (see Appendix C).

This report provides the outcome of stage 3 of the evaluation.
2 Main Conclusions of the Evaluation

2.1 The Process of Evaluation

The process, provision of documentation, presentations and discussions were extremely well organised and the Programme Director was particularly helpful during the stage 2 evaluation in Helsinki. Additionally, the contents of the presentation and reports were comprehensive and informative.

There is a large amount of possible material relevant to SAFIR2014 including detailed project and research papers. The panel was mindful that in the time available it could not cover all this material, especially all the large number of detailed technical reports. However, it did obtain a sufficient overview of the programme and its work to provide an adequate evaluation.

During the process of the evaluation it was possible to explore the administration of the programme and it was apparent that a considerable amount of material has been generated to improve management and governance of the programme. This includes self-assessments, data on international activities, and on academic qualifications achieved through the programme. Such initiatives are to be applauded and more could be done to recognise and use such self-evaluation and use it as feedback into the programme.

TVO nuclear power plant in Olkiluoto, Eurajoki. Olkiluoto units 1 and 2 (on the front right side) started operation in 1979 and 1982. In 1997 these units were granted a license to continue operation until 2018. Like other units in Finland, these units are modernized consistently to comply with current and incoming demands regarding nuclear safety. Plant unit 3 (shown on the left) is currently under construction and power production is estimated to start in 2018. This reactor’s electrical output will be 1,630 MW and its technical operating lifetime 60 years. The farmost unit in the picture shows the planned unit 4. (Source: TVO).
2.2 General Conclusions

A series of overall conclusions were arrived at from the work of the evaluation panel, viz:

- SAFIR2014 is an extensive high quality programme with much high quality nuclear related research conducted under its banner;

- the basis and development of the SAFIR2014 programme is an example to other nations and something for them to emulate in order to ensure that they develop and maintain the knowledge, skills and experience needed to underpin governments’ nuclear power programmes;

- it is generally effective in promoting new nuclear experts and maintaining the related basic infrastructure capability;

- there is good co-operation among the users and it promotes positive interactions and behaviors between the regulator and the industry without impinging on the independence of the regulator;

- evaluation of SAFIR2014 has confirmed that Finland continues to have a cadre of highly enthusiastic high quality nuclear researchers;

- it is noted that the operating environment is fast changing especially with proposals for further new nuclear power capacity in Finland and the evolution of standards, technology, etc. Some greater clarity of the role and scope of SAFIR in this changing environment and how it can respond flexibly to it would be worthwhile;

- while there is a degree of cross-working among the various technical areas and projects, given the increasing complexity of nuclear safety related issues the need for such co-operation and cross-linking is ever growing. Consequently, it is concluded that more should be done to encourage such co-operation;

- project proposals are developed from a bottom up approach with a strategic steer through the SAFIR2014 Framework Plan. Additionally, the Steering Group does seek to provide additional direction. However, there is little option than to decide among those research proposals that are put before Reference Groups and Steering Committee. It is concluded a greater balance towards achieving defined strategic objectives would be beneficial especially as otherwise the programme may become somewhat unbalanced and stagnant;

- earlier work indicates that SAFIR programmes account for about half of the nuclear power safety research in Finland. Additionally, there is a large programme of research work undertaken on nuclear waste management. Given the objective of SAFIR2014, developing nuclear related expertise for Finland, then there does appear to be scope for greater cross programme co-operation and co-ordination across these boundaries;

- while the administration arrangements for the programme are excellent, it appears to some that the demands on researchers may be too great and may be able to be streamlined.
2.3 Specific Questions

A. How well does it meet the goal laid down in the Nuclear Energy Act paragraph 53a?

The simple answer to this question is that it generally meets the goal well. However, there are some caveats to this general conclusion.

It is considered that some areas important to safety are not covered in the SAFIR programme. They may be elsewhere but this implies that the SAFIR programme should have more general oversight of areas of such research if it is intended to ensure that sufficient expertise exists in Finland to address new nuclear related issues. This is particularly important with an expanding role for nuclear power in Finland.

It is noted that the environment for safe peaceful use of nuclear energy is rapidly changing, especially post Fukushima, and with new major players emerging internationally. This raises a question as to whether the form of the SAFIR programme is amenable to responding to such rates of change. There are signs that it does have some difficulty in changing track, especially in bringing to an end well established projects. On the other hand, there was a positive dynamic approach in responding to Fukushima lessons for Finnish nuclear power plants.

The Fukushima Dai-ichi nuclear accident taught us other lessons however. In particular, how a nation has to have adequate nuclear expertise to understand an accident at any nuclear facility anywhere in the world in order for its government to be able to make decisions to safeguard its citizens and interests overseas. This is an area that does not appear to have been considered when devising SAFIR programmes.

It is apparent that the SAFIR2014 does not cover all relevant Finnish nuclear safety related experimental facilities. Again, it is considered that if the SAFIR programme is intended to completely fulfil the Nuclear Energy Act objective then it must at least have some oversight of all such facilities. This would better ensure a comprehensive response to the requirements of paragraph 53a of the Act.

The recent comprehensive Report of the Committee for Nuclear Energy Competence in Finland is an important document relevant to this question in that it provides data on recent (2010) nuclear energy sector personnel resources and future needs. Additionally, it provides an overview of nuclear related research in Finland, research infrastructure, Finnish participation in international research activities and other matters. It establishes a blueprint for the future need for nuclear related experts and therefore it is concluded that it is an essential input into future SAFIR programmes and needs to be taken fully into account in their development.
B. Is the programme effective in respect of funding, applicability of the results and the presence on international scientific forums?

The overall conclusion is that the programme is effective. The panel did not find any evidence that users or others have significant concerns about the effective use of funds or applicability of the results.

Some of the results have greater relevance than might have first been considered as the outcome of particular research projects. Additionally, the general level of research was of high quality, with some world leading.

There is significant participation in international projects and networks. For example, in 2012 there was participation in over 100 international projects and research networks with over 150 international travels by Finnish experts under SAFIR2014 projects.

There is a fair degree of self-evaluation of the programme for effectiveness. Projects are evaluated well using a weighted marking system involving end users in monitoring and making decisions on the projects. The outcome of the projects is reviewed in relation to new higher degrees on a particular area, number and type of publication, and involvement in the international fora.

Given the desire to maximise the effectiveness of the programme, it is considered that consideration should be given to other ways of achieving the objectives rather than just through individual projects. For example, using some of the SAFIR budget to fund individual academic posts. Similarly, consideration could usefully be given to funding a Finnish international nuclear safety research conference and in doing so visibly expose the SAFIR research programme to the international peers for review. This would be particularly beneficial in promoting the Finnish nuclear safety research capability, in particular its facilities, to a wider audience.

C. How well does the expertise cover the nuclear safety research field to meet the goals set down in the Nuclear Energy Act and is the entire programme balanced to all different fields?

For the areas identified in SAFIR2014 it is balanced. However, it is considered that there are some areas related to nuclear safety that are not covered such as:

- Heavy electrical engineering including electrical grid issues
- Radiological Protection and Health Physics
- Operational radioactive waste management
- Operational Events Feedback analysis
- Knowledge Management
- Ventilation
- Decommissioning
- Emergency preparedness
- Reactor site layout
- Siting
- Transport
- Security
- Safeguards.
Some of these may be covered in other programmes but under the arrangements to comply with the Act SAFIR should at least have an interest in, if not oversight of all such programmes. Additionally, some aspects covered by the present SAFIR programme may impact on other programmes; for example: fuel burn-up research for optimisation of reactor operations could impact on research for spent fuel transport or disposal, or research developing and enhancing safety cultures on security cultures, risk communication, research and radiological protection in emergency arrangements. Additionally, while some issues such as decommissioning may appear to be far off, it is important to develop expertise in this field now so that experts are available to assist in ensuring that in design decommissioning issues are capable of being addressed adequately.

**D. Does it raise sufficient new experts?**

New experts have been created with high level qualifications. For example, in 2012 of those students involved in the SAFIR2014 projects 12 were awarded Master of Science in Technology degrees and 3 Doctor of Technology Degrees. The programme does appear to be delivering sufficient new experts for short term needs. However, looking further forward with the increasing loss of older expertise and the demands of an expanding nuclear power sector there could be shortfall if the present programme is not expanded. This is illustrated by the recent Report on Finnish Nuclear Competences.

**E. Have the 2010 evaluation results been implemented successfully into the SAFIR2014 programme?**

This is considered to be patchy with evidence in some areas of successful implementation whereas in other areas the evidence is not so strong.

This may be a reflection of some in-precision in the wording of some of the original recommendations of the previous evaluation report (for SAFIR2010) or that the circumstances have significantly changed.

The reporting and monitoring arrangements may be usefully revisited to better capture data and information on this matter.

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Fortum nuclear power plant in Hästholmen, Loviisa. The Loviisa power plant has operated since 1977. Unit 1 has a valid license until the end of 2027. Unit 2’s license is valid until the end of 2030. Fortum has not yet decided what will happen after these deadlines, i.e. will it seek an extension to the operating licenses. (Source: Fortum)
3. Conclusions and recommendations for the specific topic areas

3.1 Research Area 1 – Man, Organisation and Society

The projects in this area are:

MANSCU
Managing safety culture throughout the lifecycle of nuclear plants;

SAFEX2014
Sustainable and Future Orientated (looking at HR practices in the nuclear power industry);

SISIANS
Signalled and Silenced Aspects of Nuclear Safety (seeking to better incorporate societal and cultural aspects of safety through looking at national nuclear safety practices and regulation).

There is some very good work being undertaken in this area, and the expertise pool is growing with increases in the number of people involved in this expanding field of study. Of particular note, is the work being undertaken under SISIANS on inter-cultural issues (introduced after the Fukushima Dai-ichi accident), MANSU on supply chain and design, and SAFEX2014 on leadership.

This excellent work could usefully be expanded. Recent experience has shown that cultural aspects are important for delivering high levels of safety cultures on nuclear construction sites where many nationalities are employed. Additionally, cultures in an organisation are heavily determined by the leaders in that organisation and the values that they exhibit day in day out. Society and the nuclear industry is subject to an increasing pace of change; especially where new forms of vendor/owner/operator structures are arising and relationships with the regulator may be more complex. It is therefore recommended that these projects be enhanced to include:

Recommendation 3.1.1
the impact of leadership on safety cultures and the associated resilience of an organisation’s safety culture under change of leadership;

Recommendation 3.1.2
nuclear industry structural change, and relationships with the regulator;

Recommendation 3.1.3
the multi-cultural impact on nuclear construction.

Risk communication has grown in importance since the Fukushima Dai-ichi accident. It is closely connected with social science, cultural issues, trust and perception. In Group 8 (Probabilistic Risk Assessment) there is work in place in this area but it appears not to have progressed greatly yet. It is probably better led from Group 1 where the wider social science aspects can more easily be covered. Thus, it is recommended that:
Recommendation 3.1.4
work on risk communication under the SAFIR programme should be led by Group 1.

3.2 Research Area 2 – Automation and Control Room

Projects included in this area are:
- CORSICA
  Coverage and rationality of software I&C safety assurance
- HACAS
  Human-automation in incident and accident situations
- SARANA
  Safety evaluation and reliability analysis of nuclear automation
- SARAMEN
  Safety requirements specification and management in nuclear power plants
- IFAPROBE
  Indication of fault situations propagating between different systems and disciplines.

This area has some very useful and interesting work that has wider relevance. The work touches on Probabilistic Risk Analysis (Area 8); Man, Organisation and Society (Area 1); and, knowledge management. It could usefully have closer connections with such topic areas. It is a mixture of small and large projects with comprehensive reporting of the work.

There is quite a degree of work to develop methodology for assessing systems against certification requirements but in reality the issue is how do you relate these findings to the safety on the plant, especially when taking account of human factor implications. It is therefore recommended that:

  Recommendation 3.2.1
  the research on analysis against certification and specification requirements could usefully be expanded to provide a more holistic safety analysis.

Work on control room configuration is vital to ensure optimum operator capability and effective control and protection of the reactor. It is an area where at times change can be driven by technological advances. However, just because technology can provide new equipment (such as wall displays) does not mean that it should be adopted. The requirements should be driven by the operator and safety requirements not the technology. It is therefore considered that:

  Recommendation 3.2.2
  the work on control rooms could usefully be expanded to be more focused on operator and safety requirements rather than a technology focus. This would necessitate closer co-operation between Research Areas 1 and 2.
3.3 Research Area 3 – Fuel and Reactor Physics

The projects in this area are:

**CRISTAL**
Criticality safety and transport methods in reactor analysis

**KOURA**
Reactor dynamics (transient analysis methods) and three-dimensional thermal hydraulics in reactor core and fuel bundle geometry

**KÄÄRME**
Development of Finnish Monte Carlo reactor physics code

**NEPAL**
Neutronics, nuclear fuel and burn-up

**PALAMA**
Fuel behaviour modelling in normal and accident conditions

**RASTA**
Radioactive source term analysis (one year project – 2012)

The physics modelling (KÄÄRME) is impressive in terms of what has been achieved and it exhibits very good connections with other countries. The Monte-Carlo modelling work is innovative and is of high quality. International collaboration can be inward or outward. In this area Finland is providing leadership and the tools that they are producing are being used widely within academia. Even if these tools do not in the future migrate into day-to-day use by safety regulators, their development is providing a focus for young physicists and modellers to learn about advanced reactor physics. Also, the accessibility of these models is enabling a wider group of engineers and scientists to analyse modern reactor systems in a relatively simple but sound manner.

Work in the other areas of criticality safety (CRISTAL), three dimensional modelling (KOURA), neutronics (NEPAL) and fuel modelling (PALAMA) appears to be suitably balanced.

The fuel modelling work (PALAMA) considers the classical issues of fuel swelling and cladding behaviour with a mixture of US codes, calculations specific to Finnish reactors and data from Halden. Some work is being done on LOCA effects on fuel. There is a review of the international work on fuel behaviour to determine how better to optimise the Finnish component of this work. This review is a sensible response to the challenges of a complex field that depends on irradiation data that is expensive and time consuming to develop.

There are near-term milestones for the work, however it is unclear what are the major milestone and targets. Hence, it is difficult to see when these areas of work might complete their current programmes.
This leads to a specific recommendation:

**Recommendation 3.3.1**
This area of work could benefit by having clearer integrated plans with major milestones, targets and end points.

The RASTA 2012 work was to provide activity inventories for severe accidents and releases from storage or final disposal rather than just fission products that affect fuel rod integrity. It used tools of reactor physics, fuel behaviour and severe accident analysis in a synergistic way to provide an optimum solution. It provided some very useful information for post Fukushima work. This work demonstrates the benefit of integrated approaches to particular needs and may be an area that would benefit from further investment, especially to ensure a cadre of experienced experts for the future.

It is recommended therefore that:

**Recommendation 3.3.2**
in relation to the RASTA 2012 work, further investment in projects of this nature should be undertaken to ensure that Finland continues to have a suite of appropriate codes and suitable cadre of experienced experts to predict radioactive releases and their impact after accidents of different types and severity.

### 3.4 Research Area 4 – Thermal Hydraulics

The projects in this area are:

**ESA**  
Enhancement of safety evaluation tools (e.g. APROS and TRACE)

**EXCOP**  
Experimental studies on containment phenomena

**NUFOAM**  
Use of open source Computational Fluid Dynamics (CFD) software for nuclear safety related flow simulations

**NUMPOOL**  
Numerical modelling of condensation pool and validation by comparing results to experiments performed with the PPOOLEX facility

**PAX**  
PWR PACTEL experiments (dependent on ELAINE project)

**SGEN**  
Modelling of steam generators of nuclear power plant

**UBEA**  
Uncertainty evaluation for best estimate analysis

**SPEFU**  
Thermal hydraulics and fuel integrity in spent fuel dry cask interim storage
It is a matter of debate whether to use existing commercial CFD codes and validate them for the nuclear applications or to write bespoke codes. Because the writing and validation of specific codes will be large task, this decision needs to be thought through. It is noteworthy that SAFIR is funding the general purpose CFD solver OPENFOAM for this purpose and this may provide another route to upgrade hydraulics codes. Validation will still be required and this is recognised by the EXCOP programme. It would be encouraging to see the different strategies for CFD being examined and laid-out for consideration.

It is recommended that:

Recommendation 3.4.1
a comprehensive clear strategy for CFD in Finland should be developed to guide future projects in this area.

There are several areas where further work is planned, some of which will necessitate co-operation with other areas. This work should be encouraged and it is therefore recommended that:

Recommendation 3.4.2
further work should be undertaken in co-operation with others on:
• Passive systems
• Ageing of nuclear power plants and their systems
• Using CFD for and experimental validation of two-phase flow.

The projects are involved with NEA and USNRC hydraulic programmes. This is essential because of the high cost of such experimental and validation activities. There is a domestic experimental project, PAX, involving a primary coolant loop that should provide some relevant practical experience to researchers in Finland.

Uncertainty analysis was identified by the 2010 report as a priority work area and this is being addressed by the UBEA project.

CFD users within SAFIR from different research areas have their own group that meets a few times a year. This is to be encouraged.

This area demonstrates widespread engagement of less experienced practitioners and development of their expertise.

Dry fuel storage is becoming more important as fuel accumulates at operating reactor sites. Even with the proactive Finnish waste management programme, this issue will continue to grow in prominence. Though the absolute level of decay heat of assemblies in dry fuel storage is generally low, the level of accumulated energy released means that temperatures can be high which can lead to potential materials problems. SPEFU is modelling the heat removal from dry casks. This is an area where a direct approach considering worst cases may prove fruitless and a more optimised management approach becoming necessary. Modelling heat removal from the casks by this project is a first step.
It is recommended that:

Recommendation 3.4.3
further work should be undertaken on dry cask storage as it is an area where continuing expertise will be required for years to come. It is especially important to consider long-term ageing phenomena.

3.5 Research Area 5 – Severe Accidents

The projects in this area are:

**COOLOCE and COOLLOCE-E**
Core debris coolability

**FISKE and FISKES**
Chemistry of fission products

**THERMOSAN**
Thermal hydraulics of severe accidents

**TRAFI**
Transport and chemistry of fission products

**VESPA**
Reactor Pressure Vessel failure, vapour explosion, spent fuel pool

**PCCS**
Passive containment cooling system tests.

As demonstrated by Fukushima, simple loss of cooling for an extended period of time can lead to extensive core damage, or a severe accident. Though modern reactors are more able to deal with such events, the concern of the public about the effects resulting from core damage and the economic consequence of such types of accident mean that they warrant priority in research. This area of work was enhanced post Fukushima and some excellent work has been undertaken.

The inherent uncertainties in what is being considered in severe accidents make them difficult to ‘bound’ and hence to categorise. Therefore, a broad programme of research is necessary. This seems to be the case with three groups of elements: modelling of the progress of accidents (TERMOSAN), separate effects modelling of specific problems (VESPA) including core melt/cooling (COOLLOCE-E), and fission product release and transport modelling (FISKES & TRAFI).

Also, the programme is currently looking at passive safety systems using the models developed for more conventional reactor systems. This is becoming of increasing importance. Accordingly, it is recommended that:

Recommendation 3.5.1
the work on passive safety should be expanded.

There is good international co-operation and new people are being brought up to speed with this area of work. And, there is a good spread of work across the area.
Some of the phenomena investigated are experienced in other industries. It is therefore recommended that:

- Recommendation 3.5.2
  efforts should be made to identify whether work in other industry on similar phenomena is of interest to this area of work. This could potentially widen the pool of expertise.

### 3.6 Research Area 6 – Structural Safety of Reactor Circuits

The projects in this area are:

- **ENVIS**
  Environmental influence on cracking susceptibility and ageing of nuclear materials

- **FAR**
  Fracture assessment of reactor circuit

- **MAKOMO**
  Monitoring of the structural integrity of materials and components in reactor circuit

- **RAISYS - RI-ISI**
  analyses and inspection reliability of piping systems

- **SURVIVE**
  Advanced surveillance technique and embrittlement modelling

- **WAPA**
  Water chemistry and plant operating reliability

- **FRESH**
  Fatigue affected by residual stresses, environment and thermal fluctuations

- **RICO**
  Heavy fouling and corrosion risks in the cooling water systems of NPPs and methods for their mitigation

- **REHOT**
  Renewal of Hot Cell Infrastructure (project controlled through Area 9)

This is a large programme that is well planned and aligns well with the SAFIR2014 Framework Plan. The structural safety group of projects is very well balanced covering key topics in this area, and there is a good mixture of analytical and experimental work. It provides a major contribution to the development of sufficient and comprehensive nuclear engineering expertise and deploys some key facilities. There is some excellent work being undertaken. This is a major contribution to the development of the national capability for timely analysis of emerging integrity issues.

All projects are relevant to significant reactor structural integrity assessment and they all provide evidence of the use of advanced techniques or modelling and can be classed as state of the art.
However, not all projects set out clearly what they are intending to achieve or reach clear conclusions on the value of the work. It is therefore recommended that:

Recommendation 3.6.1
all projects should all set out clear goals and demonstrate to what extent they have been achieved along with other objective conclusions on the value of that particular project.

While there has been some good international co-operation there is scope to pursue this further. This might involve a greater range of collaborative ventures including the use of unique international facilities. It is recommended that:

Recommendation 3.6.2
international collaboration is pursued further given the important work that SA-FIR is undertaking in this area.

The structural safety projects are effective for the development of inexperienced staff but some leakage occurs and needs continual replacement. This situation should be monitored and targeted actions should be taken to address identified problems.

A research needs analysis would improve the value of the future programme. It should take into account the changing environment for the nuclear industry in Finland and the areas where research can lead to the most significant benefits to nuclear safety. In doing so it should cover any likely future use of non-metallic materials and those structures or components that are important to safety but are outside the reactor circuits. Thus, it is recommended that:

Recommendation 3.6.3
a research needs analysis should be undertaken Research Area 6 that includes within scope non-metallic materials and non-reactor circuits structures and components important to safety.

3.7 Research Area 7 – Construction Safety

The projects covered under this area are:

IMPACT2014
Information on impact phenomena of an airplane against a nuclear power plant

SMASH
Structural mechanics analysis of soft and hard impacts

MANAGE
Ageing management of concrete structures inn nuclear power plants

SESA
Seismic safety of nuclear power plants: targets for research and education

The construction safety group of projects is contributing to the development of sufficient and comprehensive nuclear engineering expertise and deploys some key facilities
that are of international importance. There is evidence that some of the work is world lead-
ing. This is a significant contribution to the development of the national capability for timely
analysis of emerging construction integrity issues.

The projects provide a balanced programme in the construction safety area that allows
expertise to be developed in the key technical areas. Some projects involve a very im-
pressive combination of experimental and analytical expertise to address important top-
ics in the subject areas and provide a basis for very valuable international collaboration.
At present there is a good level of international co-operation but given the very good
nature of the SAFIR work, there is scope for further international collaborative. It is rec-
ommended therefore that:

Recommendation 3.7.1
the present high level work in this area should be built on by enhancing inter-
national collaboration.

There is potential for more cross cutting work in the future programme especially in
such areas as ageing and other areas of potential significant work would be identified
by a research needs analysis. Accordingly, it is recommended that:

Recommendation 3.7.2
a research needs analysis should be undertaken to improve the value of the fu-
ture programme and enhance cross cutting and may lead to work in the follow-
ing areas:
• Double skin structures
• Modular construction
• Fundamental review of use of codes for nuclear structures
• Greater use of integrated 4D (3 physical and time) modelling and
  integration of constructability into design
• Use of other testing facilities at VTT and elsewhere.

3.8 Area 8 –
Probabilistic Risk Assessment

The projects covered in this Area are:

EXWE
Extreme weather and nuclear power plants

LARGO
Risk assessment of large fire loads

PRADA
PRA development and application

FINPSA TRANSFER
Transfer of PRA codes and the associated knowledge from STUK to VTT.
There has been some very useful work undertaken in this area, especially that related to extreme weather and fire modelling. The level 3 PRA is an important area and would benefit by being taken further. It is noted that although there have been efforts to promote PRA into mainstream degree level engineering courses, to generate a larger pool of knowledge, this has still someway to go.

Accordingly, it is recommended that:

Recommendation 3.8.1
the level 3 PRA (involving consequence analysis) should be taken further to assist in strategic planning, risk optimisation, etc;

Recommendation 3.8.2
further efforts should be made to establish PRA, and the associated availability modelling, fault and event analysis techniques, as part of all degree level engineering courses.

PRA techniques have the potential to be used effectively in other areas of research, such as spent fuel and radioactive waste transport and disposal, security, etc. Additionally, PRA should be seen as part of a living safety case, with information from Operational Experience Feedback (OEF) providing a valuable input such a system.

It is therefore recommended that:

Recommendation 3.8.3
consideration should be given to using the work generated as part of SAFIR PRA projects in other areas related to nuclear and radioactive waste safety;

Recommendation 3.8.4
the SAFIR work on PRA should be expanded to promote its use as part of living safety cases for nuclear facilities that include information from OEF systems.

3.9 Research Area 9 – Research Infrastructure

There are two main projects:

ELAINE
Enhancement of Lappeenranta Instrumentation of Nuclear Safety Experiments

REHOT
Renewal of Hot Cell Infrastructure

This is a unique area of SAFIR2014 typically involving capital expenditure and some aspects that are not entirely within the SAFIR Steering Group’s control. Therefore it should be subject to somewhat different review and management arrangements to the other projects within the programme. More normal construction project management techniques can be applied and the reporting made on a monthly basis.
It is recommended therefore that:

Recommendation 3.9.1
consideration should be given to developing different reporting and monitor-
ing arrangements for Research Infrastructure projects that reflects more closely
those for construction, modification, operation and maintenance of capital as-
sets;

Other nuclear safety research infrastructure exists in Finland and in order for SAFIR to
fully fulfil its role under 53a of the Nuclear Energy Act these should be included within
its overall remit. It is noted that an initial internal survey has been undertaken. This
should be finalised and a case made for all such research infrastructure to be brought
under SAFIR supervision.

It is recommended that:

Recommendation 3.9.2
SAFIR should have oversight of all nuclear safety infrastructure related to 53a of
the Nuclear Energy Act.

ELAINE covers a series of upgrades to the Lappeenranta University of Technology nucle-
ar research facilities to maintain them up to date in line with the latest thermal hydrau-
lic and associated modelling requirements. It also covers some general maintenance and
coding work. These upgrades are very worthwhile and allow the associated research to
keep pace with international developments. To continue to do so however, there must
be a programme of on-going investment in this facility. Thus, it is recommended that:

Recommendation 3.9.3 -
there should long term plans for continued investment in the Lappeenranta Uni-
versity Nuclear Research Facilities to ensure that they remain at the forefront of
international research in their field.

REHOT on the other hand is a major new project at VTT to replace out of date hot cells.
This is a long term commitment and the funding arrangements for its operation, main-
tenance, etc do not appear to have established yet. This is reviewed further under Main
Conclusions and Recommendations.

Such considerations indicate that the funding arrangements for nuclear infrastructure,
being much more long term and wider ranging, should be different to those of other ar-
eas of SAFIR.

It is recommended that:

Recommendation 3.9.4 -
the funding arrangements for nuclear related infrastructure covered by SAFIR
should be considered different to that of other SAFIR projects and put on a long
term basis.
It is noted that Finland is contributing to the Jules Horowitz Reactor. Once in operation this new nuclear research facility will afford Finnish researchers a world leading research capability that would not be available solely through Finnish funding. Preparations for its use should be part of the SAFIR programme. Accordingly, it is recommended that:

Recommendation 3.9.5
a SAFIR project should be enacted for use of the Jules Horowitz Reactor.

Fennovoima’s planned nuclear power plant in Hanhikiven niemi, Pyhäjoki. Fennovoima initiated its nuclear power plant project in 2007. In 2014, the company submitted an application requesting a supplement to a 2010 government Decision-In-Principle, as the reactor unit now to be used is the Russian-made Rosatom AES-2006 pressurised water reactor, which has 1,200 MW of electric power. Construction of the plant is expected to be completed in 2024, and its estimated operating life is 60 years. (Source: Fennovoima)
4 Challenges and recommendations

4.1 Main Challenges

From the examination of the documentation and the discussions the following main general challenges to the programme have been identified:

• There is an increasing need for new nuclear safety expertise and facilities with the expanding Finnish nuclear programme, and ageing experts and facilities. This is not only local to Finland but globally.

• Uncertainties in the degree to which and when new nuclear power will be brought online in Finland.

• Changing society with different attitudes, beliefs and expectations that will impact on such issues as social trust that will demand a greater use of the social sciences.

• The changing nature of nuclear organisations and structure of the industry. This will require more expertise on organisational and structural change in a nuclear context.

• Complexity of new science and technology especially in the instrumentation and control area; for example, the increased use of digital equipment.

• The long life for new designs of plant and life extensions that will reach across generations. This has a particular impact on knowledge management.

• Constructability and the optimisation of standards – it is increasingly becoming obvious, especially in the civil field, that methods of design and construction are advancing out with the modification of existing codes. For example, 4D design is increasingly being considered for nuclear new build projects yet the codes are not necessarily aligned with its potential. Additionally, nuclear related civil codes need to be reviewed and revised as they are increasingly being layered on top of each other. Research in these areas is increasingly necessary.

There were also on-going management challenges with the SAFIR programme that were apparent from the discussion and interviews. The main ones were:

• Funding the on-going maintenance, development and replacement of the nuclear safety related experimental facilities. It appears that while the capital cost of the new hot-cell facility at VTT is covered by the SAFIR programme it is not certain how the on-going costs will be funded. Such facilities are a long-term investment and require a suitable business plan to secure the funding requirement to maximise their enduring capability, especially as science advances and they may require modification.
• Long standing projects are sometimes difficult to terminate even when it is apparent that their usefulness may have diminished and other proposals have a greater priority in developing the required expertise.

• One of the key components of the successful programme is the project management of the individual projects. There appears to be some variability in capability in this area. This is an important technical skill in itself and worth funding some professional training to ensure that the programme maximises the value from its funding of projects, and has a cadre of competent nuclear research project managers for the future.

4.2 Main Recommendations

A fundamental principle of high levels of enduring nuclear safety is continuous improvement. In the same spirit, the following suggestions are offered to further enhance the SAFIR programme to better meet future challenges. Only the more general main recommendations are provided here. Ones specific to particular research areas are covered earlier.

If the principle behind Nuclear Energy Act 53a is to ensure that there are sufficient experts in scientific and technology fields relevant to new nuclear safety issues, and SAFIR is the means whereby this position is secured, then it is recommended that:

Recommendation M.1
SAFIR role should include oversight of all nuclear safety expertise and facilities required to fulfil the obligations of clause 53a. This would enable it to better decide on the main gaps and steer funding into these areas. The recent Report of the Committee on Nuclear Energy Competence in Finland provides a vital source of information on which to base the work of the SAFIR Steering Committee in this regard. Consideration should be given to including in such a wider oversight role such the following nuclear related disciplines:

a. Heavy electrical engineering;
b. Radiological protection and health physics;
c. Operational radioactive waste management including conditioning and storage;
d. Operational Events Feedback analysis;
e. Knowledge Management;
f. Ventilation;
g. Decommissioning;
h. Emergency preparedness;
i. Reactor site and plant layout;
j. Siting;
k. Transport;
l. Security;
m. Safeguards.

Some of these areas may be covered in other programmes but SAFIR should at least have some oversight of them.
In reality, it is likely that there will be cross overs and implications amongst research areas. New issues will probably involve a variety of disciplines and they cannot effectively and efficiently be pursued in isolation from each other. Consequently, it is recommended that:

Recommendation M.2
consideration should be given to managing the SAFIR programme on a theme basis rather than through a research area basis. This would then better reflect the reality of addressing new nuclear safety issues via multi-discipline expert teams and provide more opportunities to develop technical project management skills. Additionally it would enhance the SAFIR Steering Groups ability to ensure that the strategic challenges it identifies are addressed rather than, as at present, apparently having to rely too much on bottom up proposals emerging. Figure 1 below illustrates this approach:

![Theme Programmes Management](image)

**Figure 1: Proposed Change of the SAFIR Programme From a Topic Area Driven Approach to a Theme Approach**

A “basic science theme” is included to cover areas of development in fundamental science that are considered worthy of covering in SAFIR which otherwise would not be addressed. Themes may include such matters as ageing of plant, people and process, knowledge management, new reactor designs, climate change, defence in depth, 60 year plus lifetimes, new fuels, etc.

Such an approach would assist in addressing Recommendation M.1 above allowing themes to cross what at present are separate programmes. Figure 2 below illustrates this:
The Report of the Committee on Nuclear Energy Competences in Finland illustrates the challenge that faces Finland with its ageing expert population and expanding nuclear power programme. This implies that there will be a continuing and likely expanding role for the SAFIR programme. Also, it is considered beneficial for SAFIR to have a greater oversight role in relation to all nuclear safety related disciplines. Furthermore, the funding and costing arrangements for nuclear safety related infrastructure needs establishing on an on-going basis. This implies that there will need to be some increase in SAFIR budget. Thus it is further recommended that:

Recommendation M.3
a review should be undertaken of the funding for the maintenance, operational, development, etc of all relevant nuclear safety related research infrastructure such that it can be established on a sustainable basis; and

Recommendation M.4
the budget for SAFIR should be reviewed in line with the issues identified in the Report of the Committee on Nuclear Energy Competences in Finland, other challenges and any enhancement of its role as suggested above.

Finnish experts are heavily engaged in a series of international fora. This is very beneficial and should be encouraged. Not only does this act as a very useful peer review of their work, and levers their efforts through collaborative projects, but also demonstrates to the international nuclear research community Finland’s commitment to and capability for such work. It is considered that this could be enhanced further. It is recommended therefore that:

Recommendation M.5
Finland should host international conferences related to the SAFIR programme and thereby demonstrate further the high quality of its nuclear research under the programme.
At present, it appears that the SAFIR programme has two roles - funding nuclear research projects and funding infrastructure development. There may be additional ways of meeting the obligations of 53a of the Act that would add to the effectiveness of the SAFIR programme. It is recommended that:

Recommendation M.6
consideration be given to identifying additional ways to fulfil the requirements of 53a of the Nuclear Energy Act, such as funding academic posts in some areas.

It is not obvious that the recommendations of the previous evaluation (SAFIR2010) have been fully considered, sentenced and acted on as necessary. Some of these recommendations still appear relevant. Indeed, some are echoed to some extent in this report. It is therefore suggested that:

Recommendation M.7
the recommendations of previous evaluations be reviewed and reported on as part of the reporting of the SAFIR steering committee.

Finally, the panel has some further suggestions predominately related to the administration of the programme in the changing environment. This in no way should be construed as having any adverse comment on the excellent management of the SAFIR that was obvious to the panel. These suggestions are grouped below under a general recommendation, viz:

Recommendation M.8
consideration should be given to:

1. making more use of self-evaluation of the programme as feedback (section 2.1);
2. reviewing the flexibility of the programme to better respond to the impact of the fast changing operating (section 2.2);
3. providing a greater strategic steer, which would be assisted greatly by the adoption of M.2 above, (section 2.2);
4. seeking way to minimise the administration demands on researchers while ensuring proper reporting, oversight and governance (section 2.2);
5. identifying the need for Finnish expertise in nuclear technologies used elsewhere (section 2.3.A);
6. ensuring that the comprehensive Report of the Committee for Nuclear Energy Competence in Finland, published in 2012, is fully taken into account in future SAFIR programmes (2.3.A);
7. arranging a peer review of future draft SAFIR Framework Plans to provide more effective feedback at the start of such programmes thereby maximising an appropriate strategic basis and direction.
Appendix A

Evaluation Background Material

1. SAFIR2014 Overview Presentation, Ulla Ernsten.


6. SAFIR2014 Annual Plan 2011

7. SAFIR2014 Annual Report 2011

8. SAFIR2014 Annual Plan 2012


10. SAFIR2014 Annual Plan 2013


12. SAFIR2014 Archives of Publications of the Projects in 2011

13. SAFIR2014 Archives of Publications of the Projects in 2012
Appendix B

Steering Group, Area Research Group and End User Representatives in Evaluation Meetings

Steering Group
Jorma Aurela, Jaana Avolahti, Herkko Plit, MEE
Marja-Leena Järvinen, Keijo Valtonen, STUK
Liisa Heikinheimo, Olli Hoikkala, TVO
Sami Hautakangas, Kristiina Söderholm, Fortum
Hanna Virlander, Ilkka Männistö, Fennovoima
Eija Karita Puska, Pentti Kauppinen, VTT
Filip Tuomisto, Riitta Kyrki-Rajamäki, Universities

RG1:
Matti Vartiainen, Aalto, (chairman)
Ann-Mari Sunabacka-Starck, STUK
Matti Kattainen, Fortum

RG2:
Marti Välisuo, Fortum, (chairman)
Heimo Takala, STUK
Mauri Viitasalo, TVO
Lauri Tuominen, TVO

RG3:
Antti Daavittila, STUK, (chairman)
Kari Ranta-Puska, TVO

RG4:
Timo Toppila, Fortum, (vice chairman)
Mikko Lemmetty, TVO

RG5:
Risto Sairanen, STUK, (chairman)
Tomi Routamo, STUK
Lasse Tunturivuori, TVO
Marko Marjamäki, Fortum

RG6:
Martti Vilpas, STUK, (chairman)
Erkki Muttilainen, TVO

RG7:
Pekka Välikangas, STUK, (chairman)
Timo Kukkola, TVO
Juha Rinta-Seppälä, Fennovoima

RG8:
Ilkka Niemelä, STUK, (chairman)
Matti Lehto, STUK
Kalle Jänkälä, Fortum
Risto Himanen, TVO
Jari Pesonen, TVO
Antti Tarkiainen, TVO

RG9:
Risto Sairanen, STUK, (chairman)
Liisa Heikinheimo, TVO
Esa Mannola, TVO
Appendix C

Preliminary Summary

Presented at SAFIR2014 Exit Meeting, MEE, 7 March 2014

Main Questions

1. How well does it meet the goal of generating research aimed at:

   ‘... ensuring that, should such new factors concerning safe operation of nuclear facilities emerge that could not be foreseen, the authorities have such sufficient and comprehensive nuclear engineering expertise and other facilities at their disposal that can be used, when necessary, to analyse without delay the significance of such factors.’ (Finnish Nuclear Energy Act paragraph 53a)?

2. How effective is the programme in respect of funding, applicability of the results and the presence on the international forums?

3. How well does the expertise cover the nuclear safety research field to meet the goal in question 1? In particular:
   a. Is the entire SAFIR2014 programme balanced to all different fields in nuclear safety?
   b. Does it raise efficiently new experts?

4. Have the 2010 evaluation results been implemented successfully into the SAFIR2014 programme?

5. What are the main challenges and recommendations?

Comments on the Evaluation Process

- Extremely well organised
- Good presentations and reports
- Open and responsive
- Large amount of possible material
- Not expect to cover all available relevant technical material
- Changing environment
- More useful material than you think – spend more time looking at the self-evaluation process and internal checks and balances?
- Evaluation not finished – today is snapshot on initial thoughts and may well be changed with further work and today’s discussions

General Conclusions

- Extensive high quality programme
- Very impressive especially given the basis – learning for others
- Effective in promoting new experts and maintenance of basic infrastructure capability
• Effective co-operation between users without compromising respective roles and responsibilities
• Greater clarity needed on role of SAFIR in new environment
• Greater co-operation and cross linking of projects would be helpful
• Greater co-operation and cross linking with other nuclear research programmes, in particular those related to 53b - include other aspects related to safe use of nuclear energy
• Balance too much bottom up rather than strategic steer and direction
• Impressive high quality enthusiastic researchers
• Administrative arrangements excellent
• Demands on researchers may be able to be streamlined – amount of resources involved in governance and oversight compared to resources on programmes
• Rich material accumulated by the administration of the programme could be used more

Answers to the Main Questions

Initial Response to Main Question 1

1. How well does it meet the goal of generating research aimed at:
‘... ensuring that, should such new factors concerning safe operation of nuclear facilities emerge that could not be foreseen, the authorities have such sufficient and comprehensive nuclear engineering expertise and other facilities at their disposal that can be used, when necessary, to analyse without delay the significance of such factors.’ (Finnish Nuclear Energy Act paragraph 53a)?

Answer:
• Generally yes.
• However:
  - Some areas relevant for safety of nuclear installations not covered in programme
  - Dynamic situation with changing environment
  - Finnish nuclear installations only
  - Only some relevant Finnish nuclear safety related experimental facilities covered
  - Looking to the future leads to more need

Initial Response to Main Question 2

2. How effective is the programme in respect of funding, applicability of the results and the presence on the international forums?

Answer: It is effective:
• Higher level qualifications of new experts and involvement in international activities in all areas
• High quality of research, some world leading
• Projects are evaluated well using weighted marking system and involvement of end users in decisions and monitoring
• Outcomes of projects are monitored for: production of new higher degrees in an area, number and type of publications, international activity
However:

- May be able to increase effectiveness through using some of the funds in other ways to maintain/enhance available expertise rather than just through research projects - fund academic posts, host Finnish conference, etc.

Initial Response to Main Question 3

3. How well does the expertise cover the nuclear safety research field to meet the goal in question 1? In particular:
   a. Is the entire SAFIR2014 programme balanced to all different fields in nuclear safety?
   b. Does it raise efficiently new experts?

Answer:

- For the areas identified in the present programme it is balanced and it does efficiently raise new experts and seen by most end users as offering value for money.
- However there are some areas related to nuclear safety that are not covered in the programme such as:
  - Heavy electrical engineering
  - Radiological protection and health physics
  - Operational waste management
  - Decommissioning
  - Emergency preparedness
  - Reactor site layout
  - Siting
  - Transport
  - Security
  - Safeguards

Some of these may well be covered in other programmes but under the Act SAFIR should have at least an interest in them. Additional, some aspects covered by the present SAFIR programme may impact on other programmes, such as fuel burn-up research for optimisation of reactor operations may impact on research on spent fuel transport or disposal, or research on developing safety cultures on security cultures, risk communication and radiological protection on emergency arrangements, start thinking of developing expertise related to decommissioning now especially as input to new projects.

Initial Response to Main Question 4

4. Have the 2010 evaluation results been implemented successfully into the SAFIR2014 programme?

Answer:

- This is patchy with evidence in some areas of successful implementation whereas elsewhere the evidence is not so strong.
- This may be a reflection of the in-precise nature of some of the original recommendation or that the circumstances have significantly change.
- The reporting requirements may be able to be modified to better capture this aspect.
Initial Response to Main Question 5

5. What are the main challenges and recommendations?

Answer:

• Main Challenges
  - Increasing need for nuclear safety expertise and facilities with expanding nuclear programme and ageing expertise
  - Uncertainties in the use of nuclear energy in Finland
  - Changing society (e.g. social trust) and nuclear organizations
  - Complexity and new science/technology
  - Ageing plant and people (new generations over lifetime of plants)
  - Constructability and optimising standards/requirements
  - Having a wider overview of all nuclear safety related research, expertise and infrastructure – scope and synergies
  - Funding and controlling the maintenance and enhancement of nuclear safety related facilities
  - Closing down projects
  - Variability in project management

• Main Recommendations
  In line with the fundamental principle of nuclear safety - continuous improvement – I have offer suggestions for further enhancement of the programme to meet future challenges including:
    - extending SAFIR’s role to include oversight of all nuclear safety related expertise and facilities required to fulfill the obligations of clause 53a of the Nuclear Energy Act, and consider whether this should include the programme under 53b
    - increasing SAFIR funding to assist in addressing the future nuclear expert requirements identified in the 2012 comprehensive Report of the Committee Nuclear Energy Competence in Finland and to better address the emerging other challenges
    - review funding and cost apportion arrangements, especially for nuclear safety related infrastructure
    - considering ways other than through research projects of meeting the obligations of clause 53a
    - considering enhancing the delivery of the programme through managing it on a theme basis rather than a research area basis thereby building expertise on multi-discipline expert team working and associated project management multi-discipline research
    - increasing still further the involvement of Finnish nuclear experts and facilities in international programmes including hosting international conferences to, inter alia, demonstrate the world leading nature of some Finnish nuclear research.
Initial Comments on Specific Research Areas

Research Area 1 - Man, Organisation and Society

- Some very good and useful work
- Continue to take forward work on intercultural issues (present under SISIANS) and expand to cover aspects related to design, supply chains and construction
- Expand to include: nuclear industry structural issues; leadership impact on safety cultures and associated resilience of safety cultures under change of leadership; regulatory - industry relationships; impact of changes in society on safety cultures; etc.
- Lead work on risk communication reflecting societal and human aspects (at present in Research Area 8)
- Good increase in number of people involved and expertise pool growing

Research Area 2 - Automation and Control Room

- Some very useful and interesting work that has wider relevance and great connectivity (e.g. to PRA, Knowledge Management, Human Factors)
- Can it be better targeted on nuclear safety outcomes rather than appearing to looking at meeting standards?
- Opportunity to be better driven by an operator rather than a technical focus
- Perhaps more work at a system architect level
- Comprehensive reporting of work
- Mixture of large and small projects

Research Area 3 - Fuel Research and Reactor Analysis

- Physics modeling is impressive in both achievements and international links
- Some innovative work is being undertaken and in some areas Finland is leading internationally but is it taking full benefit from this position?
- Provides a firm basis for less experienced physicists and modelers to learn about advanced nuclear physics and the various techniques
- Suitably balanced area
- Near term milestones are clear but longer term major milestones are less clear and it is difficult to see when areas of work will end

Research Area 4 - Thermal Hydraulics

- Good use of international collaboration in what can be an expensive area
- Widespread engagement of less experienced practitioners and development of their expertise
- Good use of vital experimental capacity but needs further work to validate models in some areas
- More work needed in the area of spent fuel storage
- Possible linkage with non-SAFIR programmes involving spent fuel
- Scope for greater cross-linking with other areas
**Research Area 5 - Severe Accidents**
- Good international co-operation
- New people being brought up to speed
- Good spread of work across the area
- Passive safety work will become of increasing importance and challenging
- Opportunities to look at similar work undertaken in other industries?
- Greater scope for linking in with work in other areas
- Post Fukushima enhanced importance and excellent work done
- Scope for looking at wider range of spent fuel accidents

**Research Area 6 - Structural Safety of Reactor Circuits**
- Some excellent work undertaken
- Good mixture of analytical and experimental work
- International co-operation
- Some work on none primary circuit but could do more on non-metallic materials
- Useful development of inexperienced staff but some leakage that needs continual replacement

**Research Area 7 - Construction Safety**
- World leading in some areas
- Good participation in international work but more co-operation would be useful
- Potential for more cross cutting work
- Some areas where more work may be useful:
  - Double skin structures
  - Modular construction
  - Fundamental review of use of codes for nuclear structures
  - Greater use of integrated 4D modeling and integration of constructability into design
  - Use of other testing facilities at VTT and elsewhere

**Research Area 8 - Probabilistic Risk Analysis**
- Fire study work and extreme weather very useful
- Level 3 PSA important area and needs expanding
- Need to get PRA more into mainstream degree level engineering to generate larger pool of interest
- Potential to use in other areas such as disposal and consider interplay with OEF

**Research Area 9 - Development of Research Infrastructure**
- Unique part of SAFIR with different needs
- Review and control has to be different
- Funding arrangements may need to be different
- Expand to include all nuclear safety related research infrastructure to meet 53a (internal survey completed)
- Review, develop and agree business model to ensure adequate long term financing
- LUT enhancement very satisfactory and perhaps could go further