New European initiative - NULIFE network for plant life management

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ABSTRACT

The EU's Network of Excellence NULIFE (Nuclear Plant Life Prediction) was launched in October 2006 under the EURATOM FP6 Program with a clear focus on integrating safety oriented research on materials, structures and systems and exploiting the results of this integration through the production of harmonised life time assessment methods. NULIFE will help provide a better understanding of, and information on, the factors affecting the life of nuclear power plants which, together with associated management methods, will support their safe and economic long term operation. Led by VTT (Technical Research Centre of Finland), the five-year project has a budget in excess of EUR 8 millions, with partners drawn from leading research institutions, technical support organisations, power companies and manufacturers throughout Europe.

THE VISION OF NULIFE

Research and development to assess the service life of nuclear power plants is a multidisciplinary enterprise and must therefore take into account many factors. Lifetime assessment requires knowledge not only of the ageing of materials but also of factors such as load effects and reactor water chemistry and the influence of these on plant safety. Research data arising from this work has ultimately to be utilised for the development of safe and economic operation of existing nuclear power plants and the design of new units.

NULIFE's 5-year vision is therefore to create a virtual institute with an integrated RTD platform embracing all European stakeholders within a completely new structure with improved and efficient use of public and private RTD funding. It will provide the European nuclear power industry and national regulatory authorities with information and methods to assess the service life of nuclear power plant materials and structures, as well as to underpin strategies for upgrades or refurbishment. In particular, NULIFE will serve to support the harmonisation of lifetime assessment methods and practices for nuclear power plants throughout Europe. Best practices for the prediction of life time of reactors or systems will support strategic management in the decisions on upgrading the plant. The path towards the vision is described in Figure 1, proceeding through different phases of integration evolution and finally reaching NULIFE Institute with customer-driven programme.

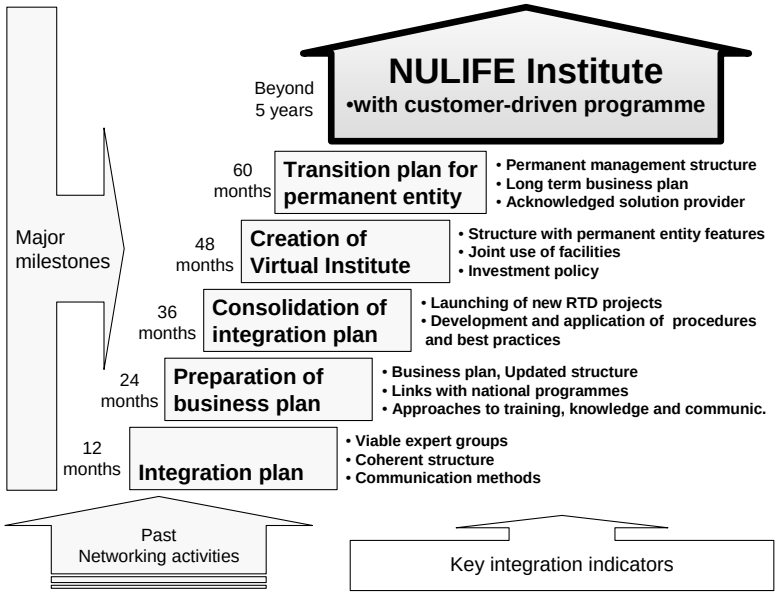

Figure 1. Planned organizational evolution during the five phases of NULIFE (2006-2011).

THE UNIQUE CONSORTIUM OF NULIFE

The core of the network comprises ten leading research institutions, technical support organisations and industrial enterprises from across Europe.

- VTT, Technical Research Centre of Finland, a Coordinator of NULIFE
- Studiecentrum voor Kernenergie - Centre d'Etude de l'Energie Nucléaire, SCK•CEN from Belgium
- Ustav jaderneho vyzkumu Rez a.s., Nuclear Research Institute Rez plc, NRI from Czech Republic
- Commissariat a L'Energie Atomique, CEA and Electricité de France, EdF from France
- AREVA NP GmbH from Germany
- European Commission Directorate General Joint Research Centre, JRC, from EC
- British Energy Generation Ltd and Serco Ltd from UK and
- Forsmark Kraftgrupp AB from Sweden.

The contractual arrangement is shown in Figure 2. The ten core organisations (contractors) are signatories to a Consortium Agreement, which defines the working arrangements and decision-making procedures in NULIFE. They are supported by the contributions of 27 organisations (Table 1) from industry and research, which contractually act as third parties under the full responsibility of contractors. A "Collaboration Agreement" mechanism is also applied whereby additional organisations can take part in specific activities on a discretionary basis but without any reimbursement of costs. This is intended mainly to facilitate the participation of utilities and other external stake-holders in the End User Group. The EU funding (EUR 5 million) is specifically targeted at a process of integration between the contributing research institutions and ensuring the long-term sustainability of the network. The third parties support this in several important ways:

- Provide a sufficiently broad representation of European nuclear countries and stakeholders to allow NULIFE to achieve its consensus/harmonisation objectives
- Contribute technically to investigation of priority issues and to assessment and benchmarking of proposed procedures, leading to their broad acceptance
- Contribute to the network's knowledge base of expertise and data from existing R&D programmes
- Provide an "in-built" mechanism for effective dissemination, both in terms of ensuring rapid uptake of proposed procedures as well as substantially extending the contact base of the network at national and regional level
- Increase the participation of PhD students and young professionals and widen the training base
- Provide increased options for mitigating possible changes to the consortium organisation
- Reinforce the influence of NULIFE at wide international level as being European Network/Centre of Excellence

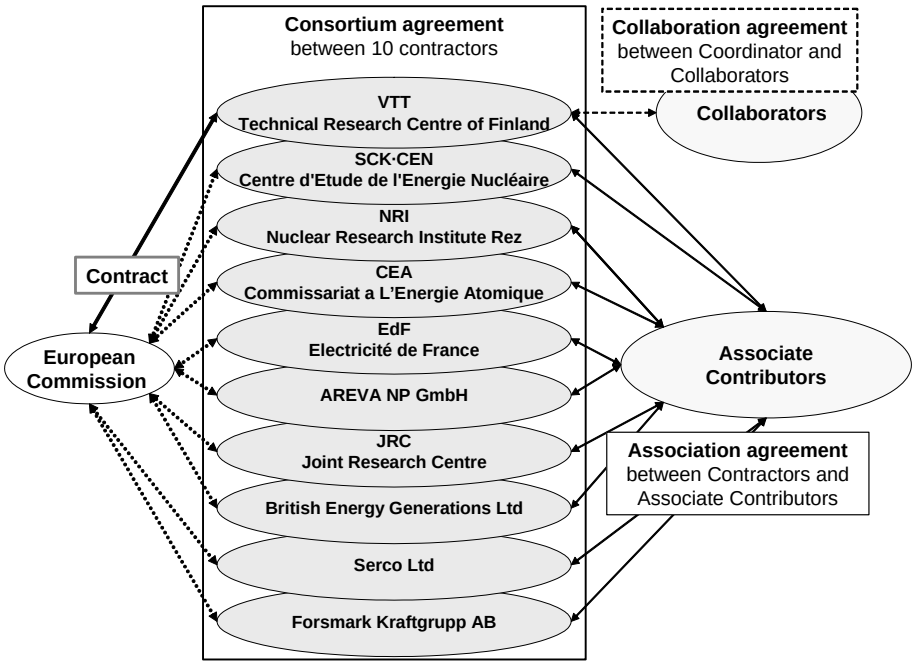

Figure 2. *The unique contractual structure of NULIFE consortium with third parties*

Table 1. Organisations participating in NULIFE as Associate Contributors.

Associate Contributors	Country
Institute of Metal Science - Bulgarian Academy of Sciences	Bulgaria
AREVA NP SAS	France
Institut de Radioprotection et de Sureté Nucléaire	France
Fraunhofer Institute for Mechanics of Materials	Germany
Forschungszentrum Dresden Rossendorf e.V	Germany
Gesellschaft für Anlagen- und Reaktorsicherheit mbH	Germany
Universität Stuttgart	Germany
Bay Zoltán Foundation for Applied Research	Hungary
AEKI Atomic Energy Research Institute	Hungary
Lithuanian Energy Institute	Lithuania
Nuclear Research & Consultancy Group	The Netherlands
Centro de Investigaciones Energéticas Medioambientales y Tecnológicas	Spain
Institute For Nuclear Research – Pitesti	Romania
Center of Technology and Engineering for Nuclear Projects	Romania
Vattenfall Research and Development AB	Sweden
Tecnatom, S.A.	Spain
Paul Scherrer Institut	Switzerland
Rolls-Royce Power Engineering PLC	UK
The University of Manchester	UK
"Josef Stefan" Institute	Slovenia
E.ON Kernkraft GmbH	Germany
ENEL Produzione S.p.A	Italy
Oskarshamm KG AB	Sweden
Studsvik Nuclear AB	Sweden
Westinghouse Electric Sweden AB	Sweden
Siempelkamp Pruef- und Gutachter-GmbH	Germany
Ringhals AB	Sweden

ORGANISATIONAL STRUCTURE OF NULIFE

The main organisational elements of NULIFE are as follows:

- **Governing Board** is the ultimate decision-making body of the Consortium and consists of one nominated representative of each contractor. Nominated representatives of the associate contributors also have the right to participate to the Governing Board meetings as observers.
- **Executive Group** is responsible for the execution of the agreed work programme and comprises nominated representatives of the Work Package (WP) leader organisations.
- **Infrastructure Group** (a sub-group of the Executive Group) develops common platforms for network administration, for experimental testing and investigations, for simulation and analyses, for data management, documentation and software tools.
- **Expert Groups** provide a mechanism for coordinating and integrate the available expertise of the researchers nominated by each of the participating organizations, for supporting the research projects and for developing advanced technical methods; the Expert Groups may have sub-groups dedicated to specific technical areas.
- **End User Group** is composed of representatives of participating utilities, other end-users and manufacturing industry; its role is to give advise on concerning research directions and to select and propose the research priorities together with the NULIFE Executive Group.

The work programme (referred to as the Joint Programme of Activities or JPA) consists in a series of work packages (WPs), which are clustered in three main areas: integrating activities; R&D support activities and spreading excellence activities (including training). The interaction between the WPs and the organisational groups is shown schematically in Figure 3.

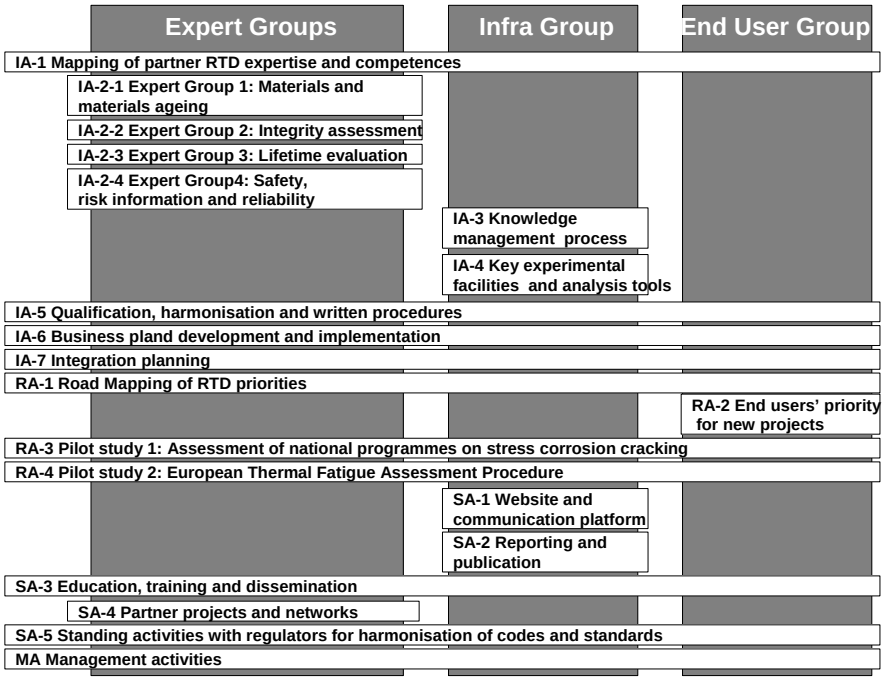

Figure 3. The main interactions between organisation groups and the cross-cutting work packages.

MAPPING OF EXPERTISE AND EXPERT GROUP ACTIVITIES

NULIFE brings together a broad range of scientific and technical competences, facilities, tools, data, operating experience and organizational skills which must be effectively integrated into the network structure and work programme (Figure 4). An important first step is therefore to perform a comprehensive mapping exercise. As a result of this complementary and overlapping resources will be identified, together with any 'gaps' that have to be addressed.

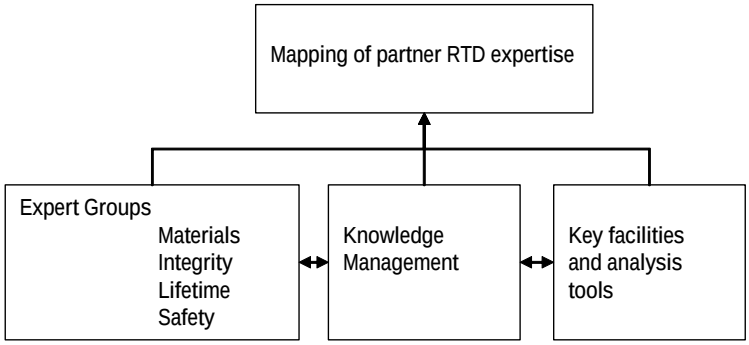

Figure 4. Integrating Activities (IA) for the development of expertise, facility and knowledge clusters for the litetime management.

The NULIFE questionnaire for mapping expertise has been launched. Research organizations and service providers are asked to define the current expertise, and end users and vendors are asked to define strategic needs. This covers different reactor types, experimental conditions, system and component types as well as material types. Life management expertise is broken down into areas such as degradation modes, load effects, condition monitoring, inspection, integrity assessment and safety management. Testing facilities, organization/process related expertise, dissemination skills as well as design, manufacturing, operation expertise are also all being considered.

The coordination of the network's combined expertise is managed principally via a system of Expert Groups covering the following generic technical areas:

- Materials Expert Group (EG1) deals with the material property issues, in particular the mechanisms of materials degradation (Environment Assisted Cracking, thermal ageing, irradiation embrittlement) and characterization of the properties of aged materials, i.e. as a function of in-service conditions.
- Integrity Expert Group (EG2) is concerned with establishing state-of-the-art in methods and tools for of assessing potential damage or failure modes. It deals not only with fracture mechanics methods, but includes also a consideration of existing Codes and Procedures, Non Destructive Examination, safety factors and certain special topics (effects of load history, crack arrest, secondary and residual stresses, WPS).
- In Lifetime Expert Group (EG3), the knowledge gaps identified by the other expert groups will be assessed in terms of their implications for through-life structural integrity. In addition, an assessment will be made of the potential for, and possible implications of, knowledge gaps outside the scope of the other expert groups. Lifetime Expert Group will take a long-term perspective of component integrity, in particular the safety justification of components over the whole of their foreseen operational life, where the demonstration of safety margins becomes dominated by considerations of fatigue (including thermal fatigue and corrosion fatigue), irradiation embrittlement and other ageing processes (including creep and creep-fatigue).
- Safety Expert Group (EG4) will add to other Expert Groups to support the Network by providing advice on identification, characterisation and management of uncertainties in lifetime evaluation, through modelling structural reliability and performing risk assessments to provide added insights into the assessment of safety margins.

The researchers named by the participated organizations are allocated to one or more of the Expert Groups (Figure 5). Each group is lead by a Contractor organisation and is coordinated by a committee representing the main technical interests. Their principal tasks are:

- plan and implement a strategy for developing NULIFE's technical expertise in the relevant area
- planning and execution of R&D and harmonisation projects, via teams selected from the EG's pool of expertise
- support horizontal network WPs such as expertise mapping, knowledge management, training, dissemination etc.

Each EG may have sub-groups dealing with specific technical topics. The EG coordination committees meet at network meetings, but sub-groups on may hold separate meetings.

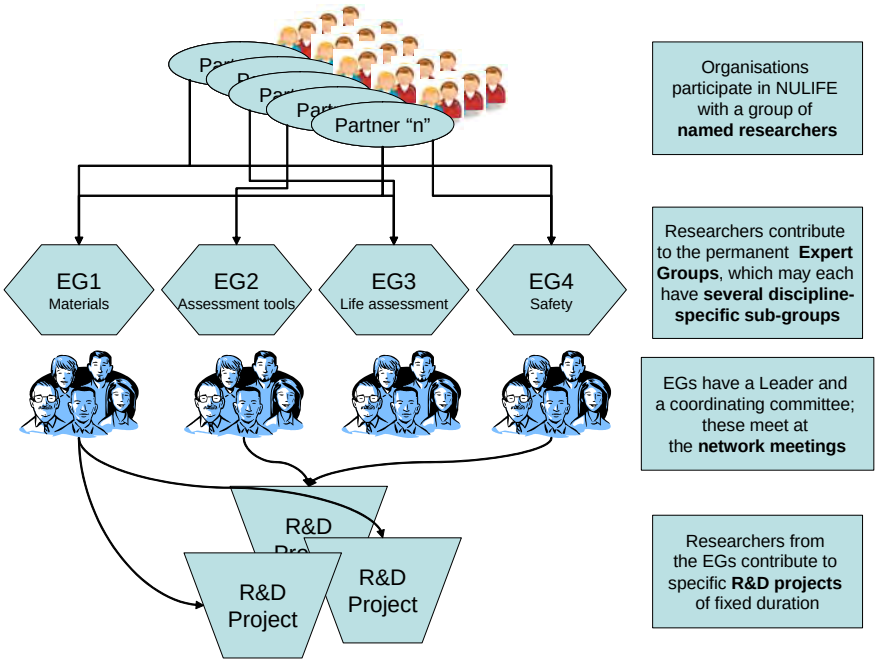

Figure 5. NULIFE's Expert Group system for integrating the efforts of the researchers nominated by the participating organizations.

RESEARCH AND DEVELOPMENT PLANNING

Effective developing R&D projects to meet stakeholder needs is essential to NULIFE's strategy. The overall process is shown in Figure 6, which underlines the End User Group's key role in setting priorities and responsibility of the Expert Group members for developing and executing projects designed to meet those needs. The network work programme therefore has a dedicated work package (RA-1 R&D Road Mapping) that is tasked to:

- set up and implement a systematic and clear process for identifying necessary research topics for NULIFE
- define the necessary work programmes
- make recommendations to the Executive Group for implementation.

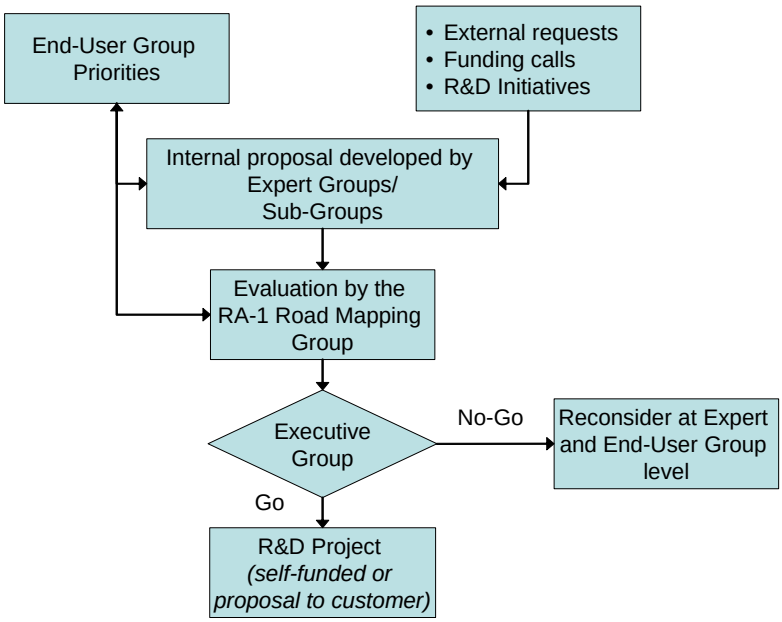

Figure 6. Flowchart for development, evaluation and approval of R&D and harmonization projects

This group has developed a system of six evaluation criteria (EC), covering technical issues relevant to operating and future reactor designs and also the strategic goals of the NULIFE Network of Excellence in promoting integration and harmonisation within Europe via the creation of a durable Virtual Institute:

- EC1 - Need: Is there a need for the research activity and what are the technical issues? What are the consequences of not performing this activity? Can the technical issues be mitigated by appropriate inspections?
- EC2 - Gaps: If the technical area is/has been the subject of research within Europe (or elsewhere) and the results are/will be available to NULIFE, does the proposed research complement that existing work? Does it address known gaps in current research? Alternatively, is the work novel?
- EC3 - Relevance: Is the proposed activity applicable to one or more than one currently operating or future reactor design, or is it type-specific? Has the degradation matrix or similar measure (see Section 2) included the scope of this activity? Is the work 'research' or 'plant assessment' in nature?
- EC4 - Timescale: Are the planned objectives realistic, both technically and with regards to the planned timescales?
- EC5 - Resource: Are the necessary resources (people, equipment, finance) available to NULIFE for the duration of the planned research?
- EC6 - Integration: Does the activity contribute to the integration of European research and harmonisation of approaches, consistent with the aims of NULIFE? Does it contribute to the maintenance of key nuclear skills and facilities within Europe?

In parallel to this, the identification selection of R&D and harmonisation has been started by the End-User Group (Table 2). In its initial meeting the Governing Board of NULIFE has also emphasized the importance of concrete structures and cables, underlined the intention that NULIFE will have a broad scope

Table 2. The End User Group's preliminary identification of research topics and application areas.

	Application areas:			
Preliminary End User Group proposals for research topics	Reactor pressure vessel and internals	Coolant system and lines	Steam generators	Other components
Thermal fatigue	**X**	**X**	**X**	
Stress corrosion cracking	**X**	**X**	**X**	
Welds and weld repairs	**X**	**X**		
Clad properties and ageing	**X**			
Safety factors/uncertainties in damage evaluation	**X**	**X**	**X**	
Stress classification		**X**		
Other ageing issues				**X**

The interest shown for stress corrosion cracking and thermal fatigue lead to these topics being chosen as the two pilot R&D projects. The respective goals are as follows:

- The stress corrosion cracking pilot project will exploit the results from relevant national programmes in which NULIFE members participate, by an information sharing process involving both the contractors and third parties. The deliverables will be an integrated database on environmental assisted cracking (EAC) of light water reactor materials, together with best practice guidelines on EAC testing.
- The thermal fatigue study will exploit results from recent international and European projects. Its main tasks include:
    - Complete the validation database for thermal stratification and thermal striping type damage
    - Extend the knowledge base on thermal hydraulic boundary conditions for high frequency loading in mixing zones of piping including probabilistic aspects
    - Extend the assessment procedure and review the best practice in predicting fatigue damage accumulation using both phenomenological criteria and proper material modelling and also provide recommendations for fatigue crack growth
    - Provide recommendation on fatigue curves, including implicit or explicit consideration of environmental effects

By providing research excellence and fostering common approaches in nuclear power plant lifetime prediction, NULIFE will contribute to the Electric Power Utilities' decision making in terms of plant operation and investments. Safety Authorities will also benefit from the knowledge in their duties to grant plant licenses for the continued operation of plants.

The ability of the network to deliver procedures and best practices documents on ageing issues will be an important measure of the network's impact. At the highest level, NULIFE will support the development of a European Common Safety Justification Framework. Since lifetime management tools are only one element in such a framework, its development will require support from other stakeholders. The broad composition of the network is a major advantage in this respect.

FUTURE TRENDS

The main technical issues that are likely to be important for lifetime management in the future are to gain a better physical understanding of ageing related damage mechanisms, to develop qualified methods for detection, surveillance and control of degradation and to develop predictive models and analysis tools.

For plant life management, analyses must show that the plant will continue to operate within its design basis. Where a change in operation is desired there will be a need for safety analyses to cover the new operational conditions. The future challenges need to have an adequate knowledge of the current design basis of the plant, to have a correct picture of the actual state of the plant and to define the analyses needed to support long-term operation within its design basis. This requires relevant and qualified generally accepted data bases and methodologies.

Risk-informed and PSA methods will be increasingly used, e.g. to identify any excessive risk contributors, to evaluate relative significance of safety issues arising from deterministic reviews, to help prioritise corrective actions and to

evaluate the effect of proposed plant or procedural modifications. Current ISI programmes are based on experience feedback and engineering judgements through a deterministic analysis. In future, more use of probabilistic safety analysis (PSA) is needed for planning of ageing management programmes. In addition, studies are underway for development of alternative methodologies for proposing an ISI programme which is in compliance with the required safety level. Periodic Safety Review (PSR) will play an important role in future in reviewing the viability of R&D and industrial infrastructure to support safe NPP operation.

Due to the current boundary conditions in the educational system, there is concern that in the future there will be less possibilities to recruit qualified personnel with knowledge from specialised vocational education. At the European level a well defined structure for training should be established. Further development of the so-called Eurocourse, offered by a consortium of organisations and covering all safety related aspects for pressure-retaining components during operation of nuclear power plants, should be continued.

Lifetime management, being a multidisciplinary process, creates a strong need to navigate, share and integrate the existing knowledge as well as to co-ordinate the initiation of new R&D activities in the international level. Future form of networking need to exploit the experience of the running networks which provide an excellent forum for specific areas. In addition to such present activities, more emphasis is needed on qualification in all relevant technical disciplines and on effective knowledge management important to PLIM.

CONCLUSIONS

NULIFE network of excellence is a new initiative for an integrated RTD platform, embracing all stakeholders at European level.

NULIFE aims to improve the delivery to end-users of best-practice life assessment methods to support optimized ageing management programmes for existing nuclear power plants and also to new builds

NULIFE intends to use of public and private RTD funding in an optimized way to launch new projects.

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