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D4.1_Roadmap of R/D needs for a better understanding of the human factor

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D4.1 - Roadmap of R&D needs for a better integration of human and organisational factors in the design and operation of nuclear installations

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Project coordinator

François Dionis, EDF - francois.dionis@edf.fr

Project partners

- ELECTRICITE DE FRANCE S.A. (EDF), France
- BRITISH ENERGY GENERATION LIMITED (BE), United Kingdom
- NUCLEAR RESEARCH INSTITUTE REZ PLC (NRI), Czech Republic
- VUJE, Slovakia
- INSTITUTE FOR SAFETY AND RELIABILITY (ISaR), Germany
- COMMISSARIAT A L‟ENERGIE ATOMIQUE (CEA), France
- TECHNICAL RESEARCH CENTRE OF FINLAND (VTT), Finland
- ABB AG, Germany
- IFE, Norway
- ERDYN CONSULTANTS, France
- ATOS ORIGIN NEDERLANDS B.V., Netherlands

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EXECUTIVE SUMMARY

MMOTION is a support action launched under FP7 targeting a better understanding of the Man-Machine-Organisation (MMO) research challenges related to the operation and the design of nuclear installations. Its main goal is to provide guidance for future research on subjects dealing with MMO and related safety aspects, and to develop a European roadmap for MMO research in the medium term, i.e. for a period of five years. With regard to this time frame, the project focused on research requirements that are related to the design and the operation of Gen II and Gen III plants.

The MMOTION approach to the definition of relevant MMO research priorities is based on the understanding that the different expert communities involved and their different views should be integrated more closely within future research programmes. The technical systems, the behaviour and attitudes of the human beings using the installation, the design perspectives, and the organisation of people and processes involved in the system's operation and maintenance are therefore considered as closely connected. The links to external factors such as actions and attitudes of regulators and other external stakeholders, market forces, national and international standards and regulations, and education and training programmes are also taken into account. The aim to achieve such integration at a European level has been a main driver for identifying European research needs.

The process for developing the MMOTION research roadmap has been in different phases, considering the international state of the art, the MMO related challenges, the main drivers for future developments, and the main stakeholders' perspectives on MMO related needs. This process resulted in the identification of 26 research topics considered most relevant in a European context and a grouping of these topics into four Research Programmes (RP) grouped around the needs of main stakeholders in nuclear safety, plant operation, plant design activities, and I&C component development:

- RP1 "Risk informed decision-making in design and operation" dedicated to balancing human and technological contributions to minimise the risk in the operation of nuclear installations;
- RP2 " Culture and practices for safety" aiming at better understanding the conditions for achieving robustness in the organisation of nuclear installations operation;
- RP3 "Integrated design approaches" focusing on better integrating human and organisational factors within the design of future nuclear installations or the renewal of existing I&C systems;

- RP4 " Technological requirements in nuclear and other high risk industry" aimed at achieving better coherence between the products offered by the industry for I&C systems and the specific needs of the nuclear and other high risk industries.

All four research programmes include three stages: a first stage comprising research to be addressed from the very beginning of the programme; a second stage comprising research which can or should start later; an integration phase to consider results from other phases and programmes. Those links to other programmes and related coordination mechanisms are required because results of several research topics are relevant to more than one research programme.

Budget estimates are given with reference to the scope and the complexity of the work to be performed, to the degree of innovation to be achieved, and to the number of countries and organisations expected to participate in the research.

A main pillar of the MMOTION working process was a structured exchange over two years between project partners representing different stakeholders, different expert communities and different EU Member States. The results of the project and particularly the research roadmap thus represent a broad consensus taking into account the diverse points of views of utilities, industry and research centres as well as the perceptions and strategic agendas in different European countries.

Regarding the implementation of the research programmes it is proposed to build on the structure of European nuclear fission research which is emerging under the SNETP umbrella. The following implementation mechanisms are considered most appropriate:

- Future calls of the Euratom Framework programmes for RP1 and RP2 as these programmes are strongly related to safety issues of high public interest.
- The industrial initiatives emerging under the SNETP umbrella for RP3 and RP4 because these programmes mainly respond to needs of the industry with respect to the long term operation of Gen II plants and to Gen III developments.

The MMOTION project also considered non-European MMO research initiatives related to nuclear fission energy. As some of those activities are very significant, especially in the USA, it is proposed to share part of the proposed research with non-European and international organisations. In view of the relatively small number of European research organisations with a focus on MMO challenges in nuclear facilities, a networking approach for MMO is considered useful in view of sharing parts of the research programmes established and to initiate negotiations with the relevant organisations.

RESEARCH TOPICS INDEX

Number	Research Topic
1.1.1	Classification and evaluation of automation types
1.1.2	Harmonisation of operational principles
1.1.3	Solutions for balancing I&C reliability and functionality
1.1.4	Man in the loop
1.1.5	Operation support
1.1.6	Managing the life-cycle of I&C at the European level
1.2.1	Innovative human-system interaction concepts
1.2.2	Advanced interaction technologies and their applicability in the nuclear field
1.2.3	Usability of HSI solutions
1.3.1	Development of shared representation supporting integrated design
1.3.2	Managing socio-technical systems complexity at the design level
1.3.3	Proactive task analysis as part of design
1.3.4	Integrated design of socio-technical systems
2.1	Safety culture
2.2	Robustness and vulnerability of organisations
2.3	Safety management practices
2.4	Risk management
2.5	Staffing
2.6	Analysis of work practices
2.7	Human performance tools
2.8	Teamwork
2.9	Occupational health
3.1	Human reliability analysis methods
3.2	Verification and validation
3.3	Operating experience on human and organisational factors
3.4	Tools and methods for assessing individual and crews

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GLOSSARY OF ACRONYMS

MMOTION	Man Machine Organisation through Innovative Orientations for Nuclear
CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives
CSCW	Computer Supported Cooperative Work
DoE	Department of Energy
DS	Deployment Strategy
ETPIS	European Technology Platform on Industrial Safety
EU	European Union
EPR	European (Evolutionary) Pressurized Water Reactor
EPTIS	European Technology Platform for Industrial Safety
Gen II	Generation II reactors (built up to the end of the 1990s)
Gen III	Generation III reactors (new evolutionary designs)
Gen IV	Generation IV reactors (next generation designs)
FP	Framework Programme for Research and Technological Development
FP7	Seventh Framework Programme
HAMMLAB	Halden Man Machine Laboratory
HF	Human Factor
HOF	Human and Organisational Factors
HU	Human Performance
HRA	Human Reliability Analysis
HSI	Human System Interface
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
INPO	Institute of Nuclear Power Operations
INSAG	International Nuclear Safety Advisory Group
ISV	Integrated System Validation
LTO	Long Term Operation
MERMOS	Method for assessing the completion of operator actions for safety
MMO	Man-Machine-Organisation

MMS	Man-Machine System
NII	Nuclear Installations Inspectorate
NRI	Nuclear Research Index
NoE	Network of Excellence
NPP	Nuclear Power Plant
NULIFE	Network of Excellence for Nuclear Plant Life Prediction
NULIFE Association	Association emerging from the NULIFE NoE
OEF	operational experience feedback
OE	Operating Experience
OHS	Occupational Health and Safety
PRA / PSA	Probabilistic Risk Analysis / Probabilistic Safety Analysis
R&D	Research and Development
RP	Research Programme
SCADA	Supervisory Control and Data Acquisition systems
SET	Strategic Energy Technology
SRA	Strategic Research Agenda
SNETP	Sustainable Nuclear Energy Technology Platform
TSO	Technical Safety Organisation
TWG	Technical Working Group
VR	Virtual Reality
VTT	Technical Research Centre of Finland
V&V	Verification and Validation
WGHOF	OECD/NEA Working Group on Human and Organisational Factors

1. Introduction

1.1 MMOTION Project Objectives

The main objective of the MMOTION project is the establishment of a European research roadmap dedicated to Man-Machine-Organisation (MMO) challenges in the nuclear field and corresponding safety related aspects. The aim is to provide the European Commission with a common European vision for R&D policies in the framework of FP7/EURATOM and beyond. It is based on an analysis of current and future needs within the nuclear industry and addressing human and safety factors related to the range of engineering, operation and maintenance activities in nuclear facilities. Special attention is to research at the European and international level which is needed to complement the ongoing national research in the MMO domain.

This report describes the project's main results, i.e. the proposed contents and structure of research that is required with special regard to the needs for improved integration of human and organisational factors in the design and the operation of nuclear installations. The selection of MMO topics addressed by this roadmap is based on the following high-level view on functions and activities implemented in the plant:

- Functions within a plant are carried out by people, supported by technology. Therefore, any design project carried out in this context should be considered as a socio-technical system design, not just as the design of technology or as fitting the technology to the humans. Therefore, one important factor for every design project is the physiological and cognitive properties of the human designing the system as well as the human using the system and how these properties are shaped by the organisational framework and other non-technical determinants such as safety culture and management practices.
- The organisational structures of the plant may either support or impede good interaction among individuals of the teams. Other factors influencing interaction between people are communication skills of the individual staff member and availability of support methods and tools. As most activities within the plant life cycle require multidisciplinary teams to be carried out properly, one major focus of the MMOTION project was to facilitate communication between people working within different disciplines.
- Particular attention has been given to the fact that MMO research must deal with complex human and technical systems and that performance of this system is closely linked to several dimensions of the socio-technical system. The appropriate management of complexity itself and the proper simplification during design is a major research challenge. Complexity also influences the ability of the human to understand the performance of the technology and to monitor and take over in case any technological component should fail.

- Finally the evaluation of the dependability of the socio-technical system is a major issue. Diverse methods should be applied to achieve an adequate assessment of this aspect. In particular the reliability of the human is important.

The MMOTION roadmap provides a set of MMO research areas defined as coherent clusters of research topics identified and assessed during the project with respect to their significance and their priority for a five year's reference period. It includes proposals for the next steps in view of implementing the proposed European MMO research.

It should be noted that the views presented in this project are the expression of a consensus among the project participants and do not necessarily express the opinion of individual partners.

1.2 How we hope this deliverable to be used

This report is intended to be used as:

- a set of coherent information for structuring the MMO parts of future EU research activities: definition of research priorities by activities under the SNETP umbrella such as the Gen II/III Working Group and NULIFE, elaboration of future calls within Framework programmes for EU research;
- a vision of research needs for national research programmes,
- a basis for co-operation with organisations outside Europe and for the development of common research programmes,
- a basis for negotiation with non-nuclear risk industries for potential collaboration in MMO research.

1.3 Timeframe for Research

Present day strategic planning for nuclear energy research generally relates to a longer time frame covering the operation of the current fleet of nuclear power plants (Generation II plants) including the extension of their operational lives as well as future reactor generations which are under construction and/or under development.

In the latter categories two main families are distinguished:

- Generation III reactors are essentially based on the proven technology of the most advanced current plants with additional "evolutionary" improvements mainly aimed at improving safety features and at reducing costs.
- Generation IV reactors are based on innovative concepts requiring more time for technological development and are assumed to be available for the market at a later stage. Depending on the technology use, deployment of those reactors may start in about three decades.

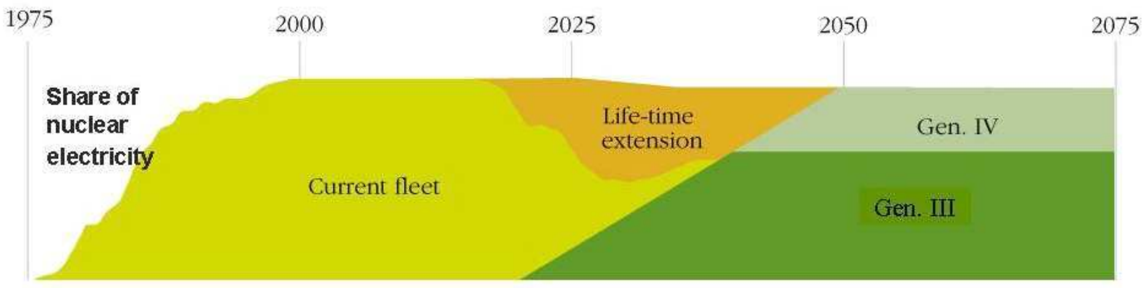

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Fig. 1-1: Deployment of generation III and IV reactors in the 21st century[1]

Regarding the MMO domain, the requirements for Generation II and Generation III plants are quite close: Both plant generations are using almost the same physical processes, and will be based on hybrid I&C technologies, as the refurbishment of Generation II plants is continuing.

According to the objectives of the MMOTION project, the work programme and the roadmap presented in this report focuses on a medium term research covering a period of approximately five years starting about one year after completion of the MMOTION project.

According to these technical and organisational considerations the attention of the MMOTION project is mainly on topics related to the design and the operation of (refurbished) Gen II and on Gen III plants. However, the knowledge developed within these projects should also be relevant for GEN IV plants.

1.4 The Significance of Man-Machine-Organisation Aspects and Research

1.4.1. Explanation of the MMO domain

The performance of technical systems depends on three main factors:

- The behaviour and attitudes of the human beings using the facility
- The technical design
- The organisation of people and processes involved in the system's operation and maintenance

These factors and their interaction must be a key consideration for designing and operating every large technical system and even more nuclear power plants needing a high level of

[1] Vision Report of the Sustainable Nuclear Energy Technology Platform, 2007 (Source: EDF, ENC, 2002)

safety. Examples of such factors are plant automation, information systems, human-system interfaces, staffing, work practices, plant organisation, management of change, management of operating experience feedback.

Traditionally many of these aspects were considered separately by specific communities of experts. With increasing demands on safety and economy, it is more and more important to proceed to a more integrated approach considering the many interactions between the various aspects and bridging the different expert communities. In this perspective, the nuclear power plant is understood as a technical system interacting with the humans and the organisational provisions involved in the plant operation. These are linked to a number of external factors such as actions and attitudes of regulators and other external stakeholders, market forces, national and international standards and regulations, and education and training programmes.

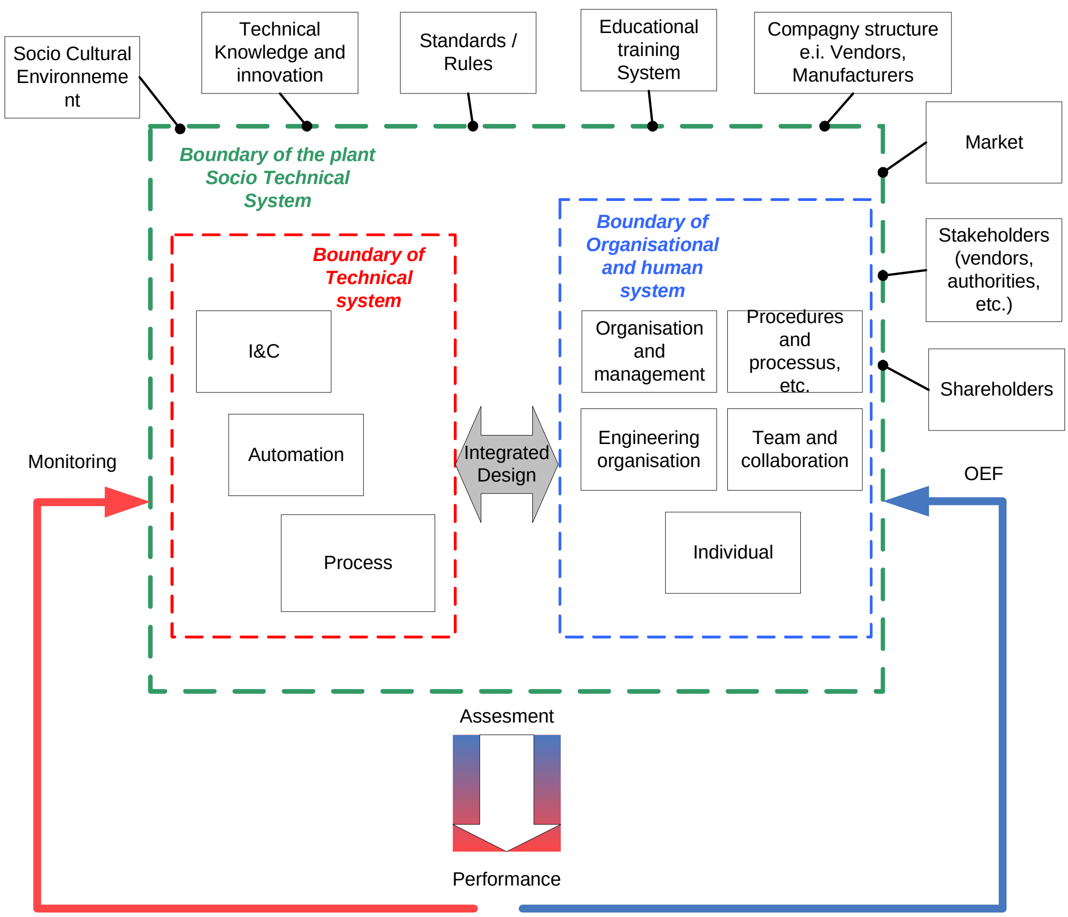

Fig 1-2: Integrated MMO view on a nuclear power plant

1.4.2. Drivers for research

As explained above, the functioning of a nuclear power plant as an MMO system depends on the interaction of many factors which are generally themselves subject of technological evolution and/or other kinds of change. Some of these developments pose challenges for the safe operation of the plants whilst others offer opportunities to strengthen the economical performance and/or the operational safety. In many cases those developments call for research in view of identifying the most appropriate responses.

The following developments have been identified to be particular drivers for the near term research needs in the MMO domain:

- There are important forces in the energy market resulting in an increased drive for productivity and organisational changes in the NPP such as outsourcing and reduction of personnel. Balancing productivity and safety is becoming an increasingly challenging practical issue.
- New digital technology is arriving and its implementation needs a better understanding of all the aspects related to its use including its integration with conventional technology. We have to consider that human factors play an even larger role for those hybrid solutions raising new issues in terms of individual and team performance.
- Trend towards more international engagements of the operating organisations and the resulting need for standardised operation, e.g. by harmonisation of operating practices, within Europe. In parallel there is a clear tendency towards international cooperation of regulators and the development international regulatory standards.
- Due to the small size of the nuclear market and the high level of technical requirements for systems, vendors may not be interested in developing I&C equipment if there is not more international standardisation of product requirements.
- The new generations of experts and plant personnel joining the workforce are from different demographics, have different educational backgrounds, different approaches to co-operative working, and adapt different behaviours for facing novel digital technology.

It is recognised that meeting the specific needs deriving from those drivers requires continuous efforts in fundamental research on human and organisational factors.

1.5 MMO-related Initiatives and Programmes

There are several initiatives and programmes at the European level and outside Europe that are relevant for identifying future MMO research priorities. They include initiatives aimed at identification of general or specific MMO related research needs and priorities as well as research programmes in the MMO domain which have been launched by national or international organisations. Such “external input” and its relation to the MMOTION roadmap are described in the following sections.

1.5.1. SNETP and NULIFE

The Sustainable Nuclear Energy Technology Platform[1] (SNETP) was launched in 2007. It presently gathers about 80 European stakeholders from industry, research and academia, technical safety organisations, non-governmental organisations and national representatives. The SNETP promotes research, development and demonstration of the nuclear fission technologies necessary to achieve the goals of the Strategic Energy Technology (SET) Plan in this field:

- For the year 2020: maintain competitiveness in fission technology and provide long-term waste management solutions,
- For the year 2050, complete the demonstration of a new generation (Gen IV) of fission reactors with increased sustainability and enlarge nuclear fission applications beyond electricity production.

A major aim of the SNETP is the identification and prioritisation of future research required to meet these goals. A Strategic Research Agenda (SRA) was issued in 2009 and a (research) Deployment Strategy (DS) in 2010. A prioritization of research topics and an implementation plan are under development. In principle theses activities address the full range of aspects relevant for the SET plan objectives. The outcomes should therefore build a kind of umbrella for any action dealing with needs of research in a more specific area related to nuclear fission energy, including MMO. The SRA, for instance, addresses in general terms some MMO–related research areas such as the human-system interface (HSI), the harmonisation of methodologies to assess the reliability of digital I&C, harmonisation of methodologies for probabilistic safety assessments (including human and organisational aspects), upgraded HSI, and simplified operation.

For its ongoing work the SNETP has adopted a structure with three pillars (see Fig. 1-3), with the intention to developed them into industrial initiatives:

- a Technical Working Group (TWG) on Gen II and III reactor technology,
- a Nuclear Cogeneration Working Group,
- ESNII: the European Sustainable Nuclear Industrial Initiative (established).

According to its general mandate the Gen II/III TWG will focus on R&D on Generation II and III type reactors and related cross-cutting R&D with the objective to coordinate, prioritise, monitor and report on Gen II/III R&D activities described in the SRA and prepare the relevant part of the implementation plan. This very broad scope covers the MMO research that has been considered within the MMOTION project.

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[1] http://www.snetp.eu

Another initiative linked to SNETP and to the MMO domain is NULIFE. NULIFE started as a Network of Excellence (NoE) within FP6 with the objective to provide harmonised R&D at European level to the nuclear power industry and to safety authorities in the area of lifetime evaluation methods for structural components. The NoE partners plan to transform this network into an association serving as a basis for customer-driven research programmes related to a broader scope of long term operation (LTO). This will address aspects such as different ageing problems, pre-normative research on codes and standards, and safety issues in instrumentation & control and electrical systems. This scope, too, covers part of the MMO research which has been considered within the MMOTION project.

Both the Gen II/III TWG and the NULIFE initiative are acting under the SNETP umbrella and are intended to cover (part of the) MMO related research needs addressed by the MMOTION project. Both initiatives could therefore serve as an umbrella for (part of) the research activities proposed by MMOTION. The working relations between the Gen II/III and NULIFE are still to be established, however. It is therefore considered necessary to co-ordinate with both Gen II/III and NULIFE the concepts for implementation of future European MMO research related to nuclear fission energy.

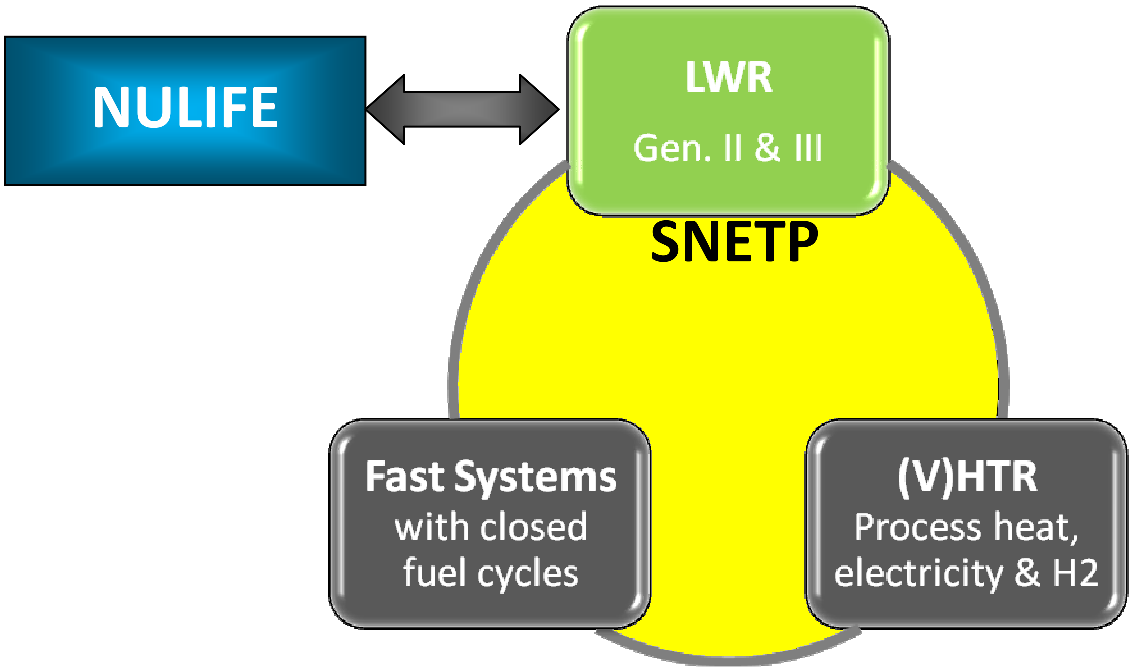

Fig. 1-3: SNETP Pillars and NULIFE

1.5.2. The ETPIS platform

The scope of the Industrial Safety Technology Platform[1] (ETPIS) is the integrated and coherent treatment of the important aspects of design, production and operation of industrial products and systems, dealing both with technical and with human, organisational and cultural aspects, as well as the actual systems and processes used for managing safety. Concerning Human and Organisational Factors (HOF) the main research domains are in this order of priority:

- Human and Organisational Factors in safety management:
  This First domain concerns the improvement of the organisations, the managerial and working practices, the feedback of experience, the safety culture, the decision making processes concerning safety and also the communication concerning HF.
- Human-Centred design:
  This topic concerns the development of methods and tools permitting the integration of human and organisational aspects in the design of new plants/equipment projects but also the revamping and modifications projects of the existing at-risk industries processes (including the integration of New Technologies of Information and Communication in the existing processes).
- Integrated Risk Assessment and Management Methods & Techniques:
  Automation, tasks sharing, organisation, working load all have an influence on the operator performance and the Integrated Risk Assessment systems requires qualitative and quantitative data. The research in this domain will focus on production of knowledge, data and methods in order to introduce dynamically, these latent conditions in safety analysis.
- Human Performance and technology usability:
  It concerns the development of knowledge related to human performance in virtual environment, team errors and decision making processes for the development of HSI or assisting systems for specific populations or working conditions.
- Human factors in emergency and crisis management:
  What are the most suitable organisational set-ups during emergency and crisis management should be one of the primary points of attention of the HOF research in the next years to come. The use of VR applications will be particularly suitable for testing reactions and predicting the dynamics of complex scenario where many actors play a key role in the resolution of the situation.

Considering these research domains and further priorities of "ETPIS Focus Groups" an EU project INTeg-RISK (Integrated Risks 2008-2013) including HOF aspects has started on December 2008 for 54 months duration in the frame of FP7. This project includes 64

[1] http://www.industrialsafety-tp.org

European partners with the European Virtual Institute for Integrated Risk Management as leader of the consortium.

1.5.3. DoE and American national laboratories

In the USA, an initiative for research in the Instrumentation, Control and Human-System Interface areas has been launched by the Department of Energy (DoE) within the frame of the global GEN IV forum for the development of advanced nuclear energy programmes. Specialists of several US National Laboratories have developed a road map addressing the future research needs[1]. Seven R&D focus areas have been identified:

- Sensors and electronics for harsh environment;
- Uncertainty characterization for diagnostic/prognostic applications;
- Quantification of software quality for high integrity digital applications;
- Plant network architecture;
- Intelligent controls for nearly autonomous operation of advanced power plants;
- Human system interaction models and analysis tools;
- Licensing and regulatory challenges and solutions.

Although those topics appear essentially focused on technology, they are also referenced in some HF-related MMOTION research topics, such as in the role of human and automation, the role of advanced operation supports, and, to a certain level, the licensing aspects associated to the development of man-machine systems.

1.5.4. OECD/CSNI/WGHOF activities on human and organisational factors

The Working Group on Human and Organisational Factors of the Committee for the Safety of Nuclear Installations has recently carried out an inventory of research gaps in the MMO domain, based on an international survey, followed by a workshop[2] (Washington-March 2010) gathering more than 50 HOF specialists. This resulted in the identification and consolidation of the following eight broad research topics:

- Operating experience from new and modernised plants;
- Evolving concepts for the operation of nuclear power plants;
- The role of automation and personnel: new concepts of teamwork in advanced systems;
- Management of unplanned, unanticipated events;

[1] Dudenhoffer & al. "Technology roadmap on instrumentation, control and man machine interface to support DOE advanced nuclear energy programs INL/EXT -06-11862

[2] Research on human factors in new nuclear plants technology, OECD/CSNI/WGHOF, Technical Opinion Paper NEA/CSNI/R (2009) 7

- Human system interface (HSI) design principles for supporting operator cognitive functions;
- Complexity issues in advanced systems;
- Organisational factors and safety culture;
- Human Factors Engineering methods and tools.

Those topics appear to be very consistent with the MMOTION research topics although their degree of granularity is not the same in both cases. (There is a larger number of more focused research topics in the case of MMOTION.) The only domain that has not been explicitly mentioned in the WGHOF report concerns the development of HRA methods. However, in the final discussion of the workshop, the need for quantitative HF assessment tools has been mentioned as a topic deserving some particular attention.

Furthermore, we can also consider that the broad WGHOF topic "organisational factors and safety culture" does not cover extensively all the fundamental human factor research issues identified during the MMOTION screening process, particularly those concerning teamwork, robustness of organisations and work practices.

This WGHOF workshop went further than identifying research needs. A bibliography summarising the work already done by the OECD organisations was also established. Furthermore, the workshop:

- Identified the motivation of organisations for the research work conducted for each subject, and
- Listed the existing facilities (simulators, etc.) and tools (software, etc.) that might be used for such research.

1.5.5. IAEA initiative on the consideration of human factors in new NPP projects

Contrary to the two first orientations, this IAEA initiative was not dedicated to the identification of research gaps, but aimed at identifying "HOF good practices" to be followed in the development of new projects of NPP. The specialist meeting organised in Vienna[1] (Nov. 2010) around this global theme was able to reach a consensus about the important HF-related topics that deserve particular attention for new NPP development, construction, operation and maintenance:

- The importance of early consideration of HF requirements in design was highlighted, as well as the need to follow an "integrated design" approach funded on the setting of multi-disciplinary design teams. The need for dedicating sufficient resource for Verification and Validation (V&V) was also reinforced as an important condition of successful project outcomes. Finally, the usefulness of human reliability tools as a

[1] Consideration of human factors in new NPP projects, IAEA technical report, to be published

support for risk management during the design and the operation has also been highlighted several times during the discussions. The efficient management of multicultural aspects has also been mentioned as an important condition for the success of the new NPP projects that are likely to be developed within an international framework.

- Concerning the operation, the importance of developing and maintaining a strong safety culture for all the levels of the organisation (particularly the managerial ones) has been confirmed as a chief condition for safety in operation. The development of teamwork skills has also been mentioned as one prominent objective of the training programmes.

All these aspects, considered as key factors for ensuring the safety and efficiency of future plants, are also identified by MMOTION important topics deserving more research, from which we could conclude the relevance of those research topics as for nuclear new build projects.

However, there seems to be an important point identified during the IAEA meeting that is not directly addressed within the MMOTION research topics, concerning the management of multi-cultural and multi-national aspects in the design and operation organisation. However, this particular aspect is considered as an integral part of both MMOTION "robustness of organisation" and "work practices" research topics.

1.6 Current MMO Research Programmes

There are numerous ongoing research programmes underway across Europe. The following are examples of programmes covering areas defined within the MMOTION roadmap.

1.6.1. EDF research

<u>Human Factor research</u>

Within EDF's R&D, there is a group of Human & Organisational Factors experts (sociologists, ergonomists and HRA engineers) developing 5-year research programme. This programme is driven by the EDF power plant needs, which are oriented towards safe management and increase of economical efficiency of existing plants, the upgrading of existing I&C and the construction and licensing of new EPR plants.

The HOF research programme is organised according to four areas, in which many issues are relevant to MMOTION orientations:

- "Work analysis and Human Centred Design" research area focuses on the design and the modification of work situation. The main topics addressed here are: Human Centred Design tools; Procedure guidance; Automation and operator's practices; Human-system interfaces in computerised control rooms (EPR) and organisational design; Socio organisational impact such as acceptability of new technologies.

- "Human and Organisation Reliability Analysis" has been developing for many years. MERMOS, a new HRA method, is based on qualitative and quantitative analysis. It aims to assess the reliability of socio-technical systems by the means of predictive or retrospective analysis of the system failure. One of the innovative aspects is the consideration of organisational features within the HRA models.
- "Human and Organisational factors for safety management" research area addresses issues such as: Robustness and the vulnerability of the nuclear plants; Understanding organisations in order to transform and to improve safety and radiation protection management; Impact of organisational and management volitions on safety culture. The aim is to inform EDF's decision makers of the impact of on –going and future implementation of management policies (i.e. human performance tools).
- "Operational experience feedback" research area investigates issues such as industrial accident and crisis studies for the understanding of organisational failures in order to assess their vulnerability and resilience faced to accidents, and feedback of experience and near misses (management, organisation, tools and data bases).

I&C research

There are four main objectives:

Consolidate the functional needs for the future HSIs:

- For the main control room:
  - Design a functional interface answering to the functional needs of the Utility
  - Highlight the interests and limits of diverse design approaches
  - Define the HSI performance criteria
- For local operations:
  - Explore the opportunities offered by the new technologies
  - Follow the guide rope « improve the communication between human »

Define a design methodology for HSI allowing rationalising the criteria to be taken into account

Built a coherent vision of our evolutions and assume our positioning to International standards

Explore new concepts of operation

1.6.2. UK nuclear research index

Within each UK Nuclear Licensee there is a requirement to conduct a suitable research programme. The main objectives of the Human Factors research are to identify, commission, and promulgate the results of research into nuclear safety issues so that licensees and the Nuclear Installations Inspectorate (NII) have the scientific and engineering knowledge necessary to make judgements about the adequacy of safety measures. The HF research is discharged through a number of programmes such as the Nuclear Research Index (NRI), the chemical processes and waste and decommissioning strategy, the HSE Major Hazards Programme.

The NRI is relevant for the nuclear generation licensees and influences the research they perform. Research projects are selected by British Energy / EDF Energy that provide practical benefits to the operating UK nuclear Licensed Sites whilst, at the same time, address issues raised by the NII. The recent research topics include:

- Nuclear Action Reliability Assessment - improving the consistency, accuracy and validity of human reliability assessments included in probabilistic safety assessments and safety cases through a human reliability methodology.
- Procedures guidance for Operations and Maintenance - a state of the art review of HF standards and guidance followed by the development of guidance and training for those modifying, writing and reviewing operations and maintenance procedures.

The Human Factors section of the NRI underwent a fundamental review in November 2007 by the UK Nuclear Directorate with consultation with all of the UK Nuclear Licensees. It is the intension to repeat this exercise following the completion of the MMOTION project to redefine the key NRI topics, their scope and the direction of human factors research.

1.6.3. Finnish nuclear safety programme

A country utilising nuclear energy is presumed to possess a sufficient infrastructure to cover the education and research in this field, besides the operating organisations of the plants and regulatory body. As part of fulfilling the competence requirements, national nuclear safety research programmes have been launched in Finland since the beginning of 1990 by the Ministry of Employment and Economy. These programmes are launched every four years to fund research projects on the defined topics. The next, the SAFIR2014 framework programme, is in its starting phase.

The SAFIR2014 framework programme is driven particularly by the needs of the licensing, and management of construction processes, of three new plants. The upgrading of the automation systems of the four units in operation and the ensuring of nuclear expertise needed in the diverse knowledge areas of nuclear power production due to the growth of the nuclear energy domain, generation change of experts, and the development of technologies are further important drivers of the programme. Effort is also needed for enabling the Finnish nuclear community to meet the requirements of international networking in regulatory issues and research.

The SAFIR2014 framework programme covers nine research areas, three of which are particularly relevant from the point of view of MMOTION:

- “Human, Organisation and Society” research area focuses on organisational and management issues of plant construction and operations. The broad topics in this research area are: safety management in networked supply organisations; practices of competence development and safety culture in operating organisations; societal issues of nuclear power production.

- "Automation and Control Stations" is a multidisciplinary research which covers mainly automation, systems modelling and human factors. Automation is the first major topic and it is particularly characterised by the research needs due to the safety requirements of digital programmable automation. Research issues are identified in particular with regard to methods for testing and validation of programmable automation and management of requirements during automation design. The second major topic is the human-system interaction and control room design. Control room operators' practices, use of emergency operating procedures and man-in-the-loop issues are among topics identified for research.
- "Probabilistic Risk Analysis" (PRA) is a research area that is particularly focused on development of methods of quantitative risk analysis. It also includes research devoted to identifying phenomena and factors relevant to nuclear safety. The broad topics of this research area are Reliability of programmable automation, External events, Human reliability, Level 2 PSA, Passive systems, PRA application, and Mathematical methods of PRA. Particular cross-sectional topics in this research domain are reliability issues caused by fire situations and human and organisational issues of safety.

Interaction between different research areas is facilitated by specific cross-area projects.

1.6.4. The German reactor safety research programme

In Germany research related to the MMO domain is covered by a reactor safety research program funded by the Federal Ministry of Economics and Technology (BMWi). This program addresses six technical fields, and MMO related research is part of one of them designated "methods development for probabilistic safety analyses, for control technology and diagnostics and also for assessing the human factor". This technical field addresses six "topic areas", two of them representing the research related to the MMO domain. These topic areas and the specific MMO topics addressed by them are:

- Topic Area "human behaviour"
    - Assessment of human reliability within a probabilistic approach
    - Systematic approach (organisation, structures, implicit standards)
    - Quantitative assessment of the contribution of organisations and safety management in safety and reliability

- Topic area "technical systems to support human performance"
    - Task distribution man / machine (degree of automation)
    - Prognostic tools (focal points: test control room, simulators)

The main directions of this research are as follows[1]:

The methods of "Human Reliability Analysis" are developed further for use in PSA for nuclear plants in order to reduce the uncertainty of such analyses. Attention is paid to the further validation of existing models and data from the non-nuclear field, using nuclear operating experience. In addition to the methods available to date, which deal primarily with "control-based" actions, methods for evaluating "knowledge-based" actions, including execution errors, are developed and trialled.

The research on a systematic approach to organisation and structures basically aims at an integral view safety culture as a part of the entire organisational culture of a nuclear power plant. It is based on theoretical approaches that describe above all behaviour, values, standards, attitudes and fundamental assumptions and proceeds to the development of practicable instruments for evaluating the quality of both the safety culture and suitable measures for its selective and sustained introduction and support.

The activities related to safety management aim at the conceptualisation and design of institutional forms of safety management systems. Attention is also paid to methods considering the influence of organisational factors within probabilistic assessments.

The research on technical systems for human support focuses on the man-machine task distribution (degree of automation) with special regard to the role of software-based systems and instruments.

Prognostic tools based on simulation are being developed for accident diagnosis and prognosis and for operator and emergency support systems. That includes the development of methods for plant simulation parallel to plant operation through an online adaptation of best estimate simulations in line with time-dependent measured data in the reactor system in view of providing improved plant status information.

In view of the political decision to extend the operational lives of nuclear power plants in Germany, the priorities of the reactor safety research programme have recently been reviewed[2] resulting in some changes of emphasis in the MMO domain. The revised

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[1] Competence Pool for Nuclear Technology (Kompetenzverbund Kerntechnik): Topics of Nuclear Safety and Repository Research in Germany 2007 – 2011, Reactor Safety Research, December 2007

[2] Kompetenzverbund Kerntechnik (Competence Pool for Nuclear Technology): Aufgabenschwerpunkte der Reaktorsicherheitsforschung aus Anlass der verlängerten Laufzeiten deutscher Kernkraftwerke, Dezember 2010

priorities focus on the needs related to the introduction of highly integrated control rooms within modernization projects and include topics such as criteria and methods for integrated system validation, organisational and staffing requirements, methods and tools for HOF evaluations and for human factor engineering analyses, evaluation of organisational impacts, questions of safety culture, complexity of advanced systems, development of innovative HSIs, the human-system relationship in automated processes, and the assessment of procedures with complex actions in the control of nuclear events.

1.6.5. Halden

The programme proposal of the Halden Project for 2012 to 2014 involves studies that have been in the research programme for several 3-year periods. By the long lasting studies of control room design, human factors and the application of computerised operation support tools the project has obtained good knowledge of experimental methods & measures of human performance. This has followed through practical studies in the experimental facilities HAMMLAB (Halden Man Machine Laboratory) and the Virtual Reality (VR) centre.

For the next 3 year's Man-Technology-Organisation research programme, a set of research topics have been proposed and are classified according to two big categories:

- Human Factors Research for Existing and New Reactors:
  This class of research topics focuses on generic socio-technical challenges considering many types of technical appliances. It comprises topics such as human reliability, human and organisational factors, human-system interfaces, control centre design processes, outage and field work, and future operation concepts.
- Digital Systems Research for Existing and New Reactors:
  This class of research topics focus on the development of specific technological appliances and methods for their verification. This class contains topics such as operational support, condition monitoring and maintenance support, and software dependability.

2. The MMOTION Roadmapping Process

The MMOTION roadmapping has been conducted in the spirit of the broader European R&D in the area of nuclear power plant technology and safety, which aims at the evolution of proven technology by combining lessons learned from experience with technological innovation capable to increase the safety and economics of nuclear energy production. Within this approach, technological innovation is appraised less as absolute value and more in proportion to its contributions to improving the operation of nuclear power plants, to the refurbishments of Generation II NPPs and to the design of Generation III plants. This needs to be kept in mind, for instance, when comparing the MMOTION roadmap to roadmaps developed in the USA with the focus on Gen IV reactors.

An essential objective of the MMOTION approach is achieving a closer integration of the different scientific communities involved in MMO related to nuclear facilities, i.e. human factor specialists, I&C engineers, and managers. Particular attention has been paid to the potential benefits of that integration for strengthening safety of existing and new power plants in a European context striving for common understanding of essential safety issues and for a harmonisation of the related practices.

The MMOTION project's road mapping exercise has been based on the following steps:

- Brainstorming on the overall view of the Man Machine Organisation considering the choices made in each country to reach an acceptable equilibrium point between man machine and organisation. Existing studies and standards were considered to establish the relevant questions and to provide a better view to each partner of how each partner is organised and to give the necessary background for the remaining work; (Work package 1)
- Identification of the research topics which are considered most relevant for Gen II/III plants in the medium term[1] considering the relevant MMO-related needs and their European dimension for three major themes: "design of human technology systems", "operation", and "evaluation and assessment". The topics identified are described in section 3.1 and in Annex A[2]; (Work package 2)
- A pilot exercise has been performed dealing with the feasibility of implementing new R&D methods discussed in WP2. It focuses on the evaluation of a methodology to support the Human Factors evaluation of an innovative technical concept; (Work package 3)
- Grouping of the research topics identified into four clusters to be addressed in a coordinated way and definition of research programmes (RP) related to the clusters by considering different stages of research and the related costs. (Work package 4)

[1] Medium term means a period of about five years after the expected begin of the proposed research.

[2] More detailed descriptions can be found in the deliverables D1.1, D2.2, D2.3 and D2.4.

In view of consistently structuring the working process and the results of the discussions among the MMOTION partners in the various areas to be covered by the roadmap, a large part of the work, in particular the work within the work packages 1 and 2, has been based on templates. This approach made it possible to have the necessary interdisciplinary discussions in plenary sessions or sub-groups and to produce the results in a structured way between meetings.

Special regard has been paid to avoiding inconsistencies between the MMO roadmap developed within the MMOTION project and the broader research prioritisation activities which are planned under the umbrella of the SNETP. Thus the MMO roadmap presented in this report can serve as a building block for the MMO area within a more general roadmap defining the needs and the priorities of European research related to nuclear fission energy

Fig. 2-1 illustrates the logic behind that process. Starting with the identification of issues, the work continues to identifying and organising research topics to build various research programmes proposed for implementation as part of future European nuclear fission research activities.

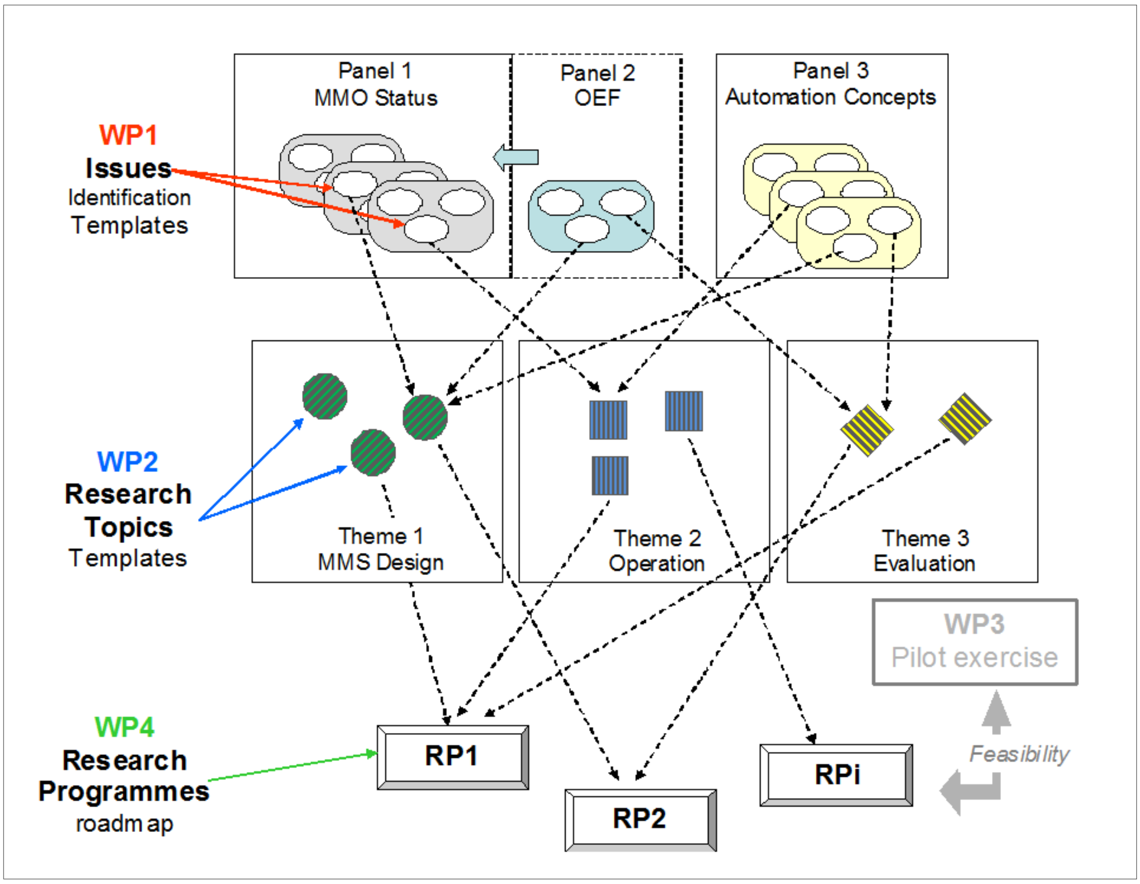


Fig. 2-1: From issues to research programmes

3. Clustering of Research Topics and Definition of Research Programmes

3.1 Research Topics

The following research topics (RT) have been singled out by the project partners as most relevant and promising for MMO related European research in a time frame of five years:

RT 1.1.1: Classification and evaluation of automation types

The main result of the work is a tentative classification framework to be tested out in use within several of the other research topics.

RT 1.1.2: Harmonisation of operational principles

This research topic deals with the identification of benefits, drawbacks and limitations of different operational principles and the feasibility of harmonising operation principles across Europe, for all plant situations including normal operation and emergency conditions.

RT 1.1.3: Solutions for balancing I&C reliability and functionality

The objective of this research topic is to establish coherent design principles for safety-related and non safety-related I&C functions, enabling the design and construction of more coherent and integrated operation systems.

RT 1.1.4: Man in the loop

Automation may force the operator out of the loop with consequences in plant efficiency and/or safety. Concepts and requirements for the automation system and the system complexity should be defined to keep the operator in the loop.

RT 1.1.5: Operation support

This research topic focuses on technological solutions to enhance operator performance during plant operation. Systems for alarm filtering, computerised procedures, critical safety function monitoring are examples. The research aims at developing approaches, methods and tools for designing and maintaining such systems in a way avoiding HF problems such as information overload and lack of system transparency.

RT 1.1.6: Managing the life-cycle of I&C at the European level

I&C systems, especially digital, have a much shorter lifecycle than nuclear power plants, making I&C modernization programmes necessary at least once during the operational lifetime of a NPP. This research topic aims at developing sustainable I&C specifications and design methods which can be shared across Europe in order to ease future I&C modernization programmes.

RT 1.2.1: Innovative human-system interaction concepts

The industry will provide modern HSI solutions based on new hard- and software. Then it becomes necessary to understand the potential for improving operation. The research will elaborate different operational concepts and bring empirically-based evidence to predict the impact of different HSI solutions on the different operation concepts.

RT 1.2.2: Advanced interaction technologies and their applicability in the nuclear field

This topic deals with the use of off-the shelf products such as touch screens and voice recognition for basic applications in the nuclear field. It aims at qualification of such products and the underlying technologies and intends to produce guidelines for their nuclear application.

RT 1.2.3: Usability of HSI solutions

Usability is a crucial issue for HSI solutions. The research topic deals with both how to assess the usability during the design process and how to validate the usability of the final product in its context of use. It aims at developing relevant methods and tools.

RT 1.3.1: Development of shared representations supporting integrated design

The purpose of this research is to improve the communication and mutual understanding within multi-disciplinary design teams, by the use of a modelling framework supporting and connecting the viewpoints of the various categories of professionals involved in the design of future nuclear installations.

RT 1.3.2: Managing socio-technical systems complexity at the design level

The purpose of this research topic is to identify the origins of the complexity of socio-technical systems in view of making the design teams able to manage it better and to minimize negative impacts on operation and safety.

RT 1.3.3: Proactive task analysis as part of design

The objective of this research is to develop new types of task analyses that are capable of predicting demands of future work. These methods should be applicable in early phases of the design process, and they should elaborate the domain-related control and psychological work demands, define constraints and possibilities for acting, and use these foundations in formulating and testing hypotheses concerning optional solutions for joint technological and human functions.

RT 1.3.4: Integrated design of socio-technical systems

The purpose of this research is to define a design organisation that is able to integrate the "non technical" design requirements (e.g. human and organisational aspects) more effectively into the design process by anticipating future work situations at very early design stages.

RT 2.1: Safety culture

Safety culture is a key area within the nuclear industry. The research will produce a common European framework creating a basis for the development of harmonised techniques for measuring and assessing safety culture and the impact of change on it as well as producing methods and guidelines to strengthen safety culture of utilities and further relevant stakeholders across the European Union and beyond.

RT 2.2: Robustness and vulnerability of organisations

Changes in the nuclear environment (e.g. in the organisation's external conditions and/or in supporting technologies) potentially results in new vulnerabilities jeopardizing the effectiveness of organisational provisions. The research aims at acquiring better knowledge of the impacts of such changes and at developing a European approach to measure the impact of organisational factors on safety.

RT 2.3: Safety management practices

Safety management depends on management practices influencing among others, decision making processes, employees motivation to deal with safety and efficiency issues, cooperation and mutual trust between managers and teams and the balance between autonomy and prescriptions. The research will be established by comparisons of management practices in different NPP's, teams and European countries in order to develop knowledge and evaluate the generic strengths and weaknesses of their practices.

RT 2.4: Risk management

The research topic deals with the development of risk management approaches tailored to MMO related decision making for the design and the operation of nuclear power plants. The objective is to identify MMO related risk management approaches capable to achieve broad acceptance across various EU member states and to provide a basis for a European harmonisation of respective approaches.

RT 2.5: Staffing

Staffing refers to the determination of human resource needs, including the amount of work assigned to each employee, the professional competencies required, and the duration of experience demanded. The research aims at better understanding the potential effects of new technologies on staffing requirements, the different functional staffing models and the possibilities to use them in NPPs, and at better predicting the staffing requirements throughout the plant's lifecycle.

RT 2.6: Analysis of work practices

The research topic deals with generating empirical evidence of individual and collective behaviour in nuclear power plant work settings. A major objective is to evaluate HSI technologies from the work practice perspective and to proactively influence their development.

RT 2.7: Human performance tools

The object of this research topic is to assess the impact of INPO Human Performance tools on NPP operations across Europe. Assessment will be made of the differences in effectiveness of the tools between countries, in different professions, and in comparison with technological aids. Consideration will be given to the financial implications of using human performance tools as compared to engineered solutions.

RT 2.8: Teamwork

The objective of this research topic is to better understand how teams function and what are the critical factors influencing performance and safety. New forms of spatial and temporal distributed teamwork should be investigated as well the role of the technical system supporting efficient collaborations between people.

RT 2.9: Occupational health

The object of this research topic is to develop an understanding of the connections and potential synergies that may be exploited between Occupational Health and Safety (OHS) and Nuclear Safety across multiple European operators. Specifically, the topic will address the issue of the impact of shift patterns and working hours upon OHS and other factors specifically within a nuclear context, and in different countries.

RT 3.1: Human reliability analysis methods

The objective of this research is to develop an advanced understanding of the performance, strengths, and weaknesses of different human reliability analysis methods used to model human response to adverse conditions in applications of risk-based approaches to nuclear power plant safety and to provide recommendations regarding solutions of weak points in the estimation of the human failure potential.

RT 3.2: Verification and validation

The object of this research is to improve methods for the verification and validation of complex socio-technical systems. The major objective is to develop methods that can support early phases of the design process by producing relevant knowledge about the strengths and weaknesses of the operational concept. There is urgent need for improved methods in this area as existing plants undergo upgrades, and new operational concepts are being developed for future plants.

RT 3.3: Operating experience on human and organisational factors

The research topic deals with human and organisational aspects of operational experience feedback (OEF) for nuclear facilities. It particularly aims at developing advanced, harmonised methods, solutions and tools for evaluation of operating experience (OE) linked to human and organisational factors, for communication and the dissemination of OE, and for assessing the efficiency of relevant OEF processes.

RT 3.4: Tools and methods for assessing individuals and crews

The object of this research topic is to assess a wide range of performance measures that could be used to gauge the impact of Human Factors interventions in the nuclear industry. The topic will specifically address the issue of how best to assess workload in complex control room tasks with multiple operators engaged in multiple, complex and potentially conflicting sub-tasks. The output of the work is expected to provide guidance for HF practitioners who have to assess the impact of their interventions in control room practices or design.

3.2 Structuring the topics according to their links and general viewpoints

As described in chapter 2 the identification of research topics during the WP 2 has been structured according to themes. Within the roadmapping process this structure has been reviewed in terms of different viewpoints associated with the role of main stakeholders:

- "I&C industry" associated with the manufacturers of I&C equipment,
- "Design" associated with the designer's of the relevant systems including HSI,
- "Operation" associated with the organisations operating nuclear facilities,
- "Safety" particularly associated with regulators and technical safety organisations.

These viewpoints were used for arranging the 26 identified research topics in a map. In this "viewpoints map" each topic is positioned[1] according to its relevance for stakeholders.

Within WP 2 a number of thematic links between the various research topics has been identified. The viewpoint's map shows them by arrows.

The links between topics, as well as the thematic proximity displayed on Fig. 3-1, show that there are some strong thematic relationships between topics of different themes (e.g. RT 1.1.2, 3.3 and 2.4). On the other hand, not all the topics of a theme have the strong thematic links (e.g. RT 1.1.2 and 1.1.1) that were initially expected.

The viewpoints map indicates that it is beneficial to deal with the topics in a co-ordinated way taking into account the thematic links and major needs related to the viewpoints. In order to keep the research organisation manageable, this has been achieved by defining four "multi-perspective" R&D programmes, each of them aggregating strongly related topics and providing consistent results for a major area. This aggregation of research topics into R&D programmes is presented in the next section.

[1] This figure must be understood as a *symbolic* representation of the thematic proximity of research topics and not as a quantitative topologic positioning.

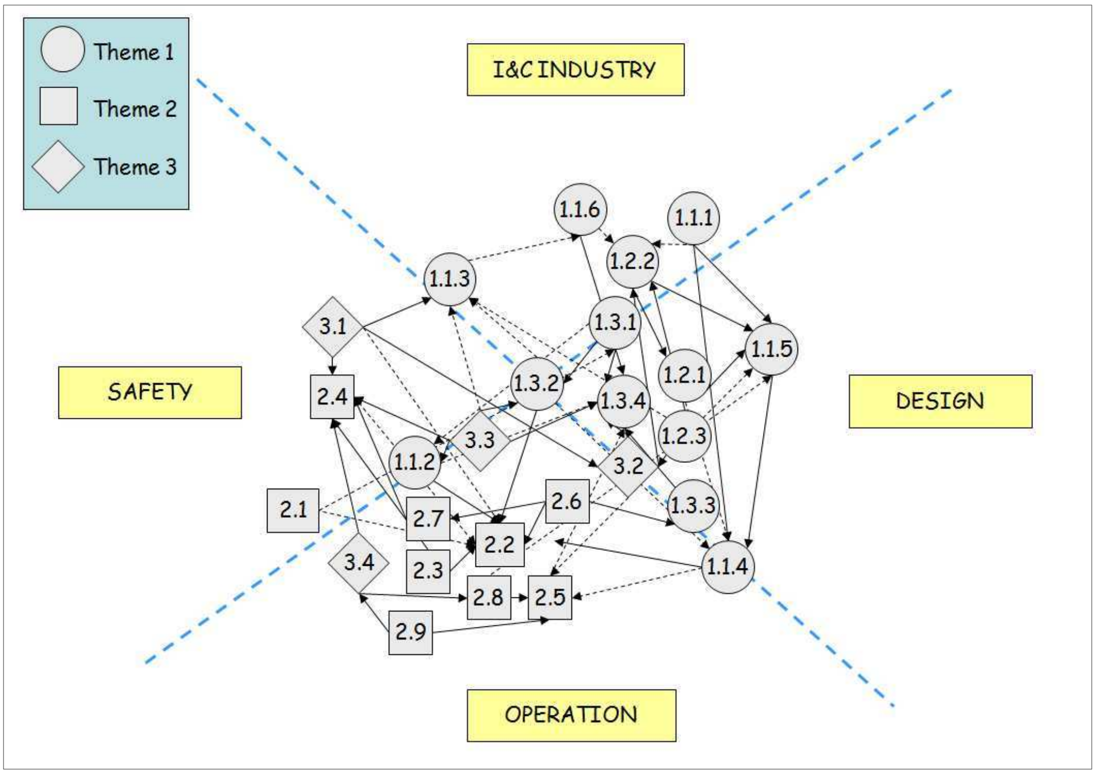


Fig. 3-1: Viewpoints map for research topics

3.3 Clustering of Research Topics and Definition of Research Programmes

The definition of Research Programmes has been based on a clustering process with the following objectives in mind:

- subdivide the set of research topics into manageable packages called clusters,
- attribute those topics with the closest thematic links to one cluster,
- limit the thematic links between clusters and provide their co-ordinated treatment within the same research framework,
- have a balanced relationship between the clusters and the viewpoints,
- Achieve visible results for major needs.

As a result of this process, four research clusters been defined each of them building the basis of a research programme:

RP1 "Risk informed decision making in design and operation"

The programme is dedicated to balance human and technological contributions to minimizing the risk in the operation of nuclear installations;

RP2 "Culture and practices for safety

The programme aims at better understanding the conditions for achieving robustness in the organisation of nuclear installations operation;

RP3 "Integrated design approaches"

The programme aims at better integrating human and organisational factors within the design of future nuclear installations or the renewal of existing I&C systems;

RP4 "Technological requirements in nuclear and other high risk industries"

The programme aims at achieving coherence between the products offered by the industry for I&C systems and the specific needs of the nuclear and other high risk industries.

This clustering approach[1] is illustrated in Fig. 3-2.

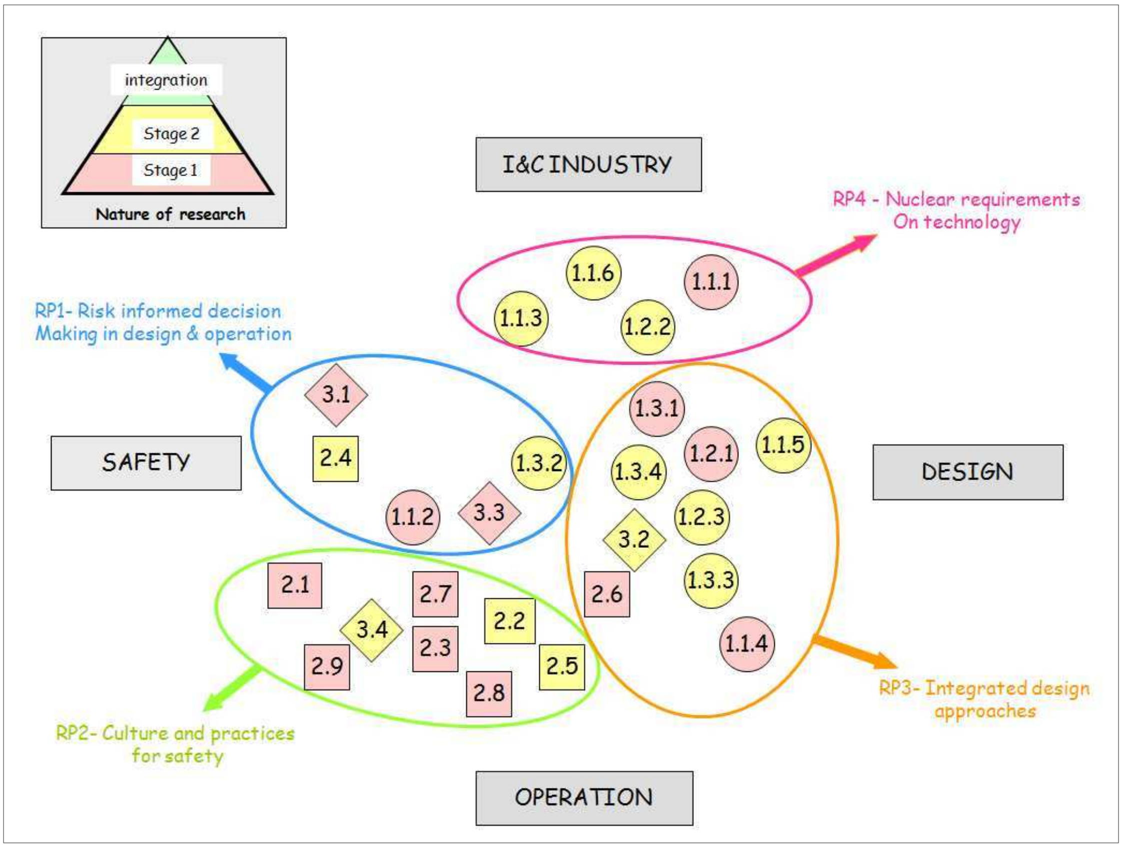


Fig. 3-2: Clustering of research topics and identification of research programmes

[1] As for the thematic positioning presented in the § 4.1, this grouping of research topics results from expert judgement and not from a systematic clustering approach based on quantitative "thematic distances"…

3.4 Research Stages

Considering the timescale aspects and the organisation of these programmes, a distinction has been made between three stages of research, the first stage (coloured pink in Fig. 3-3) comprising those research topics that should be addressed from the very beginning, a second stage (yellow) comprising research which can or should start later, and a third stage (green) devoted to integrating the results of the individual research topics in view of achieving the final outcome of the respective programme.

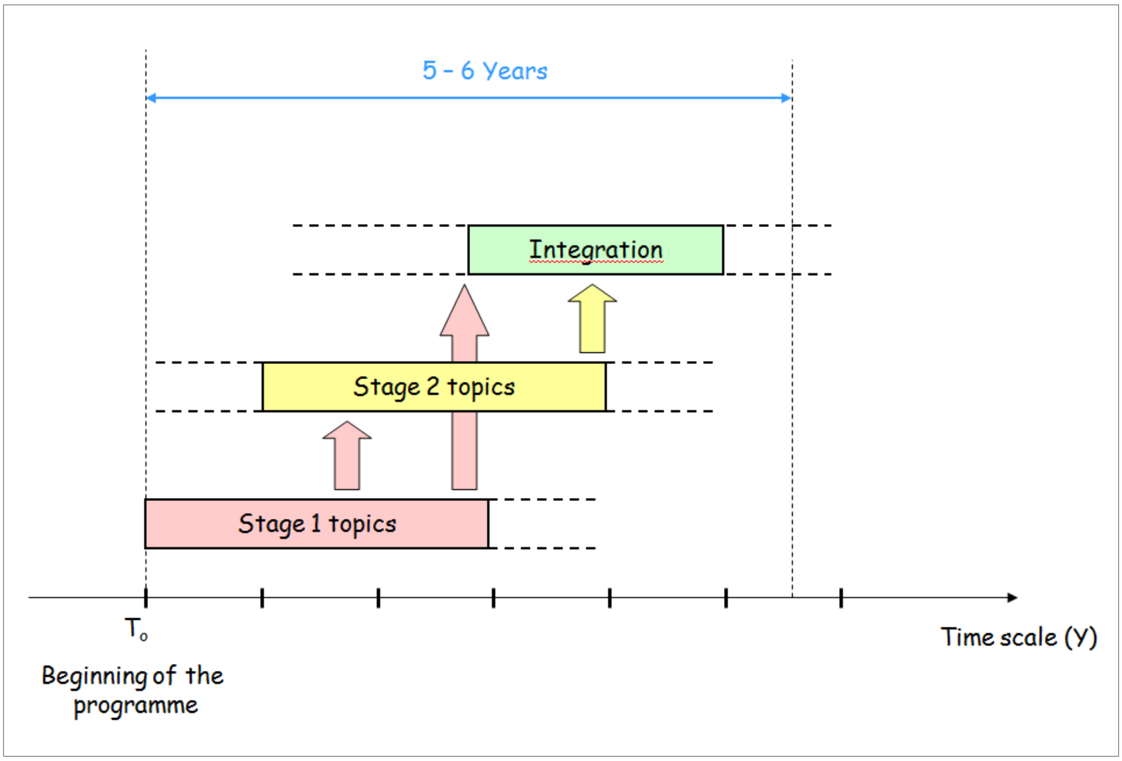


Fig. 3-3: Generic organisation of MMOTION research programmes

The following criteria have been used for this classification:

A research topic is classified stage 1 if one of the following conditions holds:

- There is a particular urgency to obtain results,
- The research or at least a significant part of it is aimed at developing
  - basic knowledge and methodologies,
  - common (European) understanding and definitions,
- Essential results of the research are required to start research on other topics

A research topic is classified stage 2 if:

- the work aims at development of solutions, tools and/or other applications,
- the start of the work requires results to be produced within stage 1.

Thus the distinction between the first and the second stage is not merely chronological but rather acknowledges that the second stage research requires results from the first stage. This is illustrated in Fig. 3-3, which also shows the integration of the stage 1 and 2 topics required to meet the overall programme objectives. The integration is expected to require considerable resources in the range of 15% - 30% of the total resources for stage 1 and 2.

4. Research Programmes

This chapter explains in more detail the proposed research programmes (RP). For each of the four programmes the following aspects are explained: the programme objectives; the programme structure with the topics to be addressed as well as the different research stages and the links to other programmes; the expected work effort; the nature of the programme with respect to the type of stakeholders involved as end users and/or participants; the umbrellas that are judged to be most appropriate for the programme implementation.

Budget indications provide hereafter are to be understood as estimations resulting from an expert judgement jointly performed by the MMOTION partners for each research topic based on a consideration of the following factors:

- The scope and the complexity of the work to be performed,
- The extent to which new basic developments and/or studies are needed and the possibility to meet the objectives by evaluating existing data,
- The number of countries and organisations to be involved.

Regarding the potential umbrellas, three possibilities are taken into account:

- Future calls of the Euratom Framework programmes are judged to be most appropriate for research, which is strongly related to safety issues of public interest, so that the regulators and the technical safety organisation (TSOs) are expected to be important end users of and/or contributors to the research.
- The NULIFE initiative, i.e. the NULIFE Association, is judged to be an appropriate umbrella for research which is mainly focusing on solving needs of the industry with respect to long term operation and life time extension of nuclear facilities.
- The SNETP industrial initiative expected to result from the Gen II/III technical working group is judged to be an appropriate umbrella for the remaining research focusing on industrial needs but not directly related to long term operation and life time extension.

4.1 RP1: Risk-informed Decision Making in Design and Operation

4.1.1. Objectives of the programme

The main objective is implementing risk-informed decision-making principles and techniques to MMO-related aspects in the design and the operation of nuclear facilities.

The research programme will provide a framework for the identification and the assessment of deficiencies and possible improvements of NPP design and operation. The goal is to strengthen the objectivity of safety judgments by using methods of risk-oriented decision making in human reliability area and to improve the cost-effectiveness and the balance of safety provisions.

The programme is essentially based on the acquisition of knowledge in the following areas:

- Benefits and drawbacks of different operational principles and the feasibility of harmonising operation principles across Europe. The goal is to propose new paradigms adapted to specific situations and new or improved operator support systems supporting various operational approaches
- Complexity of socio-technical systems and the possibilities to minimise its negative impacts on operation and safety, including design methodology
- MMO related integrated concepts for safety and risk management and tools for risk-informed decision making support
- Strengths and weaknesses of available methods to model human reliability within probabilistic risk assessments,
- Advanced and harmonised methods, solutions and tools for evaluation of operating experience linked to human and organisational factors.

4.1.2. Programme structure and volume

The programme is built on the following research topics:

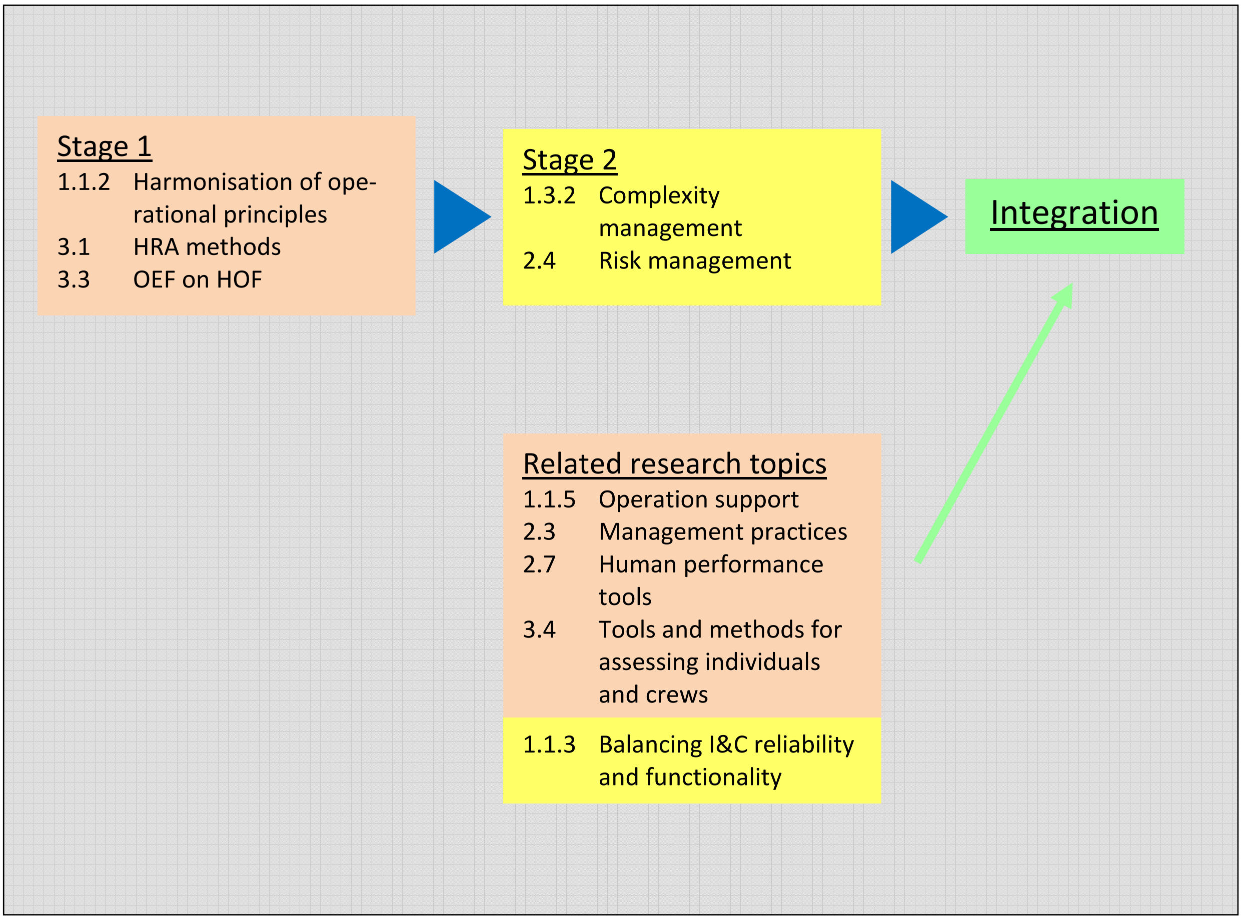
- RT 3.1 HRA methods
- RT 3.3 OEF on HOF
- RT 1.1.2 Harmonisation of operational principles
- RT 1.3.2 Complexity management
- RT 2.4 Risk management

Links to other proposed programmes exist by the following research topics:

- RT 1.1.5Operation support
- RT 2.3 Management practices
- RT 2.7 Human performance tools
- RT 3.4 Tools and methods for assessing individuals and crews
- RT 1.1.3 Balancing I&C reliability and functionality

The programme structure and the distribution of the research topics among the two research stages are shown in Fig. 4-1.

It is expected that a total of 38 person years are required to perform the proposed research. The distribution of that work effort among the research topics is shown in Table 4-1.



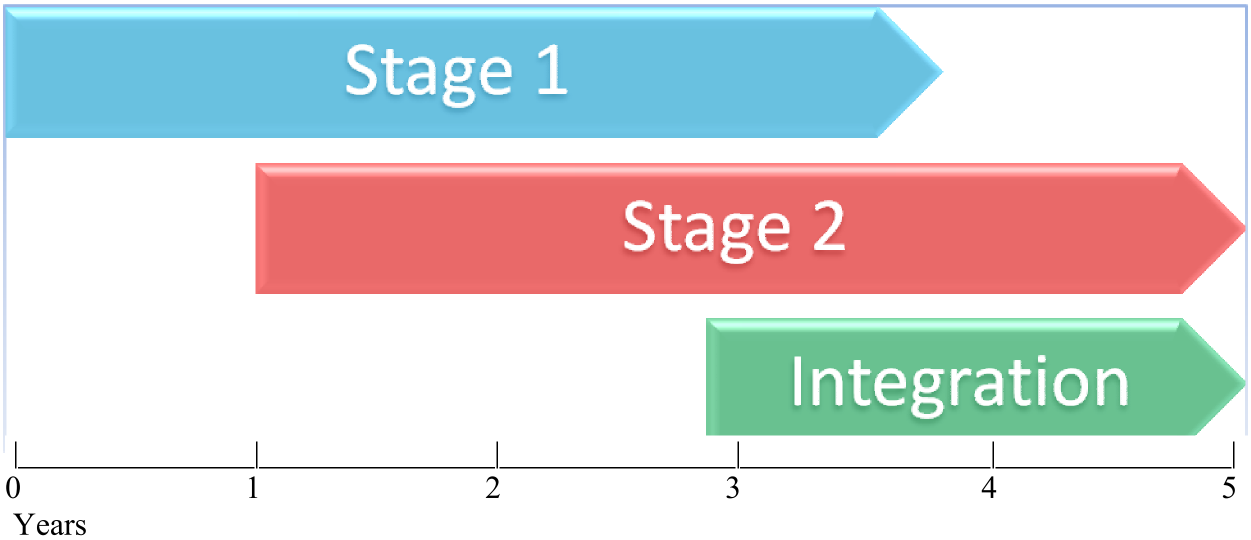


Fig 4-1: Structure of RP1 “Risk informed decision making in design and operation”

Table 4-1: Estimation of work effort for RP1 in person years

Stage 1	
1.1.2 Harmonisation of op. Principles	5
3.1 HRA methods	9
3.3 OEF on HOF	5
Stage 2	
1.3.2 Complexity management	5
2.4 Risk management	7
Integration	7
Total	**38**

4.1.3. Nature of the programme and proposed umbrella

The research is closely related to safety issues. Expected main end users are all organisations with particular responsibility for nuclear safety with a focus on NPP operators, regulators and TSOs. Best results are expected from a mixed participation of different stakeholders including utilities, regulators/TSOs and research organisations. As many results will be of public interest related to nuclear safety and highly significant also for non-industrial end users, a high share of public funding (between 50% and 75%) is believed appropriate.

Considering the nature of the research and the suggested corridor of public funding, it is proposed to consider this programme within future calls of the Euratom Framework programmes. Eventually, the SNETP Gen II/III Working Group or NULIFE might also serve as umbrellas, if the important role of TSOs and regulators as end users can be reflected within these initiatives.

4.2 RP2: Culture and Practices for Safety

4.2.1. Objectives of the programme

The main objective is optimising the performance and robustness of the organisations in charge of operating nuclear power plants focusing on the human, organisational and management dimensions of the NPP system. It will define the conditions required for ensuring the robustness of the organisations in charge of operating future NPPs based on a deep understanding of practices and culture in the operation of existing plants and also how changes can impact these dimensions of this socio technical system and consequently its performance.

It is considered how individuals, teams and organisations function and interact within the plant within a specific safety culture, and how they are supported by tools, artefacts, procedures, rules, etc. The theme does not focus on the original design or design changes to the technical system or its components. It focuses on the human and organisational components of the socio-technical system starting from psychological dimensions up to social and cultural dimensions.

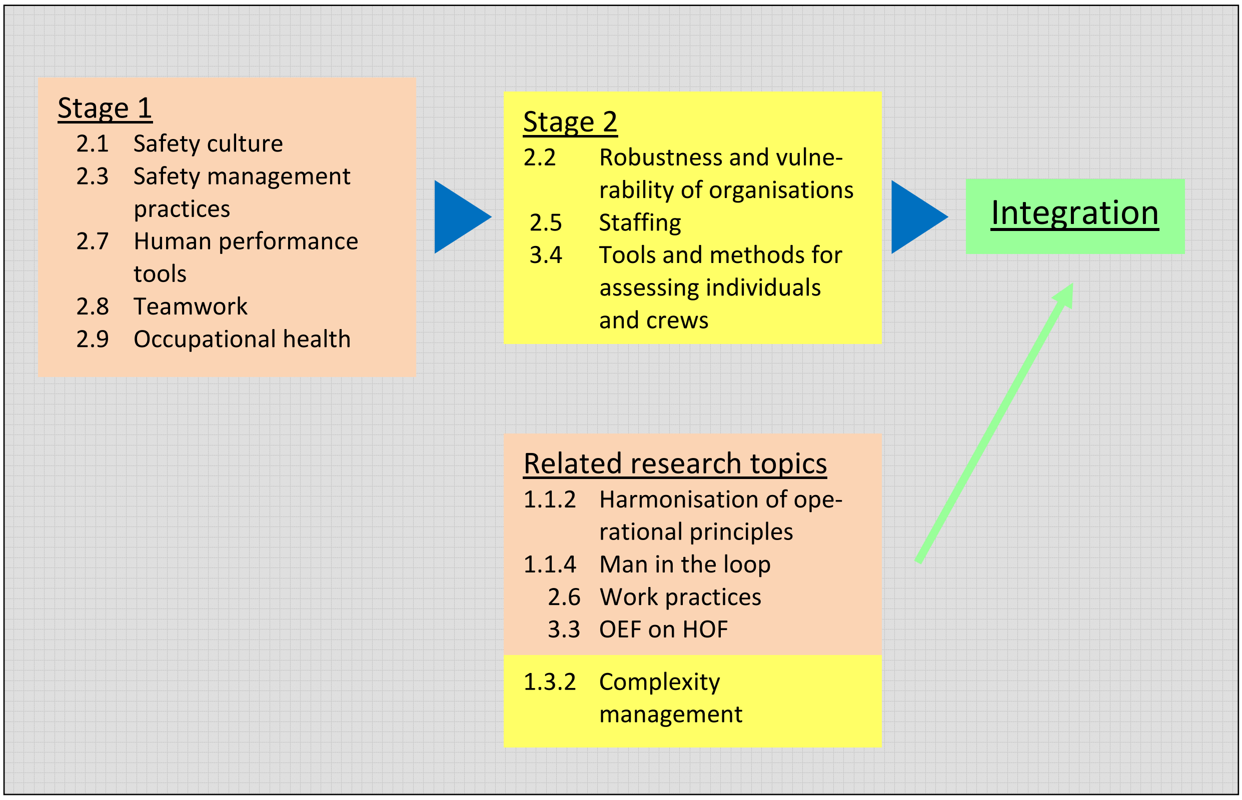
It is essentially based on the setting up of theoretical models of representation of the functioning of the socio technical system, the development of methods and tools, and the benchmark of operational practices in order to have a better knowledge and understanding of:

- Factors influencing safety culture and their measurement,
- The impact of changes in the organisation's external conditions on their robustness and their vulnerability,
- Management practices in different NPP's, teams and European countries and their generic strengths and weaknesses,
- The potential effects of new technologies on staffing and the dependence of staffing requirements on the plant's lifecycle,
- How teams behave and the critical factors that influence plant performance and safety,
- The effectiveness of tools applied to assess human performance,
- Assessment of workload in complex tasks with multiple operators engaged in multiple and potentially conflicting sub-tasks.

4.2.2. Programme structure and volume

The programme is built upon the following research topics:

- RT 2.1 Safety culture
- RT 2.3 Safety management practices
- RT 2.7 Human performance tools
- RT 2.8 Teamwork
- RT 2.9 Occupational health
- RT 2.2 Robustness and vulnerability of organisations
- RT 2.5 Staffing
- RT 3.4 Tools and methods for assessing individuals and crews



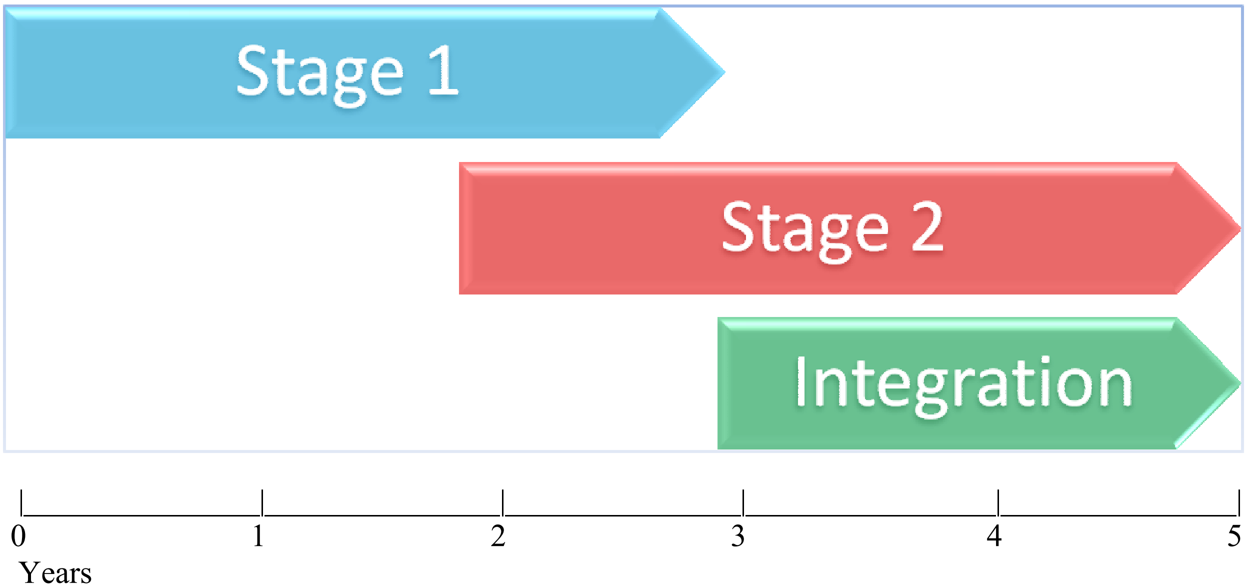


Fig 4-2: Structure of RP2 “Culture and Practices for Safety”

Links to other proposed programmes exist by the following research topics:

- RT 1.1.2 Harmonisation of operational principles
- RT 1.1.4 Man in the loop
- RT 2.6 Work practices
- RT 1.3.2 Complexity management

The topics safety culture, management practices, work practices, human performance tools, teamwork, occupational health are, at least partly, focused on creating a basis of common understanding, knowledge and definitions. Thus they are attributed to stage 1. The programme structure and the distribution of the research topics among the two research stages are shown in Fig. 4-2.

It is expected that a total of 52 person years are required to perform the proposed research. The distribution of that work effort among the research topics is shown in Table 4-2.

Table 4-2: Expected work efforts for RP2 in person years

Stage 1	
2.1 Safety culture	10
2.3 Management practices	5
2.7 Human performance tools	5
2.8 Teamwork	5
2.9 Occupational health	3
Stage 2	
2.5 staffing	8
2.2 Robustness of organisation	4
3.4 Tools and methods for assessing individual and crews	5
Integration	7
Total	**52**

4.2.3. Nature of the programme and proposed umbrella

The research is closely related to safety issues. Expected main end users are all organisations with particular responsibility for nuclear safety with a focus on NPP operators, regulators and TSOs. Best results are expected from a mixed participation of different stakeholders including utilities, regulators/TSOs and research organisations. As many results will be of public interest related to nuclear safety and highly significant for non-industrial end users, a high share of public funding (between 50% and 75%) is believed appropriate.

Considering the nature of the research and the suggested corridor of public funding, it is proposed to consider this programme within future calls of the Euratom Framework programmes. Eventually, the SNETP Gen II/III Working Group or NULIFE might also serve as umbrellas, if the important role of TSOs and regulators as end users can be reflected within these initiatives.

4.3 RP3: Integrated Design Approaches

4.3.1. Objectives of the programme

The main objective is achieving better integration of technical, human and organisational aspects in the various activities of the design process. The proposed research programme is built around the definition of approaches and methods that put the people, organisations and work practices at the very centre of the design of nuclear installations. The focus is put on the efficient integration of HOF requirements in the design by the prediction and timely assessment of the future work conditions and through the active participation of HOF specialists and end users.

The programme is essentially based on the development of models, methods and tools:

- Design method and the associated organisation that are able to effectively integrate the “non technical” design requirements (e.g. human and organisational aspects) into the design process by anticipating future work situations at very early design stages.
- Modelling framework supporting and connecting the viewpoints of the various categories of professionals involved in the design activities,
- Definition of practical criteria to predict the adaptation of different HSI solutions to the different operational principles,
- Methods and tools for using work practices and task analyses as a basis of HSI specification and early evaluation,
- Definition of concepts and requirements for the automation system and the system complexity ensuring that the operator is kept in the loop,
- Cross identification of the relevance of different HSI characteristics with respect to operational activities and work practices,
- Approaches, methods and tools for designing and maintaining such systems in a way avoiding HF problems such as information overload and lack of system transparency,

- Methods and tools to assess the usability during the design process and to validate the usability of the final product in its context of use,
- Advanced methods for the verification and validation of complex socio-technical systems both during the design process (to provide early feedback to the design) and for final V&V.

4.3.2. Programme structure and volume

The programme is built upon the following research topics:

- RT 1.1.4 Man in the loop
- RT 1.2.1 Innovative human-system interaction concepts
- RT 1.3.1 Shared representation supporting integrated design
- RT 2.6 Analysis of work practices
- RT 1.1.5 Operation support
- RT 1.2.3 Usability of HSI solutions
- RT 1.3.3 Proactive task analysis
- RT 1.3.4 Integrated design of socio-technical systems
- RT 3.2 Verification & validation

Links to other proposed programmes exist by the following research topics:

- RT 3.3 OEF on HOF
- RT 1.1.6 Managing the life-cycle of I&C at the European level
- RT 1.1.3 Balancing I&C reliability and functionality
- RT 1.3.2 Complexity management

The programme structure and the distribution of the research topics among the two research stages are shown in Fig. 4-3.

It is expected that a total of 51 person years are required to perform the proposed research. The distribution of that work effort among the research topics is shown in Table 4-1.

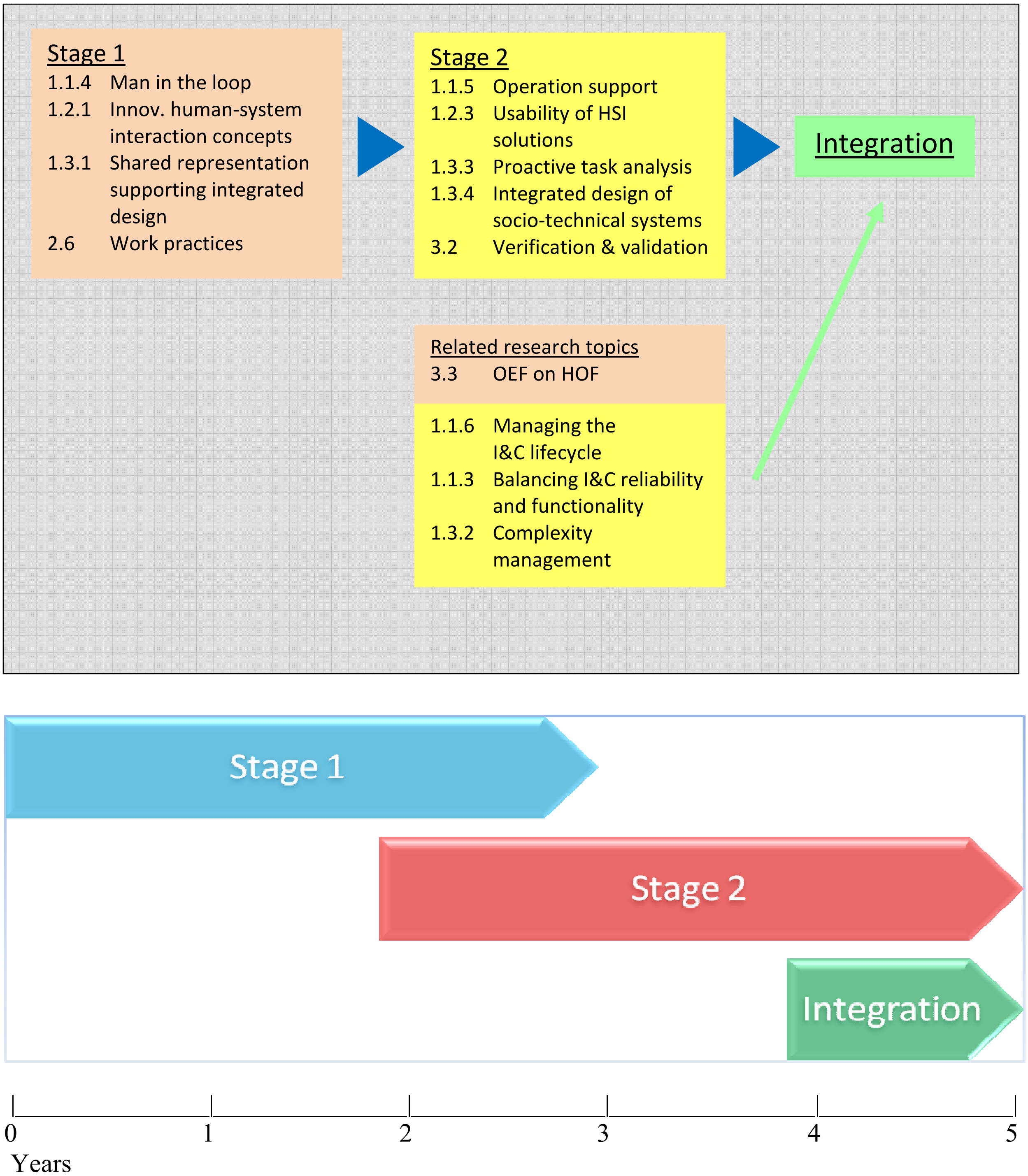


Fig 4-3: Structure of RP3 “Integrated Design Approaches”

Table 4-3: Expected work effort for RP3 in person years

Stage 1	
1.1.4 Man in the loop	5
1.2.1 Innovative human-system interaction concepts	5
1.3.1 Shared representation supporting int. design	5
2.6 Work practices	6
Stage 2	
1.1.5 Operation support	4
1.2.3 Usability of HSI solutions	5
1.3.3 Proactive task analysis	5
1.3.4 Integrated design of socio-technical systems	4
3.2 Verification & validation	4
Integration	8
Total	**51**

4.3.3. Nature of the programme and proposed umbrella

The research is essential motivated by industrial interests. Expected main end users are the utilities and plant manufacturers. Best results are expected from a mixed participation of utilities, industry, and research organisations.

There is some regulatory interest, but no specific public interest related to nuclear safety. In view of this situation and the significance for industrial end users, it is proposed to consider this programme as an industrial initiative with the SNETP Gen II/III Working Group or NULIFE as potential umbrellas.

4.4 RP4: Technological Requirements in Nuclear and Other High Risk Industries

4.4.1. Objectives of the programme

The main objective is the optimisation of NPP I&C lifecycle through a better consideration of the specific needs of relevant installations by I&C suppliers with special regard to integrating standardized "high-risk industry" requirements with respect to safety, availability and usability. The relevant installations include nuclear facilities and facilities of other high risk industries which generally use similar equipment.

The programme will deal with a range of current challenges. While more powerful, digital technology is also more complex, requiring expertise in several fields such as automation, computer science, networks, ergonomics, etc, digital technology also has much shorter lifecycles. Complexity impact on design, industrial arrangements, maintenance, potentially operation and may significantly increase the costs. Finally, engineering and validating nuclear I&C systems, for renewal or new build, is much more complicated, time-consuming, costly and less sustainable than before. Moreover, compared to other industries, the I&C domain in nuclear and other "high-risk" industries is constrained by stronger requirements, has a very long life cycle, cannot change rapidly, and represents a comparatively small market. A specific challenge is managing an existing fleet of power plants presently with an average age of 30 years over an extended period of time when the basic technology has grown more complex, with a volatile market stipulating even more severe financial conditions.

One of the best ways to face these challenges is to combine our specifications and to share common design methods between European nuclear users and other risk industry users.

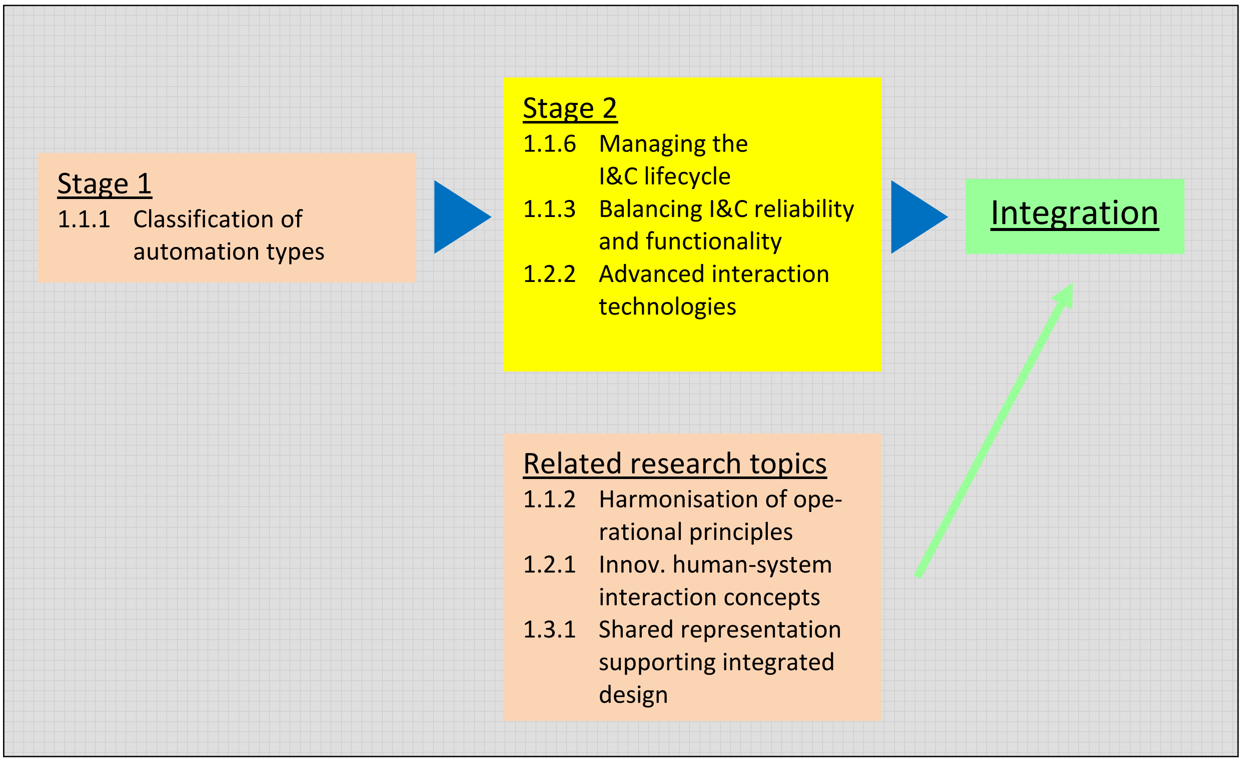
The research is essentially based on the development of models, methods and tools:

- Classification and evaluation of automation types,
- Establishment of design principles for safety-related and non safety-related I&C functions, enabling the design and construction of more coherent and integrated operation systems,
- Developing sustainable I&C specifications and design methods do deal with shorter I&C lifecycle and capable to be shared across Europe in order to ease future I&C modernization programmes,
- Qualification approaches for the using off-the shelf products and the underlying technologies for basic applications in the nuclear field,
- Development of an advanced modelling framework for communication and mutual understanding within multi-disciplinary design.

4.4.2. Programme structure and volume

The programme is built upon the following research topics:

- RT 1.1.1 Classification of automation types
- RT 1.1.3 Solutions for balancing I&C reliability and functionality
- RT 1.1.6 Managing the life-cycle of I&C at the European level
- RT 1.2.2 Advanced interaction technologies and their applicability in the nuclear field



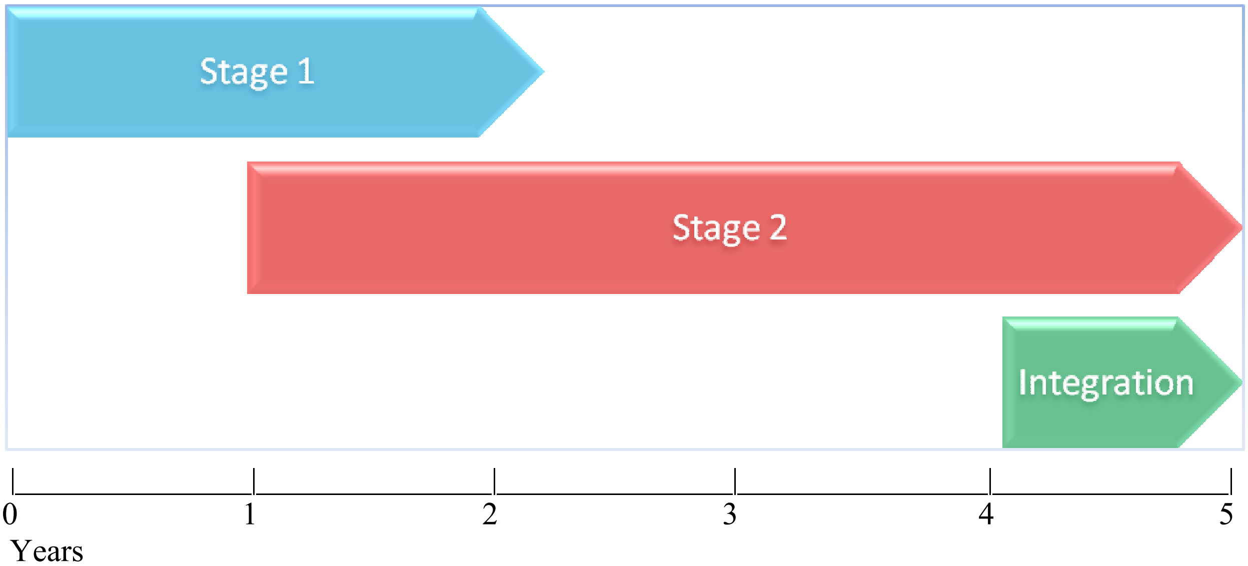


Fig 4-4: Structure of RP4 “Technologic requirements on nuclear and other high risk industries”

Links to other proposed programmes exist by the following research topics:

- RT 1.1.2 Harmonisation of operational principles
- RT 1.2.1 Innovative human-system interaction concepts
- RT 1.3.1 Shared representation supporting integrated design

The programme structure and the distribution of the research topics among the two research stages are shown in Fig. 4-4.

It is expected that a total of 27 person years are required to perform the proposed research. The distribution of that work effort among the research topics is shown in Table 4-4.

Table 4-4: Expected work efforts for RP4 in person years

Stage 1	
1.1.1 Classification of automation types	3
Stage 2	
1.2.2 Advanced interaction technologies	4
1.1.6 Managing the I&C lifecycle	5
1.1.3 Balancing I&C reliability and functionality	9
Integration	6
Total	**27**

4.4.3. Nature of the programme and proposed umbrella

The research is essentially motivated by industrial interests. Expected main end users are the utilities and plant manufacturers. Best results are expected from a mixed participation of utilities, industry, and research organisations.

There is no specific public interest related to nuclear safety, but the programme is considered to be highly relevant for European innovation capabilities. In view of this situation, a high share of industry funding (between 75% and 100%) is believed appropriate.

Taking into account the significance for the industrial end users involved in long term plant operation and life time extension, it is proposed to consider this programme as an industrial initiative with NULIFE as a potential umbrella.

5. Possible Collaboration with Non-European Organisations

The review of existing research programmes has shown that there is significant MMO related research outside Europe, particularly in the United States and at the OECD level. The comparison of contents indicates that the research priorities identified by MMOTION are quite consistent with MMO research priorities within non-European programmes: Many research topics considered significant by MMOTION are also addressed by those programmes.

However, the volume of current European MMO related research is obviously not commensurate with the non-European activities. It will therefore be difficult for the European Union to take a lead in the international discussion on MMO issues. This is problematic considering the high significance of MMO issues for continued safe operation of Gen II and for the technological developments for Gen III plants, and the regulatory relevance of the international dimension of many MMO issues. Collaboration in MMO research with non-EU countries is therefore important and should be integral part of future research programmes.

The following table 5-1 shows the relevance of international collaboration for the various topics singled out by the MMOTION project. Two types of collaboration are distinguished: co-operation inside the European Union and co-operation between European organisations and organisations outside the EU. The crosses in the table indicate that the respective type of collaboration is required or at least beneficial for the research topic.

The table indicates that European collaboration is relevant for all research topics. This is simply due to the fact that the MMOTION project focused on topics with a clear European dimension.

There are, however, more differences regarding the usefulness of collaboration between Europe and other geographical areas. That type of collaboration should start with a smaller number of topics. The selection of these topics has been based on the consideration of the following criteria:

- availability of equipment outside Europe,
- the need for world-wide standards,
- the amount of experience existing outside Europe,
- the European interest in a world-wide dissemination of European solutions

Table 5-1: Interest in international co-operation beyond the EU

Programme Topic	**Co-operation**	
	EU	**EU with non-EU**
Classification and evaluation of automation types	X	X
Harmonisation of operational principles	X	
Solutions for balancing I&C reliability and functionality	X	X
Man in the loop	X	
Operation support	X	
Managing the life-cycle of I&C at the European level	X	
Innovative Human-System interaction concepts	X	
Advanced interaction technologies and their applicability in the nuclear field	X	X
Usability of HSI solutions	X	
Development of shared representation supporting integrated design	X	
Managing socio-technical systems complexity at the design level	X	
Proactive Task Analysis as part of design	X	
Integrated design of socio-technical systems	X	
Safety Culture	X	X
Robustness and Vulnerability of Organisations	X	
Safety Management practices	X	
Risk management	X	
Staffing	X	X
Analysis of work practices	X	
Human Performance tools	X	
Teamwork	X	
Occupational health	X	
Human reliability Analysis	X	X
Verification and Validation	X	X
Operating experience on human and organisational factors	X	
Tools and methods for assessing individual and crews	X	

6. Conclusions and Outlook

The MMOTION roadmap presented in this report is the result of a support action project, launched under the “Euratom FP7 Call” on the theme of Man Machine and Organisation (MMO). Its main goal is to provide guidance for future research on subjects dealing with MMO and safety.

The roadmap covers a time period of five years addressing the MMO research topics considered most relevant for this planning horizon at the European level. Twenty six research topics have been identified and described. They are fully described in deliverables D 2.1 “Design of human Technology systems”, D 2.2 “Operation” and D 2.3 “Human factors evaluation & assessment”.

These topics have been structured in four research programmes (RP) covering the needs identified on Safety, Operation, Design activities and I&C industry:

- RP1 “Risk-informed decision making in design and operation” has for main objective to implement risk-informed decision-making principles and techniques to MMO-related aspects in the design and the operation of nuclear facilities.
- RP2 “Culture and Practices for Safety” deals with optimizing the performance and robustness of the organisations in charge of operating nuclear power plants focusing on the human, organisational and management dimensions of the NPP system.
- RP3 “Integrated Design Approaches” has for main objective to achieve a better integration of technical, human and organisational aspects in the various activities of the design process.
- RP4 “Technologic requirements on nuclear and other high risk industries” is dedicated to the optimisation of NPP I&C lifecycle through a better consideration of the specific needs of nuclear installations by I&C suppliers with special regard to integrating standardized nuclear requirements with respect to safety, availability and usability.

The results of several research topics are relevant to more than one research programme. Thus, coordination between the programmes will be necessary to share efficiently information useful to several programmes. A specific community could be set up to handle inter-programmes coordination.

The selection of relevant research topics and the definition of the research programmes reflect the consensus of the partners of the MMOTION project with respect to priorities and time frames. This consensus is the result of an intense discussion process over two years reflecting the diverse points of view of utilities, industry and research centres and the different perception and strategic agenda in different European countries.

The cross check with the work of other international groups indicates, however, that the priorities reflected by the MMOTION roadmap are quite consistent with current world-wide developments taking into account some well-known differences between the

European and other approaches to nuclear power plant design and operation. Thus some of MMOTION's proposals are shared with other international organisations, and there is no strategic need to limit the co-operative research on those proposals to Europe. International negotiations could be initiated, for example through the participation of VTT and CEA at the OCDE WGHOF group, where MMOTION has already been presented.

Regarding the implementation of the MMOTION roadmap it is proposed to build on the structure of European nuclear fission research which is emerging under the SNETP umbrella. The following implementation mechanisms are considered most appropriate:

- Future calls of the Euratom Framework programmes for RP1 and RP2 as these programmes are strongly related to safety issues of high public interest.
- The industrial initiatives emerging under the SNETP umbrella for RP3 and RP4 because these programmes mainly respond to needs of the industry with respect to the long term operation of Gen II plants and to Gen III developments.

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Appendix A: Summary of research topics

This appendix provides an overview on the research topics (RT) which have been identified during work package 2 of the project. More comprehensive descriptions of these topics can be found in the deliverables D2.1, D2.2 and D2.3 devoted to the three research themes "…".

RT 1.1.1: Classification and evaluation of automation types

One of the main difficulties of automation is to facilitate the understanding of automation malfunctions. Safe and understandable automation in all conditions of use is still a challenge.

There are currently no adequate and generally accepted methods/theories that sufficiently well assist designers in allocating tasks between human and machine, as well as insufficient understanding on how the experience of the operator combines with the level and type of automation to produce a viable socio-technical solution.

It is expected that the optimal split between human and technology depends on the type of automation.

Therefore, there is a need to establish an automation classification framework to support methods in this area.

There is a diversity of automation solutions, each providing opportunities but also challenges. This R&D topic proposes work to establish a classification framework for automation solutions to enable designers to make opportune selections regarding which solution to implement depending on the intended socio-technical context.

The intent is to provide adequate and generally accepted methods to assert that the human will be able to keep an adequate situation awareness and trust in automation under a given automation regime. In particular, the ability of the operator to detect a "beyond design" situation and act resiliently should be analyzed. Also long term effects such as de-skilling need to be more thoroughly investigated.

RT 1.1.2: Harmonisation of operational principles

The research topic deals with identifying the benefits, drawbacks and limitations of different operational principles. It investigates the feasibility of harmonising operation principles across Europe, for all plant situations including normal operation and emergency conditions. For instance, during normal operation most plants are operated using event-based approaches where events are announced by alarms and managed by sequential procedures. For emergency conditions, symptom based Emergency Operating Procedures (EOPs) or event based procedures are mostly used.

The definition of the operational principle is a key step in the design: not only when designing the I&C system but also when designing the corresponding human, organisational and social system. Therefore, identifying the benefits, drawbacks and limitations of each operational approach is of great help when designing new power plants and improving the operation of existing ones.

This topic deals with the two following issues related to operational principles:

- bringing order into the diversity of existing operational principles to improve existing solutions and to facilitate experience transfer,
- development of new operation principles available due to advances in automation and HSI technology.

New methodological (e.g. complex systems engineering) or technological solutions could also help to overcome the limitations of the existing principles. Moreover, some operational situations (start up, outages, etc…) could benefit from new or specific control approaches.

The main outputs from the research are:

- methods for evaluating advantages and disadvantages of different operational principles,
- a comparative study of currently used operational principles (benefits, drawbacks, limitations),
- a feasibility study of harmonisation of operational principles at the European level,
- and proposals for new paradigms adapted to specific situations as well as to new or improved operator support systems supporting various operational approaches.

RT 1.1.3: Solutions for balancing I&C reliability and functionality

In the domain of nuclear I&C, HSI and automation, the designers have to manage somewhat conflicting objectives of building systems with high levels of reliability, complying with the nuclear safety requirements, while ensuring more and more sophisticated functions, required for managing the complexity of modern plants.

The present situation is that the industrial offer is not able to fulfil simultaneously both kinds of objectives, which leads the designers to build “composite” architectures, mixing very highly reliable systems (with limited functionalities) and more sophisticated and less reliable functions.

This kind of solution is likely to pose usability problems for operators having to switch from one system to the other and, behind usability problems, this leads to some operational safety issues.

Considering these issues, this research topic aims at reconsidering the technical requirements for I&C and automation technology ensuring safety-related functions, in order to ensure an harmonisation with other risk-industries domains, and to avoid that too strong requirements on the technical reliability lead to adverse effects on the performance of the final users of these systems and, finally, to a lesser safety level of the global socio-technical system.

RT 1.1.4: Man in the loop

The failure of the plant operators to maintain the overview of the process development is generally referred to as operator-out-of-the-loop or man-in-the-loop problem. Increases and changes in automation may force the operator out of the loop with consequences in both plant efficiency and safety.

In order to deal with both anticipated and unanticipated situations the individual human operator and the control room crew must be able to take over the tasks of the automation at very short notice. Therefore operators must have a satisfactory overview of the recent process development and of the current activities of the automation systems.

To achieve this, the following research questions must be answered:

- What are the usable and effective artefacts that promote communication of the automation activities to the individual?
- At what level must the process and the automation be understood to perform monitoring and take over when automation fails?
- What are the requirements on operator training and re-training to keep the operator sufficiently well in the loop?
- What is the importance of trust in automation?
- What are the long term effects of changes to automation? In particular how do these effects pertain to the possibility of keeping the operator in the loop?
- Changes/increases in automation may lead to complacency - how may this be counteracted?
- What are the impacts of automation on safety culture and risk awareness?
- What are the implications in terms of reduction of process knowledge and de-skilling?

Feedback from operation of various existing automation solutions also from other risk industries can be used in comparative studies to estimate the contribution of influencing factors, e.g. how may increased training compensate for increased complexity in the automation solution? Refined models of human-computer interaction may be useful as well to predict human behaviour under designed automation conditions.

The main outputs from the research are

- Definition of the requirements of automation which is intended to keep the operator in the loop so that safety is not challenged.

- A method to balance the complexity of the automation whilst ensuring the operator can understand and remedy contingency situations involving the automation.
- Requirements on operator training and re-training to meet demands of new automation solutions.

RT 1.1.5: Operation support

Many different types of operation support systems exist today. They include but are not limited to categories such as:

- Monitoring and alarming systems, e.g. critical safety functions monitoring systems to help the operator to monitor a set of predefined safety functions of the plant.
- Diagnosis systems that apply some kind of model compared to the actual plant readings to offer a set of explanations of an observed scenario (such as a component malfunction)
- Procedure systems that assist to implement a sequence of decisions, actions and checks appropriate to a given plant situation.
- Prognostic systems that helps to predict the possible outcome of competing operational approaches

These systems all share the common feature that they are based on models that are inherently incomplete. Thus the recommendations of the systems cannot be trusted unconditionally. This raises some important HF challenges related to:

- Inadequate transparency of the system logic/model.
- Information overload which in certain cases may be caused by a too much transparency
- The human ability to act resiliently in case of a malfunctioning operation support system

Expected output of the research are approaches, methods, criteria and tools for designing, constructing and maintaining operation support systems avoiding problems seen in current operation support systems.

RT 1.1.6: Managing the life-cycle of I&C at the European level

I&C systems, especially digital, have a much shorter lifecycle than nuclear power plants, making I&C modernization programmes necessary at least once during the operational lifetime of a NPP.

The first modernization programmes have shown that the partial transition from analog to digital technology (Programmable Logic Controllers - PLCs, Distributed Control Systems - DCSs and Supervisory Control and Data Acquisition systems - SCADA systems) was not easy. One of the challenges is the lack of documentation providing design rules and rationales of previous design choices. The systems were not designed to be easily modernized or extended. Moreover, there are few people left with real expertise on the obsolete technology, making the re-engineering challenge even more difficult.

While more powerful, digital technology is also more complex, requiring expertise in several fields such as automation, computer science, networks, ergonomics, etc. Digital technology also has much shorter lifecycles. Complexity impact design, industrial arrangements, maintenance, potentially operation and may significantly increase the costs. Finally, engineering and validating nuclear I&C systems, for renewal or new build, is much more complicated, time-consuming, costly and less sustainable than before.

This research topic deals with solutions to pool I&C specifications and share common I&C design methods between European nuclear users in order to anticipate these I&C modernization programmes.

The main outputs from the research are:

- A technological survey across several industries about best design practices making room for future modifications and retrofits of I&C systems and SCADA systems. This survey should include a critical analysis of the applicability of these design practices in the nuclear context and lead to a guideline document,
- European nuclear survey on automation,
- Specification methodology and formalism, and associated tools that may support life cycle maintenance.
- White book on long term operation digital I&C systems for nuclear industry or safe processes.

RT 1.2.1: Innovative human-system interaction concepts

Aims: On-going renovations and designs of NPP control rooms indicate needs to develop more advanced control places for process control. Control room interface solutions are presently tackled one by one, without conceptual frames that could link solutions together. The proposed research should create Human-System interaction concepts that consider basic issues of human-system teamwork and define its key dimensions and characteristics. Metrics should be developed for evaluation of good human-system teamwork in future control places.

*Topics and methods:*_ This research should be both conceptual and empirical and provide answers to issues concerning the level of automation, the level and form of presentation of information, and the level of operator competences. These issues should be tackled in a coherent way in a global human-technology interaction design. Solving of these issues support understanding of the “man-in-the loop problem”, and would result in proposals for new concepts of operations.

Beyond the conceptual work feedback from already mobilized intensive research projects implementing new HSI concepts should be clarified. Information should be integrated of studies concerning e.g.

- Design effective alarm systems and indications of anomalies and how to present them.
- New means to facilitate the transparency of automation systems;
- Appropriate ways of computerizing procedures and operational documentation as part of the human system interfaces ;
- Intelligent operator support systems;
- Organisational support systems;
- HF impact of reliability requirements.

Research is also needed to develop design methods to include human factors in the definition and management of requirements during the control room design. Answers should be found to questions concerning new forms of synthesising and presenting of research results should be used to make the results more usable in the design process. Human-centred and participatory approaches could also be improved for the design of complex systems.

Outputs: An improved understanding of the future possibilities for Human-System Interaction. The studies would elaborate different operational concepts and bring empirically-based evidence to predict the impacts of different HSI solutions on the concept of operations according to which the NPP production is organised.

RT 1.2.2: Advanced interaction technologies and their applicability in the nuclear field

This topic focuses on the identification and characterization of basic interaction technologies (e.g. touch screens, voice interaction, virtual and augmented reality etc.) that exploit different kinds of interaction modalities: visual, acoustic, tactile etc. It is very important that the characteristics of enabling technologies are studied to understand how aspects of the technology can support and hinder human performance. This topic is also intended to produce recommendations and guidelines concerning the implementation, integration and use of each interaction technology and its applicability in the nuclear field.

Information and communication technologies are evolving continually and provide new technical possibilities in everyday life (e.g. electronic games, smart phones, Internet, Google etc.). To exploit the advances in these technologies the following questions should be considered:

- What are the new possibilities of interaction offered by the latest technological development like multi-touch screens, large screens, multimedia PDA for field operator?

- How can new human-system interface technology be used to implement new forms of collaboration between human and technology?
- What interaction models including corresponding data representation should be developed to support the use of the new interfacing technology?
- What is the potential of completely new interaction modes, like touch for perception, voice for decision and action etc.?
- What are the possible advantages and disadvantages of the new interaction technologies with regard to the type of operation usage in an NPP, human factors and safety constraints?

The main outputs from the research should be:

- Recommendations and guidelines regarding the implementation and use of the different HSI technologies
- Qualification of each HSI technology with respect to the advantages and disadvantages for different types of usage in nuclear power plants (e.g. control room, field operator, maintenance activities etc.)

RT 1.2.3: Usability of HSI solutions

Aims: Good usability of technologies improves the safety and reliability of their usage. This research topic deals with the knowledge needs that the conducting of Human Factors Engineering process portrays. The overall usability of human-system interaction concepts and human-system interface solutions should be repeatedly evaluated during the design and implementation process. A generic framework of usability would be needed to define requirements to be fulfilled during each HSI design phase. The topic includes both how to achieve usability during the design and how to assess the degree of usability in the final products.

Topics and methods: It would be necessary to clarify what HSI assessment methods are currently applied in design and how they are applied. Little research is available to judge the validity of methods, or how they have to be applied in order to produce valid results. It should be analysed how predictive and system-oriented HSI assessment methods and metrics should be developed to be also be used in longitudinal assessments of usability during the design process. The new metrics to be developed should capture usability as a feature of the entire socio-technical system performance. The metrics should not be entirely focused on performance outcome but also be capable of addressing cognitive processes and macro-cognitive patterns (e.g. creation of a common ground, managing attention, naturalistic decision making etc).

Interest in integrated system validation (ISV) methods has recently increased due to evaluation needs of on-going modernizations and forthcoming new-builds. Improvements in ISV methods and measures have been identified in this connection. Areas for improvement are scenario and team selection, performance indicators and acceptance criteria. An important open issue is also the validation of new-build designs for which no baseline data are available. Further questions are e.g. how to integrate ISV into the development process and into regulatory processes. There is also a need to clarify what practical tools, technologies or platforms for assessment are required. This topic aims to improve the efficiency and validity of assessment approaches through new technologies and concepts.

Output from the research: Elaborated concepts of usability of complex systems will be created that demonstrate the connections between usability of technologies and reliability and safety of human performance. New methods and tools that would improve evaluation practice by providing metrics that can support evaluation needs of the HSI design.

RT 1.3.1: Development of shared representations supporting integrated design

One of the major conditions for the efficient integration of human and organisational aspects in the design of nuclear installations (cf. topic N° 3.3.4) is the setting-up of multidisciplinary design teams. Anyway, the fact that these team members do not have the same view and the same representation of the system to be designed might be an obstacle to the efficient functioning of these multi-disciplinary teams.

Considering this issue, the specific objective of this research topic is to define a consistent modelling framework supporting the various perspectives (technical and human engineering, safety, operation, etc.) on the socio-technical system to be designed. This *multi-perspective modelling framework* should facilitate the dialogue within the multidisciplinary design team as well as with the external actors and shareholders in the lifecycle of the future system. It should also help to solve some requirements conflicts by helping the various members of the design team to understand in depth the origin of the exigencies imposed by other disciplines.

RT 1.3.2: Managing socio-technical systems complexity at the design level

For many authors, the increased complexity of modern systems might be the cause of severe threats to their safety, because of the difficulty, for the users of these systems, to understand their functioning. The simplification of future nuclear systems is thus seen as one of the privileged ways to improve their safety in operation. Anyway, one difficulty is that designers and users of these systems might not have the same vision of what is complexity, so that solutions brought by the designers to make the design simpler might finally increase the complexity of the operation of these systems.

The objective of this research is firstly to characterize the various aspects of the complexity of systems and assess their *impact on the performance* of their future users. Secondly, the aim is also to provide designers with tools enabling them to minimize this complexity, particularly during the *early design phases*, when the fundamental safety design options, impacting at most the activity and performance of operation teams, are fixed. Finally, this simplification process should also be beneficiary to the *designers* themselves, by enabling them to better master the complexity of the systems they are developing.

RT 1.3.3: Proactive task analysis as part of design

Aims: In design processes knowledge is needed concerning the contents and demands of future work. Current task analyses are typically restricted from the point of view of design as they focus on describing actual (existing or hypothesised) actions, and implicitly assume tools and technologies to be known. Needed are approaches that are capable of abstracting from specific actions and technological solutions and focus on domain related control demands, psychological work demands, constraints and possibilities for acting. Knowledge of these issues enables formulation and testing of hypotheses concerning optional solutions for joint technological and human functions.

Topics and methods: Research is needed to make task analysis an effective tool during design and ensure that the analysis is conducted in a proactive manner. Issues to be solved include

- Development of proactive formative task analysis methods that draw e.g. on functional modelling of the work domain
- Development of approaches and methods that treat technology and human elements from a joint cognitive system point of view
- Development of analysis of user experience as a predictive means to anticipate the potential faculties of new designs for the targeted work

Complementary to pro-active task analyses methods new approaches are needed for conducting interventions for the development of personnel competencies as part of design and change processes.

Detailed research is needed to understand what aspects of human activity are sensitive to changes in automation and in human-system interaction. Relevant topics for research include e.g. development of improved situation awareness, modelling tools that can be used in the design of ‘context-aware’ decision support systems, team performance and workload, etc. Design would also benefit of methods and tools for assessing workload and other reliability-related performance-shaping factors.

Outputs: New approaches to task analysis will be provided that are capable of proactively informing the design process of relevant issues concerning human competencies and practices. Also new methods of training are expected which deliver feed-back to the design process concerning the HSI concepts under development.

RT 1.3.4: Integrated design of socio-technical systems

The design of new nuclear installations now aims at building efficient and coherent *socio-technical* systems, rather than only safe and reliable *technical* systems. This leads to question the design approaches followed up to now, in order to put people, organisation and work practices at the very centre of the design of new NPPs.

Within this general framework, the objective of this research is the *timely* integration of human and organisational aspects within the design of new NPPs, particularly through the active participation of H&O factors specialists and end-users during the early project phases. This requires also to reconsider the development cycle of the systems and to adopt a systemic view of the global socio-technical system in order to found the design options on the characteristics of the future work situations.

Finally, this integrated design organisation provides a global implementation frame for the tools (e.g. Shared representation models- topic 1.3.1) and methods (e.g. pro-active task analysis- topic 1.3.3) resulting from other researches in the domain of the design of advanced socio-technical systems.

RT 2.1: Safety culture

Safety culture is a current key area of focus within the nuclear industry. It is defined by INSAG as, “that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an *overriding priority*, nuclear plant safety issues receive the attention warranted by their significance." There remains much debate on what is understood by safety culture, the individual and organisational factors that influence it and how to affect lasting change. Beyond the safety culture definition from IAEA recent researches have given an other point of view concerning safety culture (I Fucks, 2004) introducing new concepts or approaches such as « positive and negative safety culture », relations and differences between safety culture and safety climate and safety culture diversity in the at risks industries organisations. These new elements being considered in the IAEA TECDOC 1329 *Safety Culture in nuclear installations Guidance for use in the enhancement of safety culture*, 2002 and opening the way for new researches on safety culture. The research will be focused on the answers of several questions concerning the definition of the safety culture and its dimensions, the factors impacting positively or negatively safety culture, the tools and methods used to assess or to change positively safety culture and the relations between Safety culture and organisational resilience. The outputs of this research will authorise:

- A common and agreed European definition of safety culture, its components and the critical factors that influence safety culture, permitting qualitative and quantitative measurement and assessment techniques available for use by generators, contractors and regulators.

- Assessment of the impact of change on safety culture.
- Approach, guidance and methods to influence safety culture for stakeholders to promote safety culture for use by European organisations
- Dissemination of findings at a European Level.

RT 2.2: Robustness and vulnerability of organisations

The robustness of an organisation is an important attribute of the man-machine-organisation conceptual model. New challenges arise from the changing conditions for nuclear energy. If not fully recognized and properly taken into account, these have a potential to result in new vulnerabilities for organisations and hamper the effectiveness of organisational provisions. The research will be focused on the answers of several questions concerning the impacts of the external change on the organisation and managerial aspects, the real effects of the introduction in the organisation of the new formalized and integrated management systems, the possibility of assessment of the effectiveness and performance of the organisation in terms of safety, security and economical efficiency, the factors contributing to the robustness and vulnerability of an organisation and the methodologies used to measure it.. Aimed output of research is:

- improved knowledge of the impact of changes in the organisation's external environment and in the supporting technologies and tools,
- optimisation of organisational approaches in view of excellence regarding safety and cost-effectiveness,
- optimization of approaches to improve security (including the introduction of new security measures and related technologies) with special regard to their potential impact on safety,
- the development of an agreed European approach to evaluate and measure organisational factors and their impact on safety.

RT 2.3: Safety management practices

The changes arising from environment in which the nuclear utilities must operate maintaining itself competitive have introduced pressures on these complex socio technical systems. These pressures have already led to significant changes in how the nuclear enterprises are organized and managed. Thus the management practices have a confident influence on both safety and operational efficiency. The implications on safety are well recognized and have produced notions such as 'safety management'[1]. Safety management

[1] INSAG-13, IAEA 1999; INSAG-15, IAEA 2002

depends on management practices influencing among others, decision making process, motivation of the organisation and employees to deal with safety and efficiency issues, cooperation and mutual trust between the manager and its team and cooperation between different teams and also the required balance between autonomy and prescriptions. It appears also that implementation and deployment of "new" management practices or organisational changes[1] encounter sometimes resistances or difficulties[2]. If recommendations, concerning 'management practices' given by current international guidelines are adequate and effective to establish required safety standards, continued research based on grounded studies may be needed to evaluate this "on the field".

The first step of this research should focus on the understanding of the real activities of the managers and their constraints. The second step will be the critical analysis of the existing management practices. This critical analysis must be established by comparisons of management practices in different NPP's, teams and European countries in order to develop knowledge and evaluate the generic strength and weaknesses of their practices in term of:

- Deployment of safety policies in order to develop safe activities within their team (near misses, managers on-the-field approaches….)
- Development of cooperation within their team and between their team and others NPP' teams
- Leadership in order to develop and improve the motivation within their team
- Preservation of the balance between objectives, prescriptions and initiatives, implication of the members of his team
- Proactive and reactive analyses of the operational decision making process
- Change management practices.

Such studies should not only focus on the organisational motivation, but also the ability of the organisation and its staff members to deal with the problems. One aspect here is the collaborative climate and technological implements affording this.

RT 2.4: Risk management

Risk management techniques are used in many industries as a systematic approach to decision making in the presence of significant risks. They cover systematic approaches to identify of hazards, to assessment the related risks, to prioritize the ways to eliminate or to reduce those risks, and to plan the respective measures.

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[1] INSAG-18, IAEA 2003

[2] Managing and Regulating Organisational Change in Nuclear Installations. CSNI Technical Opinion Papers No. 5

The research topic deals with the development and the application of risk management approaches specifically tailored to the various MMO related provisions in the design and operation in view of optimizing the cost-effectiveness and the balance of the respective provisions taken in nuclear facilities. It specifically aims at

- identifying the areas where risk management approaches can contribute most to the cost-effectiveness of MMO approaches as well as the potential benefits and limits in that respect of qualitative and quantitative risk assessment methods,
- using risk management techniques for solving conflicts between economy and safety and to strengthen the proactive assessment of risks related to organisational changes,
- linking risk management with other management and decision making techniques such as safety management and risk-informed regulation.

The proposed research is expected to identify MMO related risk management approaches capable to achieve broad acceptance across various EU member states and to provide a basis for a European harmonisation of respective approaches. The expected outcomes include

- assessment of the maturity of present-day risk management approaches and identification of concepts for improvements,
- criteria for judging the sufficiency of risk information for their use for risk management purpose,
- integrated concepts for safety and risk management,
- guidelines for the implementation of risk management techniques for supporting decision making by industry and regulators,
- tools for risk-informed decision making support.

RT 2.5: Staffing

Aims: The term staffing refers to the determination of human resource needs, including the amount of work assigned to each employee, the professional competencies required, and the duration of experience demanded. The introduction of new technologies such as new types of plants, advanced automation and information communication technology will change the roles, responsibilities, composition and size of the crews that are required to control plant operations including emergency operations. Research should aid development of tools for assessing the effects of changes in staffing and competence levels and the amount of training needed. There is a close connection between staffing and other dimensions of a concept of operations such as level of automation and training and qualifications. Key factors influencing the number and competence requirements of the staff are, for example, the size and layout of the plant, the degree of flexibility of work rules and laws, the amount and quality of training, attrition and the number of auxiliary, part-time duties.

Topics and methods: This research should focus on analysis of the advantages and disadvantages of different functional staffing models using behavioural modelling techniques and simulation tools developed in other domains. It should also be necessary to improve understanding of what are the practical methods for the assessment of required staffing levels and of the safety effects of the modification of the staff. In this connection it should also be clarified how staff levels can be most appropriately established through benchmarking methodologies?

It would also be necessary to understand what is the impact of plant state on staffing requirements and how should their impact be included in staffing models, or how staffing requirements change and how should they should be studied at different stages of the life cycle of the plant. An important research issue is also how the possible loss of skilled staff should be managed to ensure the retention of the required knowledge and skills within the organisation and the assessment of the required staffing levels.

Outputs: The research enables improved understanding of the potential effects of new technologies on staffing requirements, of the different functional staffing models and how these can be utilised by NPPs to predict staffing requirements throughout the lifecycle of the plant.

RT 2.6: Analysis of work practices

The concept of "work practice" has been introduced as an alternative concept to the "information processing" perspective prevailing to study human performance.

Work practices are repeated and generalised ways of acting that are learned and shared in work places and communities. Work practice emphasizes the meaning of people's behaviour by drawing attention to the reasons people give to their actions and to the constraints and possibilities that they appear to take into account in their acting. Meaning provides continuity in behaviour. It explains why certain forms of behaviour are repeated; it also elaborates the role of routines.

Research on work practices should deal with the following questions:

- What are the criteria's to evaluate the impact of work practices on the plant's safety? When operating nuclear power plants, how do people balance safety goals against other intrinsic goals of production?
- From a methodological point of view, what are the articulations between analysis of work practices, organisational analysis of safety culture and resilience engineering? Would it be possible to develop a generic framework of requirements for safe practices (such as human performance tools)?
- How do practices change and develop during daily work? How can the organisation spread good practices throughout the workforce and especially to novices? How do people coordinate actions in dynamic situations? What is the role of routines and procedures in work?

- How does technology support or interfere with good work practices (especially in the context of upgrade projects involving new display systems and automatic systems)?

The output from research on work practices in the nuclear field finds application for improving the understanding of the impacts of human performance on power plant safety and a means to strengthen the positive role of the human actors. Work practices studies would produce empirical evidence for methods and metrics to evaluate technologies from user's perspective.

Work practices methods would be useful at different levels of maturity of the design, i.e. it could be used to provide guidance in requirement definition but could also be used to develop metrics to end-user studies during design or performance-based metrics in the more comprehensive integrated validation of systems. Thus it should influence the development of new technologies and concepts of operations.

RT 2.7: Human performance tools

This research topic addresses the use of INPO Human Performance tools only, leaving aside consideration of wider human performance issues in NPPs which is embedded within numerous other research topics.

INPO has developed a Human Performance programme which contains a series of concepts and principles that support the prevention of events triggered by human error in the workplace. These are based both on scientific and academic research, as well as experience from within the nuclear industry.

INPO promote the use of Human Performance tools that describe a set of discrete behaviours to help workers perform their activities more reliably. These tools aim to provide workers with proven techniques to help anticipate, prevent, or catch active errors before they cause harm to people, plant or property. The basic purpose of the tools is to help the individual or team maintain positive control of the work situation.

This topic addresses, amongst others, the following questions:

- What has been the impact of the INPO Human Performance tools on nuclear plant operations?
- Are the benefits similar across Europe?
- Which tools work best in different professions?
- Are the tools being used effectively?
- How effective are the tools compared with technological solutions?

In what circumstances is it acceptable to rely on the use of Human Performance tools to allow individuals to avoid potential errors rather than reducing the design deficiencies?

The main outputs from the research will be:

- Development of a common European position regarding the use and application of Human Performance tools.
- Provide a comparative study of the different approaches taken to embed human performance within utilities, thus allowing for an evaluation of the effectiveness of the different approaches to managing human behaviour.
- A comparison of the effectiveness of the use of Human Performance tools on their own against the use of technological devices (e.g. to check whether work is being conducted on the correct unit, equipment and plant item). This will include consideration of the financial implications of both approaches.

RT 2.8: Teamwork

Teamwork is a key issue for the stability and balance of the nuclear production process because a) people can help each other, mutually compensating for physical limitations or filling in gaps regarding skills; b) detection of a failure state and recovery from an abnormal situation often requires coordination of activities;

The team is a place where solutions are discussed when there are no rules corresponding to the situation. Conversely, poorly functioning crews contribute to the deterioration of safety standards.

Teams and collaborative work are at the junction of individuals and groups, skills and competencies, management practices, organisational modes, rules and prescriptions. This issue encompasses detailed aspects of the functioning of teams such as communications and collaboration falling into cognitive science, anthropology and activity theory, but also higher level aspects about how cultural values and norms of actions are forged and passed down by teams and professional groups falling into other disciplines, such as sociology.

Topics to be investigated are:

- What is the definition of a team? How do we take into account new forms of teamwork such as a change of venue between people cooperating through mobile computer aids or individuals belonging to several groups and having to adapt to different cultures or a different language?
- Is it possible to define a good team? Which are the characteristics of a good team? Use lessons from other industries e.g. aviation, fire and rescue.
- How are common references elaborated, maintained and passed on in collaborative settings? Is there such a phenomenon as alignment of mental representation between cooperation partners? What is the role of trust and confidence inside teams?
- What kind of modelling is required to describe cooperation between humans and intelligent agents i.e. technical system acting as humans such as computerized control room? Teamwork and procedure usage? Technologies supporting teamwork?

Output: To gain a better understanding of how teams function and the critical factors that influences performance and safety. Research should develop methods and artefacts to support teamwork including computer support (CSCW area of research) which could be used as models for the design of intelligent collaborative artefacts.

RT 2.9: Occupational health

In high risk organisations, Occupational Health and Safety (OHS) is described as "classic" where it does not apply to risks directly related to systems of production (e.g. exposure to ionising radiation). This classic OHS provides prevention for hazards such as failed equipment, dangerous substances, poor working postures, sources of stress, and risk factors such as working conditions or constraints. The approach aims to determine initiatives to reduce or eliminate identified risks. However, these prevention measures can often be local, focussed on "significant risks", and guided primarily by legislation. Furthermore, they are rarely systematically applied as prevention programmes are often fragmented by areas of expertise.

It would therefore be difficult to obtain a general assessment of management practices regarding OHS in the nuclear industry. Several areas can, however, be explored. For instance, the main feature of the nuclear industry is the existence of multiple areas of risk management (e.g. nuclear safety, environmental protection, industrial safety), so we can consider the implementation and integration of OHS within these areas for a better understanding of the implications on prevention strategies. The main thrust of the work is to analyse existing OHS integration within organisations, and between the organisation and its environment (e.g. relationships with regulatory agencies) as the framework for health and safety at work. Another area of focus will be on working hours and shift patterns, which differ between countries, thus providing the opportunity to investigate the impact of these factors specifically within the nuclear field.

This topic addresses the following questions:

- What can we learn about OHS in nuclear industries?
- What kinds of risks are related to specific jobs?
- Which prevention models are used?
- What management tools are associated with OHS?
- What are the connections to be made between nuclear safety and OHS? Is it possible to characterise the sub-cultures of risk prevention?

The main outputs from the research topic will be:

- Provision of a clear vision of the state of health and safety in the European nuclear industry,
- Identification of practices that may be shared between European operators,
- Identification of specific areas of intervention in the field for Human Factors consultants,

- Development of multidisciplinary prevention programmes and methods for a better integration of different actors (occupational medicine, ergonomists, sociologists, psychologists, HSE engineers).

RT 3.1: Human reliability analysis methods

The human contribution to risk and safety of nuclear power plant operation can be best understood, assessed and quantified using techniques of human reliability analysis (HRA). Although these have become an essential part of every probabilistic safety assessment (PSA) and are commonly used nowadays to demonstrate that NPPs conform to some prescribed safety level, looking for the most important plant operation risk contributors at the same time, even the best HRA methods have not yet been developed up to the point; they would model human behaviour sufficiently precisely and completely under all circumstances.

To a significant difference from various other PSA tools serving the analysts in the processes of risk-oriented decision making, HRA methodology is still being under development to cover all important dynamic, problematic and ambiguous aspects of human behaviour. Many HRA methods are used nowadays in European NPPs' risk-oriented studies, providing different results in estimation of human failure potential and yet not covering some specific particularly difficult subjects of the analysis at all.

The relation of HRA to PSA is crucial. Since human error represents very important or even dominant contributor to NPP operation risk, there is no credible and useful PSA application without well elaborated HRA. In addition, HRA may be used as an standalone tool for expression of abstract and complex human related risk potential by means of language of pretty simple quantitative probabilistic measures.

Basically, the research on human reliability analysis methods should be oriented two ways. First, an advanced HRA framework should be developed as a set of methods and tools, filling in possibly all the gaps in methodological support, where more sophisticated methodologies have had to be commonly replaced just with expert judgment and rough estimations in recent HRA and PSA studies. Covering of organisational factors impact with HRA may be seen as one example.

Secondly, current HRA methods thought appropriate for use in PSA should be compared and adjusted in the strongest fields of their expertise, where they still may provide pretty different estimates of human error potential. The aim is to get a harmonised approach, which will be applicable in the integrated European context. Such comparison and adjustment should be done both between selected HRA methods, comparing each against the others, and with empirical operational and particularly plant simulator data. In this part, many ideas of recent worldwide International Empirical HRA Study, documented in Halden Institute for Energy publication HWR-844 and U.S. Nuclear Regulatory Commission NUREG/IA-0216, can be employed.

The idea of HRA methodology (and, what is more important, analysis results) harmonisation over Europe is very important, because it represents a key step in objectification of estimates of nuclear power plant risk estimates made for different types (or even generations) of nuclear plants, regions, countries, cultural conditions etc.

The outputs from research on human reliability should be:

- a set of methods addressing those specific issues in HRA, which are known for decades, but still have not been solved up to now (to fill in the gaps)
- a specific sophisticated approach for HRA methods comparison, evaluation and selection, based on a set of newly developed criteria addressing HRA method quality, with respect to both current needs of HRA as an integral part of probabilistic safety assessment, and desirable features of HRA as a standalone means for human and organisation related risk-oriented decision making (to get tool for harmonisation of approach to human related risk estimation)
- harmonised integrated approach to human reliability analysis which can be proposed to be used in the European framework (to harmonise and objectify the analysis).

RT 3.2: Verification and validation

Verification and validation (V&V) are essential for any design project. V&V activities are required by regulators to demonstrate the safety of the system. In addition to this, there is a growing need for V&V methods for use early in the design process. V&V covers a broad range of activities and methods ranging from small-scale usability testing to the integrated validation of the designed system in simulator studies. There is urgent need for improved methods in this area as existing plants undergo major upgrades, and new operational concepts are being developed for future plants.

The research needs for validation can be organised into two categories, namely early and late validation. The challenge for validation at an early phase in the design process is to produce feedback about the perspectives of a concept at a time when a prototype of the new system may not yet exist. Once the design matures, other challenges emerge. When the system is tested in the simulator, e.g. for the purpose of demonstrating that the system can be operated safely, it is important to have guidelines and methods for identifying meaningful test scenarios and for defining relevant performance measures. Research on these issues is ongoing at a European level, but many challenges remain.

Verification describes the assessment of a design according to standards, e.g. ISO 11046 and NUREG-0700 for control room design. Research in this area should analyse current verification practices (including what standards are used in different countries, for what purposes, and how they are applied), and develop proposals for improved verification practices as well as improved content of the standards. Also needed are innovative tools for improving the efficiency and effectiveness of verification methods (e.g. use of 3D virtual reality tools for rapid assessment and automatic verification).

RT 3.3: Operating experience on human and organisational factors

The evaluation of Operating Experience (OE) in nuclear facilities and the translation of relevant findings into meaningful corrective actions are crucial for the safe and the economical performance of nuclear facilities. Research and development in that field is needed for strengthening the methods and tools for OE evaluation and the Operating Experience Feedback (OEF) processes implemented by the industry and the regulators.

The research topic deals with the human and organisational aspects related to the evaluation of operational experience (OE) and to operational experience feedback (OEF) for nuclear facilities. Emphasis is put on the improvement of methods and tools for evaluation of OE with human and organisational factors, on the assessment of the organisational and managerial aspects of the OEF processes, and on strengthening the communication and the dissemination of OE. The specific aims of the proposed research include:

- improving the methods to evaluate the influence of culture, management practices and regulatory framework, as well as the impact on resilience and vulnerability,
- identifying the potential of novel IT solutions (communication tools and data bases) to support HO related OEF,
- extending the possible sources of OE and information required to judge the efficiency of OEF processes related to integration of human and organisational factors findings into the management systems and decision making processes existing facilities and into the design of new plants,
- establishing the differences between the approaches and processes implemented in different EU Member States to assess the effectiveness of OEF and identifying possible improvements by harmonisation,
- strengthening the processes for OEF communication with special regard to the interaction with the regulatory oversight on OEF, the potential negative impact on internal communication within the plants, and the needs of designers for life time extensions and new plants.

The expected outcomes include:

- a European toolbox comprising of methods and IT solutions for supporting increased openness of the communication process relating to OE in nuclear power plants,
- a European guideline for the assessment of the effectiveness of OEF processes related to human and organisational factors.

RT 3.4: Tools and methods for assessing individuals and crews

Human Factors interventions are aimed at improving the performance of either individuals or of teams. In order to be able assess the effectiveness of Human factors interventions, it is therefore necessary to be able to measure the performance of a task or scenario both before and after Human Factors intervention. Related to this is the need to assess workload and the interaction of situational awareness of the operators in synthesising an understanding of the task demands and outputs.

Measurement of a complex task, such as those undertaken in NPP Control room operations is not straightforward. Often there may be multiple goals to be pursued simultaneously, multiple tasks with different relevance to goals competing for attention, and an influence of time stress and concerns over the consequences of poor performance.

The effective and reliable measurement of performance is also important as a driver for identifying areas that require HF intervention which currently relies on individuals identifying areas of concern or through the occurrence of errors, both of which are dependent on the correct identification of the underlying causes and are prone to influence by the preferences and motivations of the end user. Associated with the issue of task performance is the question of how to measure workload on complex tasks.

Improvements to procedures or equipment may be difficult to quantify as results may not become evident for some time and will only exist in the lack of reportable errors. There is a need, therefore, for a method of objectively assessing the performance of teams and individuals performing tasks. Many of the topics in Theme 2 are reliant on the methodologies and techniques available to measure them.

This research topic will address the following questions:

- Can qualitative measures be relied upon to provide a reliable indication of performance and workload?
- What quantitative measures can be used to measure workload and performance on complex tasks?
- How may we measure the performance of an operator handling multiple, mutually interacting tasks?
- Can similar methods of performance be used to measure individual and team performance?
- How to measure the safety performance of a socio-technical system in normal and emergency operational situations?

The output from this research topic will be:

- A suite of performance/workload and safety culture measures for use by HF specialists tasked with assessing the demands of various tasks undertaken either by teams or individuals.
- A method of quantifying the impact of HF interventions in complex tasks
- A method of assessing complex tasks in order to identify key instances or sub-tasks with associated high workloads in order to aid the direction of HF interventions

Appendix B: The ETPIS Platform

The scope of the European Technology Platform for Industrial Safety[1] (ETPIS) is the integrated and coherent treatment of the important aspects of design, production and operation of industrial products and systems, dealing both with technical and with human, organisational and cultural aspects, as well as the actual systems and processes used for managing safety. The main emphasis is on the use of risk-based methods for the optimal design of products, production facilities, industrial systems, activities and structures from the point of view of delivering improved safety levels at acceptable costs of maintenance and availability. ETPIS partners include representatives from European at-risks industries, universities, Safety regulators and governmental or regional authorities. ETPIS is organised in 5 Focus Groups (FG) which are:

- Risk Assessment and Management
- Advanced Risk Reduction Technologies
- Structural safety
- Human and Organisational Factors
- Emerging risks

The first action realized by ETPIS was to define a Strategic Research Agenda (SRA 1st edition on January 2006) giving a detailed description of the research topics for each FG. This SRA has been up dated, given research priorities on January 2008 during an ETPIS general assembly in Berlin. Each domain, in the SRA, is composed by several topics and each topic has been generally described with:

- A general description explaining the contents and the reasons why this topic must be treated,
- A description of the research priorities on short, mid and long terms

Concerning the FG Human and Organisational Factors the main research domains are in this order of priority:

1. Human and organisational factors in safety management;

This 1st domain concerns the improvement of the organisations, the managerial and working practices, the feedback of experience, the safety culture, the decision making processes concerning safety and also the communication concerning HF. It includes the following topics:

- Resilience engineering;
- Feedback of experience;
- Introduction of HF into safety management systems;

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[1] http://www.industrialsafety-tp.org

- Transaction costs approaches & social reports on safety management
- Safety culture and safety climate (including SME, process industries, national and regional cultures influences)
- Impact of HF knowledge throughout organisations

2. Human-Centred design;

Considering that design failures could be root causes for accidents, it is essential to improve the integration of Human and Organisational Factors during design activities; It concerns the design of new plants/equipment but also the revamping and/or modifications/ maintenance projects (technical and/or documentary projects) of at-risk industries including New Technologies of Information and Communication. In order to improve the communication within the designers' community and the relations between designer and operators, a participatory and users' centred design approach must be introduced

3. Integrated risk assessment and management methods & techniques;

Automation, tasks sharing, organisation, working load…have an influence on the operator performance and the Integrated Risk Assessment systems requires qualitative and quantitative data. The research in this domain will focus on production of knowledge, data and methods in order to introduce dynamically, these « latent conditions » in safety analysis. This domain includes the following topics:

- Integrating human factors into quantitative risk analysis (QRA);
- Operator cognitive models;
- Human factors in task management;
- Data retrieval.

4. Human Performance and technology usability;

It concerns the development of knowledge related to human performance in virtual environment, team errors and decision making processes for specific human technology interfaces or assisting systems for specific populations or working conditions. This domain includes the following topics:

- Decision making and handling of conflicting objectives;
- Human performance in virtual environments;
- Effective knowledge transfer to improving human performance;
- Team-working;
- Alarms handling & design;
- Human-centred design of tools and machines;
- Human-virtual environment interfaces;
- Development of integrated systems to implement intelligent capabilities in the PPE;
- Biomechanics and anthropometric requirements integration in PPE design;

- Rehabilitative and assistive systems: intelligent machines to enhance the abilities of disabled or elderly people;
- Research in emotion-based interfaces;
- Human-technology interfaces design for sensitive collectives at work;

5. Human factors in emergency and crisis management.

What are the most suitable organisational set-ups during emergency and crisis management have to be one of the primary points of attention of the HOF research in the next years to come. The use of VR applications will be particularly suitable for testing reactions and predicting the dynamics of complex scenarios where many actors play a key role in the resolution of the situation. The identification, definition and characterisation of salient HOF which play a key role during emergency ought to be a driving force of the short-term response.

The FP7 project INTeg-RISK (Integrated Risks 2008-2013) has started on December 2008 for a duration of 54 months. This project includes 64 European partners, with the European Virtual Institute for Integrated Risk Management[1] as leader of the consortium, and EDF R&D as leader of a sub project concerning methodological developments. This sub project aims to develop tools and methods for risks emerging management on the base of 17 studies cases (critical tasks sub contracted in at risk industries in order to identify good safety management practices for example) representing at-risks situations. These developments will take into account

- Several risks in the same analysis. The integrated risks analysis will cover simultaneously technical risks but also risks concerning environment, standards, human and organisational factors,
- Indicators concerning all the domains in order to support risks,
- Uncertainty associated to the management of emerging risks,
- Decision making in uncertain universe.

In order to update the priorities for the next EU projects the following priorities have been given to EU during an ETPIS general assembly on July 2009 in Brussels:

- Human Factors in emergency and crisis
- Human Centred design
- Human factors in organisational and managerial Safety.

[1] European Economical Interest Group founded by INERIS (France) and Stuttgart University (Germany). Further members are - among others - VTT (Finland), Iberdrola (Spain), SINTEF (Norway), EdF (France, CEA (France), GDF-Suez (France)