European Commission

FISA 2019

9th European Commission Conference on EURATOM Research and Training in Safety of Reactor Systems

Co-organised by the European Commission and the Romanian Presidency of the Council of the EU in 2019

romania2019.eu

RATEN ICN PITEȘTI
INSTITUTUL DE CERCETĂRI NUCLEARE

in cooperation with

EUROPEAN NUCLEAR SOCIETY

IAEA International Atomic Energy Agency

enen

4-7 June 2019
Pitesti, Romania

PROGRAMME & ABSTRACTS

Research and Innovation

FISA 2019 Conference Programme and Abstracts

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EUROPEAN COMMISSION

FISA 2019 Conference Programme and Abstracts

edited by Daniela Diaconu and Cristina-Alice Mărgeanu

Directorate-General for Research and Innovation
2020 Euratom Research and Training Framework Programme EN

Content

Foreword

It is with a great pleasure to welcome you here!

The European Commission (EC) is proud to co-organise the 9th EU/Euratom conferences - FISA 2019 and EURADWASTE '19 – jointly with the Ministry of Research and Innovation of Romania and the Institute for Nuclear Research (RATEN ICN), under the auspices of the Romanian Presidency of the Council of the EU in 2019.

Gathering some 500 stakeholders and policy makers, the FISA 2019 and EURADWASTE '19 conferences objectives are:

- To present progress and key achievements of some 90 projects carried out, since the previous conference edition in 2013, as part of the 7th and Horizon 2020 Euratom Research and Training Framework Programmes (FP)
- To stimulate discussions on the state of play of R&D, key challenges addressed at national, European and international levels on Research and Innovation policies, synergies and partnerships benefitting research and innovation programmes, and future perspectives.

FISA 2019 and EURADWASTE '19 conferences will address and engage with all relevant stakeholders involved: research and training organisations, academia, industry, technology platforms, European fora and European civil society, and International Organisations.

A common introduction and closure to the two conferences will provide a unique opportunity to set the scene at EU / national / international levels and to obtain a synthetic overview of issues and policies regarding the status of research on safety and implementation of programmes in both reactor systems, and high-level radioactive waste disposal in Europe.

Foreword

FISA 2019 technical sessions will cover progress of the research carried out through 78 projects on: safety of existing nuclear installations; severe accidents prevention and mitigation including emergency management; advanced nuclear systems for increased safety and sustainability, numerical simulation and digitalisation, innovative materials, research infrastructures, education & training and mobility of researchers, as well as cross-cutting actions such as International Cooperation.

There will be many opportunities for interaction and dialogue among stakeholders, through dedicated parallel & poster sessions. Additionally, FISA 2019 thematic workshops will provide key recommendations on infrastructures, international cooperation and partnerships in research and innovation, innovation beyond technology, education, training, knowledge management, lifelong learning and borderless mobility, cross-cutting research on fission, fusion and non-nuclear energy, decommissioning challenges and opportunities. Poster and MSc/PhD awards, ENEN PhD Event & Prize are providing opportunities to compete, in international conferences, for young scientists, MSc/PhD researchers, or young professionals. The latest EC proposal for a new Framework Programme for Research and Innovation for the period 2021-27, 'Horizon Europe' and 'Euratom Research and Training' programme will also be addressed.

We wish you a pleasant and productive FISA 2019 conference with many fruitful discussions for future international cooperation and partnerships in research and innovation!

A great thank you to everyone participating in our events!

On behalf of the Organising and Programme Committee
Roger Garbil (EC DG RTD, FISA 2019 Chair)
Daniela Diaconu (RATEN ICN and Romanian Presidency, Co-chair)

PROGRAMME

Tuesday, 4th June

Joint Introduction FISA2019 and EURADWASTE'19

Joint Session – International/ EU/ EURATOM Status in Radiation Protection, Safety of Reactor Systems and Radioactive Waste Management

FISA PROGRAMME

Session I - Safety of nuclear installations, Part I

Thematic Workshops 1, 2 and 3

PhD/MSc Poster Session

Wednesday, 5th June

Session II - Safety of nuclear installations, Part II

Session III - Advanced nuclear systems and fuel cycles

Thematic Workshop 4

Poster Sessions: Euratom Projects and Euratom Topics

Thursday, 6th June

Session IV - Education and training, research infrastructures and international cooperation

Thematic Workshops 5 and 6

Joint conclusions FISA2019 and EURADWASTE'19

Friday, 7th June

Technical tours

JOINT INTRODUCTION FISA 2019/EURADWASTE '19

Ramada Hotel, Diamond Room

Chair: Serban Constantin VALECA (RATEN ICN, RO)
Co-chair: Domenico ROSSETTI DI VALDALBERO (EC, DG RTD)
Rapporteur: Stefano MONTI (IAEA), Expert

09:00	**Patrick CHILD** (EC, DG RTD), Deputy Director General, Research and Innovation, European Commission Keynote: Euratom Research and Training and Horizon Europe framework programmes
09:10	**Charlina VITCHEVA** (EC, DG JRC), Deputy Director-General of the Joint Research Centre, European Commission Keynote: JRC role in Euratom Research and Training and Horizon Europe
09:30	**Nicolae HURDUC** (Minister, RO), Ministry of Research and Innovation, Romania Keynote
09:50	**Stefano MONTI** (IAEA), Section Head, Nuclear Power Technology Development section, Division of Nuclear Power, Department of Nuclear Energy Keynote: Research and Innovation for a safe, secure and safeguarded nuclear power in support of the UN Sustainable Development Goals
10:10	**Daniela LULACHE** (OECD/NEA, FR), Head of Office of Policy and Coordination, OECD Nuclear Energy Agency Keynote: Nuclear Research and Innovation successes and accomplishments looking to the future
10:30	***Coffee Break***
11:00	**Teodor CHIRICA** (FORATOM, BE), President of the European Nuclear Industry Association Keynote: Research and Innovation benefits for a low-carbon economy, Industrial Competitiveness and sustainable development
11:20	**Pierre Jean COULON** (EESC, EU), President of the Transport Energy and Networks section, European Economic and Social Committee Keynote: Research and Innovation missions and benefits to Civil Society to tackle today's Societal Challenges
11:40	**Nathan PATERSON** (ENS YGN, BE), Chair European Nuclear Society Young Nuclear Generation and **Joerg STARFLINGER** (ENEN, BE), Vice-President of ENEN, University of Stuttgart, Germany Keynote: The future of Nuclear: Collaboration, Vision and Innovation – perspectives from the YGN

12:00 Lunch and Poster Session

Tuesday, June 4th, PM

International / EU / EURATOM Status in Radiation Protection, Safety of Reactor Systems and Radioactive Waste Management

Alexandru Davila Theatre

Chair: Horia Grama (ANDR, RO)
Co-chair: Massimo Garribba (EC, DG ENER)
Rapporteur: Hans Forsström (SE), Expert

	STATUS OF EU/EURATOM DIRECTIVES
14:00	**Michael Huebel** (EC, DG ENER), Head of Unit, Radiation Protection and Nuclear Safety EU/Euratom Directives, 2013/59/Euratom on Basic Safety Standards, 2009/71/Euratom and 2014/87/Euratom update on nuclear safety of nuclear installations: status, challenges and future perspectives
14:20	**Massimo Garribba** (EC, DG ENER), Director Nuclear Energy, Safety and ITER EU/EURATOM R&D supporting Directive 2011/70/Euratom on the responsible and safe management of spent fuel and radioactive waste: status, challenges and future perspectives
	RADIOACTIVE WASTE MANAGEMENT
14:40	**Pierre-Marie Abadie** (ANDRA, FR), CEO Keynote: European & International status on the management and disposal of radioactive waste, developments and challenges ahead
15:10	**Andrew Orrell** (IAEA, Section Head for Waste and Environmental Safety) ARTEMIS in Europe, the Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation
15:40	**Christophe Davies** (EC, DG RTD), Euratom Fission, Project & Policy officer Euratom research and training programme in radioactive waste management: Overview status, vision and future perspectives
16:00	*Coffee Break*
	SAFETY OF REACTOR SYSTEMS
16:30	**Martin Murray** (Environment Agency, UK) EURATOM STC Opinion (Scientific and Technical Advisory Committee): Key recommendations from the Opinion published early 2017 and future perspectives
16:50	**Roger Garbil** (EC, DG RTD), Euratom Fission, Project & Policy Officer Euratom research and training programme in safety of the reactor systems: Overview status, vision and future perspectives
17:10	Panel and General discussion on the **Role of the Euratom R&T programme and Directive: Challenges and Research expectations (50')**

18:30 MSc/PhD Poster introduction and Conference cocktail

SESSION 1 - Safety of nuclear installations (I)

Ramada Hotel, Diamond Room

Chair: Teodor CHIRICA (FORATOM, BE), President
Co-chair: Maria BETTI (DG JRC, EC), Director of Directorate for Nuclear Safety and Security
Rapporteur: Abderrahim AL MAZOUZI (EDF, FR), Expert

The first session of two on safety of nuclear installations is devoted to reactor performance, system reliability, advanced numerical simulation and modelling for reactor safety, as well as to long-term operation of current Generation II-III reactors. As identified within SNETP-NUGENIA, for Generation II-III water cooled reactor technology and technical research areas the last topic is an important challenge since most countries are now considering prolonging the lifetime of their reactors from an originally foreseen 40 years' operation to 60 years. In order to safely extend the lifetime of these reactors, both nuclear operators and regulators need to have, in addition to a skilled and well-trained workforce, reliable tools to assess the ageing and degradation processes of components and structures, as well as methods and guidelines for their validation and safe management.

13:30	**Michel MASCHI** (EDF, FR) Keynote: SNETP-NUGENIA Research and Innovation in Nuclear
14:00	**Kevin MOTTERSHEAD** (WOOD Plc, UK) Reactor Performance, system reliability: Long-Term Operation (INCEFA-PLUS, SOTERIA, ATLAS-PLUS, MEACTOS, FP7-NUGENIA-PLUS)
14:30	**Andreas SCHUMM** (EDF, FR) Reactor Performance, system reliability: Instrumentation and control (ADVISE, NOMAD, TEAMCABLES, FP7-HARMONICS)
15:00	***Coffee Break***
15:30	**Christophe DEMAZIERE** (CHALMERS, SE) Advanced numerical simulation and modelling for reactor safety (CORTEX, McSAFE, FP7-NURESAFE, FP7-HPMC)
16:00	**Eija-Karita PUSKA** (VTT, FI) The Finnish nuclear programme, including LTO and new build
16:30	**General discussion and research perspectives** (60')

18:30 MSc/PhD Poster introduction and Conference cocktail

SESSION 2 - Safety of nuclear installations (II)

Ramada Hotel, Diamond Room

Chair: Guido BRACKE (GRS, DE), Waste Management Safety
Co-chair: Massimo GARRIBBA (DG ENER, EC), Director Nuclear Energy
Rapporteur: Giovanni BRUNA (FR), Expert

The second session on safety of nuclear installations is mainly devoted to lessons learned from the Fukushima Daiichi accident, strategic initiatives supported within Europe and internationally as a response to the accident, as well as to reviews of technical and scientific improvements in the area of severe accident management and emergency preparedness and response. Nuclear safety is also addressed through the adoption of innovative Generation II-III fuel and materials, and the development of accident-tolerant fuels. Moreover, high performance research reactors have to overcome the challenging conversion from highly enriched to low enriched uranium fuels, to fulfil a worldwide non-proliferation effort. Safety assessments and severe accidents analysis, impact of external events on nuclear power plants, studies on mitigation of strategies, and probabilistic safety assessments are further supported. As a result, nuclear and radiological emergency management and preparedness within Europe and across the whole continent highly benefit from a unified, shared and coordinated approach. As such, joint experimental research activities improve and strengthen any optimal use of shared resources, methodologies, tools, and collaboration at pan-European and international level.

09:00	**Stefano MONTI** (IAEA) Keynote: Global trends in nuclear power: advanced reactors including SMR integrated in hybrid energy systems
09:30	**Konstantina LAMBRINOU** (SCK-CEN, BE) Innovative Gen-II -III Reactors' Fuels and Materials (IL TROVATORE, FP7-MULTIMETAL, FP7-MATTER, FP7-SCWR-FQT)
09:50	**Stéphane VALANCE** (CEA, FR) Innovative and safe supply of Fuels for Reactors (LEU-FOREVER, HERACLES-CP, ESSANUF)
10:10	**Ahmed BENTAIB** (IRSN, FR) Safety assessments and severe accidents, impact of external events on nuclear power plants and on mitigation strategies (IVMR, SCO2-HeRo, FP7-SAFEST, FP7-PASSAM, FP7-CESAM, FP7-ALISA)
10:30	***Coffee Break***
11:00	**Evelyne FOERSTER** (CEA, FR) Probabilistic Safety Assessment for internal and external events (NARSIS, FP7-ASAMPSA-E)
11:20	**Federico ROCCHI** (ENEA, IT) Nuclear and radiological emergency management and preparedness (FASTNET, FP7-PREPARE)
11:40	**General discussion and research perspectives** (50')

12:30 Lunch and Poster Session

SESSION 3 - Advanced nuclear systems and fuel cycles

Ramada Hotel, Diamond Room

Chair: Franck CARRE (CEA, FR), Scientific Director at Nuclear Energy Division
Co-chair: Roger GARBIL (DG RTD, EC), Project and Policy Officer
Rapporteur: Teodora RETEGAN (CHALMERS University of Technology, SE), Expert

This third session on safety of advanced nuclear systems and fuel cycles is devoted to R&D of a new generation of more sustainable reactor technologies, the safety design and licensing of technologies also identified by the European Sustainable Nuclear Industrial Initiative (SNETP-ESNII Generation IV fast reactors and closing the fuel cycle). An important feature of advanced nuclear systems is the development of innovative fuels and materials which benefits from the development benefits of the support from EERA JPNM (Joint Programme on Nuclear Materials for fission and fusion). Additionally, the entire nuclear fuel cycle is studied, from fuel fabrication to recycling strategies, partitioning and transmutation, to waste streams and high-level waste management, in order to meet, among others, the sustainable goals of minimisation of waste and better use of natural resources. Development of new applications for nuclear such as the Nuclear Cogeneration Industrial Initiative with high temperature reactors (SNETP-NC2I, cogeneration of electricity and heat) is also presented. Cross-cutting nuclear data activities to the level needed by simulation codes to fulfil present requirements, for the safe and sustainable operation, development of existing and future fission and fusion reactors and nuclear fuel cycle facilities, will be also discussed.

14:00	**Noël CAMARCAT** (EDF, FR) Keynote: SNETP-ESNII and EERA-JPNM Research and Innovation
14:20	**Konstantin MIKITIUK** (PSI, CH) R&D in support to safety assessment, design and licensing of ESNII/Gen-IV (ESFR-SMART, ESNII+, SESAME, SAMOFAR, VINCO, FP7-ALLIANCE, FP7-SILER, FP7-SARGEN-IV, FP7-JASMIN)
14:50	**Stéphane BOURG** (CEA, FR) From fuel to fuel: Dissolution, Partitioning and fuel manufacturing (GENIORS, FP7-SACSESS, FP7-ASGARD)
15:20	**Hamid AIT ABDERRAHIM** (SCK-CEN, BE) Partitioning and Transmutation, contribution of MYRRHA to an EU strategy for HLW management (MYRTE, FP7-MARISA, FP7-MAXSIMA, FP7-SEARCH, FP7-MAX, FP7-FREYA, FP7-ARCAS)
15:50	*Coffee Break*
16:20	**Lorenzo MALERBA** (CIEMAT, ES) Innovative Gen-IV Fuels and Materials, EERA-JPNM, Fission and Fusion (GEMMA, INSPYRE, M4F, TRANSAT, FP7-MATISSE, FP7-PELGRIMM)
16:50	**Grzegorz WROCHNA** (NCBJ, PL) Nuclear Cogeneration with High Temperature Reactors (GEMINI-PLUS, FP7-NC2I-R)
17:10	**Enrique GONZALEZ** (CIEMAT, ES) Nuclear data activities (FP7-CHANDA, FP7-ERINDA, FP7-EUFRAT)
17:30	**General discussion and research perspectives** (30')

19:00 ENEN PhD Prize and Conference Dinner

SESSION 4 - Education and training, research infrastructures and international cooperation

Ramada Hotel, Diamond Room

Chair: Daniela LULACHE (OECD/NEA, FR), Head of Office of Policy and Coordination
Co-chair: Foivos MARIAS (DG RTD, EC), Project and Policy Officer
Rapporteur: Gérard COGNET (FR), Expert

Nuclear safety remains, as always, the top priority and the European Union has an outstanding nuclear safety record. However, research must continue to maintaining the highest level of nuclear safety, security and safeguards. The European nuclear sector is characterised by cutting edge technology and provides several hundred thousand people with highly skilled employment. To ensure our safety both now and in the future skilled people and well-equipped nuclear research facilities are of paramount importance. The availability of these resources is a crucial prerequisite for maintaining safety no matter what the future holds for the nuclear power sector. Europe can retain its technological leadership only if Member States maintain a diverse and well-funded nuclear R&D capability, a fit-for-purpose system for the education and training of scientists and engineers, availability of state-of-the-art research infrastructures, and reinforced international cooperation in key strategic areas with leading third countries, bilaterally or multilaterally. EU/Euratom helps to stimulate joint funding from Member States and/or enterprises, joint programming and dialogue at EU level, cross-cutting fission/fusion/non-nuclear innovative initiatives and benefits are being capitalised from the increasing interaction between European technology platforms, EU stakeholder fora, as well as International Organisations such as OECD/NEA and IAEA.

09:00	**Franck CARRE** (CEA, FR) Growing Synergies between Fission and Fusion Research towards demonstration plants
09:30	**Walter AMBROSINI** (University of PISA, IT) Education, Training and mobility: towards a common effort to assure a future workforce in Europe and abroad (ANNETTE, ENEN-PLUS, BRILLIANT, CORONA-II, FP7-ENEN-RU-II, FP7-ARCADIA, FP7-NEWLANCER, FP7-ECNET, FP7-NUSHARE, FP7-GENTLE)
10:00	**Michèle COECK** (SCK-CEN, BE) Improved expertise in radiation protection, nuclear chemistry and geological disposal (CONCERT, MEET-CINCH, FP7-ENETRAP-III, FP7-EAGLE, FP7-CINCH-II, FP7-PETRUS-III)
10:30	***Coffee Break***
11:00	**Concetta FAZIO** (DG JRC, EC) Supporting Access to key infrastructures and pan-European research (FP7-GENTLE, FP7-TALISMAN, others)
11:30	**Jean-Yves BLANC** (CEA, FR) Supporting Infrastructures and Research Reactors: Status, needs and International Cooperation (FP7 and H2020 JHR ACCESS RIGHTS)
12:00	**General discussion and research perspectives (30')**
12:30	**Lunch**

Joint Conclusions FISA 2019/EURADWASTE '19

Ramada Hotel, Diamond Room

Chair: Said ABOUSAHL (EC, DG JRC), Head of Unit, Euratom Coordination

Co-chair: Domenico ROSSETTI DI VALDALBERO (EC, DG RTD), Deputy HoU, Euratom Research

Rapporteur: Stefano MONTI (IAEA), Expert

14:00	**Nicolae Hurduc** (Minister, RO), Ministry of Research and Innovation, Romania Keynote
14:15	**Poster and PhD Awards** FISA 2019 and EURADWASTE '19 Poster and PhD Awards
15:00	**Hans Forsström** (SE), Expert rapporteur EURADWASTE '19 - Key messages and future perspectives
15:20	**Stefano Monti** (IAEA), Expert rapporteur FISA 2019 - Key messages and future perspectives
15:40	**Closing remarks from the Romanian Presidency and the European Commission**

Technical workshops

Technical workshops

Workshops' objectives:

Lessons learned and latest initiatives, challenges and opportunities, to further promote EU/Euratom collaborative research and training activities, to strengthen international cooperation, and practical **key recommendations for the FISA2019 and EURADWASTE'19 conferences' conclusions** will be the key objectives of these workshops.

Ramada Hotel	
Day 1, PM	**Tuesday, 4 June**
Opal Room	**1. Infrastructures and International Cooperation, co-funding instruments, and partnerships in research and innovation**
Onix Room	**2. Innovations beyond technology**
Ametist Room	**3. E&T networking event**
Day 2, AM	**Wednesday, 5 June**
Onix Room	**4. ALFRED: a sizeable opportunity for Europe**
Day 3, AM	**Thursday, 6 June**
Onix Room	**5. Cross-cutting fission, fusion and non-nuclear energy synergies, challenges and opportunities**
Opal Room	**6. Decommissioning challenges and opportunities**

Technical Workshop no.1

Ramada Hotel, OPAL Room

Day 1, PM	Tuesday, 4 June
14:00 – 17:00	**Infrastructures and International Cooperation, co-funding instruments, and partnerships in research and innovation**

Co-Chairs: **Helena ZATLKAJOVA (DG RTD, EC)**
Margaret McGRATH (PALLAS, NL)
Rapporteur: **Gérard COGNET (FR), Expert**

Objective

Large research infrastructures are at the core of the knowledge triangle of research, education and innovation, producing knowledge through research, disseminating it through education, and applying it through innovation. They offer unique research services to users from different countries, attract young people to science, and help to shape scientific communities through top-level research in their respective fields, and nuclear safety research and training.

To fulfil the key objectives EU/Euratom R&D programmes of maintaining high levels of nuclear safety, knowledge and building a more dynamic and competitive European industry, promoting Pan-European mobility of researchers are implemented by co-financing transnational access to research infrastructures and joint research activities through Research and Innovation and Coordination and Support Actions' funding schemes. Establishment by the research community of European technology platforms is being capitalised. Mapping of research infrastructures, financial mechanisms and funding instruments, and E&T capabilities are stimulating closer cooperation within the European Union and beyond, with the benefit from multilateral international agreements and synergies of initiatives between Euratom, OECD/NEA, IAEA and international fora.

Lessons learned and latest initiatives towards large research infrastructures and E&T, challenges and opportunities to promote further utilisation of experimental facilities for collaborative research and training purposes, and practical key recommendations to strengthen international cooperation will be the objectives of this workshop.

Round Panel

Jules Horowitz Reactor, Annabelle LOPEZ (CEA, FR)

Extreme Light Infrastructure, Ionel ANDREI, (ELI-NP, RO)

MYRRHA, Hamid AIT ABDERRAHIM (SCK-CEN, BE)

New NEA in-pile testing Framework following the positive Halden experience, **Markus BEILMANN** (OECD / NEA, FR)

Technical Workshop no.2

Ramada Hotel, ONIX Room

Day 2, PM	Tuesday, 4 June
14:00 – 17:00	**Innovations beyond technology**

Co-Chairs: **Foivos MARIAS (DG RTD, EC)**
Guillaume GILLET (EIT-KIC-InnoEnergy, FR)
Rapporteur: **Stefano MONTI (IAEA), Expert**

Objective

One of the strategic initiatives launched in 2015 by the European Commission is 'Open innovation' aiming at far more involving far more actors in the innovation process, from research and academic communities, to industry, entrepreneurs, users, governments and civil society. They all need Open innovation to capitalise on the results of European research and innovation, by creating the right ecosystems, by bringing together multi-disciplinary teams to generate ideas and solutions in an open innovation environment, and by increasing investment, by bringing more companies and regions into the knowledge economy.

'Innovation beyond technology' is about a technology developed for one sector e.g. aerospace, aircrafts, telecoms, big science, automotive or nuclear industries used in a totally different area. And technology transfer results from the process of using a technology, expertise, know-how or facilities for a purpose for which they were not originally intended.

It opens the minds and the way for strengthening relationships and for transferring new technologies to spin-offs, to industry and the marketplace, to transform European's capability for innovation in specific areas and to help capture and drive future economic growth. Exploiting the innovation potential in European and/or International industrial and academic communities will only be achieved by being a focal point where small and medium enterprises, large industry and end users can work together with researchers to challenge barriers, explore and develop new ideas, and bring these to commercial reality. Practical key recommendations to strengthen cross-sectorial cooperation in key areas will be the main objective of this workshop.

Round Panel

Space Industry, Zsuzsanna TANDI (WIGNER Research Institute, HU), ESA technology transfer

Big Science industry, **Marcello LOSSASSO** (CERN, CH)

Nuclear industry, **Antony WOAYE-HUNE** (FRAMATOME, FR)

EIT - Making innovation happen, Guillaume GILLET (EIT InnoEnergy, FR)

Technical Workshop no.3

Ramada Hotel, AMETIST Room

Day 1, PM	Tuesday, 4 June
14:00 – 17:00	**E&T networking event, Nuclear Education: A Cause for Concern?**

Co-Chairs: **Panagiotis MANOLATOS (DG RTD, EC)**
Walter AMBROSINI (University of Pisa, IT)
Rapporteur: **Teodora RETEGAN (CHALMERS University of Technology, SE)**

Objective

The dwindling education, training and knowledge management in many nuclear disciplines was interpreted as "A cause for concern?" in 2000 by the OECD/NEA report entitled "Nuclear Education and Training: A Cause for Concern?" Many bottom-up initiatives have been launched since then, resulting among others in preserving and further development of nuclear education and training. Nonetheless, the long-term sustainability of nuclear education and training seems to be exposed to larger risks than two decades ago.
The challenges to be addressed: How did this happen? What are possible bottom-up ad top down strategies to preserve and further develop the nuclear education and training for the future generations of nuclear workforce in Europe? How can we engage all nuclear stakeholders (including general public) to jointly promote the necessity of and support for nuclear education and training?
Practical key recommendations on the paramount importance of guaranteeing an adequate supply of experts and trained cross-sectorial workers will be the main objective of this workshop.

Round Panel

Prof Dr **Javier DIES LLOVERA** (Commissioner, Consejo de Seguridad Nuclear, ES)
Prof Dr **Joerg STARFLINGER** (Vice-President of ENEN, Uni Stuttgart Germany, DE)
Mr **Nathan PATERSON**, President (ENS YGN, BE)
Dr **Pavel ZHURAVLEV** (ROSATOMTECH, RU)

Technical Workshop no.4

Ramada Hotel, ONIX Room

Day 2, AM	Wednesday, 5 June
11:00 – 12:30	**ALFRED: a sizeable opportunity for Europe**

Co-Chairs: **Teodor CHIRICA (FORATOM, BE)**
Giovanni VILLABRUNA (FALCON, IT)
Rapporteur: **Giacomo GRASSO (ENEA, IT)**

Objective

The drastic reduction of the amount of radioactive waste and its long-term radiotoxicity, together with the enhancement of the safety characteristics, acted as important factors in Euratom programmes to support the development of Generation IV nuclear systems. The steady and rapid increase of the readiness of the Lead Fast Reactor technology opens to the possibility for a short-term perspective, with the deployment of commercially viable LFR-based SMRs.
To materialize this vision, the ALFRED project is being promoted by the FALCON international consortium, for a European demonstrator of the LFR technology to be realized in Romania. FALCON, led by Ansaldo Nucleare and gathering ENEA and RATEN ICN, is addressing the undeniable challenges posed by the development of an innovative technology, by investing in the design and licensing activities, and on all the supporting R&D actions, also involving other organizations at European and Romanian level, historically engaged in the LFR development.
Besides, FALCON members and supporters share the belief that ALFRED is an invaluable opportunity: for Europe, to take a synergic leadership at the trailing-edge of nuclear technology; for Romania, to host a world-class research infrastructure.
The panellists, renowned experts in the field and representatives of the above institutions, will provide background information and their strategy to address the above challenges, converting them into opportunities for European competitiveness.

Round Panel

A firm determination through passion and commitment, Prof. Serban Constantin VALECA (Senate Vice-President, RO)

A collaborative effort for a common vision, Alessandro ALEMBERTI (Ansaldo Nucleare, IT)

Achievements and challenges for the full technological readiness, Mariano TARANTINO (ENEA, IT)

Aims and ambitions of the Romanian industry, Teodor CHIRICA (ROMATOM, RO)

A cohesive national support for qualified human resources, Dumitru CHIRLESAN (CESINA, RO)

Local, regional and national preparation to be a perfect host, Marin CONSTANTIN (RATEN ICN, RO)

Technical Workshop no.5

Ramada Hotel, ONIX Room

Day 3, AM	**Thursday, 6 June**
09:00 – 12:00	**Cross-cutting fission, fusion and non-nuclear energy synergies, challenges and opportunities**

Co-Chairs: **Mykola DZUBINSKY (DG RTD, EC)**
Lorenzo MALERBA (CIEMAT, ES)
Rapporteur: **Giovanni BRUNA (FR), Expert**

Objective

Common technological constraints and methodological approaches, combined with similarities between their safety concepts, have stimulated - and should stimulate even more in the future - synergies between nuclear fission and fusion energy research. For example, at the moment two cross-cutting Research and Innovation Actions show the benefit of cross-fertilization and working in a transversal way (M4F and TRANSAT). In addition, several commonalities emerge between nuclear (fission and fusion) and other energy technologies. Cooperation opportunities have been established between national, European and international Energy research programmes for a low carbon economy within the European Energy Research Alliance (EERA, the research pillar of the EU Strategic Energy Technology Plan, SET-Plan), involving cross-fertilization through joint research programmes e.g. related to nuclear materials (JPNM) and solar thermal energy (CSP), , as well as geothermal energy (JP-GEO), bioenergy (JP-BIO) and hydrogen and fuel cells (JP-FCH).

Thus, it is straightforward that the development of state-of-the-art and innovative materials and materials manufacturing processes, the elaboration of design codes and standards, computational tools for advanced nuclear systems and the related safety approaches and culture, as well as specific issues such as remote maintenance, benefit from a successful close cooperation between EU/Euratom R&D programmes to maintain the highest levels of nuclear safety. Further cross-cutting developments, innovation and exchange of knowledge with non-nuclear research would also be highly beneficial, to tackle today's societal challenges and the world's Sustainable Development Goals, and to build a more dynamic and competitive European industry.

Mission-oriented recommendations to strengthen nuclear fission, fusion and non-nuclear energy collaboration opportunities will be the main objective of this workshop.

Round Panel

Cross-cutting fission / fusion / solar thermal energy challenges, Lorenzo MALERBA (CIEMAT, ES)

Synergies between fission and fusion: an industrial perspective, Alessandro ALEMBERTI (Ansaldo Nucleare, IT)

Synergies between nuclear and solar thermal energy, Florian SUTTER (DLR, EERA JP-CSP, DE)

Opportunities and benefits from fusion / fission energy collaboration, Christian GRISOLIA (CEA, FR)

Common challenges concerning design codes for fusion and fission components Jarir AKTA (KIT, DE)

Technical Workshop no.6

Ramada Hotel, OPAL Room

Day 3, AM	**Thursday, 6 June**
09:00 – 12:00	**Decommissioning challenges and opportunities**

Co-Chairs: **Pierre KOCKEROLS (DG JRC, EC)**
Athanasios PETRIDIS (DG RTD, EC)
Rapporteur: **Christine GEORGES (CEA, FR), Expert**

Objective

Nuclear decommissioning is an industrial activity strongly growing worldwide and creating opportunities for high-skilled workers. The European Union has acquired a large know-how in the field and can position itself today as a leader in the world. The European scientific community has a key role to play to support the European industry in this endeavor through a contribution to innovation, standardization and harmonization of the highest safety standards, development and/or capitalizing the best technologies available. Research challenges and opportunities in technical and non-technical fields identified should enable all relevant stakeholders to jointly improve safety, to support its value chain, to reduce costs and minimize environmental impact in the decommissioning of nuclear facilities.

Building confidence through the steps needed for the generation and management of knowledge on decommissioning, identifying key research areas, creating synergies between European partners, and supporting international collaborative platforms whenever applicable are all key enablers. Universities, research laboratories and industry should engage in innovative approaches, benefit from a vibrant education and training culture, basic academic MSc/ PhD/ Engineering/ Managerial education as well as continuous professional development of competences. The use of advanced technologies across all nuclear and engineering fields should guarantee a new generation of skilled experts will be available whenever needed, having high levels of safety implemented throughout the sector for decades.

Having key challenges and opportunities of decommissioning Identified, recommendations on how to support the application highest safety standards, a global positioning of the EU technologies, organisations and industries in this area will be the main objectives of this workshop.

Round Panel

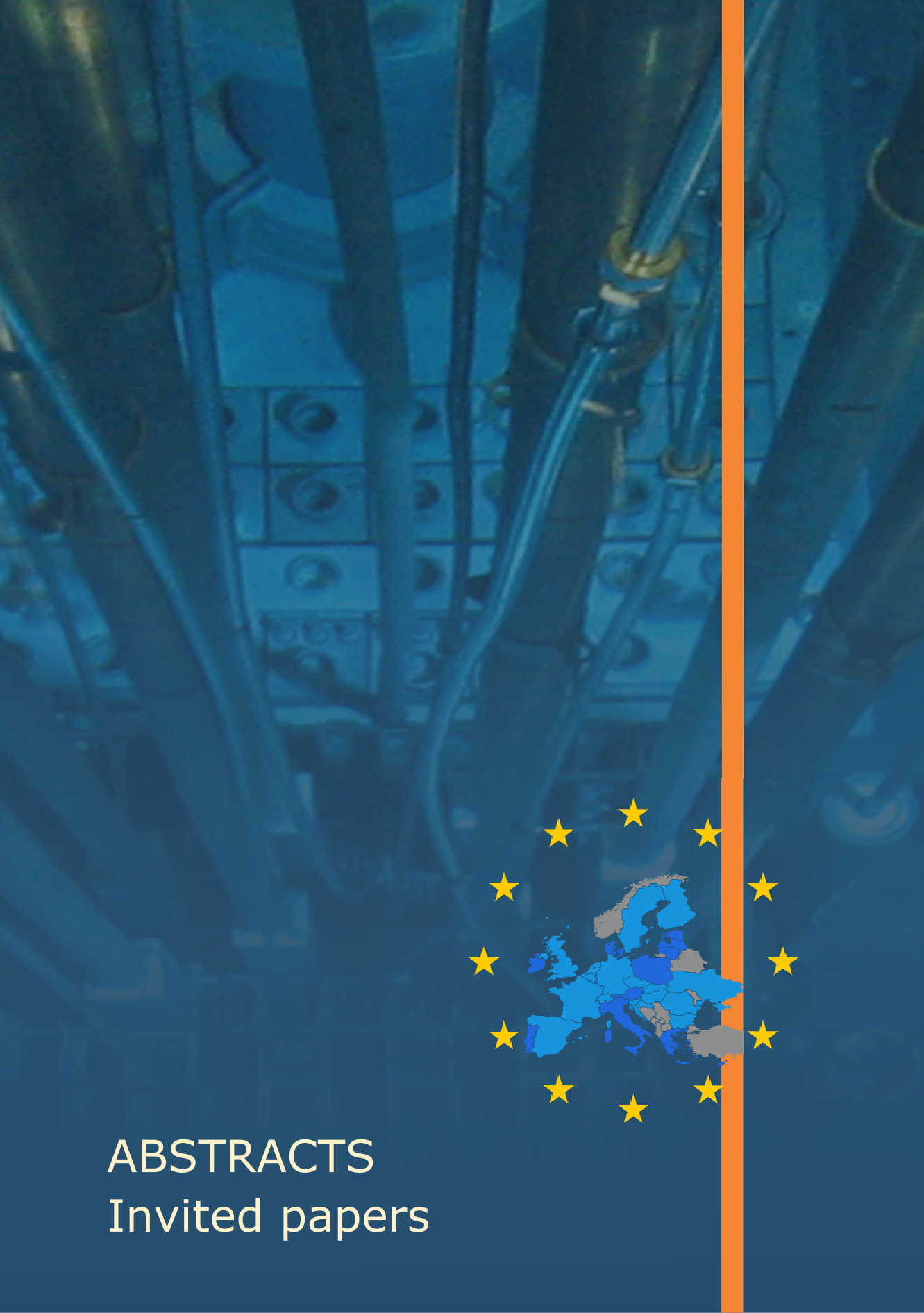
SHARE project to identify a decommissioning R&D roadmap, Christine GEORGES (CEA, FR)

Decommissioning R&D in Germany, Walter TROMM (KIT, DE)

Retrieval of graphite – development needs at EU level, Nicolas MALLERON (EDF, FR) (tbc)

Laser Cutting Techniques for Decommissioning, Julien GUILLEMIN (ONET, FR)

European learning initiatives for nuclear decommissioning and environmental remediation, Pierre KOCKEROLS (DG JRC, EC)



ABSTRACTS
Invited papers

Joint Introduction - International R&D and Euratom Directives

EU/EURATOM DIRECTIVES-2013/59/EURATOM ON BASIC SAFETY STANDARDS AND AMENDED NUCLEAR SAFETY DIRECTIVE 2014/87/EURATOM: STATUS, CHALLENGES AND FUTURE PERSPECTIVES

Dr. Michael Huebel

European Commission, Luxembourg

The presentation will be focused on the Euratom legal framework for nuclear safety and radiation protection as set out in Directives 2014/87/Euratom and 2013/59/Euratom, respectively.

Taken together with the Radioactive Waste Directive, the Directives provide a comprehensive framework to ensure a high level of radiation protection and nuclear safety across the European Union.

The Nuclear Safety and Basic Safety Standards Directives have undergone significant changes in their latest iterations, and the Commission is currently assessing their transposition into national legal systems.

The presentation will set out the main new features of the amended Nuclear Safety Directive such as the enhanced safety objective. On the Basic Safety Standards Directive it will focus on key areas of application such as emergency preparedness and response, the medical field and naturally occurring radiation and radon. The presentation will also cover non power uses of radiation and nuclear technologies. It will look into the way the legal framework has built upon lessons learnt from research, and emerging needs for new research to be launched in the future.

DIRECTIVE 2011/70/EURATOM ON THE SAFE AND RESPONSIBLE MANAGEMENT OF SPENT FUEL AND RADIOACTIVE WASTE AND ITS CURRENT IMPLEMENTATION STATUS

Dr. Massimo Garribba

European Commission, Luxembourg

Radioactive waste is generated in all EU Member States by a large variety of activities ranging from medical applications to electricity power generation. Owing to its radiological properties and the potential hazard it poses to workers and the public, it is important to ensure the safe management of such material from generation to disposal. This requires containment and isolation from humans and the living environment over a long period.

The EU nuclear legal framework has undergone significant changes in the last decade with the adoption of legislation on nuclear safety, radioactive waste and spent fuel management and in depth revision of the radiation protection acquis.

The adoption in 2011 of the Directive on the safe and responsible management of spent fuel and radioactive waste was a major step towards achieving a comprehensive and legally binding framework at EU level. Through the implementation of this Directive, Member States are required to demonstrate that they have taken reasonable steps to ensure that radioactive waste and spent fuel is managed safely and that no undue burden is passed to future generations.

The safe and responsible management of these materials is of particular importance. This is especially the case now as many existing nuclear power reactors are reaching the end of their operational lives and will need to be decommissioned. The radioactive waste generated in this process will need to be stored and/or disposed.

In 2017 the Commission was in a position to provide for the first time a comprehensive overview to the Council, European Parliament and EU citizens on this important issue. Such a report will be submitted every three years, on the basis of Member States' reports to the Commission on the status of their implementation of the Directive.

The presentation will relate the latest update of implementation of the Directive by EU Member States and challenges for the future.

EUROPEAN & INTERNATIONAL STATUS ON THE MANAGEMENT AND DISPOSAL OF RADIOACTIVE WASTE, DEVELOPMENT AND CHALLENGES AHEAD

Pierre-Marie Abadie

ANDRA, France

In nuclear energy producing countries, the 2019 international panorama concerning the management of spent fuel or radioactive waste arising from the production of electricity now includes three categories of countries:

- countries such as Sweden, Finland or France, where Deep Geological Repository projects are well advanced;
- countries such as Russia and China, where Underground Research laboratories are being constructed; and
- countries such as UK, Germany and Japan that each now have a structured siting strategy.

Due to the timeframes of these projects, and their needed safety, all actors have now realized that they require adequate Human Capacity Building and in depth Knowledge Management. The International agencies (IAEA and NEA) support these projects completely, as does the EC, and one must note the recent set up of the European Joint Programing EURAD that brings together Research entities, TSO s and WMOs to deal with Waste Management. Of course, the pros and cons of such organizations must be kept in mind.

The situation regarding the waste arising from the dismantling of nuclear Power Plants raises different challenges compared to the previous ones in view of the volumes of radioactive waste generated (with or without exemption levels). The subject is key and dealt with in ad hoc recently organized structures such as the Committee on Decommissioning of nuclear installations and Legacy Management (CDLM - NEA) and the Decommissioning and Environmental Remediation Section (DERS - IAEA). The question of the dismantling of graphite reactors raises specific questions analyzed by the countries that used this technology (mainly Russia, UK and France).

In all countries, the waste arising from the operations of research reactors, the use of radioactive sources or the waste linked to NORM raise issues that are a complex to deal with in countries were nuclear safety and waste management structures are not always present. In addition, the volumes of waste are small and need proportionate solutions. A promising solution for sources based on boreholes is currently developed with strong international support (IAEA). Other types of waste, in limited volumes, could benefit from this type of solution.

EURATOM STC OPINION (SCIENTIFIC AND TECHNICAL ADVISORY COMMITTEE): KEY RECOMMENDATIONS FROM THE OPINION PUBLISHED EARLY 2017 AND FUTURE PERSPECTIVES

Martin P. MURRAY

Environment Agency,Wallingford – England

The Euratom Scientific and Technical Committee (STC) is the only scientific and technical advisory body formally enshrined in the Euratom Treaty (Article 134) and active since 1957.

For over 60 years the STC has provided independent authoritative advice and opinion on all aspects of nuclear technology. Its members are appointed from all Member States, for a five-year renewable term, as independent experts in nuclear medicine and radiation protection, in nuclear fission reactor systems and fuel cycles, waste management and thermonuclear fusion. The STC is also responsible for nominating the experts advising the Commission on the basic standards for radiation protection (the Article 31 Expert Group) and on the assessment of the health impact of radioactive release from nuclear facilities (the Article 37 Expert Group).

The opinion published in 2017 sets out the Legacy Messages from the committee's 2013-2018 mandate. It informs the new committee on its role in being proactive in its advice to the Commission and European Parliament. It notes, given current funding, that important decisions will need to be made regarding Europe's and Member States' future research priorities and investment in scientific infrastructure in the coming years. The opinion concludes by recognising the potential for synergies between the Euratom research and cross-cutting initiatives in other EU research fields

EURATOM RESEARCH AND TRAINING PROGRAMME IN SAFETY OF THE REACTOR SYSTEMS: OVERVIEW STATUS, VISION AND FUTURE PERSPECTIVES

Roger Garbil

European Commission, DG RTD, Belgium

EU/Euratom has been the framework in which, for more than 60 years, peaceful use of nuclear energy, knowledge and competence management in nuclear science and technology have been developed in Europe. It benefits from close bi- or multi- lateral long-standing international cooperation frameworks e.g. together with OECD/NEA, GIF and IAEA. EU/Euratom Framework Research and Training Programmes are consistently significantly contributing in establishing the highest standards for safety and radiation protection, safeguards and security, as emphasized within today's legally binding EU/Euratom Directives for Member States. The EU added value of realizing a true European Research Area is constantly acknowledged. Thanks to a shared view on the main scientific or technology challenges and opportunities, e.g by establishing strategic research and innovation agendas / roadmaps, together with Member States, significant progress of EU/Euratom FP7 / H2020 innovative research projects and key achievements further strengthen the relations for all citizens between science, civil society, industry and policy makers. Thankfully, partnerships between EU/Euratom / MS / research organisations / industry / academia and/or technology platforms lead towards highly successful developments of joint research activities, unique research infrastructures networks, transnational and open access to facilities. Thanks to Horizon Europe's proposal, these science and technology research efforts should further help capitalizing fundamental competences, hands-on training and know-how, sharing capabilities in both energy and non-energy applications, contribute to maintaining the highest levels of nuclear safety and enhance further the competitiveness of our industry.

Safety of nuclear installations

REACTOR PERFORMANCE, SYSTEM RELIABILITY: LONG TERM OPERATION

Kevin Mottershead (1); Dr. Robertson, C. (2); Lindqvist, S. (3); Dr. Perosanz lopez, F. (4); Dr. Puska, E. (3)

1- Wood, United Kingdom, 2- CEA, France, 3- VTT, Finland, 4- CIEMAT, Spain

Mindful of the challenges to long-term operation, especially the severe safety and environmental consequences shown through historical nuclear power plant accidents (e.g. Fukushima, Chernobyl, etc), it is imperative that European research and innovation focuses on

demonstrating reliable long-term operation. Five examples of European Commission supported projects meeting such objectives are INCEFA+, SOTERIA, ATLAS+, MEACTOS and NUGENIA+. There are economies of scale within, and synergies across these projects which enable further advantage to be gained. Additionally, since researchers are well engaged internationally, this brings into European Organisations latest developments in understanding from further afield (e.g. USA, Japan), further enabling safety assurance advances, and enabling work overseas to be influenced consistent with European requirements. Through examples, this paper provides evidence of the advances claimed, whilst being careful to also declare areas of interest for which further work is still a priority.

REACTOR PERFORMANCE, SYSTEM RELIABILITY, INSTRUMENTATION AND CONTROL

Dr. Andreas Schumm (1); Dr. Rabung, M. (2); Dr. Marque, G. (1); Dr. Hamalainen, J. (3)

1- EDF, France; 2- Fraunhofer IZFP, Germany; 3- VTT, Finland

The effective maintenance of nuclear power plants is essential for their safe operation. Maintenance ensures that the level of reliability and effectiveness of all safety-relevant components and systems remains in accordance with design assumptions, and also that it is not adversely affected during operation. This requires an understanding of ageing mechanisms for the different components and materials used in plants, as well as a thorough and quantitative assessment of the health and reliability of safety-relevant components.

We present a cross-cutting review of three on-going Horizon 2020 projects (ADVISE, NOMAD, Team CABLES) and one FP7 project (HARMONICS) which address the reliability of safety-relevant components and systems in nuclear power plants. ADVISE and NOMAD aim to improve quantitative Non-destructive Evaluation Techniques to components in the primary loop to obtain a quantitative assessment of the structural integrity of the components at hand. TEAM Cables aims to improve the understanding of ageing mechanisms on cables used in plants, in particular to the polymers used in the insulation, to model this ageing, and to devise NDE and monitoring techniques for the health assessment. HARMONICS, the only project of the four already terminated, extends this approach to the software of computer-based I&C safety systems.

The paper discusses scientific challenges faced in the beginning and achievements made throughout the projects, including the industrial impact and lessons learned. Two particular aspects highlighted concern the way the projects sought contact with end users, and the balance between industrial and academic partners. The paper concludes with an outlook on follow-up issues related to the long term operation of nuclear power plants. The issues identified concern continuous monitoring of the structural health of components as a complement to in-service inspections at programmed intervals, the role of ageing models in paving the way for predictive maintenance, and inspection-oriented design for the nuclear new build.

ADVANCED NUMERICAL SIMULATION AND MODELLING FOR REACTOR SAFETY

Prof. Christophe Demaziere, (1); Dr. Sanchez-Espinoza, V. (2); Dr. Chanaron, B. (3)

1- Chalmers University of Technology, Sweden; 2- Karlsruhe Institute of Technology, Sweden; 3- Commissariat à l'Energie Atomique et aux Energies Alternatives, France

Predictive modelling capabilities have long represented one of the pillars of reactor safety. In this paper, an account of some projects funded by the European Commission within the seventh Framework Program (HPMC and NURESAFE projects) and Horizon2020 Program (CORTEX and McSAFE) is given. Such projects aim at, among others, developing improved solution strategies for the modelling of neutronics, thermal-hydraulics, and/or thermo-

mechanics during normal operation, reactor transients and/or situations involving stationary perturbations. Although the different projects have different focus areas, they all capitalize on the most recent advancements in deterministic and probabilistic neutron transport, as well as in DNS, LES, CFD and macroscopic thermal-hydraulics modelling. The goal of the simulation strategies is to model complex multi-physics and multi-scale phenomena specific to nuclear reactors. The use of machine learning combined with such advanced simulation tools is also demonstrated to be capable of providing useful information for the detection of anomalies during operation.

INNOVATIVE GEN-II/III AND RESEARCH REACTORS' FUELS AND MATERIALS

Konstantina Lambrinou (1); Keinänen, H. (2); Karjalainen-Roikonen, P. (2); Agostini, P. (3); Utili, M. (3); Arnoult Ruzickova, M. (4); Krykova, M. (4)

1- SCK•CEN, Belgium; 2-VTT, Finland, 3-ENEA Brasimone, Italy;
4-CVR, Czeck Republic

This paper presents important fuel and material challenges regarding innovative Gen-II/III nuclear systems and research reactors. These challenges are herein discussed alongside the key achievements of four European projects, i.e., H2020 IL TROVATORE, FP7 MULTIMETAL, FP7 MATTER and FP7 SCWR-FQT. H2020 IL TROVATORE is an ongoing project, scheduled to run in the period 01/10/17 to 31/03/22, which aims at improving nuclear energy safety in the post-Fukushima era by focusing on innovative accident-tolerant fuel (ATF) cladding materials. IL TROVATORE is an international collaboration between Europe, the USA and Japan that combines academic excellence with industrial support. The main objective of this project is to optimise promising ATF cladding material concepts for Gen-II/III LWRs (i.e., SiC/SiC composite clads, coated and surface-modified commercial clads, and ODS-FeCrAl alloy clads) and to validate them in an industrially-relevant environment via the neutron irradiation of optimised rodlets in PWR water in the BR2 research reactor. FP7 MULTIMETAL was a project conducted in the period 01/02/12 to 31/01/15. An important objective of the MULTIMETAL project was to collect field experience via-à-vis dissimilar metal welds (DMWs) in Western and Eastern LWRs, considering their characteristics and suitable performance assessment methods. A main achievement of MULTIMETAL was the recommendation of best-practice approaches to assess DMW integrity and establish leak-before-break (LBB) procedures; an example of these approaches was a test procedure to measure the fracture toughness of DMWs. FP7 MATTER was a project conducted in the period 01/01/11 to 31/12/14, focusing on a materials-oriented design research for ESNII reactors and, in particular, for the accelerator-driven (ADS) systems ASTRID and MYRRHA. In this respect, best-practice (pre-normative) material test procedures were proposed, with particular focus on grade 91 (T91) ferritic/martensitic (f/m) structural steels. An important achievement of the MATTER project was the demonstration of the severe susceptibility of T91 f/m structural steels to liquid metal embrittlement (LME) in contact with liquid lead-bismuth eutectic (LBE). The severity of LME for T91 f/m steels resulted in the exclusion of this steel grade from the candidate structural steels considered for the construction of structural components in the LBE-cooled research reactor MYRRHA. FP7 SCWR-FQT was a project conducted in the period 01/01/11 to 31/12/14. This project carried out research activities that aimed at assessing the neutronic, mechanical, thermal-hydraulic, and safety analyses that had been performed to demonstrate the feasibility of the innovative SCWR core design. The major challenges involved in proposing a viable core design for SCWRs include the accurate estimate of the heat transfer coefficient, as well as the development of suitable materials for both the fuel and core structures. The most important objective of SCWR-FQT was the design of a fuel qualification test facility comprising a 4- rod fuel bundle and the required supercritical water loop, as well as its safety and auxiliary systems. This supercritical water-cooled Fuel Qualification Test (FQT) facility was specifically designed for the LVR-15 research reactor.

INNOVATIVE AND SAFE SUPPLY OF FUELS FOR REACTORS

Dr. Valance, Stéphane (1), Dr. Baumeister, B. (2), Prof. Petry, W. (2), Dr. Höglund, J. (3)

1 - CEA, DEN, DEC, Cadarache, France, 2 - Technische Universität München, Forschungs Neutronquelle Heinz Maier Leibnitz (FRMII), Germany, 3 - Westinghouse Electric Sweden AB, Sweden

Within the Euratom research and training program 2014-2018, three projects aiming at securing the fuel supply for European power and research reactors have been funded. Those three projects address the potential weaknesses –supplier diversity, provision of enriched fissile material— associated with the furbishing of nuclear fuels. First, the ESSANUF project, now terminated, resulted in the design and licensing of a fuel element for VVER-440 nuclear power plant manufactured by Westinghouse. The HERACLES CP project aimed at preparing the conversion of high performance research reactor to low enriched uranium fuels by exploring fuels based on uranium-molybdenium. Finally, the LEU FOREvER pursues the work initiated in HERACLES-CP, completing it by an exploration of the high-density silicide fuels, and including the diversification of fuel supplier for soviet designed European medium power research reactor. This paper describes the projects goals, structure and their achievements.

SAFETY ASSESSMENTS AND SEVERE ACCIDENTS, IMPACT OF EXTERNAL EVENTS ON NUCLEAR POWER PLANTS AND ON MITIGATION STRATEGIES

Dr. Ahmed Bentaib (1); Dr. Van Dorsselaere, J.-P. (1); Dr. Albiol, T. (1); Dr. Fichot, F. (1); Dr. Miassoedov , A. (2); Prof. Starflinger , J. (3); Dr. Nowack, H. (4); Dr. Niedermayer , G. (4)

1-Institut de Radioprotection et de Sûreté Nucléaire, France ; 2- IAEA, Austria ; 3- University of Stuttgart, Germany; 4- Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Germany

The Fukushima-Daiichi accidents in 2011 underlined the importance of severe accident management (SAM), including external events, in nuclear power plants (NPP) and the need of implementing efficient mitigation strategies. For these reasons, the Euratom work programmes for 2012 and 2013 placed a total emphasis on nuclear safety, in particular on the management of a possible severe accident at the European level.

Relying upon the outcomes of the successful Euratom SARNET and SARNET2 projects, new projects were launched addressing the highest priority issues, aimed at reducing the uncertainties still affecting the main phenomena. Among them, PASSAM and IVMR project led by IRSN, ALISA and SAFEST projects led by KIT, CESAM led by GRS and SC02-HeRO lead by the University of Duisburg-Essen. Their main results are summarized in this lecture.

- PASSAM (2013-2016) or "Passive and Active Systems on Severe Accident source term Mitigation". This experimental project aimed at enhancing existing systems and working on innovative ones, with a focus on Filtered Containment Venting Systems. The new experimental data base allowed a better understanding of fission product trapping phenomena and a checking of their long term retention under severe accident conditions.
- CESAM (2013-2017) or "Code for European Severe Accident Management". Accounting for lessons from the Fukushima-Daiichi accidents, e.g. for BWR specifics, several modelling improvements were done in the ASTEC integral code for SAM analysis and improvements in the European NPPs.
- SAFEST (2015-2019) or "Severe Accident Facilities for European Safety Targets". It networks the European corium experimental laboratories, aiming at establishing coordination activities and enabling the development of common research roadmaps for the next years.
- ALISA (2014-2018) or "Access to Large Infrastructure for Severe Accidents". This unique project between European and Chinese research institutions in the area of severe

accident provides mutual access to large research infrastructures for European organizations and Chinese partners: 8 Chinese facilities and 6 European ones.

- IVMR (2015-2019) or "In Vessel Melt Retention" addresses the In-Vessel Retention (IVR) strategy for Light Water Reactors that intends to stabilize corium and fission products in the reactor pressure vessel and in the primary circuit. The project provides new experimental data about heat transfers and chemical interactions in stratified pools and a harmonized methodology for IVR taking into account transient effects and a more detailed analysis of the ablated vessel wall, both aspects that were not taken into account in the existing approaches.
- sCO2-HeRo (2015-2018). The "supercritical CO2 heat removal system" safely, reliably and efficiently removes residual heat from nuclear fuel without the requirement of external power sources. This system therefore can be considered as an excellent backup cooling system for the reactor core or the spent fuel storage in the case of a station blackout and loss of ultimate heat sink.

PROBABILISTIC SAFETY ASSESSMENT FOR INTERNAL AND EXTERNAL EVENTS

Dr. Evelyne Foerster (1); Raimond, E. (2); Guigueno, Y. (2)

1- CEA Paris-Saclay, Nuclear Energy Division, France; 2- IRSN, Nuclear Safety Division BP 17, France

The 7th EU Framework programme project Advanced Safety Assessment Methodologies: "Extended PSA" (ASAMPSA_E, 2013-2016) was aimed at promoting good practices to extend the scope of existing Probabilistic Safety Assessments (PSAs) and the application of such "extended PSA" in decision-making in the European context. This project led to a collection of guidance reports that describe existing practices and identify their limits. Moreover, it allowed identifying some idea for further research in the framework of collaborative activities. The H2020 project "New Approach to Reactor Safety ImprovementS" (NARSIS, 2017-2021) aims at proposing some improvements to be integrated in existing PSA procedures for NPPs, considering single, cascade and combined external natural hazards (earthquakes, flooding, extreme weather, tsunamis). The project will lead to the release of various tools together with recommendations and guidelines for use in nuclear safety assessment, including a Bayesian-based multi-risk framework able to account for causes and consequences of technical, social/organizational and human aspects and a supporting Severe Accident Management decision-making tool for demonstration purposes, as well.

NUCLEAR AND RADIOLOGICAL EMERGENCY MANAGEMENT AND PREPAREDNESS

Dr. Federico Rocchi (1); Dr. Devol-Brown, I. (2); Dr. Raskob, W. (3)

1 - ENEA, Italy; 2 - IRSN, France; 3 - KIT, Germany

Recent EURATOM research efforts on Emergency Preparedness and Response (EP&R) have been focussed on programs addressing some main knowledge gaps clearly identified in the outcomes of investigations carried-out in Europe in response to the Fukushima accident. The PREPARE and FASTNET projects tried to solve similar problems adopting very complementary and synergic approaches. The main achievements of both projects are detailed in this paper. In particular, the problem of the fast estimation of time-dependent, long-lasting Source Terms is discussed. This problem is not only a technical one, but is also related to the experience and skill of the code users. As the EP&R is spanning a wide range in Europe, certainly far beyond the borders of individual states, it is mandatory creating a common and shared understanding of emergencies. Both PREPARE and FASTNET recognized the fundamental role of exercises to increase the experience of emergency responders in Europe. A general recommendation can then be formulated, in that more efforts should be dedicated in the future to the realization of such important exercises.

Advanced nuclear systems and fuel cycles

R&D IN SUPPORT TO SAFETY ASSESSMENT, DESIGN AND LICENSING OF ESNII/GEN-IV

Dr. Konstantin Mikityuk (1); Dr. Ammirabile, L. (2); Dr. Forni, M. (3); Dr. Girault, N. (4); Dr. Horvath, A. (5); Prof. Kloosterman, J.-L. (6); Dr. Tarantino, M. (3); Dr. Vasile, A. (7); Dr. Jagielski, J. (8)

1-PSI, Switzerland; 2-JRC, Netherlands; 3-ENEA, Italy; 4- IRSN, France;
5-MTA EK, Hungary; 6-TU DELFT, Netherlands; 7-CEA, France; 8-NCBJ, Poland

The paper briefly presented the nine Euratom projects started since late 2011 in support of design, safety assessment, R&D and licensing of the following ESNII/Gen-IV fast neutron systems: ASTRID sodium-cooled fast reactor; ALFRED lead-cooled fast reactor; MYRRHA lead-bismuth irradiation facility; ALLEGRO gas-cooled fast reactor; Molten Salt Fast Reactor (MSFR); European Sodium Fast Reactor (ESFR) and Swedish Advanced Lead Reactor (SEALER). The EU projects presented in the paper include: 1) Proposal for a harmonized European methodology for the safety assessment of innovative reactors with fast neutron spectrum planned to be built in Europe (SARGEN_IV); 2) Seismic-Initiated Events Risk Mitigation in Lead-cooled Reactors (SILER); 3) Preparation of ALLEGRO – Implementing Advanced Nuclear Fuel Cycle in Central Europe (ALLIANCE); 4) Joint Advanced Severe accidents Modelling and Integration for Na-cooled fast neutron reactors (JASMIN); 5) Preparing ESNII for HORIZON 2020 (ESNII Plus); 6) Visegrad Initiative for Nuclear Cooperation (VINCO); 7) Thermal Hydraulics Simulations and Experiments for the Safety Assessment of Metal Cooled Reactors (SESAME); 8) A Paradigm Shift in Reactor Safety with the Molten Salt Fast Reactor (SAMOFAR); and 9) European Sodium Fast Reactor Safety Measures Assessment and Research Tools (ESFR-SMART).

FROM FUEL TO FUEL: DISSOLUTION, PARTITIONING AND FUEL MANUFACTURING

Dr. Stephane Bourg (1); Dr. Geist, A. (2); Dr. Adnet, J.-M. (1); Rhodes, C. (3); Prof. Hanson, B. (4)

1-CEA, France; 2-INE, KIT, Karlsruhe, Germany; 3-Central Lab, NNL, Sellafield, United Kingdom; 4 - University Of Leeds, United Kingdom

The nuclear fuel cycles based on GEN II/GEN III reactors are mostly operated worldwide as open fuel cycles and therefore only a few percent of the energy contained in uranium is valorized (less than 0.7 %). This efficiency can be improved up to 1% through the recycling of the uranium and plutonium from the spent fuel (as done today in France for instance), allowing the saving of about 20% of natural uranium from the mines. In the longer term, plutonium multi-recycling strategies will be deployed, potentially in GEN II/GEN III reactors, and in a much efficient way in fast GEN IV reactors. Processes such as PUREX have been implemented up to the industrial scale to allow the recovery and reuse of the uranium and the plutonium of GEN II/GEN III reactors. This process is being adapted for the recycling of the uranium and the plutonium of MOX fuels. However, if such a processing allows the spent fuel to be recycled at about 95%, it does not fix the sensitive issue of the long term management of the high active nuclear waste (HAW) and particular in its societal perception. Indeed, if the recycling of the plutonium decreases the lifespan of the HAW from million years down to a few thousands of years, only the recovery and the transmutation of the minor actinides can reduce this burden down to a few hundreds of years. It is therefore of paramount importance to propose to policy makers strategies, and processes ready to be deployed at the industrial scale, to allow not only the efficient management of the uranium and the plutonium but also the management of the minor actinides. In this context, and in the continuity of the FP7 EURATOM SACSESS project, GENIORS addresses research and innovation in fuel cycle chemistry. After a strong focus on the development of partitioning processes, from FP3 to the FP7 SACSESS project, GENIORS

focuses now on the reprocessing of MOX fuel containing minor actinides, taking into account safety issues under normal and mal-operation. The different promising options developed in SACSESS are currently further developed to address the specific challenges of GEN IV. By implementing a three step approach (reinforcement of the scientific knowledge => process development and testing => system studies, safety and integration), GENIORS will provide more science-based strategies for nuclear fuel management in the EU. It will allow nuclear energy to contribute significantly to EU energy independence. This paper presents the main highlights of SACSESS and GENIORS.

INNOVATIVE GEN-IV FUELS AND MATERIALS, EERA-JPNM, FISSION AND FUSION

Prof. Lorenzo Malerba (1); Dr. Agostini, P.(2); Dr. Bertolus, M.(3); Dr. Delage, F.(3); Dr. Gallais-during, A.(3); Dr. Grisolia, C.(4); Dr. Liger, K. (5); Dr. Giroux, P.-F. (6)

1-CIEMAT, División de Materiales de Interés Energético, Madrid, Spain; 2-ENEA - FSN, Dipartimento Fusione e Sicurezza Nucleare, Frascati, Italy; 3-CEA, DEN, DEC, Centre de Cadarache, France; 4-CEA, IRFM, Centre de Cadarache, France; 5-CEA, DEN, DTN, Centre de Cadarache, France; 6-CEA, DEN, Service de Recherche Métallurgiques Appliquées, Université Paris-Saclay, France

This paper describes six projects, most of which are part of the research portfolio of the EERA JPNM, devoted to qualification, modelling and development of structural and fuel materials for advanced and innovative nuclear systems, with also two examples of projects addressing issues of cross-cutting interest through fusion and fission. The main conclusion is that the benefit of the coordination under the umbrella of, in this case, the EERA JPNM, is clearly felt in terms of better alignment of national programmes and subsequent leveraging of institutional funding, to integrate Euratom support. Likewise, the benefit of addressing specific issues of common interest for fusion and fission is not only beneficial because of cross-fertilisation, but also because it allows more rational use of human and infrastructural resources, avoiding duplications.

NUCLEAR COGENERATION WITH HIGH TEMPERATURE REACTORS

Prof. Grzegorz Wrochna(1); Dr. Fütterer, M.(2); Dr. Hittner, D. (3)

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Clean energy production is a challenge, which was so far addressed mainly in the electric power sector. More energy is needed in the form of heat for both district heating and industry. Nuclear power is the only technology fulfilling all 3 sustainability dimensions, namely economy, security of supply and environment. In this context, the European Nuclear Cogeneration Industrial Initiative (NC2I) has launched the projects NC2I-R and GEMINI+ aiming to prepare the deployment of High Temperature Gas-cooled Reactors (HTGR) for this purpose.

NUCLEAR DATA ACTIVITIES

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Nuclear data and associated tools are critical elements of the nuclear energy industry and research, playing an essential role in the simulation of nuclear systems, safety and performance calculations and interpretation of the reactor instrumentation. Nuclear Data improvement requires a combination of many different know-hows that are distributed over many small and medium sized institutions along Europe. The Euratom programs have

facilitated the setup of pan-European collaborations getting together the required experience inside the projects CHANDA, ERINDA and the JRC action EUFRAT. The paper describes the holistic and inclusive approach of these projects that have also worked together to coordinate the European nuclear data research capabilities to improve the facilities, detectors, models and evaluation, validation and simulation tools. It also shows examples of success histories and summary of results of these projects and of their impact on the EU nuclear safety and industry, together with an outlook to the future.

E&T, research infrastructures and international cooperation

EDUCATION, TRAINING AND MOBILITY: TOWARDS A COMMON EFFORT TO ASSURE A FUTURE WORKFORCE IN EUROPE AND ABROAD

Prof. Walter Ambrosini (1); Dr. Lo frano, R. (1); Prof. Cizelj, L. (2); Dr. Dieguez, P. (2); Prof. Urbonavicius, E. (3); Dr. Cvetkov, I. (4); Dr. Diaconu,D. (5); Prof. Kloosterman, J.-L. (6); Dr. Konings, R. (7)

1 - CIRTEN - Università di Pisa, Italy; 2 - European Nuclear Education Network, Brussels, Belgium; 3 - Lithuanian Energy Institute, Kaunas, Lithuania; 4 - Kozloduy Nuclear Popwer Plant, Bulgaria; 5 - RATEN ICN, Mioveni, Romania; 6 - TU Delft, Mekelweg 15, 2629 JB Delft, Netherlands; 7 - European Commission, Joint Research Centre (JRC), Karlsruhe, Germany

The paper highlights the main features of some Euratom projects, which have been running recently in support to education, training and mobility in the nuclear fields. The described projects address various critical aspects of nuclear knowledge management, aiming at maintaining the wealth of nuclear expertise in Europe in an environment characterised by decreased attractiveness of nuclear careers. In an effort to broaden the cooperation and to further extend the opportunities for mobility, some projects ran in parallel with similar initiatives undertaken beyond the European borders. The lesson learnt in terms of successes achieved and critical aspects revealed by the different actions are finally discussed also considering recent recommendations and assessed scenarios by the European Commission for the decarbonisation of the energy sector.

IMPROVED EXPERTISE IN RADIATION PROTECTION, NUCLEAR CHEMISTRY AND GEOLOGICAL DISPOSAL

Dr. Michele Coeck (1); Dr. Perko, T. (1); Dr. Birschwilks, M. (2); Dr. Jung, T. (2); Prof. Walther, C. (3); Prof. Bazargan-sabet, B. (4)

1 - Belgian Nuclear Research Centre, Belgium; 2 - Bundesamt für Strahlenschutz, Germany; 3 - Institut für Radioökologie und Strahlenschutz, Germany; 4 - Université de Lorraine, France

In the past 5 years several projects were launched in FP7 and H2020 with the aim to support competence building in nuclear by fostering education and training (E&T) initiatives. ENETRAP III, CONCERT, CINCH II, MEET-CINCH, PETRUS and EAGLE deal with advanced E&T in the fields of radiation protection, nuclear chemistry and geological disposal and the transfer of basic knowledge about ionising radiation, its benefits and risks, to the general public. They were launched with the overall objective of maintaining and extending nuclear know-how and competences in Europe and ensuring sustainable knowledge transfer to current and future generations.

This paper describes the aims and achievements of these projects and, based on insights and experiences from these projects, provides some recommendations for future policy support regarding maintaining competences in nuclear industry and research.

SUPPORTING ACCESS TO KEY INFRASTRUCTURES AND PAN-EUROPEAN RESEARCH

Dr. Concetta Fazio (1); Dr. Nilsson, K.-F. (1); Dr. Manara, D. (2); Dr. Plompen, A. (3); Dr. Bucalossi, A. (3); Dr. Bourg, S. (4); Dr. Bosch, R.-W. (5); Dr. Bouchter, J.-C. (4); Prof. Ambrosini, W. (6); Prof. Lo Frano, R. (6); Prof. Cizelj, L. (7); Dr. Dieguez, P. (7)

1-European Commission, Joint Research Centre, Netherlands; 2-European Commission, Joint Research Centre, Italy; 3-European Commission, Joint Research Centre, Belgium; 4-Commissariat à l'énergie atomique et aux énergies alternatives, France; 5-Belgian Nuclear Research Centre, SCK-CEN, Belgium; 6-CIRTEN-Università di Pisa, Italy;7-European Nuclear Education Network, Belgium

Access to research infrastructures has been supported by the European Commission under different financial schemes. During the 6th EURATOM Framework Programme, the instruments introduced by the European Commission were the Integrated Infrastructure Initiatives (I-3). Moreover, funding schemes to support Education and Training for students and professional developments were defined also. The main difference between these two funding schemes is that I-3 are topic driven projects with access to infrastructure components, while the Education and Training related projects have a mobility component that is applied for the different research topics. The outcome of projects as TALISMAN (I-3), EFNUDAT/NUDAME (I-3), GENTLE (mobility), ENEN-plus (mobility), NUGENIA-plus (mobility within TA of NUGENIA) and ESNII-plus (I-3 similar) will be shortly presented as well as the future European Commission plans in the field of access to research infrastructure.

SUPPORTING INFRASTRUCTURES AND RESEARCH REACTORS: STATUS, NEEDS AND INTERNATIONAL COOPERATION

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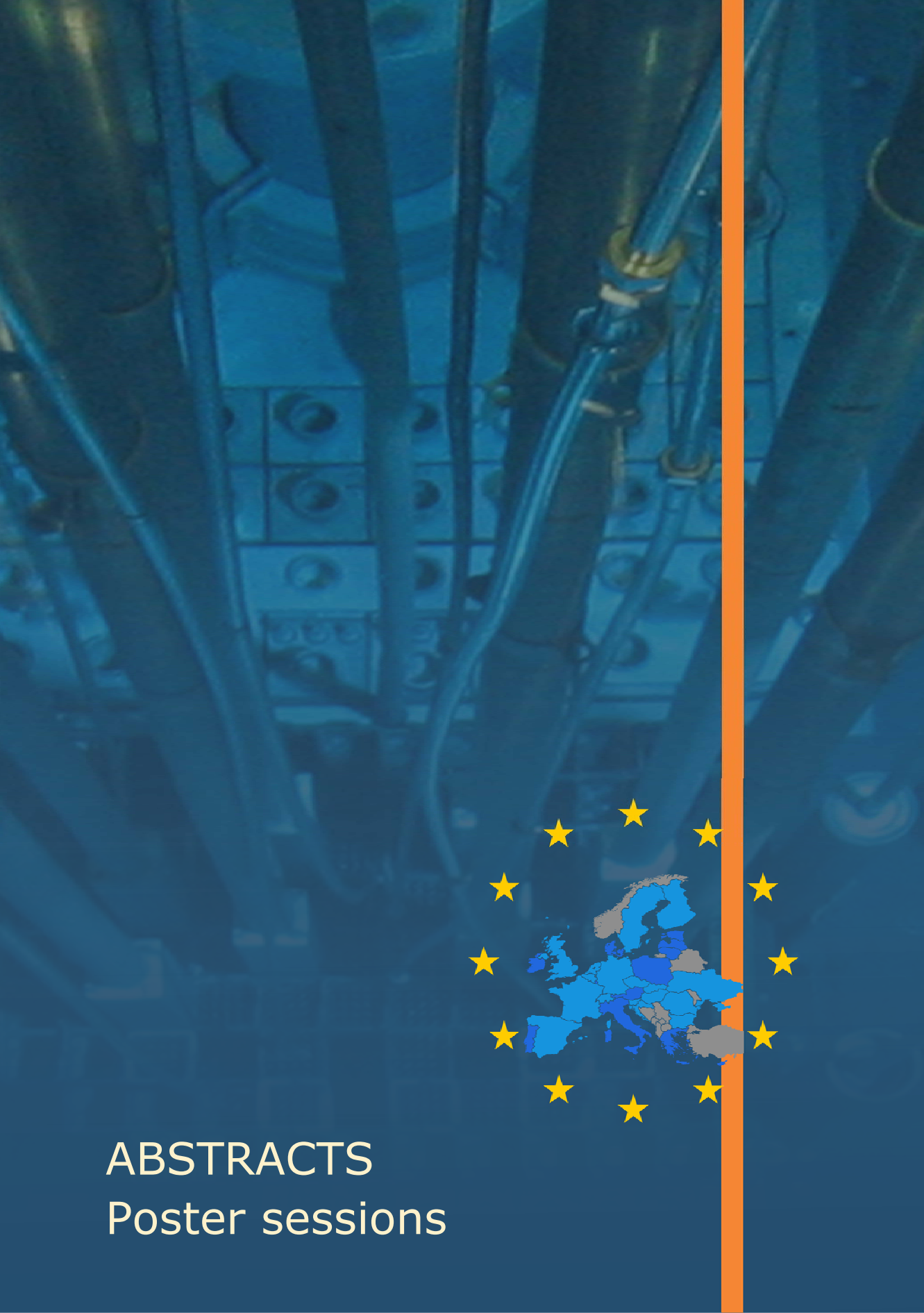
The panorama of research reactors in the world is at a turning point, with many old ones being shutdown, a very few new ones under construction and many newcomer countries interested to get access to one or to build one domestic research reactor or zero-power reactor. In this evolving context, several actions have been set up to answer this international collaboration need: the IAEA has launched the ICERR initiative, and the OECD/NEA is proposing the P2M joint project proposal. In France, the Jules Horowitz Reactor (JHR), under construction at CEA Cadarache, within an International Consortium, will be one of the few tools available for the industry and research in the next decades. The paper presents some update of its construction, its experimental capacities and the European support through FP7 and H2020 tools. This paper provides also some insights of international tools (ICERR, P2M) and about the International Group on Research Reactors (IGORR) and how they complement or interact with the JHR.



ABSTRACTS
Poster sessions

USE OF BAYESIAN NETWORKS IN NUCLEAR POWER PLANT PROBABILISTIC SAFETY ASSESSMENT

Dmohan, V. K. (1); Vardon, P. (1); Gehl, P. (2); Daniell, J. (3); Schaefer, A. (3); Van gelder, P. (4); Khakzad, N. (4); Molenaar, C. (5); Natarajan, V. (5); Jockenhoevel-barttfeld, M. (6); Potempski, S. (7); Kowal, K. (7)

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Risk assessment frameworks, currently used for nuclear power plants (NPPs), typically fail to account for interdependencies and cascading effects associated with external natural hazard events. In this study, Bayesian networks are proposed as a probabilistic risk assessment framework, to model dependencies between random variables (including NPP system components and external hazard factors) and track uncertainties effectively. A simplified, but realistic, example case of a station blackout event, caused by earthquake or flooding events (occurring alone or consecutively), was considered. Advanced hazard modelling methods were used, along with improved fragility modelling techniques using multiple intensity measures, to quantify hazard interaction with the components of the NPP. The network was used for both causative and diagnostic inference within the assumed sequence of events leading to station blackout. This study illustrates the potential of Bayesian networks in NPP risk assessments, augmenting or replacing aspects of existing Probabilistic Safety Assessment (PSA) methodology.

DEVELOPMENT OF A FREQUENCY-DOMAIN REACTOR NOISE SIMULATOR BASED ON A NEUTRON TRANSPORT METHOD

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The neutron flux measured in a nuclear reactor is characterized by fluctuations around a main trend. These fluctuations are known as reactor neutron noise, and they may allow identifying anomalies in the reactor core. In this context the CORTEX – COre monitoring Techniques and EXperimental validation and demonstration project, supported by the European Commission, aims at studying reactor neutron noise induced by different types of perturbations (e.g. vibrations of reactor components), and developing core monitoring techniques from the analysis of reactor neutron noise.

When simulating reactor neutron noise, the reactor transfer function is needed. The reactor transfer function describes the system response to possible perturbations, and it can be modelled with the neutron transport equation. Most of the past work in this area relies on neutron diffusion theory. However, recent efforts focus on advanced computational capabilities that can provide more detailed insights into neutron noise problems and be used to assess the limitations of the diffusion approach.

In the CORTEX project, Chalmers University of Technology is building a neutron noise simulator with a high-order approximation of the neutron transport equation. The equations are discretized according to a finite difference scheme for the spatial variable, a discrete ordinates approximation for the angle, and a multi-group formalism for the neutron energy. The simulation consists of two steps. The first step solves the criticality problem and calculates the static neutron flux. The second step determines the neutron noise in the frequency domain with respect to the prescribed neutron noise source and the static neutron flux previously estimated.

The numerical solution of the equations is obtained from an iterative procedure. This is a

computationally intensive task because a converged solution may require a very large number of iterations. A crucial factor in the reduction of the iterations is the implementation of a technique for the acceleration of the algorithm. For static calculations, methods such as the Diffusion Synthetic Acceleration (DSA) and the Coarse Mesh Finite Difference (CMFD) acceleration have been widely investigated. To some extent, these techniques have also been applied to time-dependent problems. On the other hand, no study on acceleration of neutron noise calculations in the frequency domain has been reported in the open literature. The current work also explores the extension of DSA and CMFD methods to the case of frequency-domain neutron noise simulations.

Preliminary results will be presented for neutron noise calculations in a 2-dimensional heterogeneous system, with 2-energy groups.

EFFICIENT SIMULATION OF FUEL ASSEMBLY VIBRATIONS IN A NUCLEAR REACTOR IN THE TIME-DOMAIN

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The monitoring of the state of nuclear reactors, while they are running, is a safety requirement. The early detection of anomalies gives the possibility to take proper actions before such problems lead to safety concerns or impact plant availability. For this purpose, the CORTEX project was funded by the European Commission whose main aim is to develop an innovative core monitoring technique that allows detecting anomalies in nuclear reactors, such as excessive vibrations of core internals, flow blockage, etc. The technique is based on primarily using the inherent fluctuations in neutron flux recorded by in-core and ex-core instrumentation, referred to as neutron noise, from which the anomalies will be detected using machine learning techniques. The modelling tools developed will be validated against reactor experiments in research reactor as the CROCUS reactor located at EPFL, Switzerland.

The mechanical vibration of fuel assemblies has been shown a cause of neutron noise and thus, the trigging of power reduction measures in operating nuclear power reactors. This work simulates and analyses the effect in the neutron field of the oscillation of one single fuel assembly without considering thermal-hydraulic feedback. Results show two different effects in the neutron field caused by the fuel assembly vibration. First, a global slow variation of the total neutron power due to a change in the criticality of the system is observed. Second, an in-phase change in the neutron flux with the assembly vibration which is highly spatially dependent.

This problem combines really different spatial scales that need the use of fine very meshes and accurate numerical approximations leading to high computational times. For this reason, in the time domain analysis, efficient solvers are requested. This paper uses a backward differentiation method implemented with a matrix-free strategy that avoids the forming of the full matrices involved in the time system and time-step control procedure.

This paper shows a comparison between a time domain analysis and a frequency domain analysis of the phenomena to verify the main approximation of this methodology. The frequency analysis is the usual strategy for neutron noise analysis. Numerical results show a really close match between these two approaches.

DEVELOPMENT OF A THERMOMECHANICAL ANALYSIS METHOD AS PART OF THE ESFR-SMART EU PROJECT FOR THE QUANTIFICATION OF SFR CORE REACTIVITY CHANGE DUE TO CORE DISTORTION

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In this paper, a reactor core thermomechanical analysis method is described to provide a tool to quantify the reactivity effect of the fuel subassembly distortion in the reactor core which is a relevant problem for certain reactor types such as Sodium-cooled Fast Reactors. The

importance of such an analysis was made evident by the A.U.R.N. (negative reactivity event) issue in the Phenix reactor as well as by the partial core meltdown of EBR-I. The proposed method consists of two major phases: 1) The simulation of the core deformation through a CAD (Computer Aided Design) based finite element solver and 2) The measurement of the reactivity effect of the core distortion in Serpent 2 Monte Carlo code through the obtained, deformed model. The technique makes it possible to obtain certain snapshots of the reactor core geometry in different points of time and to measure how the reactivity of the core is going to change as a response to a certain transient allowing an accurate prediction of the reactor behavior under the simulated conditions. In addition, the paper includes the verification process which was conducted to compare the accuracy of the finite element solver to the theoretical solutions regarding the deformation of a hexagonal subassembly. Moreover, the neutronics calculation accuracy has been demonstrated for the deformed and undeformed geometry subassemblies, equating the models obtained from the finite element solver with the model built directly in Serpent. As part of the investigation with the Monte Carlo code, the multiplication factors have been calculated and compared for different geometry subassemblies by carrying out a comprehensive analysis through the decomposition of the production and absorption terms at the various regions of the model. By means of this verification, it was demonstrated that, for the investigated conditions, the finite element solver accurately reproduces the theoretical deformation of the subassemblies and that the Serpent interface reads correctly the deformed CAD models. These conclusions open the path for the future validation work which is going to be performed on the Phenix Sodium-cooled Fast Reactor based on the data obtained from the core flowering End-of-Life test.

STABILITY STUDIES OF GANEX SYSTEM UNDER DIFFERENT IRRADIATION CONDITIONS

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In the development of more sustainable nuclear fuel cycle options, a future potential scenario involves the transition from thermal reactors to fast reactors with a closed fuel cycle to recycle actinide elements. Two recycling scenarios are considered: the heterogeneous recycling of the actinides using a modified version of the well-known PUREX process followed by additional processes; and the homogeneous recycling of all actinides together in one Grouped Actinide Extraction (GANEX) concept.

GANEX concept involves an initial U recovering (using the monoamide DEHiBA in TPH) to reduce the heavy metal content of the dissolved spent fuel solution followed by the separation of all TRU. An option for the second step of GANEX concept is the named Euro-GANEX process, where actinides and lanthanides are co-extracted from the first refined into an organic phase (a mixture of TODGA and DMDOHEMA, in kerosene), followed by a selective stripping of TRU by using a mixture of SO3-Ph-BTP and AHA. Many efforts have been done in the last years within the European framework to ensure a safe long-term operation at pilot plant. Currently, most of safety problems are focused on resistance to radiation. That is why stability to radiation of most relevant molecules involved in Euro-GANEX process has already been studied. However, they have been studied as individual molecules, but not as a full working extraction system.

This work addresses the gamma stability study of TRU stripping of Euro-GANEX process using a simplified system, TODGA/SO3-Ph-BTP, looking for the process relevant conditions that should be simulated. For that, two phases involved have been irradiated in contact with 60Co sources at Náyade facility at CIEMAT. For the irradiation, three different conditions have been chosen, air atmosphere, argon atmosphere and using an air flow sparging. Extraction experiments as well as analysis of the composition by HPLC-MS of the degraded sample have been conducted.

Results confirmed that degradation due to radiation effect depends on the irradiation condition. On the one hand, the degradation was higher in the case of air flow sparging compared to the

rest of the conditions employed. Moreover, it was observed the presence of possible new TODGA degradation compounds, pointing out to a change in the degradation pathway. And on the other hand, the An/Ln extraction behaviour of the system after irradiation showed a higher resistance when two solvent formulation are irradiated together. All these results improve the understanding of the system behaviour under irradiation and allow identifying the relevant process irradiation conditions should be simulated for a long term stability study.

3D CONVOLUTIONAL AND RECURRENT NEURAL NETWORKS FOR REACTOR PERTURBATION UNFOLDING AND ANOMALY DETECTION

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With Europe's ageing fleet of nuclear reactors operating closer to their safety limits, the monitoring of such reactors through complex models has become of great interest to maintain a high level of availability and safety. Therefore, we propose an extended Deep Learning framework as part of the CORTEX Horizon 2020 EU project for the unfolding of reactor transfer functions from induced neutron noise sources. The unfolding allows for the identification and localisation of reactor core perturbation sources from neutron detector readings in Pressurised Water Reactors. Through the monitoring of reactor signals at nominal conditions, a vast understanding can be developed for the early detection of anomalies. Many techniques have attempted to provide this insight, with many model-driven and data-driven approaches; however, deep learning provides state-of-the-art performance with the potential for real-time prediction whilst being robust to variation. This framework provides analysis of such perturbations in both the Time and Frequency domains, of which data has been modelled by the SIMULATE-3K and CORE SIM+ simulations retrospectively. In the frequency domain, 3D Convolutional Neural Networks (3D-CNN) have been employed, analysing spatial relationships within the core volume for a number of perturbations. Additionally, in the time domain Recurrent Neural Networks (RNN) were taken advantage of to learn temporal dependencies of sequential data signals. The RNN network identifies perturbations induced by fuel assembly vibrations, and thermal-hydraulic fluctuations at the core inlet. To classify perturbation type, a multi-sigmoid classification layer was implemented to handle the multiple-perturbation and multiple-classification nature of the problem. Both networks share this classification layer each concatenating the 512-dimensional representations output by the individual networks. Once a perturbation type has been classified, the network output is fed to a fully connected network utilising the extracted features to regress the coordinates of the induced perturbation source *. The results of this framework show that perturbation types can be identified successfully with an accuracy of 95.14% in the time domain with multiple perturbations. Similarly, in the frequency domain, accuracy remains high with perturbation sources being localised at high precision with 97.15% accuracy. This project helps result in a deepened understanding of the physical processes involved, allowing for the early detection of operational problems improving reliability and, further contributing to reducing the carbon footprint and impact on the environment.

* The outlined approach presents the work achieved by the MLearn Group, UoL as part of the CORTEX project.

A NOVEL NEUTRON DETECTOR FOR LOCALIZED IN-CORE MEASUREMENTS IN THE CROCUS REACTOR FOR HIGH-FIDELITY CODE VALIDATION PURPOSES

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Nowadays most of the modern neutronics codes claim to be able to predict results with high-spatial resolution. These codes need to be validated against experimental values and their applicability to specific reactor concepts must be proven. In particular, their validation has become a paramount for the safety assessment of heterogeneous reactor concepts, whose development was driven by the constant endeavour to achieve improved reactor performances

and optimal fuel utilization. However, heterogeneous fuel assemblies introduce complex within-pin reaction rate profiles that need to be investigated to meet the reactor safety requirements. As a consequence, the high-fidelity neutronics codes used to predict these behaviors need to be validated against highly-localized in-core measurements.

In view of the validation of high-fidelity neutronics codes, a PhD research at the École Polytechnique Fédérale de Lausanne (EPFL) focuses on performing highly localized measurements in the CROCUS reactor with an innovative miniature neutron detection system. CROCUS is a zero-power research reactor operated at EPFL with a maximum power of 100 W. Aside from begin accessible and flexible for experiments, it offers numerous heterogeneities in its design and the possibility to perform measurements without thermal or burnup feedback. A novel miniature neutron detection system has been developed at EPFL in collaboration with Paul Scherrer Institute (PSI). A first prototype, based on the coupling of a 6Li:ZnS scintillator screen in the millimeter range with a silicon photon multiplier (SiPM) through a 10-m optical fiber, has been successfully built for in-core localized measurements in CROCUS. The prototype characterization and testing campaigns have shown promising results for further applications in the CROCUS reactor.

The new type of detector will allow carrying out in-depth studies of spatial-dependent phenomena in the CROCUS reactor, providing extremely valuable inputs for the validation of high-fidelity transport neutronics codes. A series of localized measurements is foreseen in the next years at EPFL to study reactor physics phenomena of increasing complexity. These measurements will require the optimization of the detection system in terms of geometry and arrangement, and advanced electronics will be included to meet the required detection sensitivity. Given the miniature size, the optimized detectors can be positioned in numerous positions inside the core and they will allow performing in CROCUS three-dimensional on-line static and time-dependent flux distribution maps, as well as intrinsic neutron noise measurements. Finally, the detection system will be used to investigate mechanical noise and to validate associated modelling tools within the framework of the COLIBRI experimental program and the European Horizon2020 project CORTEX.

SENSITIVITY AND UNCERTAINTY ANALYSES OF RADIATION DAMAGE CROSS SECTIONS

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Due to the importance of mechanical and thermal property change of materials under irradiation, the calculations of radiation damage is of importance. In nuclear reactors, materials are mainly irradiated by neutrons. The computation of neutron radiation damage requires the studies on both nuclear reactions and radiation damage models. Different damage models are implemented in the nuclear reaction analysis code CONRAD. Therefore, the CONRAD code allows us to compute radiation damage and corresponding uncertainty (and covariance) from nuclear reaction models and radiation damage models. In the resonance region, the R-matrix theory is used to compute the resonant cross sections and the angular distributions. Based on the cross sections and angular distributions, the radiation damage cross sections (σ_D) are computed using a specific radiation damage model. The present work focuses on the sensitivity and uncertainty analyses of neutron scattering-induced damage cross section of 56Fe in the resonance region.

In the first step, sensitivity analyses of the damage cross section to different parameters are carried out using the direct perturbation computations. For incident energy below 1 keV, the damage cross section is quite sensitive to the average threshold energy of atomic displacement (E_d) but not sensitive to other parameters in the standard Norgett-Robinson-Torrens (NRT) model because the damage depends only on E_d for damage energy E_a<2.5E_d. The sensitivity of radiation damage cross section to the first fitted parameter before ε^(1/6) (ε is equivalent to the kinetic energy of Primary Knock-on Atom) is almost 20% for neutron energy in [5 keV, 100 keV], while the damage cross section is not sensitive to E_d nor the other two parameters in the NRT model for incident neutron energy up to 100 keV.

The uncertainties of radiation damage are determined by uncertainty propagation through the

sensitivities and the corresponding covariance matrix of parameters from nuclear reactions and radiation models. The two main sources of uncertainties, i.e. uncertainties from nuclear reactions models and radiation damage models, are compared to conclude which is more important for the radiation damage calculations. Assuming 20% relative uncertainty for E_d and 5% for the other three parameters in the standard NRT model, the NRT-DPA formula leads to 1.5% uncertainty on damage cross section for incident neutron energy from 10 keV up to 850 keV. In comparison with the uncertainties of reaction cross sections of Joint Evaluated Fission and Fusion (JEFF)-3.3 (about 5% on average) and ENDF/B-VIII (about 3% on average) nuclear data, the uncertainty from radiation damage model is negligible. However, it is noteworthy that the bias of E_d is propagated to final damage calculation via (σ_D$|\Phi$)/2.5E_d where Φ is the neutron spectrum.

TOWARDS VALIDATION OF RANS CFD APPROACH FOR FLOW AND HEAT TRANSFER IN A CLOSELY-SPACED BARE ROD BUNDLE

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One of the most important safety related aspect in the design of a new nuclear systems is the detailed knowledge of the coolant flow and heat transport inside the rod bundles. Nowadays, a good prediction of these complex 3D phenomena is a challenge for the commonly used URANS (Unsteady Reynolds-Average Navier-Stokes) turbulence models and these models need to be validated and improved accordingly. Validation procedure could be done against the experimental data or against the results of the high fidelity databases. Concerning the experiments there are a lot of difficulties and disadvantages, such as: e.g. the CFD-grade experiments of flow mixing and heat transfer in the sub-channel scale are often impossible or quite costly to be performed. Moreover, in general, there is a lack of experimental databases, which makes it impossible to validate properly and/or calibrate the available RANS turbulence models for certain flow configurations. In order to overcome these limitations, the high fidelity Computation Fluid Dynamic (CFD), namely Direct Numerical Simulation (DNS) approach, becomes a valuable research tool to analyse the thermal-hydraulics phenomenon in the fuel assembly geometries.

In a validation approach toward fuel assembly level and ultimately core level modelling, a CFD methodology needs to be developed, which provides accurate predictions for heat transport and unsteady flow phenomena (e.g. fluctuations) at sub-channel level. At sub-channel level, high fidelity CFD will provide reference data for RANS approaches. In present paper a whole CFD methodology toward validation of RANS models is presented. As a first step, the sub-channel geometry of a well-documented case, which is a hydraulic experiments performed by Hooper on a tight lattice bare rod-bundle configuration with pitch-to-diameter ratio of P/D = 1.107, was chosen. Subsequently, a set of URANS simulations were performed, in which the experimental mass flow rate was systematically scaled down, in order to estimate a computationally affordable spatial resolution for a DNS simulation. Furthermore, several simulations for different stream-wise domain lengths were conducted as well as mesh sensitivity study. Fluids with different Prandtl numbers have been applied, i.e. liquid metal, air and water. The heat transfer of these three fluids has been studied in combination with two different boundary conditions at the walls, i.e. a constant temperature and a constant heat flux. Accordingly, numerical experiment for a closely-spaced bare rod bundle was designed. In the second step, a high fidelity DNS database has been generated for a closely-spaced bare rod bundle configuration. Further, this database is used for validation of engineering simulation approaches based on RANS modelling. In the third step, extensive analyses of flow and thermal fields, have been performed and used in the validation process for RANS calculations. Mesh sensitivity, as well as a sensitivity analysis on different turbulence models, are performed. Both qualitative and quantitative analyses are presented in terms of velocity, temperature and turbulent kinetic energy profiles. Discussion on the different turbulence models adopted is presented.

ASSESSMENT OF HELIUM BEHAVIOUR IN NUCLEAR FUEL

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Understanding the helium behaviour in nuclear fuel is important for its performance in-pile, but also for its safe management after discharge in storage conditions. In fact, in addition to other inert gases, it can represent a limiting life factor for the permanence of the fuel rod in the reactor and it could also affect the spent fuel mechanical properties. In this work, we developed a new comprehensive physics-based model describing the intra-granular helium diffusion in oxide nuclear fuel, accounting for its production, solubility and diffusivity. In particular, after a detailed investigation on the key properties governing helium transport mechanisms, two new correlations for the diffusivity and the solubility have been included in this model, on the basis of a critical review of all the experimental data available in the open literature. Clearly, each of the new correlations corresponds to a limited range of application conditions, depending on the experimental data used to derive it. Accordingly, we provided recommendations regarding the proper application conditions for each correlation (e.g. in reactor or storage conditions and in powder or single-crystal samples). In order to calculate the helium production rate, we developed a meta-model able to track all the α-decays responsible for the continuous production of helium in spent fuel and its accumulation after a few centuries. The main strength of this meta-model is that it can be easily coupled with or integrated in fuel performance codes, enabling them to track the full evolution of minor actinides and consequently to simulate the helium production rate in different nuclear fuels, both in operating and in storage conditions, for various burn-up values and initial enrichments. Eventually, the model proposed in this work has been verified and validated against experimental data available in literature (i.e. annealing experiments) with promising results. However, it would be suitable to extend the validation, but the scarcity of data calls for new experiments. For these reasons, in this work was also included a part concerning the dedicated experimental set-up we are using to investigate the helium behaviour in nuclear fuel in order to enlarge the data collection available in literature so far and improve the derived correlations. In details, the experimental activities aim at understanding how helium behaves in sintered uranium dioxide samples characterized by the same crystalline structure, but with a different level of damage in the lattice. This is induced by means of the various techniques used to introduce helium in the samples themselves (either infusion, ion implantation or doping the matrix with short-lived α-emitters). Indeed, the ongoing experiments consist in infusing or implanting helium in originally identical UO_2 samples and then comparatively assessing its release. Moreover, the originality of the present work is the study of the radiation tolerance as the grain size approaches the nanoscale. In fact, the samples used in this project are disks of sintered UO_2 characterized by nanometric grain size (down to about 100-50 nm) in order to assess the effect of the presence of numerous grain boundaries. This aspect becomes technologically relevant if one considers the microstructure of nuclear fuel irradiated at large burnups where the so-called high burnup structure (HBS) forms.

PRELIMINARY INVESTIGATION OF SOME CANDIDATE MATERIALS FOR LFRS

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One of the most important factors in assessing the candidate materials for the new generation of the innovative nuclear systems is the material performance under neutron irradiation.

Various stainless steels and other alloys have been considered and investigated during time as candidates for GEN IV and a large number of studies have been performed and reported regarding their performance under different neutron spectra. The structural materials used in fast reactors must tolerate exposure to the coolant (high temperature liquid metals, gas, or liquid salts), stress, vibration, an intense field of high-energy neutrons, or gradients in temperature; dominant forms of degradation may vary greatly between different systems,

structures, and components in the reactor and can have an important role in the safe and efficient operation. Some desirable characteristics for the Gen-IV structural materials are: (1) excellent dimensional stability against thermal and irradiation creep, void swelling, etc.; (2) favourable mechanical properties such as strength, ductility, creep rupture, fatigue, creep–fatigue interactions, etc.;(3) acceptable resistance to radiation damage (irradiation hardening and embrittlement) under high neutron doses; (4) high degree of chemical compatibility between the structural materials and the coolant as well as with the fuel.

The assessment of the candidate materials for GEN IV reactors relies on the computer simulations and experimental investigation of the material performance under neutron irradiation.

The study of reactor components behaviour in harsh environment and in the presence of liquid metals as coolants is challenging because it should take into consideration a broad range of physical and chemical phenomena as well as their interdependence.

The present work aims to provide a preliminary investigation of some materials (Ti 15-15 and Mo alloys (TZM, Mo-Re5% and Mo-Re47.2%)) behaviour in a Lead-cooled Fast Reactor if they are used as fuel cladding material. Molybdenum alloys are extensively investigated, being considered as promising materials able to withstand a harsh environment due to their characteristics: high strength and melting point, high thermal conductivity or good corrosion resistance against liquid metals.

The reference core configuration of ALFRED reactor (Advanced Lead-cooled Fast Reactor European Demonstrator) conceived under the Seventh Framework Programme (FP7) - LEADER project is considered and two computational tools are used: MCNPX 2.6.0 and FISPACT.

MCNPX is used for criticality simulations and evaluation of the neutron flux in the fuel claddings using JEFF 3.1 neutron cross-section library. The actual, detailed geometry of the whole reactor system has been modelled. FISPACT is used to evaluate the activity, the isotopic inventory and the hazard factors for each alloy used as fuel cladding based on the flux-spectrum computed by MCNPX in the respective material.

The aim of the work is to estimate the activation and isotope inventories of the fuel claddings at various irradiations and cooling time steps which are also of interest as input for further analyses regarding the radioprotection and waste characterization and disposal. Moreover, the claddings activation provides useful information about the radioactivity level of the corrosion/erosion products transported by the lead coolant to the free surface in the absence of corrosion resistance treatment.

STUDY OF MECHANICAL BEHAVIOUR OF THE HYDRIDED AREAS SURROUNDING BLUNT NOTCHES FROM ZR-2.5%NB SPECIMENS DURING THE OVERLOAD TESTS

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During CANDU reactor operation, hydrides at a blunt flaw can form under a constant load, where the hydrogen diffusion and precipitation conditions are met. Under certain operation scenarios, the hydrided region can be subjected to a load level higher than the load at which hydrides are formed. This is known as “hydrided region overload”.

There are two types of overload scenarios in operating CANDU pressure tubes. One is associated with depressurization (to about 80% full pressure) before reactor cooling, and the other situation of overload is when the transient load of up to about 15% above the normal operating pressure.

This paper summarizes the overload test results, performed at room temperature on C-shape specimens with V-notch tip hydrides, prepared from un-irradiated pressure tube. The general test procedure included two steps: hydride formation and overload tests. Hydride formation involved the thermal cycling of the specimens under a constant load to achieve the accumulation and the reorientation of the hydrides at notch-tip. Overload tests involved the determining of the fracture stress on the notch-tip hydrides under monotonically increasing

load conditions at room temperature.

An analytical relationship that correlates the applied effective stress intensity factor for the notched C-shape specimen during hydride formation, K_f, and those from overload testing, K', is obtained as function of this parameters: notch depth, hydrogen concentration.

The results can be used for the structural integrity analyses of pressure tubes in CANDU fuel channels subject to periodic inspections.

STUDY OF DIFFERENT ACCIDENT TOLERANT FUEL CONCEPTS IN TRANSIENT CONDITIONS

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I designed and performed tests to allow for the comparison of different Tolerant Fuel concepts based on their performance in transient conditions when used in a typical 4-loop Westinghouse Pressurized Water Reactor core. Two kinds of Reactivity Injection Accidents were simulated: Rod Ejection Accident and Main Steam Line Break. Three different combinations of fuel and cladding were simulated and compared to the usual Uranium Oxide – zirconium nuclear fuel: doped UO_2 fuel – chromium-coated Zr cladding, Uranium Nitride fuel – Zr cladding and Uranium Silicide fuel – silicon carbide fiber-reinforced composite-monolithic SiC composite cladding. The results show that some ATF concepts can match and even outperform the current UO_2 fuel used in PWRs. I also showed that the Cr-coated Zr cladding does not have a great effect on the neutronics performances of the core, which suggests that doped UO_2 fuel and Cr-coated Zr cladding would be among of the first ATFs to be tested in commercial Light Water Reactors.

MODELING OF INDUCTION HEATING - A CASE STUDY FOR THERMOCOUPLE PASSAGE IN NUCLEAR INSTRUMENTATION

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This paper presents a FLUX2D software numerical modelling which uses the finite element method for electromagnetic and thermal calculation of the induction heating process in vacuum of pieces assembly from instrumented passage areas of the nuclear fuel irradiation device. The case study of the inductive heating simulation process of the parts of interest follows a real case scenario of physical experiments for obtaining sealed brazed passes between thermocouple sheaths and sealing stoppers, developed within the ICN Pitesti.

The LEU nuclear fuel irradiation device is a welded assembly, which is composed from a cylindrical sheath which contain Er-U-ZrH1.6 fuel cartridges. At its upper end there is a sealing plug. The sealing metallic plug has passage holes for type K thermocouple which is used to measure the fuel temperature inside this irradiation device. Experimental setting of suitable inductor shape, turns number, positioning inductor vis a vis by pieces and required thermal and electrical parameters is a costly and time-consuming task. For this reason, computer modelling is applied in design, analysis and optimization of induction heating processes.

The numerical simulations' results of the induction heating process are used in physical experiments in order to obtain the sealed brazed passes between the thermocouple sheath and the sealing stopper. Both pieces of interest are made of Inconel 600 metal alloy and BNi-7 alloy will be used as brazing filler material. Metallic materials from the study are isotropic materials. These are characterized by a magnetization law which is independent from the application direction of the magnetic field and without phase transformation at Currie point. The inductor coil supply voltage value has a constant frequency of 10 kHz. The case study particularity of the induction heating process consists in the use a vacuum tubular quartz glass chamber, which comprises the metallic pieces assembly for induction heating, from sealing plug passage area. The inductor is placed outside the vacuum chamber. The data used in

numerical simulations corresponds to existing induction brazing installation at RATEN ICN Pitesti, which has the possibility to achieve a high vacuum up to 10^{-7} torr inside the vacuum chamber.

By simulating of the induction heating process, the following results were obtained: the maps of the distribution of the magnetic flux density, current density distribution, respectively the distribution of the temperature field in the heated pieces assembly, throughout the induction heating process simulation. By repeated simulations, the value of inductor supply voltage was established at 40 V to achieve the brazing temperature value required for the brazing alloy used. An important aspect of interest is the estimation of error sources due to indirect measurements of the temperature values in the joining region of the parts of interest. The measurements are performed on the outer surface of the sealing stopper in the physical brazing process.

Also, the simulations results are used as input data for the practical realization of the brazing process, like positioning the inductor towards the pieces for heating and to estimate the necessary electrical process parameters for reaching the temperature of brazing of approximately 980°C.

SCIANTIX: A NEW MESO-SCALE MODULE ENHANCING FUEL PERFORMANCE SIMULATIONS

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Being able to bridge lower length-scale calculations with the engineering-scale simulations of fuel performance codes requires the development of dedicated intermediate-scale codes. In this work, we present SCIANTIX, a recently developed code which aims to fill this gap. SCIANTIX is a 0D stand-alone computer code under development at Politecnico di Milano since 2016. It is designed to be included as a module in existing fuel performance codes (e.g., TRANSURANUS, BISON, GERMINAL, FRAPCON/FRAPTRAN). It contains models describing inert gas behaviour, fuel microstructure, evolution of minor actinides, thermal and mechanical properties at the scale of a fuel grain, represented as a point (i.e., 0D). Since it is 0D, no spatial discretization is required, and all variables are treated as average in space. Nevertheless, the models available in SCIANTIX (covering intra- and inter-granular inert gas behaviour, and high burnup structure formation and evolution as well) are physics-based and not correlation-based. This allows overcoming current limitations in fuel performance codes, where meso-scale phenomena are generally accounted for through correlations. This approach is tailored to the simulation of normal conditions but fails in accurately predicting the behaviour in accidental scenario (where available data are scarce) or in the pre-design of new fuel concepts (such as some accident tolerant fuels, where again the data available are scarce). The main characteristic of SCIANTIX is thus the simplicity of the models (i.e., low computational burden, in line with the requirements of fuel performance codes), paired with the possibility to inform them with parameters from lower length-scale calculations. SCIANTIX is validated against hundreds of experimental data describing inert gas behaviour at the scale of fuel grains. The validation is supported by uncertainty analyses on the main model parameters. Moreover, sensitivity analyses are performed to prioritize further research activities. Showcases of validation, uncertainty and sensitivity analyses are presented in this work (e.g., concerning gas concentrations, evolution of intra- and inter-granular bubble populations, swelling, high burnup structure formation). In particular, the whole development and assessment process is showcased for the model describing the evolution of intra-granular bubble, from lower-length scale simulation and separate effect experiments up to the engineering scale of fuel performance codes. As for the numerical treatment of the model equations, SCIANTIX is developed with full numerical consistency and entirely verified with the method of manufactured solutions (verification of different numerical solvers is also showcased in this work). SCIANTIX is available open source with no restrictions.

Safety of nuclear installations

OVERVIEW OF THE CORTEX PROJECT

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This poster gives an overview of the CORTEX project, which is a Research and Innovation Action funded by the European Union in the Euratom 2016-2017 work program, under the Horizon 2020 framework. CORTEX, which stands for CORe monitoring Techniques and EXperimental validation and demonstration, aims at developing an innovative core monitoring technique that allows detecting anomalies in nuclear reactors, such as excessive vibrations of core internals, flow blockage, coolant inlet perturbations, etc. The technique is based on primarily using the inherent fluctuations in neutron flux recorded by in-core and ex-core instrumentation (often referred to as neutron noise), from which the anomalies will be differentiated depending on their type, location and characteristics. In addition to be non-intrusive and not requiring any external perturbation of the system, the method should allow the detection of operational problems at a very early stage. In order to develop a method that can reach a high Technology Readiness Level, the consortium, made of 20 partners, was strategically structured around the required core expertise from all the necessary actors of the nuclear industry, both within Europe and outside. The broad expertise of the consortium members ensures the successful development of new in-situ monitoring techniques.

THE EU FP7 PROJECT HIGH-PERFORMANCE MONTE CARLO REACTOR CORE ANALYSIS (HPMC)

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The High Performance Monte-Carlo (HPMC) project was launched in the FP7 complementary to NURESAFE to further develop Monte Carlo regarding their coupling with thermal hydraulic solvers, stable depletion schemes, good statistics, time dependence of neutron precursors, usage of supercomputers (HPC) to solve large problems, etc. For this purpose, the development and implementation of innovative methods ad approaches. The HPMC project was focused on advanced coupled MC/TH solutions, improved stable burn-up approaches, and implementation of long time-dependence of Monte Carlo methods and algorithms and methods to take advantage of massively parallel supercomputers. In this poster, the main developments of the mentioned topics will be described. Then, selected examples of the main outcome of the project will provided and discussed.

THE H2020 PROJECT MCSAFE – HIGH PERFORMANCE MONTE CARLO METHODS FOR SAFETY ANALYSIS

Dr. Sanchez-Espinoza, V. (1); Mercatali, L. (1); Dr. Mancusi, D. (2); Dr. Smith, P. (3); Dr. Dufek, J. (4); Dr. Seidl, M. (5); Dr. Milisdorfer, L. (6); Prof. Leppanen, J. (7); Dr. Hoogenboom, E. (8); Dr. Vocka, R. (9); Dr. Kliem, S. (10); Dr. Van uffelen, P. (11); Dr. Billat, H. (12)

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8 - Delft Nuclear Consultancy (DNC), Netherlands; 9 - Nuclear Research Institute Rez plc

(NRI), Czech Republic; 10 - Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany; 11 - Joint Research Centre (JRC), Germany; 12 - Electricite de France (EdF), France

The main objective of the McSAFE project is the development of the Monte Carlo based multi-physics coupled methodologies for reactor analysis and safety investigations of different reactor systems. Key-research areas are e.g. advanced depletion methods, optimal coupling of MC-codes to thermal-hydraulic solvers, time-dependent Monte Carlo and methods and algorithms for massively parallel simulations. Based on the success of the predecessor project HPMC (High Performance Monte Carlo for reactor analysis, the goal of the H2020 project McSAFE that started in September 2017 is to become a powerful numerical tool for realistic core design, safety analysis and industry-like applications of LWRs of generation II and III.

Hence, the envisaged developments will permit to predict important core safety parameters with less conservatism than current state-of-the-art methods and it will make possible to increase the performance and operational flexibility of nuclear reactors. In addition to the methods developments, multi-physics coupling is being done within the European simulation platform NURESIM that was developed with different FP7 projects such as NURESIM, NURISP and NURESAFE and is based on the open-source SALOME software platform, Monte Carlo solvers (MONK, SERPENT, TRIPOLI) are coupled with subchannel thermal hydraulics (e.g. SUBCHANFLOW) and thermo-mechanic solvers (e.g. TRANSURANUS). Finally, all developed methods and codes will be validated against plant data of VVER and PWR plants as well as using test data of the SPERT Series IV E REA tests. The poster will present the main methods developed or under development so far till the middle of the project, the advances in the dynamic Monte Carlo methods and its testing as well as the newly developed flexible coupling approach based on ICOCO-methods. An outlook will be given about the foreseen validation work and the demonstration cases selected within McSAFE.

ADVISE - ADVANCED INSPECTION OF COMPLEX STRUCTURED MATERIALS

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EDF, France

ADVISE attemps to improve the ultrasonic inspection of corrosion resistant alloys used in nuclear power plants, in particular claddings, austenitic welds and cast austenitic steels. For these materials, a complex microstructure is responsible for both structural noise and attenuation, thus degrading the performance of ultrasonic non-destructive testing and in some cases such as cast elbow pipes obliging plant owners to resort to radiography, which is highly disruptive for maintenance operations and requires radiation shielding.

Started in September 2017 and lasting 4 years, the project brings together a multidisciplinary team with complementary expertise of leading experts and key stakeholders covering construction, operation, and all aspects of in-service inspection. The project covers new nuclear power constructions, maintenance of ageing power stations and safe operation of plants at end of life, addressing both Western European and Russian designs. The ADVISE consortium is made of 13 organisations from 6 European countries which include United Kingdom, France, Germany, Lithuania, Czech Republic and Hungary.

The ADVISE project aims to enhance – and in some cases to enable for the first time - the ultrasonic inspection of complex structures materials in order to improve confidence in and reliability of the inspection of Generation II and III reactors.

The project aspires to increase the comprehension and modelling of complex structures for accurate prediction, to develop new tools for material characterisation and to provide advanced inspection and defect evaluation methods as well as assisted diagnostics.

The main output of the project is a step change improvement in performance in terms of inspectable depth, defect detection and characterisation accuracy. For austeno-ferritic cast components, an increase of the inspectable depth of 70 to 85 mm is aimed for. Equally importantly, the in-situ characterisation for specific inspections will provide the confidence needed to make safe decisions from measured indications without the significant conservatism that is needed in many cases currently.

THE EURATOM PROJECT PREPARE

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The PREPARE project has the objective to close gaps that have been identified in nuclear and radiological preparedness in Europe following the first evaluation of the Fukushima disaster. With 46 partners from Europe and Japan, it collected the key players in the area of emergency management and rehabilitation preparedness. Starting February 2013, the project has ended January 2016. Among others, the project addressed the review of existing operational procedures for dealing with long lasting releases, cross border problems in radiation monitoring and food safety and further developed missing functionalities in decision support systems ranging from improved source term estimation and dispersion modelling to the inclusion of hydrological pathways for European water bodies. In addition, a so called Analytical Platform has been developed exploring the scientific and operational means to improve information collection, information exchange and the evaluation of such types of disasters. The tools developed within the project will be partly integrated into the two decision support systems ARGOS and JRODOS. This poster presents the final achievements of PREPARE in terms of methodological, mathematical and operational improvements in the area of emergency management and rehabilitation preparedness.

THE MUSA PROJECT: MANAGEMENT AND UNCERTAINTIES OF SEVERE ACCIDENTS

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MUSA was founded in HORIZON 2020 EURATOM NFRP-2018 call on "Safety assessments to improve Accident Management strategies for Generation II and III reactors". On June 15th, 2018 obtains the NUGENIA label that recognizes the excellence of the project. The 4 years Consortium is composed by 29 Organizations (25% non EU), with an overall cost of € 5,768,452.50 (about 630 person months).

The main objective is to assess the capability of Severe Accident (SA) codes when modelling reactor/Spent Fuel Pool accident scenarios of GEN.II and GEN.III designs. Further goals are:

- Identification of Uncertainty Quantification (UQ) methodologies to be employed, with emphasis on the effect of both existing and innovative SA Management (SAM) measures on the accident progression, particularly those related to Source Term (ST) mitigation;
- Determination of the state-of-the-art prediction capability of SA codes regarding ST that potentially may be released to the environment, and to the quantification of associated code's uncertainties applied to SA sequences.

The achievement of the MUSA objectives is assured by a consistent and coherent work programme reflected in 7 technical Work Packages (WP), coordinated by the following organizations:

WP1 MUSA COordination (MUCO) - CIEMAT

WP2 Identification & Quantification of Uncertainty Sources (IQUS) - GRS

WP3 Review of Uncertainty Quantification Methods (RUQM) - KIT

WP4 Application of Uncertainty Quantification Methods against Integral Experiments (AUQMIE)- ENEA

WP5 Uncertainty Quantification in the Analysis and Management of Reactor Accidents (UQAMRA) - JRC

WP6 Uncertainty Quantification and Innovative Management of SFP Accidents (IMSFP) - IRSN

WP7 COmmunication & REsults DISsemination (COREDIS) - UNIPI. A special attention will be about the knowledge transfer towards young generation, mainly through the production of learning modules and a mobility programme. These education activities will be carried out in a close collaboration with ENEN.

The project has an "innovative research agenda" in order to move beyond the state-of-the-art regarding the predictive capability of SA codes by combining them with the best available or improved UQ tools. By doing so, not only the prediction of timing for the failure of safety barriers and of radiological ST will be possible, but also the quantification of the uncertainty bands of selected analysis results, considering any relevant source of uncertainty, will be provided.

Finally, MUSA will be an open results project for its importance on forthcoming SA analyses and it will mean a better exploitation of research previously performed within the EU framework. Furthermore, over the years, reliable and experienced teams of modellers and analytical teams have been built-up, and MUSA is a unique opportunity to achieve real feedback among them, encouraging cooperation in research, innovation and young generation's formation.

PROJECT SOTERIA: SAFE LONG TERM OPERATION OF LIGHT WATER REACTORS BASED ON IMPROVED UNDERSTANDING OF RADIATION EFFECTS IN NUCLEAR STRUCTURAL MATERIALS

Dr. Robertson, C. (1); Dr. Serrano, M. (2); Dr. Hein, H. (3); Dr. Binks, P. (4); Dr. Vidal, J. (5); Marcelles Ramirez, I. (6)

1 - CEA, France; 2 - CIEMAT, Spain; 3 - FRAMATOME, Germany; 4 - WOOD, United Kingdom
5 - EDF, France; 6 - Technatom, Spain

SOTERIA began work in September 2015, building on many years of collaboration for consortium members within earlier projects. A total of 23 organisations work in this project, which is funded by €5M over 4 years from the European Commission, and by additional €1M from national sponsors. The project is developing understanding of ageing phenomena in reactor pressure vessel steels and reactor internals, i.e. the life-limiting components of nuclear power plants. Experiments are performed to explore flux and fluence effects, effects of metallurgical heterogeneities and environmental effects on materials ageing behaviours. Emphasis is laid on developing mechanistic understanding of the degradation processes, and using this to develop models that can be used to extrapolate to long-term operation. The understanding in this project derives from detailed examination of materials at various scales from sub-atomic to whole macroscopic test specimens. SOTERIA's multi-scale approach will deliver advances that are implemented in an integrated computer simulation platform, for better dissemination within the nuclear community. This tool includes a user-friendly interface and has been evaluated by a broad panel of end-users (including universities and nuclear utilities) during SOTERIA training school (held in September 2018) and several End-user group meetings.

However, considering the high cost of the tests, the actual number of generated data points remains limited. Hence, deciding on the statistical significance of the new test results remains a challenge. The SOTERIA consortium will likely keep focusing on this issue, even after the project termination. The SOTERIA Final Workshop is planned in June 2019 in Miraflores de la Sierra (Madrid). The objective is to disseminate project final results among nuclear research and industrial communities, and particularly end-users, as well as identifying future research needs. The workshop will be a forum for regulators, user groups, experts and industry, to exchange information and experiences on radiation effects on nuclear power plant components.

INCEFA+SAFETY IN NPPS BY COVERING GAPS IN ENVIRONMENTAL FATIGUE ASSESSMENT

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INCEFA-PLUS is a five year project supported by the European Commission HORIZON2020

programme. The project commenced in mid-2015. 16 organisations from across Europe have combined forces to deliver new experimental data which will support the development of improved guidelines for assessment of environmental fatigue damage to ensure safe operation of nuclear power plants. Within INCEFA-PLUS, the effects of mean strain and stress, hold time, strain amplitude and surface finish on fatigue endurance of austenitic stainless steels in light water reactor environments are being studied experimentally, these being issues of common interest to all participants. The data obtained is being collected and standardised in an online environmental fatigue database, implemented with the assistance of an INCEFA-PLUS led CEN workshop on this aspect. Towards the end of the project it is planned that INCEFA-PLUS will develop and disseminate methods for including the new data into assessment approaches for environmental fatigue degradation.

TEAM CABLES – EUROPEAN TOOLS AND METHODOLOGIES FOR AN EFFICIENT AGEING MANAGEMENT OF NUCLEAR POWER PLANT CABLES

Dr. Marque, G.

EDF, France

TeaM Cables – European Tools and Methodologies for an efficient ageing management of nuclear power plant cables – is a research project which has received 4.2 M€ of funding from the European Commission's EURATOM programme, which is part of the Horizon 2020 framework programme for Research and Innovation. The project is coordinated by Electricité de France (EDF) and will run until 2022.

With an average of 25 000 electrical cables for a total length of ~1 500 km per NPP (Nuclear Power Plant) unit, all organisations involved in the current and next generation of NPPs have recognised the importance of cable qualification, condition monitoring, and ageing management. Electrical cables are the nerves and blood vessels of NPPs!

The overall ambition of TeaM Cables is to allow NPP operators to improve their capacity to safely manage the lifetime of cables and thereby contribute to ensuring the lifetime extension of NPPs to 60-80 years. The main innovation of the project is the radically new way of estimating the lifetime duration of cables, using much more precise information and more relevant methods to analyse the data based on multi-scale studies of the materials. Specific goals include the characterisation of cables at molecular, micro and macro level, the development of multiscale models, the definition of criteria and protocols for on-site monitoring with non-destructive testing techniques (NDT) and finally the development of a tool which can be used by utilities for a better ageing management of their NPPs.

The TeaM Cables multiscale modelling approach and associated tools will allow NPP operators to safely extend the plant life duration of generation II and III reactors and thus contribute to the production of sustainable energy responding to future energy needs.

HERACLES-CP: THE COMPREHENSION PHASE FOR HIGH-DENSITY U-MO FUELS FOR RESEARCH REACTORS

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In the framework of the joint international efforts to reduce the risk of proliferation by minimising the use of highly enriched uranium, a new research reactor fuel based on uranium-molybdenum (UMo) alloys is being developed by the HERACLES group. There are two types of UMo fuel - fine particles dispersed in an Al matrix, and monolithic foils. The HERACLES-CP project prepares the way toward the qualification with an initial comprehension phase, to improve the understanding of the fuels' irradiation behaviour and consequent the manufacturing/industrialisation process. One of the key components in the project is the SEMPER-FIDELIS irradiation test, which investigates the fuel swelling phenomenon and the effects of coating, with a view to arriving at procedures for fuel engineering.

FASTNET - FAST NUCLEAR EMERGENCY TOOLS PROJECT

Dr. Rocchi, F.

ENEA, Italy

The FASTNET (Fast Nuclear Emergency Tools) project started in October 2015 and is expected to end in September 2019. It gathers 20 partners, coordinated by IRSN, together with IAEA. The events at the Fukushima NPPs and Spent Fuel Pools dramatically illustrated that the need for a common understanding and, whenever possible, a common approach in the field of EP&R also exists for accidents happening even at great distance from Europe. On top of the many actions undertaken by IAEA, OECD/NEA and the EC, further harmonization efforts are needed with regard to what should be recommended to the public during an emergency occurring in Europe or abroad. The objective of the FASTNET project is the qualification of a graduated response methodology that integrates several fast tools and methods to ensure both diagnosis and prognosis of SA progression and estimates the consequences on the surrounding population and the environment.

The aims of FASTNET are centered on three major pillars: 1) the development of a reference SA scenarios database, inclusive of time-dependent, isotopic STs, created using best-estimate SA codes; 2) the extension of existing methods (3D3P) and fast-running codes (PERSAN and RASTEP) to predict STs to all current nuclear power plant technologies deployed in Europe (PWR, BWR, VVER, CANDU, EPR, including a generic model for SFPs); and 3) the dissemination of best-practices on the use of the methods and tools developed within the project to estimate STs in real-time and during conditions typical of real emergencies. The poster will present the main results obtained so far, including the status of development of the database, which now contains about 120 sequences, the status of development of PERSAN and RASTEP, and some insights on the main outcomes of the exercises done by the project partners to test the tools and the methodologies.

NUGENIA-PLUS

Dr. Puska, E. K.

NUGENIA/ VTT Technical Research Centre of Finland, Finland

NUGENIA-PLUS (NUGENIA+) project Preparing NUGENIA for HORIZON 2020 started on 1 September 2013 with 18 partners and extended on 1st of March 2015 into a project of 50 partners as the result of the pilot call for small R&D tasks launched in September 2014. The project lifetime was extended by one month in order to enable project participation in an IAEA technical meeting and organisation of NUGENIA side event during 60th IAEA General Conference on 27th of September 2016. The Project duration was 37 months, volume approximately 10.3 M€, and 820 person months, whereof 585 person months in the 14 selected pilot R&D tasks.

A substantial number of young researchers were involved in these tasks of cross-cutting research worth of 5.2 M€ during the last 18 months of the project. 79 specified deliverables were produced as the result of these small research projects. The poster will present the main results of the NUGENIA-PLUS project and how it has helped to enhance the functions of the NUGENIA Association in its work for European R&D and how the small research projects have served as the seeds of larger research projects already on-going or in planning within the EU research community.

NONDESTRUCTIVE EVALUATION (NDE) SYSTEM FOR THE INSPECTION OF OPERATION-INDUCED MATERIAL DEGRADATION IN NUCLEAR POWER PLANTS

Dr. Rabung, M.

Fraunhofer Instute for Nondestructive Testing IZFP, Germany

The long-term operation (LTO) of existing nuclear power plants (NPPs) has already been accepted in many countries as a strategic objective to ensure adequate supply of electricity over the coming decades. In order to estimate the remaining useful lifetime of NPP

components, LTO requires reliable tools. The objective of NOMAD is the development, demonstration and validation of an NDE tool for the local and volumetric characterisation of the embrittlement in operational NPPs. The approach being developed within NOMAD will deliver information complementary to and exceeding the information obtained by destructive tests of surveillance samples. Six NDE methods including electrical, ultrasonic and micro-magnetic techniques have been developed. After that they have been applied for the characterization of multiple sample scales from full Charpy samples over non-cladded to cladded blocks made from different eastern, western, base and weld materials in different neutron-irradiated and thermally-aged conditions. The results have been correlated with results of Charpy tests. Moreover, the NDE results will be compared, correlated and validated in a novel software tool, which will be of great use for energy companies in the long term. The most relevant parameters affecting the NDE measurements and the application of the NDE tool in the field have been specified for each method.

NEW TRENDS IN PROBABILISTIC SAFETY ASSESSMENT FOR EXTERNAL EVENTS: THE H2020-NARSIS PROJECT

Dr. Foerster, E. (1); Prof. Bazargan-sabet, B. (2); Dr. Daniell, J. (3); Dr. Gehl, P. (2); Prof. Vardon, P. (4); Dr. Rastiello, G. (1); Dr. Štrubelj, L. (5)

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The methodology for Probabilistic Safety Assessment (PSA) of Nuclear Power Plants (NPPs) has been used for decades by practitioners to better understand the most probable initiators of nuclear accidents by identifying potential accident scenarios, their consequences, and their probabilities. However, despite the remarkable reliability of the methodology, the Fukushima Dai-ichi nuclear accident in Japan, which occurred in March 2011, highlighted a number of challenging issues (e.g. cascading event - cliff edge - scenarios) with respect to the application of PSA questioning the relevance of PSA practice, for such low-probability but high-consequences external events. Following the Fukushima Dai-ichi accident, several initiatives at the international level, have been launched in order to review current practices and identify shortcomings in scientific and technical approaches for the characterization of external natural extreme events and the evaluation of their consequences on the safety of nuclear facilities.

Based on the ASAMPSA_E lessons and also on the theoretical progresses and outcomes from other recent European projects (e.g. FP7-SYNER-G, FP7-MATRIX, FP7-INFRARISK), the H2020 project "New Approach to Reactor Safety ImprovementS" (NARSIS, 2017-2021) aims at proposing some improvements to be integrated in existing PSA procedures for NPPs, considering single, cascade and combined external natural hazards (earthquakes, flooding, extreme weather, tsunamis).

The project will lead to the release of various tools together with recommendations and guidelines for use in nuclear safety assessment, including a Bayesian-based multi-risk framework able to account for causes and consequences of technical, social/organizational and human aspects and a supporting Severe Accident Management decision-making tool for demonstration purposes, as well. The applicability of the foreseen improvements in natural hazards characterization and fragility assessment of SSCs, as well of the proposed multi-risk framework will be tested on a simplified virtual PWR for different European "hot spots", where various single and multi-hazard scenarios will be studied.

Advanced nuclear systems and fuel cycles

SUMMARY AND HIGHLIGHTS OF THE ASGARD PROJECT

Prof. Ekberg, C. (1); Dr. Devisser- tynova, E. (2); Dr. Retegan, T. (1); Prof. Sarsfield, M. (3); Prof. Wallenius, J. (4)

1 - Chalmers University of Technology, Swede; 2 - Nuclear Research & consultancy Group

(NRG), Netherlands; 3 - National Nuclear Laboratory, United Kingdom; 4 - Royal Institute of Technology, Sweden

The aims of the ASGARD project (2012 - 2016) were originally multi-dimensional with the overall focus on the recyclability of novel nuclear fuels. The main dimensions were: the scientific achievements, investigating how to increase the industrial applicability of the fabrication of these novel fuels, the bridging of the often separate physics and chemical communities when dealing with nuclear fuel cycles and last but not least to offer an extensive education and training to younger scientists including a broadening of their experience by visiting and performing work at other facilities than their own.

At the end of the project 27 papers in peer reviewed journals were published and it is expected that the real number will be the double.

The success of the integration and cross disciplinary training is shown by the successful implementation of the Travel Fund. It allowed that 4 young scientists were each spending more than one month at another partner laboratory, funded 23 young scientists to visit conferences and meetings presenting their achievements as well as the organisation of 3 dedicated summer/winter schools having about 15 participants each which in the case of the last one dealing with plutonium chemistry was the absolute maximum possible. For the scientific domains there are naturally many different achievements but among the more important ones by domain are as follows.

In the oxide domain the recyclability of the inert matrix fuels based on MgO or Mo was investigated and it was clear that it is possible to both dissolve the fuels in a good way but also to pre-treat the dissolution liquor in a way that it can be fed into the already existing reprocessing process. Moreover, it was shown that fabrication of pure 50/50 (Pu, Am)O_2 was possible.

In the nitride domain it was shown that the pivotal cost for production of 15N can be reduced significantly but is still a bit high for competitive fuel production. UN production technique was optimised to obtain a total control of e.g. oxygen impurities and controlling porosity obtaining a 99.88% dense pellet. A significant achievement was also the production of pure PuN by using both nitriding from oxides and by sol-gel rote. It is unsure if this kind of material was ever produced by these means before.

In the carbide domain the alleged pyrophoricity of carbide material was investigated showing that by controlling oxygen and water access even fine power can be handled safely. The parameters for ignition of both power and pellets were determined thus increasing the safety of this kind of fuel handling significantly. A new sol-gel technique based on microwave gelation was also developed. By this ground breaking invention the industrial applicability of the sol-gel technique for production of any fuel precursor from solution was increased significantly. Now there is no need for washing, drying etc, the microspheres and also the production of contaminated oils being prevented.

HORIZON-2020 ESFR-SMART PROJECT ON SODIUM FAST REACTOR SAFETY: STATUS AFTER 18 MONTHS

Dr. Mikityuk, K. (1); Dr. Álvarez velarde, F. (2); Dr. Bankhead, L. (3); Dr. Bubelis, E. (4); Dr. Bukasa kampata, N. (5); Dr. Buligins, L. (6); Dr. Carluec, B. (7); Dr. Chauvin, N. (8); Prof. Demaziere, C. (9); Dr. Fridman, E. (10); Dr. García herranz, N. (11); Dr. Gerbeth, G. (10); Dr. Girardi, E. (12); Dr. Girault, N. (13); Prof. Gradeck, M. (14); Dr. Guidez, J. (8); Dr. Hering, W. (4); Dr. Krepel, J. (1); Dr. Latge, C. (8); Dr. Lindley, B. (15); Dr. Lombardo, C. (16); Dr. Payot, F. (8); Dr. Rineiski, A. (4); Prof. Schwageraus, E. (17); Dr. Seubert, A. (18); Dr. Tsige-tamirat, H. (19)

1 - PSI, Switzerland; 2 - CIEMAT, Spain; 3 - NNL, United Kingdom; 4 - KIT, Germany; 5 - LGI, France; 6 - IPUL, Latvia; 7 - Framatome, France; 8 - CEA, France; 9 - Chalmers University, Sweden; 10 - HZDR, Germany; 11 - UPM, Spain; 12 - EDF, France; 13 - IRSN, France; 14 - LEMTA, France; 15 - WOOD, United Kingdom; 16 - ENEA, Italy; 17 - UCAM, United Kingdom; 18 - GRS, Germany; 19 - JRC, Netherlands

To improve the public acceptance of the future nuclear power in Europe we have to demonstrate that the new reactors have significantly higher safety level compared to traditional reactors. The ESFR-SMART project (European Sodium Fast Reactor Safety Measures Assessment and Research Tools) aims at enhancing further the safety of Generation-IV SFRs and in particular of the commercial-size European Sodium Fast Reactor (ESFR) in accordance with the European Sustainable Nuclear Industrial Initiative (ESNII) roadmap and in close cooperation with the Advanced Sodium Technological Reactor for Industrial Demonstration (ASTRID) program.

The project aims at 5 specific objectives:

- Produce new experimental data in order to support calibration and validation of the computational tools for each defence-in-depth level.
- Test and qualify new instrumentations in order to support their utilization in the reactor protection system.
- Perform further calibration and validation of the computational tools for each defence-in-depth level in order to support safety assessments of Generation-IV SFRs, using the data produced in the project as well as selected legacy data.
- Select, implement and assess new safety measures for the commercial-size ESFR, using the GIF methodologies, the FP7 CP-ESFR project legacy, the calibrated and validated codes and being in accordance with the update of the European and international safety frameworks taking into account the Fukushima accident.
- Strengthen and link together new networks, in particular, the network of the European sodium facilities and the network of the European students working on the SFR technology.

By addressing the industry, policy makers and general public, the project is expected to make a meaningful impact on economics, environment, EU policy and society.

Selected results and milestones achieved during the first eighteen months of the project will be briefly presented, including:

- proposal of new safety measures for ESFR;
- evaluation of ESFR core performance;
- benchmarking of codes;
- experimental programs; and
- education and training.

ESFR SMART: NEW OPTION OF SAFETY VESSEL SUPPRESSION, TO INCREASE GLOBAL SAFETY OF SFR.

Dr. Guidez, J.

CEA, France

The ESFR SMART is a four years European project begun in September 2017, with the main objectives to increase safety on SFR project. One of the options proposed is to suppress the safety vessel and to assure his functions by a new organization of the pit.

All existing sodium fast reactors, built or operated, have a safety vessel around the main reactor vessel. Its function is, in case of leakage of this main vessel, to recover the sodium, while avoiding the dewatering of the exchanger inlet windows which would have the effect of interrupting the cooling of the core by natural convection.

In this accidental situation, the reactor will never start again and an unloading of the core is necessary. But this unloading will take at least one year because it is necessary to wait the decrease of assemblies' residual power. So we have a prolonged situation with an inter tank filled with sodium.

Since a sodium leak occurred on the Superphenix drum vessel, the question of the safety authorities could be: what happens in case of leakage of this safety vessel during this long

time? In addition it is also asked to have a reactor sized for severe accident mitigation. Under these new conditions it becomes useful to have a pit design able to fulfil the safety vessel functions, to receive a sodium leak and to assure a good mitigation.

The European ESFR SMART project then proposed in one of its new safety options to design a pit that can withstand sodium leakage from the main vessel and then assure the functions of this safety vessel. This option also has a number of advantages, with for example a much more effective radiative decay heat removal by the pit cooling system and a better mitigation of severe accidents scenarios.

The purpose of this paper is to present this pit organization allowing the suppression of this safety vessel A certain number of pre-calculations and related sizing are also presented in support, with a summary of the advantages of the final solution .

CHANDA NUCLEAR DATA TOOLS, FACILITIES, METHODS AND RESULTS FOR SAFETY OF EU FACILITIES

Prof. Gonzalez Romero, E. M. (1); Dr. Cano-Ott, D. (1); Dr. Leray, S. (2); Dr. Leconte, P. (2); Dr. Plompen, A. (3); Dr. Schillebeeckx, P. (3); Dr. Sibbens, G. (3);Dr. Chiaveri, E. (4); Dr. Junghans, A. (5); Prof. Koning, A. (6); Dr. Erasmus, B. (7); Dr. Stankovskiy, A. (8)

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Nuclear data, ND, and associated tools are critical elements of the nuclear energy industry and research, playing an essential role in the simulation of nuclear systems, safety and performance calculations and interpretation of the reactor instrumentation. Nuclear Data improvement requires a combination of many different know-hows that are distributed over many small and medium sized institutions along Europe. The Euratom programs have facilitated the setup of paneuropean collaborations getting together the required experience inside the projects CHANDA, ERINDA and the JRC action EUFRAT.

The poster will describe CHANDA that stands for "solving CHAllenges in Nuclear DAta for the Safety of European Nuclear Facilities". The CHANDA project that started on December 2013 and has been completed on May 2018, brought together the majority of the European nuclear data community, infrastructures and resources to prepare the methodologies, detectors, facilities, nuclear models and tools to produce and use nuclear data with the quality required to comply with the needs for the safety standards that are mandatory for present and future European nuclear reactors and other installations using radioactive materials.

The poster will describe some of the main technical achievements of the project in regards of improving the experimental facilities used for ND, integrating and developing target fabrication capabilities, new methods for cross section measurements, new and improved evaluation models and tools, validation and improvement of data using integral experiments and comprehensive tools for transport problems, including those involving high energy reactions. In addition, it will describe the methods used to provide efficient transnational access to experimental facilities for ND, for fast and comprehensive dissemination of results, for the publication of results for specialized users. There will be also information about the efficient contribution of the research in the project to the training young scientists (30 PhD theses and 18 Master theses).

Finally, the poster will describe the strategic perspectives used for the configuration and management of the CHANDA project, combining an inclusive approach with a strong internal competition, and several success stories, like significant improvements on measurements of

very difficult isotope/reaction combinations, sharing sample materials between differential and integral experiments, a long list of target produced and a fruitful utilization of the transnational access to facilities.

The poster will conclude with some lessons learnt and suggestions for follow-up actions.

MULTISCALE MODELLING FOR FUSION AND FISSION MATERIALS (M4F)

Prof. Malerba, L.

CIEMAT, Spain

The sustainability of nuclear fission energy will be ensured when Generation IV systems are deployed. Thermo-nuclear fusion represents in the longer term a virtually inexhaustible source of energy, with potentially very high standards of sustainability, efficiency and safety. Despite differences between GenIV fission and fusion reactors, in both technologies materials will be exposed to high levels of irradiation and high temperatures, in contact with potentially aggressive non-aqueous coolants. Thus, several materials issues are common.

In this context, the M4F project (Multiscale modelling for fusion and fission materials) promotes cross-fertilization between the nuclear fission and fusion materials modelling and characterization communities, to work on structural materials that are of interest for both, namely ferritic/martensitic (F/M) steels. These offer excellent radiation-induced swelling resistance and thermal properties, as compared to austenitic steels, but suffer from low temperature neutron irradiation hardening, embrittlement and loss of uniform elongation, with impact on design rules and codification activities.

Specifically, two are the overarching objectives of the M4F project:

- Develop physical understanding and predictive models of the origin of localised deformation under irradiation in F/M steels and its consequences on the mechanical behaviour of components, starting from modelling and understanding the changes caused by irradiation on the microstructure and microchemistry of the materials involved;
- Develop a methodology to use ion irradiation as a tool to evaluate radiation effects on materials, minimising artefacts with respect to neutron irradiation experiments and allowing evaluation of not only microstructural change, but also mechanical property changes, via nanoindentation, applying it to F/M steels.

The complexity of the processes that drive the production and evolution of microstructural damage induced by neutron irradiation and the consequences it has on the material's behaviour require large R&D efforts, that advise synergies to be exploited and collaboration to be promoted between fusion and fission materials research groups, applying a multidisciplinary approach. In it, both modelling and experiments at different scales are integrated to enable the understanding of the complex phenomena associated with irradiation damage in F/M steels, providing input to design codes.

This poster will succinctly present the approach that is followed and first preliminary results.

GEMMA PROJECT

Dr. Agostini, P. (1); Dr. Angiolini, M. (1); Dr. Tucek, K. (2); Dr. Weisenburger, A. (3); Dr. Nastar, M. (4); Dr. Stergar, E. (5)

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GEMMA means GEneration IV Materials MAturity. The ambition of GEMMA is in the name itself: "Bring to maturity the materials for GenIV prototypes in Europe", allowing a big step forward to be taken towards the next phase of design for all four ESNII systems. GEMMA aims at performing applied research, focusing in priority on the most crucial issues that concern structural materials for ASTRID, MYRRHA, ALFRED and ALLEGRO. By doing so, GEMMA contributes to the priorities expressed by the EERA JPNM, which are the demonstration, through extensive experiments in representative conditions, of the applicability of the

reference structural materials and welded joints in the harsh environmental conditions of ESNII reactors. The contribution to ASTRID consists of:

- Development of physical models of microstructure evolution under irradiation in austenitic alloys, both at low flux and focused on swelling;
- Measurement of residual stresses in welded joints representative of ASTRID vessel.

It is then expected to enhance the predictive capability in terms of microstructural evolution under irradiation up to 60 years. Additional outcomes will be guidance for development of swelling resistant austenitic steels and better qualification of high responsibility welded joints.

The GEMMA contributions to heavy liquid metal cooled ESNII reactors (MYRRHA and ALFRED) are very similar although referring to different operating environments: 400°C LBE for MYRRHA and 480°C lead for ALFRED. The main activities carried on in GEMMA are:

- Testing of selected austenitic steels, including welds, in contact with heavy liquid metal, to measure corrosion and to assess possible degradation of mechanical properties;
- Development and testing in HLM environment of corrosion/erosion resistant materials such as alumina forming austenitics and mitigation techniques such as surface engineering.

At the end of the Project it is expected the production of a large database on chemical and mechanical behavior of structural materials in HLM. Additionally it is expected the development of design correlation for corrosion of austenitic steels in HLM as well as the determination of safe operating conditions in terms of time, temperature and oxygen content with regard to HLM corrosion. Finally a first screening of materials with superior HLM compatibility will be available.

GEMMA contribution to ALLEGRO regards Testing of selected austenitic steels, including welds and corrosion resistant materials in flowing He at relevant high temperatures: 550°C and 850°C. The expected progress for ALLEGRO will be the experimental evaluation of effects on structural materials of typical operational conditions, providing clearer bases for design.

EUROPEAN RESEARCH INFRASTRUCTURES FOR NUCLEAR DATA APPLICATIONS (ERINDA)FP7 (269499)

Dr. Junghans, A.

Helmholtz-Zentrum Dresden-Rossendorf, Germany

The CSA project European Research Infrastructures for Nuclear Data Applications (ERINDA) has provided a convenient platform to integrate all scientific efforts needed for high-quality nuclear data measurements in support of waste transmutation studies and design studies for Generation IV systems.

The objectives of ERINDA included the following:

- to provide access for nuclear data measurements at the consortium's facilities;
- experiments should account for nuclear data requests of highest priority and scientific value;
- simulation methods to predict the running conditions of innovative reactor systems and the transmutation of nuclear waste;
- generation of complete, accurate and consistent nuclear data libraries and measured nuclear reaction cross-sections.

To reach these objectives, ERINDA coordinated the European efforts in order to exploit up-to-date neutron beam technology and novel research on advanced concepts for nuclear fission reactors and the transmutation of radioactive waste. ERINDA offered transnational access to the nuclear data research infrastructures of 13 partners (HZDR, JRC-GEEL, CERN, CENBG, IPNO, UU-TSL, PTB, NPI, IKI, IFIN-HH, NPL, FRANZ and CEA.) over a 36-month period from 1 December 2010 to 30 November 2013. Special attention was placed on the selection of supported experiments, to take into consideration their contribution to the competence

building of young scientists.

Finally, the main results achieved in the ERINDA project are:

Nuclear data measurements for:

- optimisation of existing power plants' design and operation of advanced reactor systems, nuclear waste management strategies and transmutation,
- advancing nuclear safety and security,
- development of new experimental techniques;

The ERINDA project has supported 3015 additional hours of beam time in 26 experiments as transnational-access to European groups at the consortium facilities including technical and travel support for the user groups. In addition 16 short term visits (with a total duration of 106 weeks) of scientists to the consortium institutes were supported. In this way theoretical data analysis and computer simulations relevant to the experiments were performed. Four European scientific meetings (Dresden, Prague, Jyvaskylä, Geneva) were organized to communicate the progress and disseminate the results of the ERINDA project. Up to February 2019, 74 peer-reviewed scientific publications have resulted from the activities in ERINDA.

NUCLEAR COGENERATION INDUSTRIAL INITIATIVE - RESEARCH PROJECT NC2I-R

Prof. Wrochna, G.

National Centre for Nuclear Research NCBJ, Poland

Industrial cogeneration of power and heat relies heavily on fossil fuels. However, fossil fuel prices and their insecurity of supply together with carbon taxation have put considerable pressure on the European industry. Nuclear energy is an excellent source of process heat for various industrial applications, and nuclear cogeneration will bring a host of environmental, economic and societal benefits.

The Sustainable Nuclear Energy Technology Platform (SNETP) recognised nuclear cogeneration as one of its three technology pillars. Under the SNETP umbrella, the Nuclear Cogeneration Industrial Initiative (NC2I) was set up to demonstrate an innovative and competitive energy solution for the low-carbon nuclear cogeneration of heat and electricity.

The EU-funded project NC2I-R (Nuclear cogeneration industrial initiative - Research and development coordination) was established to support NC2I activities by preparing the conditions for developing a European cogeneration industrial demonstrator for next-generation nuclear reactors.

The aim of NC2I-R was to commission a nuclear cogeneration prototype for testing and deploying this low-carbon energy technology in several energy-intensive industries. Project partners investigated several legal and safety issues for developing nuclear cogeneration and licensing technology. They focused on drawing up strict specifications for the demonstrator to ensure its viability and replicable production, and satisfy market demand.

GEMINI+ PARTNERSHIP FOR HTR DEPLOYMENT

Prof. Wrochna, G.

National Centre for Nuclear Research NCBJ, Poland

GEMINI+ project will provide a conceptual design for a high temperature nuclear cogeneration system for supply of process steam to industry, a framework for the licensing of such system and a business plan for a full scale demonstration.

It will rely on modular High Temperature Gas cooled Reactor (HTGR) technology, which is a mature technology with several industrial prototypes that have been constructed and operated in the world.

HTGRs have a unique intrinsic safety concept preventing in any circumstances significant degradation of the nuclear fuel and consecutive radioactive releases, with no need of any human intervention.

With available materials and technology, such a system can provide steam to industrial steam distribution networks presently operating on industrial sites up to 550°C, simply substituting to fossil fuel fired cogeneration plants, without any need for adaptation of the steam distribution infrastructure or of the industrial applications. In the longer term, HTGR technology can be further developed to provide higher temperature process heat e.g. for hydrogen production.

Beyond industrial cogeneration, the flexibility, robustness and simple design of modular HTGR will allow extending application of the system developed by GEMINI+ to small isolated electric grids, to electric grids with increasing proportion of intermittent renewables, to new nuclear countries, etc.

The GEMINI+ project gathers an international team from nuclear industry and research, Technical Support Organisations of different national nuclear safety authorities, engineering companies of non-nuclear sector and end-users of process steam, mainly European, but with US, Japanese and Korean contributions.

RATEN INVOLVEMENT IN CROSS-CUTTING ACTIVITIES FOR TRITIUM MANAGEMENT IN FISSION AND FUSION FACILITIES WITHIN TRANSAT PROJECT

Dr. Fako, R. (1); Guga, L. (1); Dr. Deaconu, M. (2); Meglea, S. (1); Petre, G. (1)

1 - Center of Technology and Engineering for Nuclear Projects (RATEN CITON), Romania;
2 - Institute for Nuclear Research Pitesti (RATEN ICN), Romania

Activities developed by RATEN specialists in the first half of the project planned period will be emphasized in the paper. Expectations of research team regarding the assessment of term sources relevant for fusion and fission reactors and potential applications for engineering activities to improve tritium management in the nuclear open-cycle are highlighted. Tritium source in heavy water reactors is discussed considering time evolution of the tritium activity in the moderator system of a CANDU 600 reactor. There are identified main interfaces between tritiated heavy water and light water fluxes in the Moderator System (reactor assembly, heat exchangers) and Primary Heat Transport System (steam generators).

Four main barriers against tritium release in CANDU 600 reactor are analysed (e.g. reactor barriers, heat exchangers and recirculated cooling water barriers, steam generator & main condenser barriers, containment/technological barriers).

The role of design & engineering team for input data mining and for potential further implementation of experimental activities within TRANSAT (TRANSversal Actions for Tritium) project is described.

SESAME PROJECT: ADVANCEMENTS IN LIQUID METAL THERMAL HYDRAULICS EXPERIMENTS AND SIMULATIONS

Dr. Tarantino, M. (1); Dr. Roelofs, F. (2); Dr. Shams, A. (2); Dr. Batta, A. (3); Dr. Moreau, V. (4); Dr. Di piazza, I. (1); Dr. Gerschenfeld, A. (5); Dr. Planquart, P. (6)

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Liquid metal cooled reactors are envisaged to play an important role in the future of nuclear energy production because of their possibility to use natural resources efficiently and to reduce the volume and lifetime of nuclear waste. Liquid lead(-alloys) and liquid sodium are good candidates for cooling such reactors. Thermal-hydraulics of these liquid metals plays a key role in the design and safety assessments of these reactors. Therefore, this was the subject of the Horizon 2020 collaborative project SESAME sponsored by the European Commission which ran from 2015 till 2019. This paper will present the main outcomes of this project.

The main topics to be addressed are liquid metal heat transfer, core thermal-hydraulics, pool thermal-hydraulics, and system thermal-hydraulics. With respect to liquid metal heat transfer, the purpose was to start from the most promising RANS models which can simultaneously deal with different flow regimes (natural, mixed, and forced convection). To put these models to the test, a wide range of new reference data, both experimental and numerical has been

generated.

Regarding core thermal-hydraulics, further steps have been taken in liquid metal fast reactor fuel assembly modelling, mainly focusing on validation, both hydraulically and thermally, and on the effect of the inter-wrapper flow during accidental conditions. With respect to pool thermal-hydraulics, new validation data was created to validate sufficiently accurate methods to model the coolant behavior in a liquid metal reactor pool. Special attention was given to the understanding and modelling of liquid metal solidification behavior. And finally, when considering the system scale, the new integral system scale validation data was generated to validate and improve system thermal-hydraulics models and codes, but also to further develop and validate multi-scale approaches under development. In all cases, experiments and numerical simulations were performed in a close cooperation. For all topics addressed above, development of best practice guidelines and methods for verification, validation and uncertainty quantification were also addressed.

FP7-ARCAS

Dr. Van den eynde, G. ; Prof. Aït abderrahim, H.

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The ARCAS project, as a successor of the 6th framework program PATEROS, compared the transmutation in fast neutron reactors and accelerator-driven systems. Using a minor actinide stream representative (and scalable) for Europe, the transmutation of this stream in the sodium cooled CP-ESFR design developed in the 7th framework program using homogeneous and heterogeneous modes (two different load factors for the minor actinides in the fuel/target), taking into account the limits in certain safety parameters like Doppler and void effect was estimated. The transmutation of the same minor actinide stream was also studied in the EFIT accelerator-driven system design developed in the 6th framework program IP-EUROTRANS. Next to these simulations also a state-of-the-art was established including assigning Technological Readiness Levels for the required fuel reprocessing and fuel fabrication. It was clear that if Europe wishes to progress the concept of P&T, an R&D effort should be made in the fabrication (and testing) of minor actinide bearing fuel and the reprocessing of such fuel. At the end of the project, the transmutation performances were compared in scenario studies showing that for countries in nuclear phase-out, a regional scenario with P&T using Accelerator Driven Systems would be beneficial.

H2020-MYRTE

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The goal of MYRTE is to perform the necessary research in order to demonstrate the feasibility of transmutation of high-level waste at industrial scale through the development of the MYRRHA research infrastructure. Activities are devoted to the realization of the injector part of the MYRRHA accelerator and to demonstrate its reliability needed for an Accelerator Driven System. Outstanding technical topics in heavy liquid metal thermal hydraulics as pool thermal hydraulics and thermal hydraulics of the fuel assembly are addressed by numerical simulations and experimental validation. Results are consolidated in a database for thermal hydraulic code validation. Lead Bismuth Eutectic (LBE) coolant chemistry is carried out, in particular, the quantification and characterization of the release of radionuclides from LBE and the development of capture method. Experimental reactor physics relevant for MYRRHA are realized the at the zero-power facility GUINEVERE. Finally, advanced studies on Americium-bearing oxide fuel are carried out to demonstrate the capability of developing minor actinide fuel for transmutation.

INSPYRE: INVESTIGATIONS SUPPORTING MOX FUEL LICENSING IN ESNII PROTOTYPE REACTORS

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Fuel is at the heart of all nuclear reactor systems. Mastering the understanding of its behaviour is challenging due to the complex coupled phenomena induced by fission. Fuel performance predictions for licensing under normal and accidental conditions have relied traditionally upon extensive integral irradiation testing to generate empirical laws. Though successfully deployed in the past, these laws are not easily extrapolated to other conditions prevalent in the first MOX cores for the reactor systems of ESNII.

Leveraging the knowledge from past integral irradiation testing programmes is essential to overcome the challenges of timely cost effective licensing of ESNII first cores. The solution lies in harnessing basic science approach to applied research to develop physic-based models.

The goals of INSPYRE, focussed almost exclusively on MOX fuel, are:

- To utilise out of pile separate effect experiments and modelling to investigate four important operational issues: Margin to fuel melting; atom transport and fission product behaviour; mechanical properties; fuel thermochemistry and interaction with cladding.
- To perform additional examinations on selected irradiated samples
- To combine the results to extend the reliability regime of traditionally deduced empirical laws
- To use the models developed to enhance the efficacy and reliability of operational codes.

DEVELOPMENTS ON AM-BEARING FUELS UNDER PELLETIZED AND SPHEREPAC FORMS: OUTCOMES OF THE FP7-PROJECT PELGRIMM (2012-2017)

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The PELGRIMM project was a FP7-European project carried out from 2012 to 2017 which was devoted to the investigation of spherepacked and pelletized fuel forms for Minor Actinide transmutation in homogeneous and heterogeneous recycling modes. PELGRIMM aimed at constituting a new step in the long term process of the Minor Actinide-bearing fuel qualification rationale, initiated within the European projects ACSEPT, F-BRIDGE, CP-ESFR and FAIRFUELS.

The present paper intends to make a overview of the main technical outcomes gained within PELGRIMM. The first results of behaviour under irradiation of spherepacked and pelletized fuel forms are provided from Post-Irradiation Examinations on $(U,Pu,Am)O_2$ and $(U,Am)O_2$ fuels respectively irradiated during SPHERE and MARIOS experiments, along with the description of the latest irradiation experiment, MARINE, constituting the next step in the $(U,Am)O_2$ fuel qualification rationale.

The developments of alternative processes in order to simplify manufacturing routes and to limit secondary waste streams for Minor Actinide-bearing fuel fabrication are detailed. In parallel, the capabilities of existing models and calculation codes have been improved to describe the Minor Actinide-bearing fuel behaviour under irradiation in a more reliable way, and their predictive results have been compared to available Post-Irradiation Examinations.

Finally, to start linking fuel behaviour with core neutronic problematics, a preliminary design of a Sodium-cooled Fast Reactor core loaded with spherepacked (U,Pu,Am)O2 fuels and correlated preliminary safety assessment have been performed.

E & T, research infrastructures and international cooperation

AIMS AND ACHIEVEMENTS OF THE 7FP ENETRAP III PROJECT

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For a vast amount of nuclear applications in industry, healthcare, research and other sectors, understanding of radiation protection (RP) is fundamental in order to protect workers, the public and the environment from the potential risks of ionizing radiation. Effective education and training (E&T) is a critical element helping to prevent the decline in expertise and to meet future demands for RP competences.

ENETRAP, the European network for education and training in radiation protection was first established in 2005 and conducted a first project in FP6 focusing on analysing needs in E&T in RP and developing first approaches for optimization. The ENETRAP II project built further on the previous project and tackled some of the perceived challenges in E&T in RP related to defining job profiles such as radiation protection expert or radiation protection officer, harmonization of training and recognition, and mobility of workers.

ENETRAP III added new and innovative topics to E&T approaches established so far. It further developed the European RP reference training scheme with additional specialized modules for Radiation Protection Experts working in the medical sector, geological disposal and nuclear power plants (NPPs).

ENETRAP III also introduced a train-the-trainer strategy; a unique first-of-a-kind training topic in Euratom's E&T projects. All organized pilot sessions were open to young and more experienced students and professionals. In this way, ENETRAP III aims to contribute to increasing the quality of different actions involving transfer of knowledge and skills, facilitating competence building.

A web-based platform containing all relevant information about E&T activities in RP as well as other opportunities such as jobs or internships will enable the end user to easily find a suitable opportunity for initial or advanced E&T, or career and capacity building activities. ENETRAP III built such a Platform and made it sustainable via the EUTERP Foundation which will keep the platform active beyond the project duration.

Furthermore ENETRAP III proposed very important guidance for implementing E&T for Radiation Protection Experts and Officers, hereby providing extremely important assistance to all Member States who were expected to transpose the Euratom BSS requirements into their national legislations.

Moreover, ENETRAP III demonstrated the practical feasibility of earlier developed concepts for mutual recognition and thus provided leading examples in Europe demonstrating effective borderless mobility.

For all these activities ENETRAP III connected with all stakeholders, i.e. end-users, E&T providers, legal authorities, and to other relevant international organizations, groups and networks dealing with E&T in radiation protection. Over all these years, it developed a strong E&T in RP community. All achievements of the project are fostered by the sustainable EUTERP Foundation, assuring retrievability and further use of the project results.

ANNETTE PROJECT

Prof. Cizelj, L.; Dieguez Porras, P.; Prof. Ambrosini, W.

European Nuclear Education Network, Belgium

ANNETTE (Advanced Networking for Nuclear Education and Training and Transfer of Expertise) represents an effort delivered by a Consortium of 25 members, coordinated by ENEN. The project responded to the Euratom call of 2014 under item NFRP-10, mainly asking for Masters and Summer Schools for Continuous Professional Development (CPD).

It is structured into eight Work Packages (WP). The first work package is devoted to

"coordination" among the different nuclear fields of Nuclear Technology and Safety, Radiation Protection, Waste Management and Nuclear Fusion, the latter represented in the project by the sister network of ENEN, Fusenet (https://www.fusenet.eu/) and by its third parties. Together with networking, coordination represents the leitmotiv of the project that, in addition to the specific actions developed under the different work packages, aims at catalysing the cooperation among the different nuclear sectors. Coordinated E&T efforts in terms of a Summer School and of pilot courses for a "master" for CPD, to be established at the end of the project through an appropriate certification, are the subject of WP2. WP3 aims at reviving the production of educational material in the frame of ENEN and in Europe in general, while WP4 develops a challenging first-of-the-kind cross-border and cross-company mobility of professionals under the rules being established for granting European Credits for Vocational Education and Training (ECVET). WP5 and WP6 are assigned the task to set up courses for reinforcing nuclear safety culture and to address the novel issues coming from the process of "nuclearisation" of fusion, i.e., the transformation of the nuclear fusion sector into an industrially mature field. WP7 and WP8 keep the necessary contacts with stakeholders and manage the whole project.

WP1, thanks to a detailed planning, has already reached most of its objectives, carrying on a broad inquiry on the state-of-the-art about nuclear E&T and the facilities available for life-long learning, exploring networking mechanisms, studying tools for information exchange and reflecting on the ENEN certifications, to plan for future ones. WP2, WP5 and WP6 offered pilot courses, being delivered from June 2018 to July 2019, and collected more than 230 multiple expressions of interest for courses to date, though actual attendance figures are expectedly less exciting. In this frame, a very successful Summer School was organized by the Aalto University in June 2018 (www.annette.eu/summer-school/), involving lecturers selected among project participants and hosting 52 students for a full week. The students of the Summer School were selected among 85 applicants from over 20 nationalities, on the basis of nine criteria including background, command of English language, recommendation by a supervisor, gender balance, etc. MOOCs are also being prepared on nuclear safety culture and nuclear safeguards. WP3 has already planned the delivery of educational documentation in selected nuclear sectors. WP4 has successfully tackled a challenging exchange of personnel, producing reflections on ECVET use in industry, worth of a future project to be fully exploited. WP7 is keeping tight contacts with platforms, industrial representatives and stakeholders in general; it organised an ANNETTE event at the NESTet Conference held in Berlin in 2016 and networking events were organised a later of the General Assembly of ENEN and at this FISA Meeting.

The most challenging part of the project will be certainly the long-term sustainability of the educational offer for the "master", to be broadened and settled into a permanent pan-European effort by catalysing the joining of additional actors, also involving the release of a new ENEN certification based on modular courses to be attended in incremental steps. The process of advanced networking, led by ENEN and materialised in the consortium by the representation of the most important nuclear fields, needs also to be settled, by coagulating further contributions, aiming to create synergies among the different groups operating in favour of E&T in the nuclear fields.

ECNET PROJECT

Prof. Cizelj, L.; Dieguez Porras, P.

European Nuclear Education Nework, Belgium

The main objective of the ECNET project was to coordinate the cooperation between the EU and China in the field of Nuclear Education, Training and Knowledge Management in the three areas of Nuclear Engineering, Radiation Protection and Nuclear Waste Management and Geological Disposal. The expected impacts of the project were:

- to promote mutual recognition of Education and Training programmes of EU and China;
- to expand exchanges of students, lectures and lecturers;

- to secure the knowledge management as appropriate.

The main work packages were related to the definition of the needs in the three mentioned nuclear fields, linked by specific interests for E&T facilities and to establish a possible system for credit recognition among the two areas of the world.

As in the case of the ENEN RU projects, ECNET involved two different consortia and mirror structures on the EU and the Chinese sides. The participants on the side of EU were ENEN, SCK•CEN (Belgium), CEA-INSTN (France), the Institute National Polytechnique de Lorraine (France), KIT (Germany), CIRTEN (Italy), the Universidad Politecnica de Madrid (Spain), the Imperial College of Science Technology and Medicine (UK). On the Chinese side, the Tsinghua University, the North China Electric Power University, the Southwest University of Science and Technology, the Harbin Engineering University, the Shanghai Jiao Tong University, the China National Nuclear Corporation Graduate School and the Xi'an Jiao Tong University participated in the endeavour.

The project impacted into some difficulties intrinsic in the exchange at the time, among which the language barrier. As a matter of fact, information received from Chinese partners was at the time not sufficient to allow useful comparisons of the situations in Europe and in the fast growing economy and to develop efficiently a Europe-wide cooperation with China in nuclear E&T. However, some exchanges were possible, e.g., a double degree agreement established between the Politecnico di Torino (belonging to CIRTEN) and the Shanghai Jiao Tong University, to be considered as pilot examples that provided satisfactory results.

Though the experience of this project turned out to be not completely successful, the interest for exchanges between the nuclear education and training system in EU and in China has recently increased. This previous experience, if fuelled by a renewed interest for exchanges on both sides, may provide a useful starting point for setting up a better and deeper cooperation than it was possible with ECNET.

ENEN+ PROJECT

Prof. Cizelj, L.; Dieguez Porras, P.

European Nuclear Education Network, Belgium

The ENEN+ project (Attract, Retain and Develop New Nuclear Talents Beyond Academic Curricula,) proposes cost-effective actions to attract, develop and retain new talents in nuclear professions. This is a contribution of the ENEN Association, supported by the European Commission, to the common strategic goal of all nuclear stakeholders: to preserve, maintain and further develop the valuable nuclear knowledge for todays and future generations. The ENEN+ project focuses on learners and careers in nuclear reactor engineering and safety, waste management and geological disposal, radiation protection and medical applications.

The project activities are organized in 7 work packages, depicted in Figure 1. Work packages 1-4 are devoted to the attraction, development and retention of learners in different stages within the education systems (1: high school pupils, 2: B.Sc. and M.Sc., 3: nuclearization and 4: Ph.D., postdoc and lifelong learning). Work package 5 is focusing on the development of voluntary accreditation functionality within ENEN. The project is supported by the WP 6 focussing on informing and consolidating the nuclear stakeholders and WP7 dealing with the management of the project.

The ENEN+ project consortium is a well-balanced blend of relevant actors in the development of knowledge, competences and skills in different nuclear sectors in Europe. It is formed by 22 partners consisting of 9 universities (Université de Lorraine (France), Aalto Korkeakoulosaatio (Finland), Budapesti Muszaki es Gazdasagtudomay Egyetem (Hungary), Universidad nacional de education a distacia (Spain), Univerza v Ljubljani (Slovenia), Universidad Politecnica de Madrid (Spain), Univesitatea politehnica din Bucuresti (Romania), Consorzio Interuniversitario Nazionale per la Ricerca Tecnologica Nucleare (Italy) and Institut Mines-Telecom (France)), 6 international organisations (ENS, FORATOM, NUGENIA, EFOMP, JRC and ENEN), 4 leading nuclear research centres (SCK-CEN (Belgium), CEA (France), Jožef Stefan Institute (Slovenia), Centrum Vyzkumu Řež (Czech republic))and, last but not least, 3 major industrial companies

(Westinghouse (France), Tecnatom (Spain) and EDF (France)). In addition, several third parties including IAEA and further members of the ENEN and NUGENIA are contributing to the project.

The academic education is expected to remain the very basic building block of the future nuclear experts and scientists. A sound balance between the knowledge, skills and responsibilities may nevertheless need further shift from thinking about pedagogy in terms of "teaching" to one that considers "learning" as the primary goal. This may allow to associate pedagogy more strongly with learning outcomes and student experience, as for example engagement in the professional development activities with the support of industry, including course-release for such activities. For the main nuclear fields, the strategic priority of the community has changed to the consolidation and sustainable development of the existing courses and programs. This will be achieved through a mobility grant program for learners and the development of the voluntary accreditation functionality for nuclear education and training activities within the ENEN AISBL (AISBL = "International Non-Profit Organization" in French).

The most notable action of the ENEN+ project is mobility funding for learners at different stages of the early career. The budget for mobility grants exceeds 1 million EUR and represents more than 1/3 of the EC contribution to the project. The mobility grants are accessible through the web application and selection system (http://plus.enen.eu) to the individuals aiming at starting or improving their careers in nuclear. The individual career guidance resulting in "Personal Career Plans", developed jointly by the candidate with mentors from industry and academia, represents an essential part of the selection process, which is performed and managed by the ENEN+ project management committee. In the first 12 months of the project execution, more than 120 applicants have received mobility grants totalling at roughly 300.000 EUR.

Another notable action of the ENEN+ project is development and introduction of a communication strategy ensuring active industry and policy maker engagement in the ENEN+ initiative. The purpose of the communication strategy is to ensure consistent communication to the industry, regulators and legislators to align all stakeholders around the strategy to provide sufficient and sustainable resources for attraction, development and retention of new nuclear talents. Making the case for adequate and sustained funding and support is principally a matter of giving clear indication of the benefits to be accrued as well as periodic updates of progress achieved. ENEN+ will need to lead an advocacy effort to influence policy-making and increase the commitment towards nuclear education and research. Partnerships with media will also be attempted to develop pop-culture appeal.

The attraction, retention and development of the new nuclear talent can only be sustained beyond the project life through strong partnership and support of all nuclear stakeholders. Involvement of various nuclear stakeholders including academia, industry, international organisations (ENS, FORATOM, IAEA, NUGENIA) in the ENEN+ consortium and its communication strategy is therefore of primary importance for the success and sustainability of the proposed activities also beyond the life of ENEN+.

ENEN-RU II PROJECT

Prof. Cizelj, L.; Dieguez Porras, P.; Prof. Ambrosini, W.

European Nuclear Education Network, Belgium

The ENEN-RU II project was aimed at the "Strengthening of Cooperation and Exchange for Nuclear Education and Training between the European Union and the Russian Federation" and consisted of two parallel projects, on the EU side and the Russian side.

The Consortium on the EU side was composed by ENEN (B), SCK•CEN (B), CTU (CZ), Centrum Vyzkumu Řež S.R.O.(CZ), Universität Stuttgart IKE (D), TUM (D), CIRTEN (I), UPB (RO), STUB (SI), TECNATOM (E) and University of Manchester (UK). The Russian Consortium included in particular Rosatom, the MEPhI-National Research Nuclear University (NRNU) and Rosatom CICET (today named as Rosatom Technical Academy), together with other Russian organisations.

The objectives of the entire project have been:

- to further define a common basis for effective cooperation between the European and Russian networks for nuclear Education &Training (E&T);
- to define an implementation plan based on the needs of cooperation in the long-term;
- to solve the difficulties for cooperation found during the ENEN-RU project;
- to implement a collaboration plan in a sustainable manner;
- to operate the knowledge management framework;
- to list up and promote further use of E&T facilities, laboratories and equipment.

The project involved several meetings and the participation in Workshops and Conferences held on either side, producing a high level of involvement in the respective environments. Among the achievements, the following can be mentioned:

- the comparison of curricula for Nuclear Engineering in EU countries and Russian Federation, showing that credit systems in use in the two regions are compatible;
- as the outcome of the discussion within the ENEN RU E&T Forum, bilateral agreements were signed between the participants on either side (e.g., University of Pisa and MEPhI) and ENEN renewed its cooperation with MEPhI and with Rosatom Technical Academy;
- participation in joint courses at master and PhD levels was made possible for more than 40 students and a distance learning course was deployed;
- more than 30 individuals participated in 4 joint training courses, ("Engineering aspects of Fuel Fabrication" in Obninsk, Russian Fed. on 23-27 November 2015; Joint Education course on the "Introduction to Nuclear safety analysis of Nuclear Reactors with state-of-art Computer Programs" by TU Munich, Germany, on 25-28 April 2017; Joint Education course on "Multiphysics simulation of nuclear systems" organized at the POLIMI campus in Milan, Italy, on 17-19 May 2017; Joint E&T course on "Simulation of different NPPs operation" organized at CTU in Prague, Czech Republic, on 30 May-2 June 2017) while exchanges of trainees and facilitators were made possible, also performing technical visits to fabrication and training centres;
- a web based database for E&T facilities, laboratories and equipment was developed; access can be granted following a registration process also to external users too and several database access levels being available;
- participation in several important events on either side was recorded.

The project put the basis for continuing the cooperation of ENEN with MEPhI-NRNU and Rosatom Technical Academy, making also possible to establish bilateral agreements among partners. Successfully overcoming the language barriers that were encountered in the first of the ENEN-RU project was another relevant outcome of ENEN-RU II.

NUSHARE PROJECT

Prof. Cizelj, L.; Dieguez Porras, P.; Prof. Ambrosini, W.

European Nuclear Education Network, Belgium

NUSHARE was a project implementing a European Education, Training and Information (ETI) initiative proposed by the Commissioner for Research and Innovation and the Commissioner for Energy after the Great East Japan Earthquake and Tsunami on 11 March 2011 (Fukushima). Its main objective was to develop and implement education, training and information programmes strengthening competences required for achieving excellence in nuclear safety culture. Particular attention was paid to lessons learned from stress tests conducted on all EU nuclear Power Plants in response to the Fukushima accident and to sharing best practices at the European level.

NUSHARE addressed the specific needs of different stakeholders in the nuclear safety by the development and EU wide dissemination of programmes for three target groups:

- Target Group 1 (TG1), represented by journalists and civil society representatives;
- Target Group 2 (TG2), represented by staff members of Nuclear Regulatory Authorities (NRAs) and Technical Safety Organisations (TSOs);
- Target Group 3 (TG3), represented by electric utilities, systems suppliers, and providers of nuclear services at the level of responsible personnel, in particular managers.

As a result of a planned restructuring of the initial Consortium, composed by ENEN as main beneficiary and CEA-INSTN, UPM and TECNATOM, as Third parties, with ENSTII as subcontractor, other parties joined, namely ISaR, INBEx, the World Federation of Science Journalists (WFSJ), IRSN and ENS.

Nuclear safety culture is known to be a fundamental concept, whose neglect can be easily found as an important contributor in occurred nuclear reactor accidents. As such, the project addressed its components, undertaking the difficult task to speak about it in the language appropriate to the different target groups. In relation to TG1, a first approach was based on workshops addressing French organisations of journalists. After this first phase, also owing to the stepping in of the new parties, it was possible to set up a more general Media Educational Package developed by journalists for journalists and the wider society, on the basis of the material provided by the experts of the other parties.

(http://wfsj.org/v2/2017/06/15/new-toolkit-on-nuclear-safety-for-journalists/).

TG2 was managed since the very beginning in a very systematic way by ENSTTI, developing training modules targeted for personnel of NRAs and TSOs. To this, INBEx added the implementation of pilot courses held in different parts of Europe with a specific training tool (named after Fermi) which gained great recognition.

Finally, TG3 was addressed by TECNATOM mainly considering the managerial levels, having so fundamental relevance in promoting safety culture among the nuclear workforce. Specific learning outcomes and pilot sessions (also with the use of micro-e-learning tools) were developed and implemented, gaining in return a positive assessment of the overall activities.

The efforts spent in the frame of NUSHARE coped with a definitely challenging subject, as implied by the ETI character of the action: the different languages to be spoken with the target groups were reflected in the diversity of the products and in the countless workshops, meetings and sessions delivered in the four and more years in which the project was developed. NUSHARE leaves behind a wake of useful material and reflections that inspired also the specific stress on nuclear safety culture impressed in the ANNETTE project.

MEET-CINCH: MODULAR EUROPEAN EDUCATION AND TRAINING CONCEPT IN NUCLEAR AND RADIOCHEMISTRY

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In order to maintain European nuclear operations, expertise in nuclear and radiochemistry (NRC) is of strategic relevance. NRC contains key knowledge and techniques needed by a modern society and is certainly needed in addressing many societal challenges.

The MEET-CINCH project is the third CINCH-based project aiming on cooperation in education in nuclear chemistry and radiochemistry. In the first two projects, CINCH and CINCH-II, status quo in NRC education at European universities was assessed, minimum requirements for bachelor, master and postgraduate programs to achieve approved NRC curricula were defined, and a number of theoretical and practical courses were developed using hands-on and e learning approaches and platforms.

The third consecutive project is designed to address the end-users in a more focused way offering platforms for immediate practical value. Building on the results of the previous projects, MEET-CINCH aims at counteracting the massive lack of NRC expertise by three actions. A teaching package for high schools and a MOOC on NRC for the general public are built in order to attract young persons to the NRC field and convey them its fascination and

relevance.

Two additional actions focus on vocational training and (university) education. MEET-CINCH is developing new education and training approaches based on remote teaching and the flipped classroom concept further developing material generated in the previous projects, such as the NucWik platform (http://www.nucwik.com/) and the remote controlled RoboLab experiments (http://nucwik.com/exercises/robolab/index.html).

MEET-CINCH will provide ECVET course modules in an e-Shop adapted to the needs of end-users which have been surveyed in the previous projects.

After the end of MEET-CINCH the e-shop will be continuously operated by The European Network on Nuclear and Radiochemistry Education and Training (NRC-network, http://nrc-network.org/) as part of a sustainable European Fission Training Scheme (EFTS).

The consortium includes 13 partners from ten European member states; both academia and nuclear laboratories are represented. All partners are experienced in conducting training and education.

Networking on national and European level is an important part of the project, facilitated by having ENEN (European Nuclear Education Network) as one of the partners and by having structural links with other European associations such as the EuChemS Nuclear and Radiochemistry Division and the NRC-Network.

To meet the objectives of the project, the proposed activities have been organised into three technical and two managerial work-packages that closely copy the project pillars listed above. Each of the work-packages is further subdivided into several Tasks. The WPs are:

- WP1: Nuclear Awareness and Dissemination
- WP2: Sustainability and Evolutionary Development of VET tools
- WP3: Novel Education and Training Approaches (Flipped Classroom)
- WP4: Mobility, dissemination and exploitation
- WP5: Project Management and Administration

All the work-packages have been running in parallel since the start of the project.

These activities are supported by Euratom under a Horizon 2020 project No. 754972 (Call NFRP 2016-2017-1.)

BALTIC REGION INITIATIVE FOR LONG LASTING INNOVATIVE NUCLEAR TECHNOLOGIES (BRILLIANT)

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A different level of nuclear safety and radiation safety knowledge as well as Research, Development and Education infrastructure exists in the countries of the Baltic region. In Lithuania and Poland the construction of new NPPs is considered for decades, but the final decisions is postponed many times. Estonia and Latvia were considering joining the new NPP project but has very little knowledge of NPP operation, while Sweden has full scope of nuclear power infrastructure from nuclear fuel manufacturing to deep geological disposal.

BRILLIANT project was initiated to discover the benefits of regional cooperation in development of large projects in the energy sector, to share the knowledge and reduce the differences in understanding the nuclear power project among the countries as well as to better utilise the scientific potential of the countries in the region. BRILLIANT project was implemented by the leading research and education organisations in Estonia, Latvia, Lithuania, Poland and Sweden and covered the following areas related to nuclear power development: nuclear fuel cycle including management of radioactive waste, safety of nuclear power plants, planning of the energy sector development, security of energy supply, macroeconomic impact in the region,

education and training.

After SWOT analysis a concept of EUROBaltic Centre of Nuclear Research and Technology and the roadmap to its implementation was developed by the project partners. In accordance with proposed concept the competence centers in relevant areas are foreseen in each participating country. BRILLIANT project has demonstrated how the innovative approaches in training and education could be utilised to strengthen the cooperation and development of the countries in the Baltic sea region.

CORONA II - A STEP FORWARD IN ENHANCING COMPETENCE AND MOBILITY OF PERSONNEL AMONG VVER TYPE REACTORS OPERATING COUNTRIES

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The safe and sustainable use of the nuclear energy requires operating personnel possessing adequate scientific and engineering capabilities. Correspondingly, the necessary regulating, engineering and technical support in all related fields should be available throughout the lifetime of a nuclear power plant. Training is essential, particularly when state-of-the-art science and technology must be implemented.

Following its general objective - to enhance the safety of nuclear installations through further improvement of the training capabilities, the project has established a state-of-the-art regional training network for VVER competence as a viable solution for supporting transnational mobility and lifelong learning among VVER operating countries.

The adequate addressing of the new target sub-groups' training needs, defined based on the global trends in the area, will also attract trainees outside the EU.

The training programs and training materials cover different categories of personnel from students studying nuclear disciplines to nuclear professionals, non-nuclear professionals and subcontractors.

The recognition of qualifications and the transparency of what learners have achieved abroad are the core to mobility in vocational education and training. Within the project scope of work, large amount of activities was devoted to pilot implementation of ECVET with the aim to facilitate transnational mobility and lifelong learning for recognition of achieved qualifications in the different training systems of VVER countries. Realising that leadership is one of the most important aspects in enhancing safety and culture in nuclear organisations, special attention was devoted to the elaboration of management and leadership pipeline training scheme. In this respect three levels of training have been established that are completed with pipeline developed by the academy. Moreover Human Factors Simulator has been established to allow reinforcement of personnel safety behaviours and use of human error prevention tools simulating real task performance. Considering the current technology developments e-learning platform has been identified and is currently up and running in the frames of project implementation. It provides a wide variety of opportunities, resources and new strategies for nuclear education and training. The creation of a VVER Technology Academy has provided the resort to structure and offer education and training on VVER technology from the CORONA consortium to organisations interested in the VVER technology. The link with the ENEN Association will be set up in order to develop a long term vision and to create a coherent and dynamic strategy for achieving the integration of the education and training on VVER technology in the European level.

EUROPEAN JOINT PROGRAMME FOR THE INTEGRATION OF RADIATION PROTECTION RESEARCH – CONCERT

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The radiation protection research landscape in Europe has been significantly modelled by research platforms such as MELODI, ALLIANCE, NERIS, EURADOS and EURAMED. The EJP-

CONCERT acts as an umbrella structure for the platforms, to facilitate joint research programming across the different scientific disciplines and contributing to the sustainable integration of European and national research programmes in radiation protection.

Based on the platforms' SRAs and joint programming, CONCERT develops research priorities, aligns them with priorities from participating Member States and seeks further input from society and stakeholders. In addition, a strategic research agenda (SRA) was developed for social sciences and humanities, thus strengthening the multidisciplinarity and integration of the European research community in the field of radiation protection research. Furthermore, CONCERT strives to stimulate the Member States' contribution to the development of a joint European SRA in the field of radiation protection. The cooperation of the platforms towards joint priorities, and, ultimately, a joint roadmap has been fostered successfully. Based on this success, two open CONCERT calls have covered multidisciplinary approaches together with more specific research topics and were allowing an increased cooperation between research teams coming from different fields of radiation protection research.

Finally yet importantly, CONCERTs mission is to further reduce uncertainties in the assessment and management of radiation risks to the environment and to humans by targeted science. To achieve this, CONCERT initiates an open exchange of knowledge and information between science, regulation and society.

ARCADIA - ASSESSMENT OF REGIONAL CAPABILITIES FOR NEW REACTORS DEVELOPMENT THROUGH AN INTEGRATED APPROACH

Dr. Diaconu, D. (1); Dr. Constantin, M. (1); Grasso, G. (2), Alemberti, A. (3), Di Gabrielle, F. (4)

1 - RATEN ICN, Romania, 2 – ENEA, Italy, 3 – Ansaldo Nucleare, Italy, 4- CVR, Czech Republic

ARCADIA assessed the ALFRED demonstrator feasibility in Romania exploring key components of a successful implementation: competences and infrastructure, licensing and public participation, socio-economic impact, risks analysis, national support and financing schemes.

The existing competence at regional and European level can cope with the technical and scientific challenges raised by the final R&D on ALFRED; a set of gaps in skills and competence still exists and ARCADIA proposed methods and practical solutions to address the E&T required to cover them in due time.

The national infrastructures for ALFRED implementation are in place in Romania and a number of facilities, available in Europe, can support R&D, qualification and E&T, while some others needed to complete the qualification/validation of materials/components/systems and computer codes, are already planned.

The current procedures for siting and licensing have to be followed for ALFRED construction as well, and steps and corresponding requirements were clearly identified.

ARCADIA collected strong arguments for key elements of the Feasibility Study (core value, competitive advantages and social-economic impact, risks, cost-benefit analysis, financing sources) and assisted the FALCON International Consortium to engage from the early phase the most relevant stakeholders in identifying actions and procedures to declare ALFRED as a major project.

Safety of nuclear installations

TECHNICAL AND SCIENTIFIC SUPPORT OF THE REGULATORY BODY' ACTIVITIES: OVERVIEW OF THE NATIONAL PRACTICE AND EXPERIENCE, CURRENT CHALLENGES

Dr. Dybach, O.

State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS), Ukraine

Nuclear safety is a comprehensive and science-based discipline. Regulatory body activities often need support from external technical and scientific organizations (TSO). This paper discusses the Ukrainian framework of the technical and scientific support to the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU).

It describes the practice and approach of the State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS) as a TSO of the SNRIU. Specifics of the SSTC NRS' supportive services relevant to the different Nuclear Installations: NPPs, Research reactors, Spent Fuel Storage Facilities, RAW facilities are covered. Unique national experience in safety review of the New Safe Confinement, diversification of the nuclear fuel supplying, construction of the ADS-System (Neutron Source) and Consolidated Spent Fuel Storage Facility are presented.

New technologies are requiring new knowledge and competence that are the challenges discussed. It concluded that technical and scientific support plays an important role within the national regulatory infrastructure.

THE ANALYTIC HIERARCHY PROCESS IN GLOBAL ASSESSMENTS

Dr. Simic, S.

Canadian Nuclear Safety Commission, Canada

In Canada, Class I Nuclear Facilities Regulations were amended in 2017 to require nuclear power plant (NPP) licensees to carry out a Periodic Safety Review (PSR) at an interval specified in their operating licence. Canadian nuclear power plant licensees conduct their PSRs in accordance with the CNSC's regulatory document REGDOC-2.3.3 "Periodic Safety Reviews" which is consistent with international guidance provided in the IAEA's Safety Guide SSG-25.

A PSR is an established method for identifying safety improvements for aging NPPs, and has also been shown in Canada to be an effective means for determining scope of their refurbishments. A Global Assessment and an Integrated Implementation Plan (IIP) represent the results of a PSR, with the overall objective of presenting an integrated evaluation of an NPP's overall safety against modern codes and standards. This is achieved by taking into account a balanced assessment of all findings identified in Safety Factor Reports (SFRs). Global Assessments identify the Global Improvement Opportunities (GIOs) and take into account all the strengths and gaps from SFRs and practicable corrective actions and/or safety improvements proposed in IIP to provide an overall assessment of safety and the acceptability of long-term operation. GIO ranking is an important step of a PSR, owing to its impact on the extent and timeliness of the benefits to be achieved by the resolution each opportunity for improvement identified.

Analytic Hierarchy Process (AHP) is one of the methodologies used to rank GIOs. The application of AHP begins with a problem being decomposed into a hierarchy of criteria (Value Trees) so as to be more easily analyzed and compared in an independent manner. In Global Assessments, a Value Tree begins with a cardinal objective such as "Enhanced confidence in the continued NPP safety and reliability of electricity production" and a set of fundamental objectives as main branches, such as "Enhanced confidence in the design basis" or "Enhanced confidence in the safety analysis". Each fundamental objective (Tier 1) is then expanded and supported with more specific objectives (Tier 2 and Tier 3). After Value Trees are constructed licensees make systematic pair-wise comparisons of objectives within the same Tier, in order to assign them varying weights depending on importance to the cardinal objective. Thereby, AHP transforms the pair-wise comparisons, which are most often empirical, into numerical

values that are further processed and compared. This capability of converting empirical data into numerical values is the main distinctive contribution of the AHP technique when contrasted with other comparing techniques.

TRANSFER, CONTROL AND DAMPING OF SEISMIC MOVEMENTS BUILDINGS

Postolache, L. (1); Comsa, O. (2); Lungescu, G. (2); Gherase, R. (2); Dr. Serban, V. (1); Postolache, V. (1)

1 - SC SIGMA PATENT STUDIO SRL, Romania; 2 - University of Bucharest, Faculty of Physics, 3Nano-SAE Research Center, Atomistilor 405, Romania

The construction or rehabilitation of high-rise buildings to make them withstand future earthquakes, is requiring the evaluation of the following problems:

- the seismic energy transfer from the foundation ground to the building;
- the control, limiting and damping of the seismic movement transferred to the building;
- the assessment of the mechanical device contribution to isolate, control, limit and damp the building seismic movements.

In order to solve the above mentioned problems, the paper is proposing a mathematical evaluation of the building dynamic behaviour, considering the seismic action in the form of inertia forces, in case of rigid buildings, and of elastic and damping forces, in case of flexible buildings, also taking into consideration the limited duration of an earthquake.

The contents of the paper is a proposal to evaluate the seismic energy transfer from the foundation ground to the building throughout the seismic event duration, function of the ratio between the building dynamic characteristics and the seismic movement kinetic characteristics.

The paper presents a mathematical model for the evaluation of the seismic movement transfer from the foundation to the building in case of flexible or seismically isolated structures.

The experimental results were obtained by employing SERB mechanical devices in accomplishing the transfer, the control, the limiting and the damping of the seismic movement in case of a high-rise building.

For a better relevance, the paper presents the results of strengthening a 6 storey reinforced concrete frame building by means of SERB mechanical devices. The building strengthening employing SERB mechanical devices developed in Galati City – Romania.

Advanced nuclear systems and fuel cycles

DEVELOPMENT OF ACCOMPANYING TECHNOLOGIES OF IV GENERATION NUCLEAR REACTORS WITH COOLANT GAS

Dr. Simeiko, K.

The Gas Institute of the National Academy of Sciences of Ukraine, Ukraine

High-temperature nuclear reactors with coolant gas have several advantages for application in power generation and industry. For the design and implementation of reactor facilities of this type, the development of accompanying technologies is necessary. Such technologies include the production of nuclear-grade graphite, pyrocarbon protective coatings of nuclear microfuel, production of helium.

The Gas Institute of the National Academy of Sciences of Ukraine conducted a series of research and development works in this field. The research results allow to create energy-efficient and environmentally safe technology for purification of natural graphite to high levels of purity (nuclear purity). Research of application of pyrocarbon coating on nuclear microfuel model was carried out in reactors with electrothermal fluidized bed. As a result, material with a wide spectrum of pyrocarbon content (from 2 to 97% wt.) was obtained. Cryogenic technology

for the production of helium concentrate from natural gas was developed.

To continue research in the development of accompanying technologies for nuclear reactors with coolant gas, international consortium for participation in EURATOM and Horizon 2020 grant programs is being set up.

SEALER-UK, A SMALL LEAD-COOLED REACTOR FOR COMMERCIAL POWER PRODUCTION SUITABLE FOR SERIAL PRODUCTION IN A FACTORY

Prof. Wallenius, J.

KTH, Sweden

SEALER-UK is a 55 MWe lead-cooled reactor using uranium nitride fuel. The purpose of the design is to produce base-load power on the UK grid. In a reference configuration of four units, a SEALER-UK power plant may produce 220 MW of electricity at an estimated cost of £47-55/MWh. A single fuel load will last 22.5 full power years, corresponding to 25 calendar years of operation. Five years after shut-down, the primary system is transported as a single package to Sellafield for safe surface storage until the UK high level waste repository becomes operational.

The integrity of steel surfaces exposed to liquid lead is ensured by use of alumina forming steels, containing 3-6 wt% aluminium. These steels are applied either as weld overlay, as a surface alloy, or as bulk material, depending on the radiation damage dose tolerance and mechanical strength required for a particular component.

Passive safety of the reactor is ensured by removal of decay heat from the core by natural convection of the lead coolant. Transport of the decay heat from the primary system is accomplished by dip-coolers, or ultimately by radiation from the primary vessel to a reservoir of water surrounding the guard vessel. In the event of a core disruptive accident, volatile fission products are retained in the lead coolant and no evacuation of persons residing at the site boundary will be required.

The SEALER-UK reactor assembly plant would be capable of producing ten reactors per year, supported by a uranium nitride fuel manufacturing plant providing an annual supply of 200 tons of 12% enriched UN fuel. Such facilities may become operational in 2028, allowing for commercial deployment of SEALER-UK plants in 2030. LeadCold estimates that by reducing the time for on-site construction and commissioning to 24 months, an owner's cost per reactor unit of £160M can be achieved.

In this poster, aspects of design, safety, economics and licensing of SEALER-UK will be presented.

ADVANCED CORE CHARACTERIZATION AND MONITORING TECHNIQUES FOR TRANSMUTATION REACTORS

Dr. Bécares, V. (1); Dr. Villamarín, D. (1); Dr. Baeten, P. (2); Dr. Billebaud, A. (3); Dr. Chabod, S. (3); Dr. Chevret, T. (3); Dr. Krása, A. (2); Dr. Kochetkov, A. (2); Dr. Lecolley , F.-R. (3); Dr. Lecouey, J.-L. (3); Dr. Lehaut, G. (3); Dr. Marie, N. (3); Dr. Messaoudi, N. (2); Vittiglio, G. (2); Dr. Wagemans, J. (2)

1 - CIEMAT, Spain; 2 - SCK-CEN, Belgium; 3 - CNRS, France

One of the most promising alternatives for the management of high-level radioactive waste (HLW) is the reduction of its long-term radiotoxicity through the transmutation of long-lived radionuclides into shorter lives ones. This can be achieved in fast reactors or Accelerator Driven Systems (ADS). Europe has played a pioneering role in the development of ADS, from the Energy Amplifier concept, developed at CERN during the 1990s, to the projected MYRRHA facility, which is to become world's first prototype of an industrial scale ADS.

EU Framework Programs (FPs) have included a large number of projects devoted to HLW transmutation and ADS development. In particular, research in the field of experimental neutronics and reactor physics has been carried out within the MUSE-4 project (5th FP), the

2nd domain (ECATS) of EUROTRANS (6th FP), the FREYA project (7th FP) and the Work Package 5 of MYRTE (H2020). Last two projects have been centered on a series of experiments carried out at the VENUS-F zero-power fast reactor facility of SCK•CEN coupled with a (D,T) neutron source based on the GENEPI-3C deuteron accelerator designed at CNRS. These projects have been led by SCK•CEN, with the CNRS as second major contributor and the participation of CIEMAT and other European institutions.

The combination of VENUS-F and GENEPI-3C has contributed to the development and validation of advanced core characterization and monitoring techniques for transmutation reactors. The achievements of these projects can be classed into two major categories:

- Validation and improvement of reactivity monitoring techniques. The main objective of these projects was the development and validation of techniques for accurately monitoring the subcriticality of ADSs during operation, and thus ensuring that safety margins are respected. The experimental data obtained during the FREYA and MYRTE projects will serve to validate existing reactivity monitoring techniques as well as improved and new ones developed by the project partners.
- Core characterization experiments. Integral experiments are required to validate the neutronics design tools (neutron transport codes and nuclear data libraries) that will be used in the design of large scale facilities such as MYRRHA. A large number of reactor physics experimental data in cores characteristic of MYRRHA have been generated during the FREYA and MYRTE projects. They include reactivity measurements with the rod drop and MSM techniques, control rod calibration, measurements of axial and radial traverses and spectral indexes, and neutron noise.

E&T, research infrastructures and international cooperation

INNOVATIVE TECHNOLOGIES IN TRAINING AND EDUCATION FOR MAINTENANCE TEAM OF NPPS

Dr. Szávai, S.; Dobos, G.; Soós, R.; Dr. Beleznai, R.

Bay Zoltán Nonprofit Ltd. for Applied Research, Hungary

Virtual and Augmented Reality (VR/AR) in the last few years became more important in the education and training field system for different industries. Many factories and plants such as nuclear power plants, chemical industry, oil and gas industry have a dangerous working environment and hazardous conditions for employees. Moreover, these plants sometimes located in areas difficult to access due to geographical, weather or any other conditions. Maintenance, inspection, and decommissioning activities in these areas pose a serious safety risk. Furthermore, to improve the reliable plant operation and ensure the highest safety level, it is necessary to have periodic employees' training to provide the safety-related work practices, as well as organize "lesson learned" courses.

VR/AR supported systems can provide the possibility for the user to be trained in safe conditions, be prepared for unexpected scenarios, as well as ask and receive assistance at a distance from the experts in challenging situations. The employees can have training for maintenance of equipment, dismantling of facilities at closed NPP Units (decommissioning process), co-operation between the operators in the control room and the field worker at the plant. The system makes it possible to accumulate and manage the existing knowledge that should be shared with the new employees.

The training platform allows one to develop the Assistant System that can provide support for the user during specific activities. AR displays give additional information, instructions, warnings, etc. to users during their activities depending on the situation, locations and other settings in the real-world environment. Users can have long-distance communication or immersive augmented meeting. This technology makes their work more effective and safe, on the other hand, the entire working progress can be documented/controlled/tracked, which might promote a deeper understanding of human performance. This new modern information

system makes it possible to identify design weaknesses and improve the reliability of human actions.

All of the above-mentioned tools and methods can increase the accuracy, safety, reliability, and accountability of the maintenance and decommissioning procedures, as well as provide modern and economic solutions to existing problems. These technologies can inspire the younger generation to work at plants which can be the solution to their ageing workforce challenges.

THE VIRTUAL CENTRE SUPERMAT: AN EUROPEAN NETWORK FOR SUSTAINABLE DEVELOPMENT OF MATERIALS FOR EXTREME ENVIRONMENTAL APPLICATIONS

Dr. Piticescu, R.-R. (1); Dr. Rinaldi, A. (2); Prof. Largeteau, A. (3)

1 - National R&D Institute for Nonferrous and Rare Metals-IMNR, Romania; 2 - ENEA Cassacia Centre Rome, Italy; 3 - CNRS-ICMCB Bordeaux, France

The SUPERMAT project had as main objective the creation of a permanent multi-disciplinary, trans-regional center SUPERMAT for sustainable advanced materials operating under extreme conditions in order to boost:

- the knowledge and technology degree of innovation potential in developing new technologies, products and services with high-added value for regional, national and international clients;
- Cooperation with SME and academia partners in regional, national and international projects
- Up-taking valuable research results in Regional and National companies from the machinery and equipment design and production requiring materials with highly improved performances under extreme conditions for energy generation.

The partnership between IMNR Pantelimon-Romania, ENEA Rome-Italy, University of Burgos-Spain, KTH Stokcholm-Sweden, Strathclyde University Glasgow-UK and CNRS-ICMCB Bordeaux cover topics and services regarding modelling and simulation, green chemical synthesis of nanomaterials, advanced coating pilot systems using Electron Beam Physical Vapor Deposition on large surfaces, advanced sintering technologies and a full range of chemical and structural characterization methods.

EURATOM SUCCESS STORIES IN FACILITATING PAN-EUROPEAN EDUCATION AND TRAINING COLLABORATIVE EFFORTS

Garbil, R.

European Commission DG Research and Innovation, Euratom, Belgium

The European Atomic Energy Community (Euratom) Research and Training framework programmes are benefitting from a consistent success in pursuing excellence in research and facilitating Pan European collaborative efforts across a broad range of nuclear science and technologies, nuclear fission and radiation protection. To fulfil Euratom R&D programmes key objectives of maintaining high levels of nuclear knowledge and building a more dynamic and competitive European industry, promotion of Pan-European mobility of researchers are implemented by co-financing transnational access to research infrastructures and joint research activities through Research and Innovation and Coordination and Support Actions' funding schemes. Establishment by the research community of European technology platforms are being capitalised. Mapping of research infrastructures and E&T capabilities is allowing a closer cooperation within the European Union and beyond, benefiting from multilateral international agreements and from closer cooperation between Euratom, OECD/NEA, IAEA and international fora. 'Euratom success stories' in facilitating Pan-European E&T collaborative efforts through Research and Training framework programmes show the benefits of research efforts in key fields, of building an effective 'critical mass' and implementing European MSc curricula, of promoting the creation of 'Centre of Excellence' with an increased support for 'Open access to key research infrastructures', exploitation of research results, management of knowledge, dissemination and sharing of learning outcomes.

JRC IN EURATOM RESEARCH AND TRAINING PROGRAMME – 2014-2020

Abousahl, S.; Bucalossi, A.; Esteban Gran, V.; Martin Ramos, M.

European Commission - Joint Research Centre, Belgium

The Euratom Research and Training Programme 2014-2018 and its extension 2019-2020 (the Euratom Programme) is implemented through direct actions in fission – i.e. research performed by the Commission's Joint Research Centre (JRC), and through indirect actions in fission– i.e. via competitive calls for proposals, and in fusion – i.e. through a comprehensive named-beneficiary co-fund action managed by the Commission's Directorate-General for Research & Innovation (RTD). The general objective of the Programme is "to pursue nuclear research and training activities with an emphasis on the continuous improvement of nuclear safety, security and radiation protection, in particular to potentially contribute to the long-term decarbonisation of the energy system in a safe, efficient and secure way." The Programme is an integral part of Horizon 2020, the EU Framework Programme for Research and Innovation

The direct actions implemented by the JRC constitute an important part of the Euratom Programme and pursue specific objectives covering: nuclear safety, radioactive waste management, decommissioning, emergency preparedness; nuclear security, safeguards and non-proliferation; standardisation; knowledge management; education and training; and support to the policy of the Union on these fields.

The JRC multi-annual work programme for nuclear activities fully reflects the aforementioned objectives. It is structured in about 20 projects, and allocates 48 % of its resources to nuclear safety, waste management, decommissioning and emergency preparedness, 33% to nuclear security, safeguards and non-proliferation, 12% to reference standards, nuclear science and non-energy applications and 7% to education, training and knowledge management. To ensure that direct actions are in line with and complement the research and training needs of Member States, JRC is continuously interacting with the main research and scientific institutions in the EU, and actively participating in several technological platforms and associations.

JRC also participates as part of the consortia in indirect actions, which allows JRC scientist to engage in top level scientific research, and yields maintaining and further developing JRC's scientific excellence. At the same time, the members of the consortia can have access to unique research infrastructure.

The participation of JRC in indirect actions can be improved by exploiting synergies inside the Euratom Programme, and also with the future Horizon Europe Framework Programme. In preparation of the next Euratom Programme 2021-2025, two pilot projects on knowledge management and on open access to JRC research infrastructure will explore and test this improved involvement of JRC in indirect actions.

This paper highlights some of the achievements of recent JRC direct actions with a focus on the interaction with EU MS research organisations, as well as some of the most important elements of the Commission Proposal for the next (2021-2025) Euratom Programme, with a focus on the new positioning of the JRC as regards its participation in indirect actions.

Technical Workshops

Laser Cutting Technology for Nuclear Decommissioning

Guillemin, J.; Roulet, D.

Onet Technologies, France

We propose to present the Laser Cutting Technology for Nuclear Decommissioning at the conference Technical Workshop.

Starting from a R&D program of the French Alternative Energies and Atomic Energy Commission (CEA), Onet Technologies industrialized the proven laser cutting technology to rise to the complex nuclear dismantling challenges. We deployed the technology and demonstrated its benefits when cutting operations of highly radioactive, thick and complex equipment or materials can be considered only with remote handling systems. Thus, we believe that it falls well within the theme of the fifth Technical Workshop "Decommissioning challenges and opportunities".

In addition to the presentation of the state of the art and of the on-going innovative developments, we would like to share with the audience our practical experience acquired during operations in real conditions. We propose to present the advantages of the laser cutting technique, when a remotely-operated solution is necessary, which lead to its selection by End Users for such applications.

Introduced by Onet Technologies as a world first in December 2015, the technology has demonstrated its full potential in an industrial-scale project to dismantle dissolvers in the UP1 spent-fuel reprocessing facility at the CEA Marcoule site in France.

This technology was selected by the Japanese government for the removal of fuel debris from the damaged Fukushima Daiichi reactors. The CEA and Onet Technologies are working together since 2014 to further develop the laser cutting for this very complex application. Underwater and deep gouging techniques to cut the corium have been simultaneously developed. We are now continuing the works focusing on guaranteeing safety and minimizing secondary waste, in particular by improving the management of dust and fumes generated.

We have also recently studied for Dounreay Site Restoration Limited the feasibility of using this technology for the dismantling of highly radioactive systems and components on the site of Dounreay.

We believe that one of the biggest decommissioning challenges for the coming years lies in the high-activity field and that the benefits of this technology will allow improving the dismantling projects of the stakeholders, particularly in the context of early decommissioning demands. This is why we are currently preparing further development projects with the purpose of bringing the benefits of an already mature technology to further fields of applications, such as nuclear reactor components dismantling, in particular by removing the remaining technical obstacles in respect of safety.

Day 4	Friday, 7 June
AM/PM	**TRIGA research reactor and Hot Cells facilities (at the Institute for Nuclear Research) and Nuclear Fuel Factory (in Pitesti-Mioveni)** Technical visits of the RATEN ICN experimental facilities (TRIGA research reactor HEU to LEU converted, Hot Cells, Material Testing Laboratories and Radioactive Waste Treatment Plant) will be organized. Pitesti Nuclear Fuel Plant, FCN Pitesti ensures the production of about 10.080 CANDU nuclear fuel bundles nuclear fuel annually for the operation of the two units at Cernavoda NPP. **Departure - 8:30; Return in Pitesti - 15:00** **From/To: Muntenia Place and Ramada Hotel** **ELI – Extreme Light Infrastructure (in Bucharest-Magurele)** Extreme Light Infrastructure (ELI) will be the only European and International Centre for high-level research on ultra-high intensity laser, laser-matter interaction and secondary sources with unparalleled possibilities. This infrastructure will create a new open access European laboratory with a broad range of science covering frontier fundamental physics, new nuclear physics and astrophysics as well as applications in nuclear materials, radioactive waste management, material science and life sciences. **Departure - 8:00 from Ramada Hotel** **Return: 13:00 Bucharest Center and 14:00 Bucharest Airport** **Cernavoda NPP and Waste management facilities (Cernavoda–Constanta)** Cernavoda Nuclear Power Plant ensures the safe operation of Units 1 and 2, each with an installed power of 700 MW. The two nuclear reactors from Cernavoda NPP ensures about 20% of Romania's energy demand. Cernavoda NPP uses Canadian CANDU 6 technology (Canadian Deuterium Uranium) with natural uranium as fuel and heavy water as moderator and cooling agent. Cernavoda NPP Unit 1 was commissioned on 2 December 1996 and Unit 2 on 28 September 2007. **Departure - 7:00 from Ramada Hotel** **Return: 18:00 Bucharest Center and 19:00 Bucharest Airport** **or 16:00 Constanta (for those planning the weekend in Romania, the Black Sea side could be a good choice!)**

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- ADVISE - Advanced Inspection of Complex Structured Materials
- The EURATOM project PREPARE
- The MUSA project: Management and Uncertainties of Severe Accidents
- Project SOTERIA: Safe lOng TERm operation of light water reactors based on Improved understanding of rAdiation effects in nuclear structural materials
- INCEFA+ INcreasing safety in NPPs by Covering gaps in Environmental Fatigue AssessmentFalfred
- TeaM Cables – European Tools and Methodologies for an efficient ageing management of nuclear power plant cables
- HERACLES-CP: THE COMPREHENSION PHASE FOR HIGH-DENSITY U-MO FUELS FOR RESEARCH REACTORS
- FASTNET - Fast Nuclear Emergency Tools Project
- NUGENIA-PLUS
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FISA - Advanced nuclear systems and fuel cycles: Open call posters

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- The Virtual Centre SUPERMAT: an European Network for sustainable development of materials for extreme environmental applications
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- Development of a thermomechanical analysis method as part of the ESFR-SMART EU project for the quantification of SFR core reactivity change due to core distortion
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FISA 2019, the 9th European Commission (EC) conference on Euratom Research and Training in Safety of Reactor Systems will be held under the auspices of the Romanian Presidency 2019 of the European Union (EU) in Pitesti, on 4-7 June 2019. It will be organised concurrently with the 9th EURADWASTE '19 conference on the management of radioactive waste and geological disposal in Europe.

FISA 2019 and EURADWASTE '19 conferences objectives are:

- to present progress and key achievements of some 90 projects carried out, since the previous conference edition in 2013, as part of the 7th and Horizon 2020 Euratom Research and Training Framework Programmes (FP)

- to stimulate discussions on the state of play of R&D, key challenges addressed at national, European and international levels on Research and Innovation policies, synergies and partnerships benefiting research and innovation programmes, and future perspectives.

FISA 2019 and EURADWASTE '19 conferences will address and engage with all relevant stakeholders involved: research and training organisations, academia, industry, technology platforms, European fora and European civil society, and International Organisations.

There will be many opportunities for interaction within dedicated parallel & poster sessions, and thematic workshops. The latest EC proposal for a new Framework Programme for Research and Innovation for the period 2021-27, 'Horizon Europe' and 'Euratom Research and Training' programme will also be addressed.

Studies and reports

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