**OECD Nuclear Energy Agency**
**Nuclear Science Committee**

# 20th Meeting of the Working Party on Nuclear Criticality Safety (WPNCS)

**4-8 July 2016**

NEA Headquarters, Room BB12
46, quai Alphonse Le Gallo
Boulogne-Billancourt, France

The Working Party on Nuclear Criticality Safety (WPNCS), and its five associated Expert Groups met during the week of 4-8 July 2016 at NEA Headquarters:

- The Expert Group on Criticality Excursions Analyses (EGCEA)
- The Expert Group on Assay Data of Spent Nuclear Fuel (EGADSNF)
- The Expert Group on Burn-up Credit Criticality (EGBUC)
- The Expert Group on Uncertainty Analyses for Criticality Safety Assessments (EGUACSA)
- The Expert Group on Advance Monte Carlo Techniques (EGAMCT)

## 1. Introduction and Welcome

The WPNCS Chair, E. Létang (IRSN), presided over the meeting. He opened the meeting and welcomed the participants who briefly introduced themselves. Sixty-seven people registered for the week-long meetings (see participant list in Annex C).

## 2. Review of Actions from Previous Meeting

There were no outstanding actions to review.

## 3. Approval of the Previous Summary Record and Agenda

The summary record of the previous meeting was approved and country reports that had been submitted were included. The agenda (Annex B) was approved without any modification.

## 4. Feedback from the Nuclear Science Committee Meeting

J. Gulliford (Head of Division of Nuclear Science) reported on the outcomes of the NSC meeting held on 22-24 June 2016. The NSC approved the one-year extension of the WPNCS mandate and the Task Force proposal for one year.

He pointed out that, in follow-up to the recommendations by the Data Bank Task Force, it was decided to rename the Executive Group of the Nuclear Science Committee (NSC/EG) the Management Board for the Development, Application and Validation of Nuclear Data and Codes (MBDAV). This new governing body for the Data Bank reports directly to the Steering Committee.
J. Gulliford noted that MBDAV co-operates very closely with NSC in several areas, such as evaluated nuclear data, integral experiments and benchmarks validation, emphasising the new role of MBDAV in the area of benchmarking and validation.

He further gave an overview of the NEA Nuclear Education, Skills and Technology (NEST) Framework, which was initiated and later endorsed by the NEA Steering Committee in April 2016. He presented the concept and its main objectives to sustain and transfer practical science, technology skills and expertise to the young generation. In this regard, NEA countries will engage in a multinational approach to young people presenting the opportunity to work with recognised international experts to gain experience by being part of a complex nuclear research effort.

He also highlighted that, in the context of the growing importance of activities related to experimental needs, a new NEA activity would be proposed in the Division of Nuclear Science to support and co-ordinate experimental needs review in different areas in collaboration with other NEA standing committees.

## 5. Reports from the WPNCS Expert Groups

Individual progress of all the WPNCS Expert Groups was presented by their respective Chairs and is summarised below.

### Expert Group on Used Nuclear Fuel Criticality (EGUNF)

EGUNF was proposed as a follow-up to EGBUC with an enlarged scope. K. Suyama (JAEA) reported on the progress of activities in the EG. This EG is currently carrying out work on Phase I Benchmark *Study on the Reflector Effect of Silicon Dioxide ($SiO_2$) for the Criticality Safety of Direct Disposal of Used Nuclear Fuel*. The report is expexted to be delivered in 2016. A proposal was made for a follow-up study on *Code Comparison for Gadolinium-bearing Fuel Pins in Boiling Water Reactor Assemblies,* which is on-going and its preliminary results were presented at this meeting.

### Expert Group on Assay Data of Spent Nuclear Fuel (EGADSNF)

I. Gauld (ORNL) reported on the progress of activities in the EG. EGADNSF overlooks the development of the SFCOMPO-2.0 database. Modernisatison of the SFCOMPO database was completed with significant support from NEA Data Bank while data review continues to be supported by external consultants and ORNL: more than 730 samples coming from 44 different reactors of 8 different types will be available from the database. In follow-up, a public release of SFCOMPO-2.0 is expected after completion of cross-check review data, after July 2016. The Guidance Report for Evaluators of Assay Data was published in 2016.

### Expert Group on Criticality Excursions Analyses (EGCEA)

Y. Miyoshi (JAEA) reported on recent activities on-going within the EG. He gave an update on the status of the report on TRACY Benchmark III on the long duration of criticality experiments/low-enriched uranyl nitrate solution, the final report on which is expected to be delivered in 2017.

### Expert Group on Advanced Monte Carlo Techniques (EGAMCT)

E. Dumonteil (IRSN), who was elected new chairman of the expert group, reported on the progress of acitivites. The main focus of activity in this EG is preparation of a *Report on Quantifying the Effect of Under Sampling Biases in Monte Carlo Reaction Rates,* which is expected to be delivered in 2017.

### Expert Group on Uncertainty Analyses for Criticality Safety Assessments (EGUACSA)

B. Rearden (ORNL) reported on recent activities within the EG, which is currently focusing on completion of two benchmark studies: *Benchmark Phase IV on Correlations between Criticality Safety Benchmark Experiments and Benchmark Phase V on Blind Benchmark on Validation of damp MOX powders calculations*. The specifications of the latter have already been distributed.

### International Criticality Safety Benchmark Evaluation Project (ICSBEP)

J. Bess (INL) reported on progress made on the ICSBEP database. The technical review group met in April 2016 and reviewed six new evaluations and seven revised evaluations. The *2015 International Handbook of Evaluated Criticality Safety Benchmark Experiments* was published containing 4913 critical and subcritical benchmarks and 45 criticality-alarm/ shielding configurations. A working document on guidance for correlation matrices of benchmark uncertainties is currently under development.

## 6. The Future of the WPNCS, Preparing the 2017-2020 Mandate

E. Létang (IRSN) outlined the activites of WPNCS, presenting a proposal to create a task force to prepare the future of the Working Party and its EGs. Among the main objectives of the task force are to collect propositions from EGs and criticality experts, prepare and update the EG mandates, improve cross-cutting activities in the field of nuclear data, codes, experiments, and focus on end-users' needs. It was also decided that this task force should finalise a summary report with recommendations on a wide range of criticality issues by 2017. The structure, programme of work and schedule of the task force were also detailed and a need was formulated to create a programme committee, which would be composed of EG chairs, NEA Secretariat and WPNCS experts.

## 7. Updates on Nuclear Criticality Safety National Programmes

Delegates were requested to submit a written country report providing an overview of criticality safety related programmes or issues to report from their home countries. Country reports aim to:

- Provide convenient formats for disseminating information on national programmes/ incidents/policies.
- Identify items of common interest for consideration by WPNCS as potential collaborative activities within NSC programmes of work.
- Highlight significant changes in national programmes at subsequent meetings.
- Help NEA identify items of common/special interest.

The written reports received are included in Annex A.

## 8. Impact on $k_{eff}$ of Low Temperatures

G. O'Connor (ONR) gave an overview of the impact of low temperatures on criticality safety. In his presentation, he outlined that nuclear data used in criticality safety cases are measured at room temperature and lower temperatures could increase reactivity of low-enriched systems due to several factors. He also pointed out that impact of temperature on $k_{eff}$ is dependent on package design and for packages moderated by polyethylene or oil rather than water and low temperatures could lead to greater increases in $k_{eff}$. He summed up his results noting that temperature dependent nuclear data below $20^0$C is required in order to determine the effect of low temperature on transport package reactivity.

## 9. Any other business and Date of Next Meeting

The next meeting will be held on 26-30 June 2017. With no other business to discuss, the meeting was adjourned.

## 10. List of Actions

**Preliminary list of actions agreed upon at the 20th Meeting of the WPNCS**

| # | Action | Person(s) | Due Date |
|---|---|---|---|
| | Organisational matters | | |
| 1 | Update list of official representatives of member countries to the WPNCS | NEA | September 2016 |
| 2 | Submit to NEA the written National Reports for 2016 to be included in the minutes | All | July 2016 |
| | Cross-cutting | | |
| 4 | Highlight to the NEA ND-related groups the needs for temperature dependent S(a, b) data, including data for low temperatures (-40C) | NEA | Forthcoming WPEC and JEFF meetings |
| | WPNCS Task Force survey | | |
| 5 | Provide a form for the survey | E. Letang, NEA | August 2016 |
| 6 | Submit completed survey | All | October 2016 |

**Input data for the WPNCS Task Force: Potential cross-cutting activities**

| # | Topic | NEA Committees, EG, WPs involved |
|---|---|---|
| 1 | Nuclear data including covariances | WPNCS, WPEC, JEFF |
| 2 | S(a,b) for ice | |
| 3 | Cross-cutting benchmark on depletion calculation | EGADSNF, EGUACSA, IRPhEP |
| 4 | CEA proposal on a guidance for criticality excursion | Expertise in the field of radiological protection |
| 5 | SILENE benchmark for IRPhEP | IRPhEP, expertise in the field of radiological protection |
| 6 | New experimental data needs | ICSBEP, IRPhEP… |
| 7 | Data preservation from existing experimental programmes | ICSBEP, IRPhEP… |
| 8 | CS issues related to the fuel debris | JAEA… |
| 9 | CS issues in the final/geological disposal | Finland, UK, Switzerland |

**ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT**
**Nuclear Energy Agency**
**Nuclear Science Committee**
**Working Party on Nuclear Criticality Safety**
**ANNEX A**
**Country Reports on Nuclear Criticality Safety National Programmes**

## 1. Finland

National Context

Posiva is a company owned by TVO and Fortum and is responsible for the disposal of the spent nuclear fuel from the plants operated by TVO and Fortum. Posiva submitted the application for the Construction Licence for the disposal facility to the Government in 2012 and the construction licence was granted to Posiva in 2016. According to the statement of the Radiation and Nuclear Safety Authority in Finland (STUK) final disposal facility designed by Posiva can be built to be safe.

The construction licence was granted to Posiva in 2015. The repository will be built in Olkiluoto in the municipality of Eurajoki and has been designed for the spent nuclear fuel from the power plants operated by Posiva's owners, TVO and Fortum. Following the requirements laid by STUK, Posiva continues its studies on the long-term safety and further develops the analysis of scenarios and the safety case before application for the Operating licence. According to the current schedule Posiva plans to submit the application for the Operating licence in 2020.

Fennovoima has submitted the construction licence application for the Hanhikivi 1 nuclear power plant to the Ministry of Employment and the Economy (MEE) in 2015. Processing the construction license application is expected take two to three years. Fennovoima has two owners, Finnish Voimaosakeyhtiö SF and Russian Rosatom's subsidiary RAOS Voima Oyj with shares 66 % and 34 %, respectively. According to the obligation set by the Government in the Decision-in-Priniple, Fennovoima shall present by the end of June 2016 the environmental impact assessment for the disposal facility for spent fuel or a co-operation agreement with Posiva. In June 2016 Fennovoima signed with Posiva a 10 year contract for co-operation on nuclear waste management. The co-operation involves research and development with the aim that Fennovoima will be in a position to submit an application for a decision-in-principle regarding the final disposal of its own spent nuclear fuel. According to the schedule agreed with Rosatom, Hanhikivi 1 nuclear plant will produce electricity in 2024.

R&D Programmes, code development

Criticality safety research is carried out in the national research programme SAFIR2018 which is a four-year long programme in 2015-2018 (safir2018.vtt.fi). Themes under criticality safety discipline cover the validation of criticality and burnup calculation codes and the development of standardised criticality safety analysis. The main target of the tasks is the education of new expertise. The validation of codes is carried out mainly for SERPENT and MCNP.

Posiva has submitted criticality safety analysis for the encapsulation plant and the disposal facility to STUK during construction licence application. Posiva further develops its criticality safety analysis of final disposal of spent fuel under a three-year project for the years 2016-2018. The main target of the project is to demonstrate criticality safety of final disposal before submitting the application for the operating licence in 2020.

The project includes:

- criticality safety analysis of the encapsulation plant,
- long-term criticality safety analysis of KBS-3V and KBS-3H concepts,
- development of burnup credit methodology for final disposal,
- validation of burnup calculation,
- validation of criticality calculation,
- analysis consequences of criticality in the final repository.

The main codes applied in Posiva's criticality safety analysis are CASMO-4E and MCNP5.

International Collaborations

- Participation in the OECD/NEA/WPNCS activities, particularly,
- ADSNF: review of the datasets Fukushima-Daini-1, Fuksuhima-Daini-2, Fukushima-Daiichi-3, Novovoronezh-4, Kola-3 (TVO/Posiva & STUK),
- EGUNF: Phase II benchmark (TVO).

Future Challenges

- Use of BUC for disposal,
- Long-term criticality safety analysis,
- Consequences of criticality in the final repository.

**2. Swiss**

National Context

No updates since the previous meeting.

R&D Programmes

Major R&D on criticality safety and burnup credit aspects are ongoing in Switzerland in relation to preparation for licensing the final repository project, which is led by Nagra (Swiss National Technical Competence Centre in the field of deep geological disposal of radioactive waste) in cooperation with PSI. PSI goal is to derive the final loading curves for the spent fuel canisters designs selected by NAGRA and for the entire park of fuel assemblies operated and stored in Switzerland.

On the other end, additional Nagra activities are directed to investigate different disposal canister designs aiming to calculate the global reactivity of the system and, accordingly, to optimize the canister design. These studies, which run in parallel to the NAGRA/PSI BUCSS-R project, are carried out by means of coupled criticality/shielding calculations using the SCALE packages (KENO VI, MAVRIC).

In addition to the Nagra's project and with an objective to support basic researches in the CSE+BUC area, two little-scale projects on characterization of spent fuel and quantification of associated uncertainties have been launched in 2016 in co-operation between PSI and the swissnuclear association. The projects both investigate fuel inventory calculations during irradiation in reactor and consequent cooling and storage after discharge from the reactor. The primary quantities of interest are the evolution of nuclide inventories, decay heat, radiation sources and emission rates.
Among the sources of uncertainties the nuclear data (cross-sections, fission yields, etc.), operating conditions and manufacturing tolerances will be considered based on calculation methodologies previously developed and assessed at PSI (SHARK-X, SHARK-RMB, MTUQ, NUSS and partly TMC).
For validation studies, dedicated non-destructive measurements by neutron and gamma flux scanning are planned, for which a new measurement station is going to be constructed at PSI's Hotlab. For calibration purposes, well characterized spent fuel samples previously analyzed by destructive analyses within the past LWR-PROTEUS experimental program at PSI will be used. A possible future development of the measurement system would allow measuring the neutron source axial distribution along a full-length fuel pin and reconstruct the axial burn-up profiles in a reasonable time.

In parallel, verification and validation studies of the fuel depletion and decay simulations are continued using set of both deterministic and Monte Carlo based codes (CASMO, MCNP, Serpent, etc.) mainly based on proprietary PIE data and since recently using significantly refined irradiation histories available at PSI. These histories are available as part of Swiss reactors operated cycle core-follow models, which are developed and maintained at PSI mainly for core licensing analysis in cooperation with Swiss Federal Nuclear Safety Inspectorate, ENSI. Considerable improvement of C/E values was observed in general when comparing the refined and simplified irradiation history modeling options for the PIE experiments.

Additionally, Nagra started developing an experimental program together with the EPFL and the Joint Research Centre, Institute for Transuranium Elements (JRC-ITU), European Commission on spent fuel integrity during interim storage, aiming to expand the scientific understanding of phenomena related to representative spent fuels under dry storage conditions. Impact tests and loading tests on real SF rods are planned to be conducted in the hot cell facilities of ITU. One of the outcomes of the impact test is meant to be the quantification of the possible fuel released from cladding if a fuel rod crashes, which would serve as experimental bounding case for criticality safety assessment in the licensing process of the T/S SF casks.

International Collaborations

- In cooperation with E.ON a work on uncertainty quantification for Cm-244 in spent nuclear fuel inventory predictions has been performed in 2015/2016, resulted in the improved confidence in isotopic inventory predictions.
- PSI has hosted the set of recent WPRS (working party on scientific issues of reactor systems) meetings, including UAM benchmark, where PSI is continuously and actively participating.
- In the context of joint WGAMA-WGFS activity recently launched at OECD/NEA, PSI is participating in evaluation of Phenomena Identification and Ranking Table on Spent-Fuel Pools in Loss-of-Cooling/Coolant Accident Conditions, which includes criticality assessment.
- PSI also participates in the EU project NURESAFE and in IAEA TWG-LWR (Technical Working Group on Light Water Reactors).
- PSI staff participates in the JEFF project of the OECD/NEA Data Bank and contributes to the JEFF library next release preparation and validation assessment.

Future Challenges

Maintenance of the Hotlab facility at Nuclear Energy Division of PSI requires dedicated and stable budget, which is being in part provided by the Swiss utilities through swissnuclear/PSI R&D collaboration programs. PSI Hotlab is one of the very few facilities of its kind in Europe. At the current unfavorable conditions affecting Swiss Nuclear Industry, it is very important to continue support of the Hotlab operation to avoid permanent loss of the key area of expertise and research capabilities in the nuclear energy technology. Therefore new international research programs should be initiated to keep efficient operation of the Swiss Hotlab facility.

A follow-up of the Nagra/PSI collaboration on the BUCCS-R project is also foreseen. Calculations will be performed for degraded configurations, such as may occur in the long term in the repository after extensive corrosion and structural degradation of the canister and fuel assemblies

Input to/from NEA/NSC Programs of Work

No news comparing to the past years.

**3. Slovak Republic**

National Context

- Government Policies:
  - the new Regulations of NRA SR: 101/2016 (storage and manipulation with radioactive material and spent fuel), 102/2016, 103/2016 (nuclear safety), 104/2016, 105/2016 (transport of radioactive material), 106/2016.
  - the work on final depository was stopped several years ago and from year 2014 has started again
- Industry Requirements: -
- Operating Issues:
  - the work on new dry storage (vault system). Feasibility study and EIA study are already finished, the international tender for supplier will be issued by the end of year 2016 or by the begin of year 2017.
  - a delay in start-up of Unit 3 NPP Mochovce increases

R&D Programmes, in particular

- Code development:
  - not developed codes
  - in Slovakia we use SCALE 6, SCALE 6.1.2, MCNP5, MCNP-X, we start to use SCALE 6.2
- Experiments, Facilities, Skills/Staff requirements:
  - inspection stand in ISFSF in Jaslovske Bohunice is in construction, some parts are in operation (gamma spectrometric measurement, TV monitoring)
- Experimental needs:
  - measurement of decay heat of fuel in transport cask is in progress (methodology was already developed, the real measurement will be in future – lack of money)

International Collaborations

- Ongoin
  - IAEA: Technical working group on fuel performance and technology
  - OECD/NEA: WP NCS
  - AER (Atomic Energy Research): working group "Physical problems of Spent Fuel and Decommissioning"
  - project ALLEGRO – fast gas cooled reactor
- Planned: -

Future Challenges

- Urgent need for a new cask for a new fuel with higher enrichment and burnup. Problems by using existing cask and storage facility for a new fuel with higher enrichment and burnup are with criticality (possible solution is to use BUC), decay heat removal and shielding (possible solution is increasing of cooling time in pool at reactor, it redounds to higher crowdedness of pool at reactor or to decrease number of assemblies in cask).
- Urgent need for a new storage facility, because existing wet ISFSF in Jaslovské Bohunice will be full in year 2023. Intention is dry storage (vault system), commissioning in 2022.

Input to/from NEA/NSC Programmes of Work

- Items for discussion at WPNCS: -
- Items to be discussed in WPNCS Expert Groups: -
- Items to be forwarded to Nuclear Science Committee: -

## 4. United Kingdom

National Context

**Government Policies (related to issues discussed)**

The UK Government provides central regulation of the UK nuclear industry via its Office of Nuclear Regulation (ONR), who regulate day-to-day operations, and its various environment agencies, who regulate waste disposals.

The UK Government also funds the central co-ordination and management of nuclear legacies, via the Nuclear Decommissioning Authority (NDA) and Radioactive Waste Management Limited (RWM).

Most of the operations in the rest of the UK industry are now either privatised (e.g. in the case of civil nuclear fuel manufacture and power stations) or contracted out, to consortia employed by the NDA to manage former BNFL and UKAEA nuclear sites.

From this background, the UK government owned National Nuclear Laboratory (NNL) is now beginning to receive some government funding to assist with issues that are (or will be) of strategic importance to the future of the UK nuclear industry.

In the past, the ONR used to provide funding to allow the UK industry to participate in activities such as JEFF, ICSBEP and IRPhE. However, the ONR is no longer able to fund these activities. Hence continued UK involvement now requires any such activities to be directly funded by UK industry.

Following decades of decline in the nuclear industry, a UK government review of energy policy in 2006 gave the green light to a new generation of nuclear power. However, any new reactors would need to be wholly financed and built by the private sector with no direct subsidy.

There are plans to build up to 16GW of new nuclear power capacity (€70 billion). Eight sites around the UK have been identified as suitable for new nuclear power stations by 2025 (Sellafield, Sizewell, Hinkley Point, Oldbury, Wylfa, Bradwell, Heysham and Hartlepool), all of which contain existing nuclear plants.

Three reactor designs are currently being considered for UK new build: Areva's European Pressurised Reactor (EPR) (1600MW), Westinghouse's AP1000 (1150MW) and Hitachi's Advanced Boiling Water Reactor (ABWR) (1350MW).

The generic design assessment (GDA) for AREVA's EPR was completed by ONR in 2012. The GDA for Westinghouse's AP1000 reactor is currently scheduled for completion by March 2017. The GDA for Hitachi's ABWR is in progress.

EDF Energy propose to build four EPRs at the Hinkley Point and Sizewell nuclear sites. A strike price for the electricity generated has been agreed with the UK government. China General Nuclear Power Corporation (CGN) shall invest 1/3 of the cost of the project via a new company called General Nuclear International (GNI). However the final investment decision from EDF Energy is not likely before September 2016.

NuGen, a joint venture between Toshiba and ENGIE (formerly GDF Suez), is intending to build 3.8GW of new capacity, potentially using Westinghouse's AP1000 reactor.

Horizon Nuclear Power, was purchased by Hitachi-GE Nuclear Energy Ltd is planning to provide at least 5.4GW of new nuclear capacity to the UK. It is possible that an ABWR could be built at Wylfa and Oldbury.

The UK Government has agreed in principle for Chinese companies to own and operate Chinese designed nuclear power plants in the UK at some stage in the future.

Although the Sellafield MOX Plant (SMP) closed in 2011, due to reported technical and commercial failures, the preferred policy of the Nuclear Decommissioning Agency (NDA) to deal with the UK's plutonium stocks is to convert the material into MOX for commercial light water reactors (LWR). A second MOX plant could therefore be built.

However, other options are being considered for the disposition of the plutonium. For example, there is the Enhanced CANDU 6 reactor and the American fast PRISM reactor by General Electric-Hitachi. The PRISM reactors would be built as a pair at Sellafield and would be attractive to the UK taxpayer as there would be no upfront cost. Instead a charge would be levied per kg of plutonium disposed. The NDA will consider the output of the feasibility studies currently in progress. Licensing and operation could potentially occur within a decade.

Sources: http://namrc.co.uk/industry-intelligence/uk-new-build-plans/; http://namrc.co.uk/industry-intelligence/uk-new-build-plans/developers/; http://www.guardian.co.uk/environment/2012/jul/20/china-uk-nuclear-power-plants; http://www.theguardian.com/politics/2013/jul/05/davey-minister-nuclear-power-hinkley-point;http://www.edfenergy.com/about-us/energy-generation/new-nuclear/; http://www.horizonnuclearpower.com/technology; http://www.nugeneration.com/our_plan.html; http://www.nda.gov.uk/news/plutonium-management-alternatives.cfm; http://news.onr.org.uk/2014/08/hitachi-ge-design-for-new-nuclear-power-station-clears-first-regulatory-assessment-hurdle/; http://www.energypost.eu/saga-hinkley-point-c-europes-key-nuclear-decision/; http://www.world-nuclear-news.org/NP-UK-government-paves-way-for-Chinese-nuclear-plant-18061401.html and http://www.theguardian.com/environment/2014/mar/11/russian-nuclear-firm-build-power-station-uk and http://www.onr.org.uk/new-reactors/quarterly-updates.htm.

**Industry Requirements (skills capability, training, etc.)**

In March 2013, the UK government set out its Nuclear Industrial Strategy allowing a coordinated approach to the UK's future nuclear research and development demands. The Nuclear Innovation Research Advisory Board (NIRAB) and the Nuclear Innovation and Research Office (NIRO) are now operational although it is too early yet for any impact to be made.

Source:https://www.gov.uk/government/organisations/department-for-business-innovation-skills/series/nuclear-industrial-strategy

**Operating Issues (e.g: unusual occurrences to report)**

Nothing to report

R&D Programmes, in particular

**Code development**

RWM have been sponsoring the development of post-closure criticality consequences codes, to answer "what-if" questions relating to the potential local effects of a criticality excursion on the multiple engineered barriers that comprise a geological disposal facility. This approach is required to satisfy UK regulatory requirements; applications for waste disposal permits require safety cases to show that the risks of criticality accidents have been minimised and any potential consequences of criticality to be assessed. Much of the work carried out by RWM is subsequently published via the NDA website (see http://www.nda.gov.uk/publications/).

Commercial code developments are also carried out by the ANSWERS team within AMEC Foster Wheeler. The details are commercially sensitive and are not reported in detail here. However, ANSWERS submitted a number of papers to ICNC 2015 which provide a good overview of their latest work.

**Experiments, Facilities, Skills/Staff requirements**

There are currently no experimental criticality facilities in the UK.

**Experimental needs**

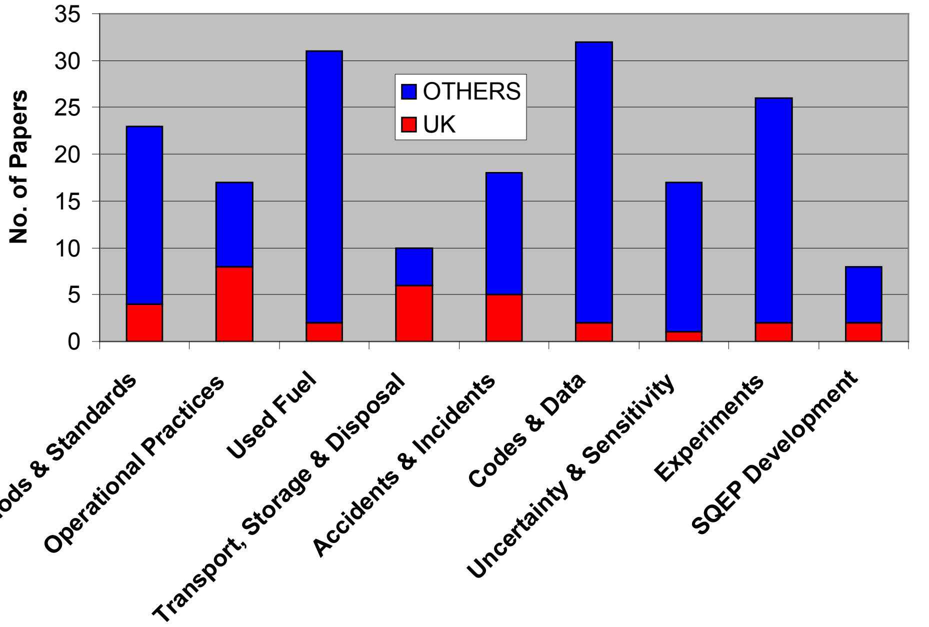
The recent interest of ONR Transport in more explicit criticality safety assessments for the full operating range of transport package operating conditions may lead to requirements for validation experiments at temperatures below room temperature. As these needs originate from the IAEA Transport Regulations, it seems most likely that the UK would seek to collaborate with the operators of (international) experimental facilities, to see if suitable experiments can be conducted.

International Collaborations

**Ongoing**

Until recently, UK government funding, via ONR, provided for the participation of ANSWERS in the ICSBEP, JEFF and IRPhE. As noted above, this funding has now ceased and UK industry may need to come up with alternative ways for funding future participation in these activities.

Many UK industrial and governmental organisations were actively involved in the delivery of ICNC 2015. 32 papers from UK authors were accepted into the conference programme, which comprised a total of about 180 presentations, as shown below.




Sellafield Ltd and the NNL are also leading UK work, to propose and develop new ISO standards for fissile waste management and criticality training for plant operators. These efforts are being carried out in conjunction with the UK Working Party on Criticality (WPC). The WPC is a national non-executive body that seeks to bring together UK regulators and industry to share best practices in criticality safety management.

ANSWERS have participated in a number of OECD/NEA expert group benchmarks, including:

*"Expert Group on Advanced Monte Carlo Techniques", (AMCT), Benchmark on Quantifying the Effect of Undersampling Biases in Monte Carlo Reaction Rate Tallies.*

*"Expert Group on Uncertainty Analysis in Criticality Safety Assessment" (UACSA), Benchmarks II and IV.*

*"Expert Group on Criticality Excursion Analysis" (CEA), Benchmark II.*

EDF Energy have also submitted some benchmark results for the EGUNF benchmark on used PWR fuel in the presence of $SiO_2$.

**Planned**

A general UK industry view would be that continued participation in ICSBEP (etc.) would be worthwhile. At the time of writing, it is not clear how this might be funded.

Future Challenges

Funding for UK activities. The WPC is investigating the availability of UK strategic funding for important issues.

The revised fissile exception criteria in the new IAEA transport regulations SSR-6 (2012) has now become UK law. In line with other member states, this will present challenges to both the operators and the UK Competent Authority in regard to the implementation of the new provisions and approval of the material as being fissile excepted respectively. An application has been received for approval under the new fissile exception provisions; it is currently being assessed.

Input to/from NEA/NSC Programmes of Work

**Items for discussion at WPNCS.**

Paragraphs 673(a)(vi) and 679 of the IAEA Transport Regulations, SSR-6, state that low temperatures (down to –40°C) should be considered (unless the competent authority specifies otherwise in the certificate of approval for the package design); further information is presented in paragraph 673.8 of the IAEA Transport Guidance, SSG-26.

Historically, criticality safety cases have used nuclear data at room temperature (20°C). However, low temperatures could increase the reactivity of low enriched systems due to:

i) Thermal contraction of moderating material,
ii) Doppler 'narrowing' of non-fissile nuclide capture cross-sections
iii) Increased ability of moderator to reduce speed of neutrons

For high enriched systems, Doppler broadening of the fissile nuclide capture cross-sections could lead to an increase in reactivity with temperature.

The latest Bingo nuclear data library, JEFF3.1.2, does not contain temperature dependant data below 20°C. For transport criticality safety assessments, it is considered that nuclear data ranging from -40°C to 20°C is required.

**5. France**

French Context

During the **COP21 conference** in Paris on December 2015, governments agreed on an ambitious agreement to limit climate change below 2°C. The current and future role of nuclear in meeting these objectives was recognized during side events and as part of the 'Nuclear for Climate' initiative led by nuclear societies.

**EDF CEO recently stated the long term strategy** regarding the French nuclear fleet :

- installed capacity limited at 62.3 MWe (French Energy Transition Law)
- nuclear fleet lifetime extension to 50 or 60 years (under Safety Authority agreement).

Regarding the **EPR under construction in Flamanville** : the construction is on track with the completion of the installation of large components; divergence is planned for 2018.

The **governance of French nuclear public bodies** has recently been reformed:

- A new decree specifies the role and governance of CEA with defense and civil nuclear as the first two missions of the research organization;
- A new decree specifies the role and governance of IRSN as a technical support for the Nuclear Safety Authority and as a research institute in nuclear safety. Its expertise can also be solicited in complex situations such as during the Fukushima-Daiichi nuclear accident;

The **restructuration of AREVA** with the takeover of AREVA NP by EDF is progressing according to the plan set out by the French government and the two companies.

In 2015, **CEA completed the Conceptual Design phase of the ASTRID SFR reactor**. This includes the preparation of a preliminary safety options case for ASTRID for the French safety authority (ASN). The project is progressing well with the greenlight given by the French Government to launch the Basic Design phase (deadline: end of 2019).

**French-UK cooperation**:

- During the World Nuclear Exhibition WNE, Paris 29 June 2016, SFEN and NIA (Nuclear Industry Association involving 260 companies) signed a partnership agreement.
- CEA and National Nuclear Lab (NNL) have signed a cooperation agreement that aims to enhance civil nuclear cooperation, particularly GEN-4 reactors and ASTRID. - EDF is expected to take very soon its final investment decision for the construction of two EPRs at Hinkley Point. Both the French and British governments have recently reaffirmed their support for the project (again confirmed after the BREXIT).

**French public acceptance**: AFP opinion pool shows that support for nuclear power remains strong in France ; **62%** of interviewed people agree that nuclear should not be phased-out.

R&D Programmes, in particular:

**Continuation of R&D work on Burnup Credit:**

- Report of the French Working Group on Burnup Credit has been published (2015): NSE vol 181, 'Burnup Credit Implementation for PWR UOX Used Fuel Assemblies in France'.
- Burnup credit at low burnup (C. Riffard, A. Santamarina, ICNC2015).
- Implementation of Burnup Credit in SFR fuels (C. Carmouze, ICNC2015).
- IRPhE evaluation of the 'separated-FP worth' experiment in MINERVE-CERES is completed.

**CRISTAL-V2/JEFF3.1.1 new package:**

- Experimental validation by CEA and IRSN is completed (E. Gagnier, N. Leclaire, ICNC2015).
- RIB/MACSENS automated tools (calculation bias and uncertainty) are extended to CRISTAL-V2.
- Release to the OCDE/NEA/Databank in 2016.

**CEA: CIRCEE Development,** a code allowing fast assessment of operational dose and CAAS.

**IRSN:**

- Release of the CE MORET 5D version (with sensitivity calculations capabilities) to the OCDE/NEA/Databank in 2017
- Neutron Random Behavior Simulation capabilities in the future MORET release of code.
- VESTA-MORET coupling capabilities available in the next VESTA release at the Databank.
- French **Criticality Training at INSTN** for "Center Criticality Engineer"

International Collaborations

- IRSN/CEA involvement in nuclear data evaluations - Collaboration with JEFF Group and European IRMM (Geel) to improve nuclear data.
- IRSN and CEA Participation in different WPNCS, WPEC and WPRS Expert Groups and ICNC 2015 conference at Charlotte (US).
- In the framework of CHANDA European programme, a new experiment AMSTRAMGRAM devoted to nuclear data and burnup credit was performed in MINERVE : oscillation of $^{241}$Am and $^{99}$Tc samples, in collaboration with IRMM.
- CEA/DOE Collaboration in WG4 'Advanced Modeling and Simulation' (nuclear data, HPC, Safety-Criticality: criticality dosimetry, CAAS, experiments at GODIVA-IV machine).
- IRSN participation in the ISO working group on NCS (ISO TC85/SC5/WG8 standards).
- IRSN/DOE-NCSP collaboration regarding Analytical Methods, Integral Experiments and Nuclear Data. 2016 Key points: criticality accident dosimetry exercise with GODIVA and design of TEX experiments.

- IRSN/JAEA collaboration in the framework of criticality fuel debris studies following Fukushima accident.
- IRSN/ENEA collaboration regarding the variance reduction methods.
- IRSN/CEA/SCK possible collaboration to perform critical experiments in VENUS.

Future Challenges

- UACSA Phase-5 Blind Benchmark on MOX wet powders
- Safety-Criticality of GEN-4 SFR cycle.
- A Criticality Safety Guide, supplementing the Criticality Resolution of the French Safety Authority, is expected in 2016
- Contribution to the organization of the ICNC'2019 in France

Input to/from NEA/NSC Programmes of Work

- Realistic correlations are needed in ICSBEP experiments, particularly for LCT benchmarks.
- Importance of maintaining a close relationship between research and assessment in Nuclear Criticality Safety. NEA Expert Groups should contribute to this issue (see presentation E. Létang).
- Benchmark on fuel depletion : calculation methodology and uncertainty quantification on fuel inventory (Actinides and major FPs).
- Within the WPNCS/EGCEA work, establish a Guide for criticality accident studies.

**6. Spain**

National Update

Presently 7 nuclear power reactors are in operation in Spain. The 500MWe BWR Garoña NPP stopped operation few years ago to avoid the application of new fiscal charges implemented by the government to face public debt problems and applied on the transfer of fuel from core to spent fuel (fuel tax). The decision on the continuity of this plant operation is pending of the fiscal policy. For the operating plants and due to the new taxes there is a claim on the lack of economic profit in the plant operation by the utilities, which can put into risk their continuity.

Over the last year, no safety significant event or unusual occurrence has been reported regarding Nuclear Criticality Safety (NCS).

A new application for the Interim Spent Fuel Storage Installation (ISFSI) from Garoña NPP (BWR-3 reactor, 466 Mwe, 1970), is being licensed. It will be the first interim spent fuel storage facility licensing process for BWR fuel in Spain.

The ENUN52B metallic dual purpose cask system from ENSA (Spain) was selected for Garoña ISFSI. The cask capacity is 52 fuel bundles and has no option for damaged fuel loading. In this first stage, the scope of the application is limited to a specific population of 8x8 GE-6 and GE-7 fuel, low burnup and long cooling time, stored in the Garoña Spent Fuel Pool, and no credit is taken from burnup, neither from Gadolinium. The licensing process of the cask design has recently finished, with specific authorization for storage and certificate of compliance for transportation.

The evaluation of the application for a Spanish design dual purpose cask, ENUN32P, for storage and transport of KWU-16x16 and W-17x17 PWR spent fuel is at the end of the licensing process. A single criticality safety case supports both dry storage and transportation, and the criticality safety analysis gives credit to burnup (BUC) at the major actinides level only.

The licensing process of a Centralized Interim Spent Fuel Storage (ATC) is also ongoing. At the ATC facility the spent fuel and HLW, coming from ISFSIs in the country, will be retrieved from the transportation casks, encapsulated in SS welded canisters specific to the facility and stored in wells cooled by natural circulation. Final design of the canisters is currently being defined. A bounding

NCS analysis for the different fuel designs stored (PWR 17x17, 16x16, 14x14, BWR 8x8, 9x9, 10x10) will be required as well as a bounding NCS analysis for the different loaded casks (DPT, HI-STAR 100, ENUN52B…) arriving to the ATC Interim Loaded Cask Storage.

A Spent Fuel and Radioactive Waste Laboratory is also projected in the CTS facility, provided with several concrete and metallic hot cells, as well as glove boxes to perform studies on spent fuel and other wastes in support of R&D objectives for long term storage and disposal. An NCS analysis of this laboratory will be required. This laboratory will be open to international collaboration.

R&D

The research effort to validate BUC codes, in the range of enrichment and burnup actually operated in Spanish reactors, continues. No additional experimental project is currently in place, but analytical work based on the results of PWR (2002-2008, 9 samples, 17x17W fuel, operated in Vandellos II reactor, 4.5% $U^{235}$ and BU 64-78 MWd/kgU) and BWR (2009-2012, 8 samples, GE14 fuel, manufactured by Enusa and operated in Forsmark, 3.95% $U^{235}$and BU 39-53 MWd/kgU) projects is being performed.

The 4-year project (2012-2016), collaboration CSN-Enresa performed by SEA, to evaluate 7 samples from SFCOMPO (GU3, DU1, BM5 and GU1 from ARIANE, M11 from REBUS and GGU1 and GGU2 from MALIBU) is on-going. Up to date four samples have been evaluated (DU1, M11, GU3, BM5), and ongoing evaluation results from one sample (GGU1) have been presented to EGADSNF.

The main concerns and R&D gaps identified have to do with BWR fuel NCS data and methodologies, where there is lack of experimental data and experience for BUC applications. Analytical work to address experimental results continues ongoing.

International Collaborations

Long-term collaboration with ORNL regarding analytical work supporting all of the research programmes described above is ongoing. Recently, this collaboration is mainly focused in the understanding of BWR fuel isotopic experimental results. This collaboration is expected to be continued.

Participation in NEA working/expert groups:

- NSC/WPNCS Expert Groups (EGADSNF, EGBUC)
- CSNI Working Group on Fuel Cycle Safety (WGFCS). Active participation in the workshop “Operational and Regulatory Aspects of Criticality Safety ORACS” (US, May 2015).

Future Challenges

As already mentioned, on a first stage the ISFSI in Garoña NPP will provide dry storage only for a limited number of BWR spent fuel assemblies actually wet stored in de NPP spent fuel pool. In the near future, the license should be extended to the whole inventory of the pool and credit to gadolinium and/or burnup should be given. There is no previous national experience on this issue regarding dry casks.

The criticality safety aspects of the single Centralized Interim Spent Fuel Storage (ATC) will be shortly undertaken, also as a new licensing challenge. The ATC generic design was approved in 2006 and is based in a vault system, i.e. storing the fuel elements in canisters loaded in vertical position, and inserted into wells. The construction and preliminary licensing steps are ongoing, but no detailed design of the spent fuel canisters has been provided yet. Bounding NCS analysis will be mandatory for the different fuel designs (PWR 17x17, 16x16, 14x14, BWR 8x8, 9x9, 10x10) loaded in the canisters, for the different loaded casks (DPT, HI-STAR 100, ENUN52B…) arriving to the ATC Interim Loaded Cask Storage and for the Spent Fuel and Radioactive Waste Laboratory.

Input to/from NEA/NSC Programmes of Work

- Items for discussion at WPNCS.
- Items to be discussed in WPNCS Expert Groups
- Items to be forwarded to Nuclear Science Committee

**7. Hungary**

National context

More than 50% of Hungarian energy consumption is covered from import resources. The four VVER-440 nuclear power units at Paks site generate about 40% of the domestic energy production. There is a governmental decision to expand Paks NPP capacity with two new AES-2006 VVER units of 1200 MWe. The corresponding contracts were signed between the representing organization of Hungarian government and that of ROSATOM on 9 December 2014.

The contract main points comprise

- the construction,
- the operation,
- the fuel supply.

The project estimated cost is 12,5 billion Euros, 80 % financed from loan provided by Russian organizations.

The first step of the licensing procedure is submitting the Preoperational Safety Report, which is scheduled to the end of 2016. According to the Hungarian legal regulations, independent safety analysis results must also be submitted. The discussions on this topic have been started with the domestic professional institutions. Not all the necessary technical details, data are available up to now for them.

Another direct consequence of planning the new units is a renewal of some regulatory documents, guides. The domestic professional institutions are involved also in this process. From the guides the following ones – related to nuclear science - can be mentioned:

- Guide for deterministic analyses,
- Guide for fuel handling,
- Guide for core design and monitoring.

R&D programs

A further, indirect consequence of planning of new units is the full launching of the Hungarian Sustainable Nuclear Energy Technology Platform („HSNETP"). The "full launching" means that Hungarian Technical Development Bureau (state organization) accepted and decided to support a 4 year R&D project in the fields of the nuclear energy production. Additional financing parties beside Technical Development Bureau are Paks1 NPP, Paks2 and the Hungarian Atomic Energy Agency (Regulatory Body).

The main goal of the Platform is coordinating and financing the nuclear energy research and development activities in Hungary concerning

- the needs of the existing units of the Hungarian nuclear power plant,
- the possible requirements of the new units to be built,

- the development of the future significant Generation IV nuclear power plants as well as the problems of the fuel cycle.

Activities related to criticality safety:

In the framework of the Platform described above, Paks NPP finance a project carried out at the Center for Energy Research, Hungarian Academy of Sciences (EK). The aim of this project is the testing by HZP states of the units at Paks the burnup credit computational procedure used in Hungary. This procedure consists of subsequent use of the KARATE core design code (developed at EK) for composition calculation and the MCNP Monte Carlo code for criticality calculation. Recently, a new version of KARATE (called statistical KARATE) taking into account the uncertainties from nuclear cross sections, technological data and operational history in a statistical consistent way has been developed. Based on the sampling method, this procedure gives a number of 3D isotopic composition distributions for the critical states of the reactor core corresponding to the distributions of the uncertainty sources (cross section, etc.) Using a 3D Monte Carlo model of the core HZP states based on these isotopic distributions and performing the sufficient number of criticality calculations for the core, the 95%/95% confidence interval for the multiplication factor can be determined. It is expected, that performing this analysis for a number of HZP states the confidence interval contains the experimental $k_{eff}$ (i.e. 1.0) approximately 95 % of the investigated states.  Meeting this assumption would support the application of the KARATE+MCNP procedure. However, for definite conclusion, further investigations on the similarity of the HZP states and the spent fuel storage facilities are necessary.

**8. Germany**

<u>National Context</u>

a. Nuclear power in Germany in 2015
   i. 9 NPPs → 8 NPPs (- Grafenrheinfeld)
   ii. Installed power: 12.7 GWe → 11.3 GWe
   iii. Produced Energy: 91.8 TWhe (4 German NPPs in top 10)
   iv. Availability: 91.76 %
b. Phase out of nuclear power in Germany (until 2021)
   i. Grafenrheinfeld went off the grid in June 2015
   ii. Gundremmingen B/C are planned to get off the grid in the beginning of 2017 because of an exceedance of cumulative energy production
c. German repository commission (different organisations including universities, churches, labor unions, NGO's) has submitted its final report to the German Government on July 5
   i. Process started end of 2013
   ii. Objective: safe inclusion of HLW for 106 years, site with "best safety" shall be selected (salt, clay, crystalline?)
   iii. Develop criteria, processes and decision bases to evaluate the site selection law
   iv. Make proposal for public participation and transparency
   v. Previously explored possible site Gorleben not excluded in selection procedure, but
      - Exploration shall be stopped
      - Requirement of retrievability may exclude Gorleben (salt)
   vi. Currently HLW in interim storage facilities mostly at reactor sites
d. Reportable event at BWR NPP Gundremmingen B:
   i. Head of fuel assembly at Gundremmingen tore off during handling in spent fuel pool (break of water channel), FA slid back into storage channel
   ii. Fuel rod lattice intact, no fuel rod damages

   - Protection objective subcriticality and confinement of the radioactive materials fulfilled
   - Event and similar events covered by design base criticality safety and radiological analyses of fuel handling accidents

e. DIN 25712 ("criticality safety with BUC for transport and storage of irradiated LWR fuel elements in casks": new release in 2015 – editorial changes

f. First storage license (1996 IAEA regulation) for CASTOR® V/52 for BWR fuel in 2015/2016
   i. Application for an update of the transport license with gadolinium credit

g. Eon has lost 380 Million Euro
   i. No compensation for 3 month moratorium of Isar 1 und Unterweser after Fukushima event
      - E.ON should have sued the federal states in 2011

h. Closure of AREVA Offenbach site on June 30

<u>Code Validation and Development:</u>

i. GRS: The modular research depletion calculation code MOTIVE has been further developed. The inventory calculation includes now several different solvers and libraries. First validation studies have begun.

j. AREVA GmbH: The Monte Carlo/Bayes code system NUDUNA/MOCABA has been successfully tested for reactor physics applications: prediction of reactor cycle parameters of a Spanish NPP using the Spanish SEANAP PWR analysis system. NUDUNA/MOCABA is currently tested with AREVA's reactor core simulator ARTEMIS™.

<u>International Collaborations</u>

k. GRS: Numerous bi- and multilateral cooperations with universities, research institutions, and TSO's.

l. AREVA GmbH: Cooperations with universities and research institutions, e.g. UPM, CEA, and SCK•CEN

<u>Future Challenges</u>

m. Criticality safety research for final disposal – site / host rock comparison;

n. Degraded fuel configurations (destructed assembly structures) under accident (SFP, transport) or disposal conditions;

o. Criticality safety of long term interim storage of used nuclear fuel

## 9. Japan

<u>Overview of National Context</u>

- Since the sever accident in the Fukushima Daiichi Nuclear Power Station in March 2011, all nuclear power plants in Japan stopped and have not been in operation. The Nuclear Regulatory Authority of Japan made a new Regulatory Requirements for commercial nuclear power reactors in 2013. Based on this new Regulatory Requirements, safety reviews of nuclear power plants and research reactors started. Sendai Nuclear Power Station (2 PWRs, in Kagoshima prefecture, Kyushu Electric Power Company) obtained the first licensing in September 2014.
- As of September 2016, Sendai-1 and -2, Ikata-3 (PWR in Ehime Prefecture, Shikoku Electric Power Company) and Takahama-3 and -4 (PWRs in Fukui Prefecture, Kansai Electric Power Company) hold the license to be operated commercially. However, Takahama-3 and -4 are not

operated complying with the temporary injunction of the Ohtsu district court.

- New Regulatory Requirements for research reactors including critical assemblies were discussed taking into account their features about power, nuclear fuel and fission products inventory, coolant system etc.
- Concerning the new Regulatory Requirements for research reactors by Nuclear Regulatory Authority of Japan, safety reviews of research reactors (HTTR, JMTR, JRR-3 in JAEA, KUR in Kyoto Univ. and so on) started since October 2014.
- Applications of a critical assembly KUCA in Kyoto Univ. and of a research reactor UTR-Kinki in Kinki Univ. were approved by NRA in April 2016.
- Application of a research reactor KUR in Kyoto Univ. was approved by NRA in July 2016.

R & D program

- JAEA are designing low-enriched heterogeneous cores moderated by the light water. This is designed for the modified STACY. The main nuclear characteristics of the cores are evaluated including the feasibility study of reactivity measurement for small fuel samples. Mockup tests of safety devices for emergency situation were performed. The licensing procedure of STACY modification by NRA started in March 2015.

International Collaboration

- Information exchange in the nuclear criticality safety field between JAEA and IRSN were conducted by the contract. (Cooperation of uncertainty analyses of STACY modified core composed of low enriched $UO_2$ fuel rod array with water moderator)
- JAEA participates in ICSBEP for providing the criticality data for low enriched uranyl solution system continues.

Future Challenges

- Concerning Fukushima issue, JAEA started to research on critical control technology for fuel debris under the program of Nuclear Regulatory Authority of Japan. In this program, preparation of criticality map for debris treatment, criticality risk assessment, and critical experiments for supporting criticality management technology are planned.
- JAEA carries out a research program concerning the option of direct disposal of nuclear spent fuels, in which the criticality safety evaluation for long term are made using Japanese standard burn-up and criticality codes.

## 10. Sweden

National Context

### Government Policies

In 2016 there was a political agreement including government and opposition parties to change the legal and financial conditions for operating nuclear power stations in Sweden:

- No political enforcement of nuclear power phase-out;
- Tax on nuclear power will be phased out;
- Nuclear third-part liability coverage to be increased substantially;
- New nuclear power plants are allowed to replace existing plants;
- There will be no governmental support for research or development of new nuclear power.

Some older nuclear power units are being shut-down or will be shut-down soon due to economic pressure (very low electricity prices and expensive maintenance).

### Used Nuclear Fuel and Final Disposal

- In June 2016 the Swedish licensing authority approved the application for final disposal according to environmental and general laws.

- Detailed nuclear and radiation safety issues will be a later step (nuclear safety law)
- Increase of enrichment to 5 % $^{235}U$ has been applied for and reviewed.

**Burnup and Burnable Poisons**

- The industry has recently changed the strategy on burnup credit slightly.
- Burnup credit is applied to PWR fuel.
- BA credit is applied to BWR fuel.
- This is a change to previous plans but used since 1990's for the intermediate storage CLAB.

## 10. United States

<u>National Context</u>

The United States has fissile material operations involving all portions of the nuclear fuel cycle. Although advanced reactor concepts continue to investigate use of fuel with >5wt% enrichments, the focus of industrial and government activities is on production and fabrication of reactor fuel with enrichments <5wt%. Delays in the MOX fuel fabrication plant (caused by funding and design/construction challenges) have limited the need for attention to criticality safety issues involving transport or storage of MOX fuel.

After the government decision to terminate further work on the repository site at Yucca Mountain, both the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) are working to assure the technical information and regulatory framework is in place to support long-term safe storage and subsequent transport of spent fuel. The NRC has recently received an application for a Consolidated Interim Storage Facility (CISF) in Andrews County, Texas from Waste Control Specialist. The NRC is anticipating to receive a second application for an interim storage facility by the end of 2016. Final repository options and overall storage, transport, and disposal systems are being studied by DOE to provide the technical information for future decisions regarding the back end of the fuel cycle.

The DOE, including its autonomous National Nuclear Security Administration (NNSA), and the NRC each have responsibility for providing regulatory oversight on criticality safety – DOE for operations within the DOE complex and NRC for industry operations. The American Nuclear Society (ANS) is the US professional organization that works to develop consensus standards for criticality safety and organize technical meetings on criticality safety. (The ANS will be the US organization hosting ICNC2015.) Each of these organizations develops, sponsors, or supports training classes and workshops to support education and knowledge exchange in the field of criticality safety. The number of universities offering classes and degree certificates focused on criticality safety has risen over the last few years.

<u>R&D Programmes</u>

The DOE and NRC both support research activities in the area of nuclear criticality safety. The DOE Nuclear Criticality Safety Program (NCSP) has provided a central focus for research and technology development for over 15 years. The DOE NCSP (see http://ncsp.llnl.gov/) has five elements: Integral Experiments, Analytical Methods, Nuclear Data, Information Preservation and Dissemination, and Training and Education. Integral experiments (and hands-on training classes) are conducted at the Nuclear Criticality Experiments Research Center (NCERC) and at Sandia National Laboratories (SNL). Experiments at NCERC are conducted by Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL).

All four critical experiment machines at NCERC (Planet, Godiva, Comet, and Flattop) are available, and the facility operates as a user facility to help meet national and international program needs. During the past year, NCERC efforts have largely focused on restart efforts for Godiva following a uranium uptake event in 2014. Godiva restart has been granted and resumption of critical experiments using Godiva began in 2016. For fiscal year 2016, twenty-four NCSP-funded experiments are underway at NCERC by LANL and LLNL and each are at various stages of the Critical Experiment

Design process, e.g., conceptual design, experiment execution, data publication, etc. Additionally, five NCSP-funded experiments are currently underway at the Sandia Pulse Reactor Facility.

The NCSP has conducted "hands-on" critical experiment training classes at NCERC during the past year. Specifically, the NCSP conducted a 2-week training class for NCS practitioners in February 2016, and an additional 2-week training class will be conducted in August 2016. The 2-week classes include one week of classroom training at the Nevada Field Office or at the National Atomic Testing Museum followed by one week of hands-on critical experiment training at either SNL or NCERC. In addition, the NCSP conducted 1-week hands-on critical experiment training classes for regulators, managers, and operations professionals who need to understand the fundamentals of nuclear criticality safety. A 1-week manager's course was conducted at SNL in January 2016, and a 1-week class was conducted at NCERC in June 2016. Since establishing the NCSP hands-on training courses in 2011, 253 students have taken the NCS hands-on training course.

With regard to integral benchmarks, the NCSP in collaboration with CEA completed the benchmark evaluation of the first of three pulsed SILENE experiments that were performed in 2010. The benchmark evaluation was published in the 2015 edition of the ICSBEP Handbook. The evaluations for the remaining two SILENE pulsed experiments were presented to the ICSBEP in April 2016 and are scheduled to be published in the next release of the ICSBEP Handbook. In addition, the NCSP completed the LEU-COMP-THERM-096 benchmark, and this evaluation was published in the 2015 edition of the ICSBEP Handbook. During the past year, the NCSP has conducted critical experiments at SNL using the $U(7\%)O_2$ lattice assembly. In addition, a new epi-thermal critical experiment design is in execution phase at SNL, and the new experiment design is expected to provide epi-thermal benchmark experiment data to support NCS operations. The multi-laboratory Critical/Subcritical Experiment Design Team works to assess experiment needs and assure the experiments are designed and performed to achieve stated technical objectives. Most of the experiments are evaluated as benchmarks for dissemination as part of the Information Preservation and Dissemination program element.

NRC continues its support for research focused on use of Burnup Credit in designing criticality control systems for BWR spent fuel storage casks and transportation packages. The first phase of research which was focused on BWR peak reactivity was completed by issuing a NUREG report. The second phase of the research, which is examining beyond peak reactivity, is currently underway and is planned to be completed in the next year or two. BWR research is being driven primarily by loss of geometry concerns of storing high burnup fuels and the planned extension of fuel storage time limits beyond 20 years.

With regard to Analytical Methods, MCNP, SCALE, and COG are key codes used for criticality safety within the DOE complex and are supported by the NCSP. A key area of development has been sensitivity/uncertainty methods using continuous energy data. The multi-laboratory Nuclear Data Advisory Group (NDAG) prioritizes nuclear data measurements and evaluations supported by the NCSP and coordinates NCSP activities with the US National Nuclear Data Center to assure inclusion in the Evaluated Nuclear Data Files (ENDF). Funding to help support processing of ENDF data for the criticality safety codes is also provided by the NCSP and ENDF/B-VII.1 libraries are available for the key NCS analyses code packages.

In the Nuclear Data program element, prioritized nuclear data measurements and evaluations continue to be performed to support NCS operations in the US. During the past year, new differential measurements have been performed on Ca, Ce, and Fe. Also, substantial progress has been made to expand the RPI linear accelerator neutron capture measurement capabilities into the keV range that is important for many nuclei pertinent to criticality safety. Furthermore, the NCSP has partnered with NNSA Naval Reactors to invest in an accelerator refurbishment effort at RPI to ensure the US has a differential data measurement capability for performing needed cross-section measurements. With regard to new cross-section evaluation work, the NCSP has completed new resonance region evaluations for $^{63,65}Cu$, $^{56}Fe$, $^{16}O$, and $^{182,183,184,186}W$. These new evaluations are undergoing testing and are expected to be available with the next release of the ENDF data library.

International Collaborations

The NNSA continues to interact with AWE in the UK and CEA and IRSN in France to identify and collaborate on nuclear criticality safety issues of mutual interest, such as integral experiments, computational methods, and improved nuclear data. During the past year, the collaborations have resulted in personnel from the US performing collaborative work at IRSN, CEA, and AWE. Likewise personnel from AWE and IRSN have visited the US to perform collaborative work tasks at NCSP sites. Within the DOE NCSP, ORNL and IRMM collaborate to perform neutron cross-section measurements in the resonance region to address differential data needs identified as important to improvement of nuclear criticality safety analyses.

Under OCED/NEA WPEC, US national laboratories are working with other international partners to the CIELO (Collaborative International Evaluated Library Organization) to improve nuclear evaluations, many of which support improved evaluations for nuclear criticality safety. Specifically, the CIELO collaboration has focused efforts on completing new evaluations for $^{235}U$, $^{238}U$, $^{239}Pu$, $^{56}Fe$, and $^{16}O$.

In addition, the NCSP provides support for the US participation in the ICSBEP. With NCSP support, new benchmark evaluations have been submitted for inclusion in the next release of the ICSBEP Handbook. The new evaluations include the first of three pulsed experiments using the SILENE solution assembly for CAAS benchmark calculations and an evaluation of the SNL 7uPCX 0.800 cm pitch with variable depth in pure water experiment.

Future Challenges

Organizations face a continuing challenge to maintain a fully compliant criticality safety program with qualified personnel experienced in both the principles of criticality safety and the fissile material operations. In addition, a challenge is related to succession planning for key staff expertise needed to support NCS. To meet this challenge, the NCSP is continuing to invest in succession planning for key NCS technology capabilities that include specialists in integral experiments, nuclear data, and analytical methods.

Holdup residues can contribute significantly to the inventory of nuclear material within process equipment and, at any time, can represent the largest portion of inventory uncertainty. As such, these residues can challenge assumptions and limits needed for nuclear criticality safety. The NNSA has initiated work to establish a safety-related *in situ* nondestructive assay (NDA) program to manage and direct research and development (R&D) tasks needed to improve NDA capabilities for quantifying nuclear material holdup. A mission and vision document for the NDA technology program is in development and should be published in the coming year.

Input to/from NEA NSC Programmes of Work

The U.S. continues to engage in each of the Expert Groups of the Working Party on Nuclear Criticality Safety. These engagements are sponsored by numerous agencies, but the DOE/NNSA or NRC are the primary sponsors of the participants and their contributions.

**ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT**
**Nuclear Energy Agency**
**Nuclear Science Committee**

**20th Meeting of the Working Party on Nuclear Criticality Safety (WPNCS)**

**AGENDA**

**ANNEX B**

*Proposed Meeting Schedule:* ***9h00 – 17h00***

| | |
|---|---|
| 1. Welcome | E. Létang (Chair) |
| 2. Approval of the agenda | |
| 3. Approval of the summary records of the previous meeting and Review of actions | |
| 4. Feedback from the Nuclear Science Committee meeting | J. Gulliford |
| 5. Reports from the WPNCS Expert Groups and extension of mandates | |
| - Used Nuclear Fuel Criticality (EGUNF) | K. Suyama |
| - Assay Data for Spent Nuclear Fuel Expert Group (EGADSNF) | I. Gauld |
| - Criticality Excursions Analyses Expert Group (EGCEA) | Y. Miyoshi |
| - Advanced Monte Carlo Techniques Expert Group (EGAMCT) | E. Dumonteil |
| - Uncertainty Analyses for Criticality Safety Assessment (EGUACSA) | B. Rearden |
| - International Criticality Safety Benchmark Evaluation Project (ICSBEP) | J. Bess |
| 6. The future of the WPNCS, preparing 2017-2020 mandate | E. Létang/All |
| 7. Updates on Nuclear Criticality Safety National Programmes | All |
| 8. Impact on $k_{eff}$ of Low Temperatures | G. O’Connor |
| 9. Any other business | |
| - Date and place of the next meeting | Secretariat |
| - Adjourn | E. Létang (Chair) |

**ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT**
**Nuclear Energy Agency**
**Nuclear Science Committee**
**Working Party on Nuclear Criticality Safety**

**ANNEX C**
**Registrants to the 2016 Working Party on Nuclear Criticality Safety meetings**

**BELGIUM**


Mme Daniele BOULANGER
Avenue des Arts, 14,
B-1210 Brussels
Tel.: +32 2 2121057
E-mail: d.boulanger@nirond.be

Dr Mireille GYSEMANS
Head of the Radiochemical Analyses Lab
SCK/CEN
Boeretang 200
B-2400 Mol
Tel.: +32 14 33 32 80
E-mail: mgyseman@sckcen.be

Dr Nadia MESSAOUDI
SCK/CEN
Institute for Advanced Nuclear Systems
NSP Group, BR1,
200 Boeretang
B-2400 MOL
B-1200 Bruxelles
Tel.: +32 14 33 22 23
E-mail: nmessaou@sckcen.be


**CZECH REPUBLIC**


Mr Milan GREN
Nuclear Reserach Institute Rez
Husinec - Rez, cp. 130
250 68 Rez
Tel.: +420 266 172 294
E-mail: gre@ujv.cz


**FINLAND**


Mr Anssu RANTA-AHO
Teollisuuden Voima Oyj
Töölönkatu 4
FI-00100 Helsinki
Tel.: +358 9 6180 5452
E-mail: anssu.ranta-aho@tvo.fi

Dr Karin RANTAMAKI
VTT
PO Box 1000
FI-02044 VTT
Tel.: +358 405493212
E-mail: karin.rantamaki@vtt.fi


**FRANCE**


Mr Jeremy ALT
AREVA
TN International
1, rue des Herons
F-78182 Montigny-le-Bretonneux
Tel.: +33 1 34 96 54 89
E-mail: jeremy.alt@areva.com

Ms Coralie CARMOUZE
CEA Cadarache
13108 St. Paul-lez-Durance cedex
Tel.: +33 (0) 4 42 25 64 19
E-mail: coralie.carmouze@cea.fr

Mr Pierre CASOLI
CEA/Saclay
DEN/DANS/DM2S/SERMA/CP2C
91191 Gif-sur-Yvette cedex
Tel.: +33 1 69 08 14 74
E-mail: pierre.casoli@cea.fr

Mr Bertrand COCHET
IRSN
PSN.EXP/SNC/LNC
BP 17
92262 Fontenay-aux-Roses cedex
Tel.: +33 (0) 1 58 35 81 04
E-mail: bertrand.cochet@irsn.fr

Ms Isabelle DUHAMEL
IRSN
BP 17
31 avenue de la division Leclerc
92262 Fontenay-aux-Roses Cedex
Tel.: +33 01 58 35 74 17
E-mail: isabelle.duhamel@irsn.fr

Dr Eric DUMONTEIL
IRSN/PSN-EXP/SNC
BP 17
92262 Fontenay-aux-Roses Cedex
Tel.: +33 1 58 35 73 60
E-mail: eric.dumonteil@irsn.fr

Mr Frederic FERNEX
IRSN
B.P. N° 17
92262 FONTENAY AUX ROSES CEDEX
Tel.:
E-mail: frederic.fernex@irsn.fr

Dr Wim HAECK
IRSN - PSN-EXP/SNC/LNR
Service de Neutronique et de Criticité
Laboratoire de Neutronique des Reacteurs
BP 17
92262 Fontenay-aux-Roses cedex
Tel.: +33 (0) 1 58 35 90 83
E-mail: wim.haeck@irsn.fr

Dr Raphaelle ICHOU
IRSN
PSN-EXP/SNC/LNR
BP 17
92265 Fontenay-aux-Roses Cedex
Tel.: +33 01 58 35 74 42
E-mail: raphaelle.ichou@irsn.fr

Alexis JINAPHANH
IRSN
31, avenue de la Division Leclerc
92260 Fontenay-aux-Roses Cedex
Tel.: +33 1 58 35 72 88
E-mail: alexis.jinaphanh@irsn.fr

Ms Ludyvine JUTIER
IRSN PSN-EXP/SNC/BERAC
BP 17
92262 Fontenay-aux-Roses Cedex
Tel.: +33 (0) 1 58 35 94 45
E-mail: ludyvine.jutier@irsn.fr

Dr Michael LAGET
CEA/Saclay
DM2S SERMA B470
91191 Gif-sur-Yvette cedex
Tel.: +33 (0) 1 69 08 36 82
E-mail: michael.laget@cea.fr

Mr Nicolas LECLAIRE
IRSN
B.P. 17
92262 FONTENAY-AUX-ROSES CEDEX
Tel.: +33 1 58 35 91 66
E-mail: nicolas.leclaire@irsn.fr

Mr Eric LETANG
IRSN/PSN-EXP/SNC
B.P. No. 17
F-92262 FONTENAY-AUX-ROSES
Tel.: +33 1 58 35 91 65
E-mail: eric.letang@irsn.fr

Fausto MALVAGI
CEA/Saclay
DEN/DM2S/SERMA/LEPP
Bat 470
91191 Saclay Cedex
Tel.: +33 1 69 08 89 49
E-mail: fausto.malvagi@cea.fr

Mr Mathieu MILIN
IRSN
PSN-EXP/SNC/BERAC
B.P. 17
92262 Fontenay-aux-Roses
Tel.: +33 1 58 35 87 69
E-mail: mathieu.milin@irsn.fr

Mr Wilfried MONANGE
IRSN/PSN-EXP/SNC
31 Avenue de la Division Leclerc
92260 Fontenay-aux-Roses
Tel.: +33 1 58 35 74 18
E-mail: wilfried.monange@irsn.fr

Mr Marcel TARDY
Areva - TN International
1, rue des Hérons
78180 Montigny-le-Bretonneux
Tel.: +33 01 34 96 52 99
E-mail: marcel.tardy@areva.com

Mr Andrea ZOIA
CEA/Saclay
91191 Gif-sur-Yvette cedex
Tel:
E-mail: andrea.zoia@cea.fr

Prof. Alain SANTAMARINA
CEA Cadarache
DEN/DER/SPRC
Bat. 230
F-13108 ST. Paul-Lez-Durance Cedex
Tel.: +33 4 42 25 70 46
E-mail: alain.santamarina@cea.fr

**GERMANY**


Mr Maik HENNEBACH
AREVA
Manager Design and Development
DAHER Nuclear Technologies GmbH
Rodenbacher Chaussee 6
Amtsgericht Hanau HR B 4428
D-63457 Hanau
Tel.: +49 (0) 6181 501 241
E-mail: m.hennebach@daher.com

Dr Axel HOEFER
AREVA GmbH
Kaiserleistr.29
D-63067 Offenbach
Tel.: +49 69 2557 31250
E-mail: axel.hoefer@areva.com

Dr Elisabeth PETERS
Gesellschaft fuer Anlagen-
und Reaktorsicherheit (GRS) mbH
Forschungszentrum
Boltzmannstr. 14
D-85748 Garching
Tel.: +49 8932004455
E-mail: elisabeth.peters@grs.de

Dr Benjamin RUPRECHT
Bundesamt fuer Strahlenschutz
Willy-Brandt-Straße 5
38226 Salzgitter
Tel.: +49 3018333 1707
E-mail: bruprecht@bfs.de

Mr Fabian SOMMER
Gesellschaft fur Anlagen-
und Reaktorsicherheit (GRS)gmbH
Forschungszentrum
Boltzmannstr. 14
D-85748 Garching
Tel.:
E-mail: fabian.sommer@grs.de

Dr Maik STUKE
GRSmbH
Forschungsinstitut
Boltzmannstr. 2
85748 Garching n.Munich
Tel.: +49 89 32004 486
E-mail: maik.stuke@grs.de

Sven TITTELBACH
WTI GmbH
Karl-Heinz-Beckurts-Str. 8
52428 Juelich
Tel.: +49 2461 933 153
E-mail: tittelbach@wti-juelich.de

Dr Stefaan VAN WINCKEL
EG-JRC
Directorate G: Nuclear Safety and Security
D-76125 Karlsruhe
Tel.: +49 (0) 7247 951 328
E-mail: stefaan.van-winckel@ec.europa.eu

**HUNGARY**

Dr Gabor HORDOSY
Centre for Energy Research,
Hungarian Academy of Sciences
P.O. Box 49
1525 Budapest 114
Tel.: +36 1 392 2222 ext. 3442
E-mail: hordosy.gabor@energia.mta.hu

**ITALY**

Dr Kenneth BURN
ENEA
Via Martiri di Monte Sole, 4
I-40129 Bologna
Tel.: +39 051 6098 417
E-mail: kenneth.burn@enea.it

**JAPAN**

Mr Yoshinori MIYOSHI
Japan Atomic Energy Agency
Shirakata 2-4, Naka-gun, Ibaraki
319-1195 Tokai-mura
Tel.: +81 29 282 6020
E-mail: miyoshi.yoshinori@jaea.go.jp

Mr Shigeki SHIBA
Nuclear Regulation Authority
18F Roppongi First Bldg
1-9-9 Roppongi Minato-ku
Tokyo 106-8450
Tel.: +81 08041418879
E-mail: shigeki_shiba@nsr.go.jp

Dr Kenya SUYAMA
Group Leader, Research Group for Reactor
Physics & Standard Nuclear Code System
JAEA
2-4 Shirataka-Shirane
Tokai-mura,Naka-gun,Ibaraki-ken 319-1195
Tel.: +81 29 282 5827
E-mail: suyama.kenya@jaea.go.jp

Dr Toshihisa YAMAMOTO
Nuclear Regulation Authority
Roppongi-First Bldg., 9-9 Roppongi 1-chom
106-8450 Minato-ku, Tokyo
Tel.: +81 3 5114 2113
E-mail: toshihisa_yamamoto@nsr.go.jp

Dr Yuichi YAMANE
Assistant Principal Researcher
Nuclear Safety Research Center, JAEA
Tokai-mura, Naka-gun,Ibaraki-ken
319-1195
Tel.: +81 29 282 6743
E-mail: yamane.yuichi@jaea.go.jp

**KOREA**

Gil Soo LEE
KINS
62 Gwahak-ro, Yusong-gu
305-338 Daejeon
Tel.: +82 42 868 0783
E-mail: gslee@kins.re.kr

**POLAND**

Mr Lukasz KOSZUK
National Centre for Nuclear Research
ul. Andrzeja Soltana 7
05-400 Otwock, Swierk
Tel.: +48 222731205
E-mail: l.koszuk@gmail.com

**SLOVAK REPUBLIC**

Vladimir CHRAPCIAK
VUJE Trnava a.s
Okruzna 5
918 64 TRNAVA
Tel.: +421 33 599 1312
E-mail: vladimir.chrapciak@vuje.sk

**SPAIN**

Ms Consuelo ALEJANO MONGE
Core Engineering Department
Consejo de Seguridad Nuclear
Justo Dorado, 11
28040 Madrid
Tel.: +34 91 3460 264
E-mail: cam@csn.es

Mr José M. CONDE
Enusa Industrias Avanzadas
C/Santiago Rusiñol, 12
28040 Madrid
Tel.: +34 91 34 74 261
E-mail: jose.conde@enusa.es

Prof. Pedro ORTEGO SAIZ
SEA Ingenieria y Analisis de Blindajes S.
Av. Atenas 75 Locales 106-107
28232 Las Rozas (Madrid)
Tel.: +34 91 6317 807
E-mail: p.ortego@seaingenieria.es

Ms Candan TORE
SEA Ingenieria y Analisis de Blindajes S.
Av. Atenas 75 Locales 106-107
28232 Las Rozas (Madrid)
Tel.: +34 91 631 7807
E-mail: candantore@yahoo.es

**SWEDEN**

Dr Dennis MENNERDAHL
E. Mennerdahl Systems
Starvägen 12
SE-183 57 TÄBY
Tel.: +46 8 756 58 12
E-mail: dennis.mennerdahl@ems.se

**SWITZERLAND**

Dr Alexander VASILIEV
Laboratory for Reactor Physics
and Systems Behaviour
Paul Scherrer Institut, OHSA/D01
CH 5232 Villigen PSI
Tel.: +41 56310 2702
E-mail: alexander.vasiliev@psi.ch

Dr Stefano CARUSO
NAGRA
Safety, Geology and Radioactive Materials
Hardstrasse 73
CH-5430 Wettingen
Tel.: +41 56 4371 218
E-mail: stefano.caruso@nagra.ch

**UNITED KINGDOM**

Robert W. MILLS
National Nuclear Laboratory
Central Laboratory, B170
Sellafield, Seascale
Cumbria CA20 1PG
Tel.: +44 19 467 79317
E-mail: robert.w.mills@nnl.co.uk

Mr Gregory O'CONNOR
Criticality & Radiological Protection
ONR - RMT
Desk 3, GSW Rose Court,
2 Southwark Bridge
London SE1 9HS
Tel.: +44 (0) 207 556 3474
E-mail: greg.o'connor@onr.gsi.gov.uk

Prof. Paul N. SMITH
AMEC Foster Wheeler Nuclear UK LTD
Kimmeridge House,
Dorset Green Technology Park,
Winfrith Newburgh
Dorchester, Dorset DT2 8ZB
Tel.: +44 (0) 1305 85 12 14
E-mail: paul.smith3@amecfw.com

Mr Anthony WILSON
Sellafield Ltd
anthony.r.wilson@sellafieldsites.com
B1668 zone 1
Seascale, Cumbria
CA20 1PG
Tel.:
E-mail:

**UNITED STATES OF AMERICA**

Dr John BESS
Idaho National Laboratory
2525 Fremont Avenue
Idaho Falls, ID 83415-3855
Tel.: +1 208 526 4375
E-mail: john.bess@inl.gov

Dr Michaele C. BRADY RAAP
Pacific Northwest National Lab. (PNNL)
902 Battelle Blvd
P.O. Box 999, MSIN K8-34
Richland, WA 99352
Tel.: +1 509 375 3781
E-mail: michaele.bradyraap@pnnl.gov

Dr Forrest BROWN
Los Alamos National Laboratory
P.O. Box 1663, MS A143
Los Alamos, NM 87544
Tel.: +1 505 667 7581
E-mail: fbrown@lanl.gov

Dr Ian C. GAULD
ORNL
Bldg. 6011, MS-6370
P.O. Box 2008
Oak Ridge, TN 37831-6170
Tel.: +1 (865) 574 5257
E-mail: gauldi@ornl.gov

Dr Germina ILAS
Oak Ridge National Laboratory
Post Office Box 2008
Oak Ridge, TN 37831-6172
Tel.: +1 865 241 4672
E-mail: ilasg@ornl.gov

William MARSHALL
Oak Ridge National Laboratory
PO Box 2008
MS6170
Oak Ridge, TN 37831-6170
Tel.: +1 (865) 576 7872
E-mail: marshallwj@ornl.gov

Dr Chris PERFETTI
Radiation Transport and Criticality Group
Nuclear Science and Technology Division
Oak Ridge National Laboratory
P.O. Box 2008, M.S. 6170
Oak Ridge, TN 37831-6170
Tel.: +1 727 698 0647
E-mail: perfetticm@ornl.gov

Dr Meraj RAHIMI
U.S. NRC/NMSS/SFSD
Office of Nuclear Material
Safety & Safeguards
6003 Executive Blvd
Rockville, 20854
Tel.: +1 301 492 3338
E-mail: meraj.rahimi@nrc.gov

Dr Bradley REARDEN
Oak Ridge National Laboratory
Reactor and Nuclear Systems Division
One Bethel Valley Rd. M.S. 6170
Oak Ridge, TN 37831-6170
Tel.: +1 865 574 6085
E-mail: reardenb@ornl.gov

Dr Michael RISING
Los Alamos Natl. Lab
P.O. Box 1663 MS F663
Los Alamos, NM 87545
Tel.: +1 505 667 0758
E-mail: mrising@lanl.gov

**RUSSIA**

Anatoly DUDNIKOV
National Research Center (Kurchatov Institute)
Institute of Nuclear Reactors
Dep. Research of Advanced Reactors
Kurchatov Sq. 1
123182 Moscow
Tel.: +7 495 196 73 77
E-mail: dudnikov_aa@nrcki.ru

Mr Ilya IVANOV
MISRU
Saint-Petersburg

Tel.: +7 812551516
E-mail: isivanov@khlopin.ru

Dr. Boris RIAZANOV
Head of Nuclear Safety Division
Institute for Physics and Power Engineering (IPPE)
Bondarenko Square 1
249020 Obninsk

Tel.: +7 48 43 99 85 90
E-mail: ryazanov@ippe.ru

**INTERNATIONAL ORGANISATIONS**
**OECD Nuclear Energy Agency**

Dr Franco MICHEL-SENDIS
OECD/NEA
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt

Tel.: +33 (0) 1 45 24 10 99

Ms Tatiana Ivanova
OECD/NEA
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt

Tel.: +33 (0) 1 45 24 11 70

Mr Ian Hill
OECD/NEA
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt

Tel.: +33 (0) 1 45 24 10 94