ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

Nuclear Energy Agency
Nuclear Science Committee
Working Party on Nuclear Criticality Safety

THE SIXTEENTH MEETING OF THE WORKING PARTY ON NUCLEAR CRITICALITY SAFETY

Friday 11 October 2013

NEA Headquarters, Issy-les-Moulineaux, France

SUMMARY RECORD

The Working Group on Nuclear Criticality Safety (WPNCS), the Expert Groups on Criticality Excursions Analyses (EGCEA), Assay Data of Spent Nuclear Fuel (EGADSNF) and Burn-up Credit Criticality (EGBUC) met during the week of 7-11 October 2013 at NEA Headquarters.

Exceptionally, two other WPNCS Expert groups, on Uncertainty Analysis for Criticality Safety Assessment (EGUACSA), and on Advanced Monte Carlo Techniques (EGAMCT) held separate meetings on 24-25 October 2013, in Moscow, hosted by the Kurchatov Institute. This was the first time Russia participated as an official delegate to the WPNCS and its EG meetings after Russia's accession to the OECD NEA on January 1st 2013.

1. Introduction & Welcome

The WPNCS chair, Ms. Michaele Brady-Raap (USA) presided over the meeting. **Brady-Raap** opened the meeting and welcomed the participants; those present briefly introduced themselves. Fifteen countries were officially represented by their delegates, with some observers present (see participant list in annex A).

Note : Jim Gulliford, Head of Nuclear Science, had some words to the memory of Richard D. McKnight, who recently passed away. Dick was a long time participant to many activities at the OECD NEA and the WPNCS in particular, and will be remembered by all as great physicist and an extraordinarily kind man. Dick passed away on August 28 2013.

2. Review of actions from previous meeting

There were no outstanding actions to review.

3. Approval of the summary records and agenda

The summary records of the past meeting were approved with minor editorial modifications.

4. Feedback from the Nuclear Science Committee meeting

5. Nuclear Criticality Safety National Programmes and other International Organisations Activities

Before the meeting, delegates were kindly requested to submit a written country report providing an overview of criticality safety related programmes or issues to report from their home countries. Some delegates provided an oral report only and were requested to submit it in written form after the meeting. National Activities Reports at Working Party meetings aim at:

- Provide convenient format for disseminating information on national programmes/incidents/policies.
- Key output is identification of items of common interest for consideration by WPNCS as potential collaborative activities within NSC programmes of work.
- After a first detailed report, the delegate from each country would highlight only significant changes at subsequent meetings.
- Help NEA identify items of common/special interest.

Below are the reports received in written form.

5.1. Belgium (Otonnello, Van den Eynde)

5.1.1. National Context in Belgium

Belgium is still in a phase-out scenario after the government passed legislation in 2003. After reaching a lifetime of 40 years all reactors should be shut down. This limit would be reached by all power plants by 2025. However such a decision is currently under re-evaluation, both for the economic impact it would cause, and for the difficulty of meeting the requirements on CO_2 emissions of the Kyoto Protocols without nuclear power, which currently generates at least 50% of the electricity in many areas of the country.

After finding faults in the reactor pressure vessels of Doel 3 and Tihange 2, these reactors were shut-down. On May 17th, 2013, the Federal Agency for Nuclear Control gave a positive opinion on the restart of those two reactors after evaluation of a number of scientific studies and safety analyses.

5.1.2. Code development

Since 5 years, an isotopic evolution code named ALEPH2 is being developed at SCK•CEN. ALEPH2 is based on a coupling between a stochastic neutronic analysis code and a deterministic time-dependent isotopic evolution code. In its current version, ALEPH2, the code capabilities have been extended to problems where different sources of radiation are present. ALEPH2 has been optimized in particular for:

- Burn-up calculations for different types of reactor cores
- Calculation of structural material activation
- Source term calculations for any system containing radioactive material
- Calculation of activation by spallation neutrons (with applications in Accelerator Driven Systems)
- Analysis of shielding for transport and storage of radioactive waste and radiotherapy installations.

ALEPH works with any modern version of the MCNP/MCNPX family. Its major advantages are:
Nuclear data consistency: the same nuclear data is used for the static calculation (to obtain particle fluxes and spectra) as for the time-dependent evolution calculation. The nuclear data libraries in the ALEPH2 package are available at different nuclide temperatures (for neutron induced reactions) and for different particles (neutrons, protons, photons, alpha particles) based on currently available master libraries like ENDF/B-VII.1, JEFF-3.1.2, JENDL-4.0 and TENDL-2012. Each library is

complemented with nuclear data from the same master library for fission product yields, radioactive decay constants and spontaneous fission data.

Ease of use: the user has only one input file to maintain namely the original MCNP/MCNPX input file with some extra, ALEPH specific, input cards. Typically the user has to indicate which materials should be considered for isotopic evolution, the irradiation history, the cooling down history, … Once launched, the chain of calculations (static calculation to obtain particle fluxes and spectra, evolution of isotopes, update of the materials) is done automatically by the code. A calculation that was stopped can be restarted from the last irradiation step.

Output of one-group cross sections: at each irradiation step, ALEPH2 will generate a set of one-group (spectrum averaged) cross sections. These are made available to the user and can be used for other means (simple back-of-the-envelope calculations).

Applicable for Accelerator Driven Systems: ALEPH is one of few codes that can work in "fixed source mode" and not only in critical mode. This makes it the obvious choice for the analysis of Accelerator Driven Systems and particle accelerators in general.

Stable and precise solving routine for the evolution equations: ALEPH2 uses a solver of type RADAU5, an implicit Runge-Kutta scheme. This guarantees a very accurate solution to the stiff evolution equations. Excellent stability and precision of the results have been shown.

5.1.3. Experiments, facilities, skills/staff requirements

The GUINEVERE (Generation of Uninterrupted Intense Neutrons at the lead Venus Reactor) project was launched in 2006 within the FP6 IP-EUROTRANS programme. During the project the existing zero-power VENUS reactor at the SCK-CEN site in Mol (Belgium) was modified towards VENUS-F, a fast spectrum lead reflected system that can be operated in both critical and subcritical mode. In the latter mode, the reactor is coupled to the GENEPI-3C accelerator, an updated version of the GENEPI-1 machine previously used for the MUSE experiments. Deuterons accelerated to 220 keV hit a Ti-T target in the middle of the core, producing 14 MeV fusion neutrons. The unique GENEPI-3C accelerator is able to work in both pulsed and continuous mode coupled to a subcritical core. Criticality of the VENUS-F core was obtained in February 2011. A reference critical state was characterized which allowed to study well-defined subcritical cores. Current experiments are on-going to validate nuclear data, reaction rates, neutron spectra relevant for the MYRRHA fast spectrum irradiation facility currently under design at SCK•CEN and the Lead Fast Reactor.

5.1.4. Input to NEA (Data Bank)

The MCNP code has always been a key player in the nuclear criticality safety world. With the recent merger between MCNP5 and MCNPX 2.7.0 in MCNP6, licensing has become stricter. Members of OECD countries can no longer apply for the code through the NEA databank in Paris. They have to apply to RSICC which charges a cost recovery fee of approximately $800. This is a reasonable amount for scientists and criticality safety experts employed at NPPs, research centers and regulatory bodies. However, we also need to train the future generation which means that we should be able to give access to this code to students. Paying this cost recovery fee for each student is a too large sum for universities and research centers with large number of students. We would like therefore to ask the NEA Databank to present this position to the United States representatives.

5.2. Czech Republic (Markova)

Tendering process for building of 2 new units of the Czech Temelin NPP (2x1000 MW up to now) will not finish this year as planned. Originally there were 3 tenderee (Westinghouse, MIR-

Czech/Russian consortium, Areva) but Areva was excluded due to breach of some tender requirements. Due to Areva appeal, current development of electricity consumption and prices as well as turbulent discussion on the currently questioned necessity of the new units for the country (AP1000 or VVER-1200 or EPR 1650), the tender becomes longer and the winner (if any) will be chosen only in the end of 2014.

In the Czech Republic, some changes in research organization structure have happened. Nuclear Research Institute at Rez (NRI) was transformed to fulfill industry orders and its daughter company called Research Center is to be focused on the research for the future. New current name of NRI at Rez is UJV Rez, a.s.

5.2.1. Czech R&D Programmes

Large project on the study of properties of the materials for safe disposal of radioactive wastes (2009-2013, supported by the Czech government), inside which also preliminary source determination and criticality control study were developed, is just completing.

Safety analyses assessment of the BUC implementation in the currently used CASTOR 84/M casks for higher enriched new VVER-440 spent fuel with Gd burnable absorber (up to initial enrichment of 4.9 wt.% ^{235}U) and safety analyses of the PBC implementation in the current pools at VVER-440 reactors of DUKOVANY NPP were successfully finished. Not having any assay data for the samples of VVER fuels containing burnable absorber the approach neglecting BA was used in the both implementation analyses.

To assess ^{10}B neutron degradation of VVER-440 pool rack materials an analysis started this year and will continue in 2014 at request of the DUKOVANY NPP owner.

5.2.2. International Collaboration in Czech Republic

Czech experimentalists take part in IRPhEP. As a new contribution within the activity of Technical Review Group for the International Criticality Safety Benchmarks Evaluation Project a new benchmark entitled *VVER Physics Experiments Hexagonal Lattices (1.275 cm Pitch) of Low Enriched UO2 Fuel Assemblies - VVER dosimetry Mock-up* (containing data from VVER-1000 mock-up experiment at LR-0 zero power reactor at Rez) is close to completion.

5.2.3. Future Challenges in Czech Republic

A new project on spent fuel disposal in the Czech Republic related to spent fuel cask design and several other repository issues should be supported by government since 2014.

5.3. Finland (Ranta-aho, Rantamakki)

This report provides a brief update to the national activities presented in the National Activities Report Finland 2012 available in the Summary Record of the Sixteenth Meeting on the Working Party of Nuclear Criticality Safety (NEA/NSC/WPNCS/DOC(2013)6).

5.3.1. National Context in Finland

Teollisuuden Voima Oyj (TVO) received bids on the 31st of January 2013 regarding the new Olkiluoto 4 nuclear power plant unit (1450 - 1750 MWe) to be constructed in Olkiluoto in Finland. The construction licence application will be submitted to the Finnish Government by mid-2015. The construction of the power plant unit can start after the investment decision has been made and the construction licence granted. (www.tvo.fi).

Fennovoima Oy is planning to build a nuclear power plant Hanhikivi 1 in Pyhäjoki in the northern part of Finland. Fennovoima has proposed its owners an investment decision for Rosatom AES-2006 nuclear power plant. According to the schedule agreed with Rosatom, the plant will produce electricity in 2024. Fennovoima's 60 Finnish owners each decide by the end of October for their part if they are continuing in the project. Fennovoima and Rosatom's target is to sign the contract for supplying Hanhikivi 1 power plant unit at the end of the year. Simultaneously the companies will agree upon the detailed project schedule, financing arrangements, and Rosatom's 34 per cent ownership. (www.fennovoima.fi).

Posiva Oy is a company owned by Fortum and TVO and is responsible for the disposal of the nuclear fuel from Loviisa and Olkiluoto power plants. Posiva submitted its Construction Licence Application for a Final Repository for Spent Nuclear Fuel to the Government on the 28th of December 2012. The repository to be built in Olkiluoto has been designed for a total of 9,000 tonnes of uranium fuel to be disposed of from six plant units, which include the four existing units, Olkiluoto 3 currently under construction, and Olkiluoto 4 that is being planned. (www.posiva.fi).

5.3.2. R&D Programmes, code development in Finland

Criticality safety research is carried out in the national research programme SAFIR2014. Current issues include the validation of burnup and criticality calculation codes used for Gd credit and burnup credit.

The criticality safety analysis of the BWR, PWR and VVER-440 disposal canisters in the final disposal facility was submitted to the regulatory authority in the end of 2012. The analysis covered timescales up to 1 million years with various scenarios of degraded fuel and canister. Burnup credit was applied in the analysis.

Posiva has initiated a project for the years 2013-2018 that includes tasks related to:

- improving the validation of burnup and criticality calculation codes with the focus on the criticality safety analysis of the final disposal canisters,
- development of an approved burnup credit criticality safety methodology for the final disposal canisters,
- possible radiochemical assay of the spent fuel from TVO's and Fortum's reactors,
- demonstration of the long-term criticality safety.

Code development is carried out at the research facilities and utilities. On-going projects include:

- LoKriTu for criticality safety analysis of the fuel from Loviisa NPP. LoKriTu is a system built around MCNP and includes sensitivity analysis.
- MCNPLINK for automated Gd credit and burnup credit analysis of PWR and BWR fuel. Recent updates include the extension to MCNP5 1.60 + ENDF/B-VII and enhanced post-processing of the results.
- Serpent continuous-energy Monte Carlo code.

TVO is developing a methodology for using reactor cold critical measurements for combined validation approach of the burnup credit and Gd credit criticality safety analysis of BWR fuel. A tool for generating benchmark calculation input from the critical experiments for CASMO-4E/MCNP5 has been developed. The same tool can be used for the burnup credit analysis of arbitrary rack or canister geometry.

5.4. France (Santamarina)

The build-up of the French EPR (1600MWe) is going on at Flamanville plant : the dome (260 tons) was set above the reactor containment on july 2013. Concerning ASTRID design (French GEN-IV-

SFR industrial demonstrator 600MWe), the CFV heterogeneous core is chosen that allows negative Na void worth. JEFF3.1.1 library is used by CEA, EdF, AREVA in French Reactor Physics codes (APOLLO2 and ERANOS) and Criticality-Safety code CRISTAL.V2. This library is also implemented in the international package ARCADIA of AREVA.

5.4.1. French R&D Programmes

The implementation of Burnup Credit for MOX assemblies in CRISTAL.V2/JEFF3.1.1 safety-criticality calculations is achieved, using Isotopic Correction Factors from French MOX P.I.Es and separated-FP oscillations in the Minerve MOX lattice (see NCSD2013 paper). The improvement of the RIB automated tool (assessment of calculation bias and uncertainty) is pursued. A test version of TRIPOLI4 including the IFP method is available. 3D continuous-energy adjoint fluxes are computed (MC adjoint fluxes were validated against accurate deterministic transport calculations). Small reactivity worth, such as the one in MINERVE and DIMPLE measurements, can be accurately calculated using Exact Perturbation Theory. Sensitivity profiles are also calculated using 1^{rst} order perturbations.

Covariances associated with the JEFF3.1.1 evaluations of ^{149}Sm, ^{103}Rh and ^{155}Gd were estimated using separated-FP worth measurement. These covariance matrices are introduced in the CEA covariance library and in the RIB code.

The MAESTRO experiment in MINERVE devoted to structural materials. Oscillations of various elements were performed in a LWR-type spectrum. The JEFF3.1.1 analysis of the measured reactivity worth has shown that the capture cross-sections of Mn, Co, V and Rh are satisfactory (within 1.8% experimental uncertainty)

After the current FLUOLE2 experiment in EOLE devoted to the study of neutronics damage to the PWR vessel, the design of the EGERIE experiment dedicated to GEN3 EPR reactor is completed.

5.4.2. International Collaborations

Collaboration with ORNL and JEFF Group, as well as the CIELO project, to improve nuclear data.
Contribution to the OECD Database, particularly FP integral data measured in MINERVE within the French/UK CERES programme (IRPhE benchmark)

5.4.3. Future Challenges

Completion of covariance matrices (Actinides & FPs) associated with JEFF3.1.1 evaluations.
Edition in December-2013 of the BUC-PhaseVIII intermediate Report (Exercise 1 and 2)
Completion in 2014 of the IRPh evaluation of the CERES-Minerve experiment (separated FPs oscillation).

After the recent agreement by German safety authorities GRS of the French BUC approach in the TN24-E cask, total-BUC application should be extended to French facilities.

5.4.4. Input to/from NEA/NSC Programmes of Work

Realistic correlations are needed in ICSBEP experiments, particularly for LCT benchmarks. Importance of UACSA Phase-IV exercise to highlight the effect of integral experiment correlations. This exercise would also increase the reliability of codes such as TSURFER and RIB to derive bias and bias uncertainty. Blind benchmark on Bias and bias Uncertainty, and new UACSA exercise on MOX wet powders should be settled.

5.5. Germany (Kilger)

5.5.1. Overview of National Context in Germany

In terms of final disposal of heat generating radioactive waste including spent nuclear fuel, in July 2013 a new Repository Site Selection Act came into force in Germany, in order to restart a country-wide, consensual and open-ended site search without preselecting. The up to then preferably investigated salt dome at Gorleben is now equal to any other potential site. The preliminary safety case study for the Gorleben site has finished but did not conclude in terms of a positive or negative acceptability statement for the site, or for a salt dome in general.

Nevertheless, the German ”Safety Requirements Governing the Final Disposal of Heat-Generating Radioactive Waste” still stipulate exclusion of criticality for the whole reference period of one million years. Further site-independent studies on this issue are planned both for saline and non-saline host formations, currently not focused to burn-up credit due to the accompanied difficulties in practical application.

5.5.2. R&D Programmes in Germany: Code Development

At GRS, the development of the new, improved and modernized version of KENOREST is ongoing. Regarding the development of a new, advanced inventory code, close cooperation of GRS with Paul Scherrer Institute (PSI), Switzerland, is performed.

The extension of the SUnCISTT package for uncertainty and sensitivity analysis is also being continued. The primary development goal of the SUnCISTT approach to perform uncertainty analyses in burn-up credit scenarios based on Monte Carlo sampling techniques is near completion. It now comprises inclusion of axial burn-up profiles, with an integrated inventory determination and subsequent criticality calculation route. Sampling on parameters relevant for the inventory and for the resulting multiplication factor in any model is featured within one single calculation path. Due to the modular design of the SUnCISTT, any burn-up code and any criticality code are easily implementable into the overall approach. It now also includes the capability to determine bias contributions resulting from correlated benchmark experiments and experiment series. The next major application of this toolset will be extensive burn-up credit parameter studies on irradiated BWR fuel, in order to evaluate the potential for a justifiable qualification and validation of a burn-up and criticality code system for application to BWR fuels in practice.

AREVA Offenbach / Erlangen: 3 year R&D project (2013 – 2015) on Uncertainty Analysis and Uncertainty Propagation in Nuclear Design Systems:

Target of this R&D project is to acquire the competency to consistently and completely propagate the impact of the uncertainties of all the input parameters required to perform nuclear core design and safety analysis and to include the validation results obtained for the applied design and safety calculation codes on the results of nuclear design and safety analysis calculations. The project shall result in the ability to investigate the propagation of uncertainties within the ARCADIA system, AREVA’s future code system for nuclear design and safety analysis.

In the framework of this R&D project, a code system shall be developed which includes Monte Carlo sampling and Bayesian updating algorithms. This code system shall be capable of propagating nuclear data covariance information, information from the evaluation of integral experiments and system parameter uncertainties into probabilistic confidence statements for the physical quantities of interest, e.g., for the power distribution within a nuclear reactor.

5.6. Italy (Burn)

5.6.1. General context in Italy

By 2011 plans were underway to restart the programme of nuclear energy production in Italy by firstly ordering four EPR's from AREVA. A nationwide referendum had been organized for June 2011 with the objective of repealing (or not) legislation allowing for the production of nuclear power. (This referendum had already been organized before the Fukushima accident following the tsunami of the 11th March that year.) The referendum rejected the use of nuclear power and as a consequence the planned nuclear power plants were cancelled. The current status of nuclear power in Italy is that it has been discontinued.

Four nuclear power plants (Garigliano, Latina, Trino, Caorso) were operated until the middle of the 1980's. They are at present being decommissioned. The spent fuel and most of the radioactive waste to be dealt with in Italy derives from the operation of these NPP's and from a small number of fuel cycle facilities. The transfer of the spent fuel from these plants to France (or to the U.K. in the case of Latina) for reprocessing has nearly been completed. (Under an agreement with the U.K., some MAGNOX spent fuel was sent to Sellafield from the AVOGADRO spent fuel storage facility in the first years of this century.) The reprocessed fuel must be shipped back to Italy from France and the U.K. by the end of 2025.
At present little spent fuel – just a few tons – coming from Italian NPP operation is currently stored at the TRINO NPP and at the Avogadro AFR facility. There remain some spent fuel assemblies from the US Elk River reactor (U-Th cycle), employed in a pilot reprocessing scheme in the 1970's, which are stored at one of the fuel cycle facilities. [Of the three research reactors operating in Italy, two (at ENEA Casaccia and at the University of Pavia) store spent fuel on site.]

The national site to accommodate the nuclear waste is being designed as a LLW near-surface disposal facility and an Interim Storage for ILW and HLW returned from reprocessing. The siting procedure, which is regulated by the Legislative Decree 31/2010 and subsequent modifications, is at initial stage (a site has not yet been selected). These preliminary steps are governed by the technical siting criteria applied by ISPRA, the National Nuclear Regulatory Authority. A Technical Guide establishing such criteria will soon be issued by ISPRA. On the basis of these criteria, SOGIN SpA, the project executor, will propose a list of potential sites complying with the established criteria.

5.6.2. Code development in Italy

In the last year, ongoing development in Monte Carlo algorithms at ENEA has changed focus from fixed source to criticality problems. It is hoped that this may find application in calculating local responses situated within, or outside, sub-critical arrays of fissile material.

5.7. Japan (Miyoshi)

Overview of National Context

Utilization of nuclear energy has been the main energy strategy of Japan from 1950's. After the severe accident occurred at the Fukushima Daiichi nuclear power station following the 2011 off the Pacific coast of Tohoku Earthquake, the public opinion is leaning toward opposition to nuclear power in Japan. From 2011, the government of Japan (GOJ) has started the reconstruction of its energy strategy. It is expected that the share of the nuclear in the total electricity supply in Japan will be decreased drastically. Industry sector opposites to decrease in the nuclear energy because it will increase the electricity cost.

Industry Requirements (skills capability, training, etc.)

Because of the severe accident at Fukushima, almost all research and development activities had been focused on the countermeasure to the Fukushima accident. Criticality safety is one of the main topics in such activities. But if the reprocessing project is stopped, direct disposal should be considered. For this idea, few ministries have plans to setup research activities on the direct disposal. In order to

develop technologies for recovering Fukushima pants, JAEA has newly formed three Fukushima Project Teams in Tokai and Oarai research centers. The Fukushima Project Team and Department of Fukushima Technology Development in Tokai center will promote research on nuclear criticality safety.

R&D Programmes, Code development

There are several code development activities going on in JAEA;

- SRAC and MOSRA (deterministic neutron transport)
- MVP (Monte Carlo code for vector/parallel processor)
- SWAT (burnup codes; SRAC/MVP/MCNP + ORIGEN2.2)
- PHITS (particle transport)
- AGNES and DOCTORIN (kinetics of transient behavior)

Nuclear reactor vendors and fuel suppliers develop own neutronic codes.

After the severe accident at Fukushima, operation of the research reactors (including critical assemblies) in JAEA has been stopped. JAEA is conducting integrity inspection and seismic resistant evaluation of the research reactors. JAEA hope to start reactor operation in FY2012 to FY2013. But the schedule may change depending on revision of the safety standard.

Post irradiation examination to obtain the assay data of spent nuclear fuel had been carried out in JAEA for BWR fuel assembly during FY2010 to FY2011 under the contract with JNES. From FY2012, further PIE is planned for BWR and PWR fuels for fostering the ability to measure the isotopic composition data for Fukushima.

Criticality data for fuel debris (melted/broken fuel system) is required. JAEA has a plan to carry out mockup experiments in revised STACY. STACY in JAEA-Tokai is a tank-type, solution system critical assembly. In order to utilize it for various reactor physics experiments including the fuel debris criticality problem, STRACY will be modified and re-criticality in FY2016 is planned. For simulating the neutronic characteristics in core vessel, FCA (Fast Critical assembly) will be used to mockup fuel debris condition with solid fuel and structural material. Development of sub-criticality monitoring system during treatment of mixture of fuel and constructional material will be important for criticality safety control.

Challenges

Criticality safety data and methods for treating fuel debris in Fukushima site is our challenge. Because of Fukushima accident, direct disposal of spent fuel will be considered in future. In this case, criticality safety issue will be studied.

5.8. Slovakia (Chrapciak)

Updates on Slovakian national context are as follows

Government Policies:

- not decided back end of fuel cycle (“wait and see” policy)
- the work on final depository was stopped several years ago
- new atomic law was issued in May 2013. The owner and operator of spent fuel storage is only state organization (100%) and NPP must transfer spent fuel to this state organization.
- new safety reports for transport cask C-30 with basket KZ-48 and ISFSF in Jaslovske Bohunice for fuel 3.82%, 3.84% and 4.25% was issued by March 2013, licensing process will finish by March 2014

Operating Issues:

- new safety analyses for transport cask C-30 with basket KZ-48 and ISFSF in Jaslovske Bohunice for fuel 4.87% is in progress (finished by February 2014)

5.8.1. R&D Programmes in Slovakia

Concerning codes, most widely used codes in Slovakia are SCALE 6, SCALE 6.1.2, MCNP5, MCNP-X. For Experiments, Facilities, Skills/Staff requirements, the inspection stand in ISFSF in Jaslovske Bohunice is in construction, some parts are in operation (gamma spectrometric measurement, TV monitoring). As for experimental needs, the measurement of decay heat of fuel in transport cask is in progress (methodology was already developed).

5.8.2. International Collaborations in Slovakia

- IAEA: participation on Dual Purpose Cask Safety Case (report of WASSC/TRANSSC joint working group 2011 - 2013)
- OECD/NEA/WPNCS participation
- AER (Atomic Energy Research): working group "Physical problems of Spent Fuel and Decommissioning"

5.8.3. Future Challenges

Urgent need for a new cask for a new fuel with higher enrichment and burn up. 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).

Urgent need for a new storage facility, because existing wet ISFSF in Jaslovské Bohunice wil be full in year 2023. Intention is dry storage for old fuel with low enrichment, low burnup and long cooling time, commissioning in 2019-2020.

5.8.4. Input to/from NEA/NSC Programmes of Work

Items to be discussed in WPNCS Expert Groups are criticality analyses of reactor/at reactor pools by losing of coolant.

5.9. Spain (Conde, Ortego)

In Spain, US regulatory approach is followed, with some specific national guidelines collected in CSN safety instructions:

- Nuclear Safety Council Instruction number IS-20, of January 28th 2009, establishing safety requirements relating to spent fuel storage casks.
- Nuclear Safety Council Instruction IS-26, of 16th June 2010, on basic nuclear safety requirements applicable to nuclear installations.
- Nuclear Safety Council's Instruction IS-27, of 16th June 2010, on general nuclear power plant design criteria.
- Nuclear Safety Council's Instruction IS-29, of 13th October 2010, on safety criteria at spent fuel and high-level radioactive waste storage facilities

Additionally, two standards specific to criticality control have been issued:

- UNE 73501 – Criticality Requirements in the design of fuel storage racks

- UNE 21725 – Warning equipment for criticality accidents

Over the last year, no safety significant event or unusual occurrence has been reported regarding NCS.

A new on-site Interim Spent Fuel Storage Installation has been licensed in 2013 in Ascó NPP (two units Westinghouse-PWR 17x17 fuel design plant: Unit-I 1032 Mwe, 1982; Unit-II 1027,2 Mwe, 1985) whose spent fuel pool capacity is about to be over, allowing the storage of up to 16 casks. A canister-type multipurpose system (HI-STORM 100 for dry storage and HI-STAR 100 for transportation designed by Holtec-USA) has been selected for this installation. Burnup credit is taken for the transportation safety case, assuming major actinides plus a number of fission products, while credit is given to the boron concentration in the Spent Fuel Pool in the storage safety case. The main evaluation issues regarding NCS are those related to BUC methodology, arising from the definition of conservative assumptions for the depletion calculations, essentially axial power profiles. Two casks (12,5% of the storage capacity), 32 FAs each, were loaded during this year.

The evaluation of the application for a Spanish design dual purpose cask for 16x16 and 17x17 PWR spent fuel is ongoing. A single safety case supports both dry storage and transportation, with burnup credit implemented only for major actinides.

A new application for a Spanish design dual purpose cask for 8x8 BWR fuel, and for the corresponding ISFSI of Garoña NPP (BWR-3 reactor, 466 Mwe, 1970), has been received in CSN. It will be the first interim spent fuel storage facility licensing process for BWR fuel in Spain. In the first stage of this application, for a number of high cooling time FAs, no credit is taken from burnup, either from Gadolinium.

The Integrated Safety Analysis (ISA) required to the Juzbado Fuel Fabrication Facility (1985, manufactures PWR, BWR and VVER fuel assemblies starting from UO2 powder, no conversion process) has been completed. As a result of the analysis, design modifications and controls (administrative, engineering) to decrease the potential risks (mainly criticality-related) of the sequences analyzed, and to increase the safety margins in the facility operation, are being implemented.

5.9.1. R&D in Spain

An important research effort is being performed to obtain spent fuel experimental isotopic composition data for BUC code validation, in the range of enrichment and burnup actually operated in Spanish reactors. Up to now, two experimental projects, both performed at the Studsvik Labs, have been completed:

PWR project (2002-2008): 9 samples, fuel rods from 17x17W fuel, manufactured by Enusa and operated in Vandellos II reactor, with initial enrichment of 4.5% and burnup range 64-78 MWd/kgU. Results provided to SFCOMPO.

BWR project (2009-2012): 8 samples, fuel rods from GE14 fuel, manufactured by Enusa and operated in Forsmark 3 swedish reactor, with initial enrichment of 3.95% and burnup range 39-53 MWd/kgU.

Consistent with the application and understanding of these experimental results, a project with the Polytechnic University of Madrid is ongoing aiming to the development and validation of BUC methodologies, with implementation of an in-house developed methodology coupling neutronic anf thermalhydraulic calculations. Within this framework, comprehensive analysis on uncertainty and reactivity calculations data sensitivity are being performed.

Finally, a number of projects devoted to the evaluation of SFCOMPO experimental data are being developed (EGADSNF presentations) performed by SEA and sponsored by CSN:

4 Samples (BM1, DM1, FFBU, F3F6) from ARIANE and Forsmark-3 projects evaluated through direct collaboration with EGADSNF (2009-2011)

A new 4 years project (2012-2016), in collaboration with Enresa, is on-going for the evaluation of 11 samples: GU3, DU1, BM5 and GU1 from ARIANE, M11 from REBUS and GGU1 and GGU2 from MALIBU. 2 samples evaluated (DU1, M11) and a third one ongoing (GU3)

Main concerns and gaps identified are related to BWR fuel NCS data and methodologies, where there is lack of data and experience for BUC applications.

5.9.2. International Collaborations in Spain

Long-term collaboration with ORNL regarding analytical work supporting all of the above described research programmes. Recently, this collaboration is mainly focused in BWR fuel understanding of 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). Task on "Operational and Regulatory Aspects of Criticality Safety" ongoing.

5.9.3. Future Challenges in Spain

Besides the above mentioned lack of experience and knowledge related to BWR fuel, the licensing of a single Centralized Interim Spent Fuel Storage (ATC) will be shortly undertaken. In December 2011 the Government announced the decision to build the ATC to provide safe interim dry storage for spent fuel from Spanish nuclear power plants in Villar de Cañas. Up to now, only a conceptual design of the installation has been assessed, discussed and approved by the CSN. The Generic Safety Analysis Report, with implementation of French and US regulations and guidelines, describes the use of a Dry Vault type Storage System, with spent fuel and HLW encapsulated in SS welded canisters and loaded inside storage wells to provide a double barrier, in inert atmosphere (Argon or Nitrogen) and natural convection cooling. The project is ongoing and the main engineering companies have already been selected. A Research Center is also planned to support the operation of the ATC. The installation is expected to be operational in 2018.

5.10. Switzerland (Vasiliev)

5.10.1. National Context in Switzerland

No changes to report since the past meeting in 2012.

5.10.2. R&D Programmes in Switzerland

Basically no changes since the past year. The methodology for Criticality Safety Evaluation (CSE) including Burnup Credit is continuously under development at PSI with support from the Swiss industry through swiss*nuclear*, which is the Nuclear Energy section of the swiss*electric* organization. In parallel, R&D on criticality safety and burnup credit aspects specific to the final geological depository is ongoing at PSI in collaboration with NAGRA (an organization formed by nuclear utilities and the federal government and responsible for investigations for geological disposal of radioactive wastes in Switzerland and a member of swiss*nuclear*).

One of the major current objectives at PSI in the field of CSE is to pursue the development of computation tools for the assessment of relevant uncertainties in routine criticality calculations with

the Monte Carlo code MCNPX and general-purpose neutron data libraries. Namely, the statistical sampling tools for propagation of uncertainties on the nuclear data and on the technological parameters are under development. In addition to the above, works towards assessing the methodological uncertainties and uncertainties in the decay data and fission products yields in the depletion calculations are on-going.

CASMO-5 code, which at PSI belongs to the suite of tools employed in BUC calculation methodology, is also currently being validated against the LWR-PROTEUS Phase II experiments (i.e. reactivity worth and isotopic compositions of LWR spent fuel samples). A mean to assess with CASMO-5 the representativity of LWR-PROTEUS experiments to NPP applications and estimate the uncertainty due to cross-sections and manufacturing tolerance in the calculation-to-experiments comparison is also under development.

Status of Proteus facility: The facility is in the post-operation phase transitioning to decommissioning. The decommissioning plan has been submitted to the relevant authorities and is under assessment.

5.10.3. International Collaborations in Switzerland

In the frame of collaboration between PSI and IRSN, the IRSN code VESTA was received by PSI and by now has passed some assessment studies using the PIE data available at PSI. More extensive validation studies for the MC-based fuel depletion methods and tools including cooperation with IRSN on the VESTA code assessment are foreseen.

In the frame of collaboration between PSI and NRG, the PSI's tool NUSS (Nuclear data Uncertainty Stochastic Sampling) for nuclear data uncertainties propagation was assessed against the NRG TMC method. For the time being, only two 'simple' fast benchmark experiments have been analyzed (Jezebel and Godiva). The study was presented at the ND-2013 conference. Continuation of the collaboration is foreseen.

Collaboration with GRS is foreseen on the uncertainty propagation topics for criticality and depletion calculations, in particular towards inter-comparison between the XSUSA and NUSS tools.

Regarding the WPNCS activities:

- EG BUC: PSI has provided contributions to the Phase III-C benchmark with the codes CASMO-5 and MCNPX-2.7.0
- EG UACSA: In 2012, the Benchmark Phase-II, (tasks 1and 2) was analyzed using MCNPX-2.7.E code in combination with a statistical sampling method based on SUSA software (GRS/Germany). Recently, additional studies have been done for this benchmark with other sampling tools (pstudy/LANL and URANIE/CEA). Results are planned to be reported to the UACSA EG at the forthcoming meeting.
- EG AMCT: PSI will primary continue assessment of advanced MC-based depletion methodologies.

5.11. UK (O'Connor)

5.11.1. Government Policies (related to issues discussed)

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), with the first reactors expected to be operational by the end of the decade. 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 plant. Preliminary work for Hinkley Point C is currently underway. Peak construction activity was scheduled for 2014-16 for completion in 2018 but EDF Energy is currently adjusting its timetable as agreement must first be reached on the price that the generated electricity can be sold. Once this occurs, EDF Energy has plans to build four reactors at Hinkley Point and Sizewell.

Three reactor designs are 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). Areva's EPR and Westinghouse's AP1000 reactor have undergone a generic design assessment (GDA) by the Office for Nuclear Regulation (ONR) and have been granted interim acceptance. There are still outstanding issues with these designs; Westinghouse do not intend to address their issues until a customer for the AP1000 has been secured. The GDA for Hitachi's ABWR commenced this year and is expected to take a number of years to complete.

Horizon Nuclear Power, was purchased by Hitachi-GE Nuclear Energy Ltd is planning to provide at least 5.2GW of new nuclear capacity to the UK.

NuGeneration, a joint venture between Iberdrola and GDF Suez, is intending to build 3.6GW of new capacity. A reactor design has not yet been selected; final decision is expected around 2015 with a view to starting production in 2023.

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 up front 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.

5.11.2. 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.

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

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

The UK Working Party on Criticality (WPC) has been working with the Nuclear Industry Fire Safety Coordinating Committee (NIFSCC) in order to produce a more holistic ALARP approach in the provision of fire fighting advice.

5.11.4. R&D Programmes in UK

5.11.4.1. Code development

The MONK neutronics code is currently the UK industry standard however there is increasing interest in other codes such as MCNP.

The latest version of MONK is 9A. This code is developed by the ANSWERS software service, currently part of AMEC (used to be SERCO).

MONK10A will be available from the end of the year. The BINGO continuous energy nuclear data libraries based on JEFF3.1, ENDF/B-VII and CENDL3.1 have been produced and are being used with the MONK verification and validation test sets.

Development versions of MONK include a CAD (computer aided design) import capability as well as the ability to parallel process burnup calculations. This novel parallelization method is based around the use of distributed computing elements.

The graphical visualization program, Visual Workshop, used with MONK allows the user to view their input models in 3D (with the use of 3D goggles). The program can also be used to view the location of the neutron action events that occurred in the system to produce the final value of k_{eff}.

Sellafield Ltd, previously British Nuclear Fuels Plc (BNFL), is in possession of the source code and intend to develop MONK separately to ANSWERS.

5.11.4.2. Experiments, Facilities, Skills/Staff requirements

There is a large amount of old experimental data at various UK sites, for example Dounreay. UK funding is required to write up this information; although some is being written up on a best endeavours basis.

5.11.5. International Collaborations in the UK

ISO standard on waste [from a criticality perspective], the IAEA guide on criticality safety, ICSBEP (International Criticality Safety Benchmark Evaluation Project), JEFF (Joint Evaluated Fission and Fusion) Scientific Co-ordination Group, IRPhE (International Reactor Physics Benchmark Experiments), various ANS Nuclear Criticality Safety Division committees / ANS.8 standard committees and various OECD/NEA expert groups the Working Party on Nuclear Criticality Safety (WPNCS).

Time and money issues are impacting on the UK nuclear industry to get involved in various international activities. We are aware that there is insufficient coverage of various OECD/NEA and ANS standards committees. There is also inadequate UK funding to appropriately support nuclear data activities such as ICSBEP. The UK Nuclear Science Forum used to monitor and interface with related international activities but is now no longer meeting, possibly due to lack of funding. There are concerns that this will impact on the UK's ability to both submit and receive information in this area.

5.11.6. Future Challenges in the UK

- Development activities within the field of criticality and sharing information / best practice has deteriorated over the last few years. Namely due to fragmentation of the site licensing companies, increased commercial pressures, increased focus on intellectual property rights and the closure of various industry bodies.
- UK funding is needed to support various international activities and to write up old experimental data.

- Due to the anticipated new nuclear build, the current skills capability of the UK will also need to be increased.
- UK funding for the NEA Data Bank has been secured for another year. However, there is no current certainty beyond then.
- Another major challenge currently facing the UK nuclear industry is the criticality safety assessment of fissile wastes and the development of a strategy for packaging, long term storage, transport and ultimate disposal of fissile waste material. Traditional methods of assessing fissile wastes have resulted in pessimistically low fissile mass limits for transport packages. Several pieces of work have been performed in order to produce a consistent UK approach for the derivation of appropriate fissile waste package limits. The aim of this is to relax some of the fissile limits while allowing an acceptable criticality safety case to be made. The benefit will be that there will be fewer package movements which will lead to a reduced conventional as well as radiological risk in addition to considerable cost savings. A risk based methodology will be used and this is likely to be a key area for capability development in criticality safety assessment in the UK over the next few years.
- Approval for the GDF (Geological Disposal Facility) safety case is ongoing. The operation of such a facility is still considered to be a number of decades in the future.

6. Reports from the WPNCS Expert Groups

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

6.1. Expert Group on Burn-up Credit (EGBUC)

Brady-Raap reported on progress on the EG:

- Phase VIII benchmark (on *reactivity worth calculations / analysis of small-sample reactivity experiments*) is nearing completion. Results from all sub-phases have been received and the final report is expected at the next EG meeting, in 2014.
- Results for Phase IIIC benchmark on *Nuclide Composition and Neutron Multiplication Factor of BWR Spent Fuel for Burn-up Credit and Criticality Control of Damaged Nuclear Fuel* have been received and presented. Report is nearing completion and will be ready by the next EG meeting.
- Final Phase II-E report on *the Impact of Changes in the Isotopic Inventory due to Control Rod Insertions in PWR UO_2 Fuel Assemblies* has been received.
- The Summary Report on the findings of the Expert Group on Burn-up Credit is still pending. The EG has discussed the complexity of reaching and validating general conclusions due to the specifics of the systems discussed. A complementary Handbook on PWR Burn-up Credit methodologies as applied to PWRs is being prepared. The compilation work of this Handbook has been undertaken by a graduate student of the University of Florida under the guidance of key participants of the EG.

A discussion on the future of this EG was held. The Chair of the WPNCS and the EGBUC, Mikey Brady-Raap, discussed the possibility of having the Expert Group on Burn-up Credit change or broaden its focus after more than twenty years of existence. The EG still has pending deliverables. In this context, a draft proposal for modifications to the mandate has been circulated internally and discussed by key participants. The EG concluded that modifications to the mandate must be motivated by new activities proposals. This will be re-discussed at the next meeting once new activity proposals are received. If no new activity proposals are received, it was understood the group should close down after producing its currently pending deliverables.

O'Connor highlights that the new direction of this or a potential follow-up EG should come from industry, clearly addressing industry needs. **Ranta-aho** also agrees with this statement and points out

BWR burnup credit is one of the aspects the EG should be looking at. One methodology may not be applicable to BWR fuels (assay data and criticality for instance) and other aspects (reactor physics and dedicated reactor experiments) may be needed to validate BWR fuels. In this context, the Handbook of Burnup credit Criticality should be expanded to include BWR aspects.

6.2. Expert Group on Assay Data for Spent Nuclear Fuel (EGADSNF)

Michel-Sendis presented apologies for absence on behalf of I. Gauld and reported on progress on the EG.

- The Guidance Report on the Evaluation of Assay Data was discussed and is nearing completion. Substantial changes have now allowed consensus among EG participants and the report is expected to be published in 2014.
- The SFCOMPO 2.0 prototype has been developed by the Data Bank. The new SFCOMPO database more than doubles the amount of assay data sets as compared to the first version. The capture of publicly available experimental assay data continues with strong support from ORNL and the final objective is to triple the amount of isotopic assay data with a larger spectrum of reactor types (data from 42 reactors compared to data from 14 reactors initially) This new database has not yet been released to the public but only internally at the EG-ADSNF level. Review of data will continue by the EG; and further development of the tool is expected. Once this internal review process is finished, the new SFCOMPO is expected to be released in 2014.

6.3. Expert Group on Criticality Excursions (EGCEA)

Miyoshi reported on progress on the EG Analysis of the Phase II benchmark exercise on slow transient experiments at TRACY and SILENE reactors is now nearly complete and the final report is expected. A proposal for a study on dilute Pu solutions with positive reactivity feedback coefficients will be presented at the next meeting.

6.4. Expert Group on Uncertainty analyses for Criticality Safety Assessment

Ivanova reported on progress on the EG The latest meeting of the Expert Group was exceptionally held in Moscow, hosted by the Kurchatov Institute on October 24, 2013.

- The first part of the State-of-the-art report is ready for publication.
- A new Phase IV Benchmark on establishment of correlations in experimental uncertainties was proposed. Different approaches on this exercise were discussed, specifically the mathematical terminology used was subject of numerous discussions within the EG. The final specifications are expected by the end of 2013.
- A new blind benchmark aimed at providing a more realistic test of consistency of various methods was proposed by CEA.

6.5. Expert Group on Advanced Monte Carlo Methods (EGAMCT)

Miss reported on progress on the EG The latest meeting of the Expert Group was exceptionally held in Moscow, hosted by the Kurchatov Institute on October 25, 2013.

Preliminary results of the Phase I benchmark on *Quantifying the Effect of Under-sampling Biases in Monte Carlo Reaction Rate Tallies* were reviewed. The group discussed the results which show the non-convergence of the reaction rates tallies in the exercise proposed. A simplification of the specifications was suggested before proceeding further, which should be received by the end of 2013.

6.6. International Criticality Safety Benchmark Evaluation Project

Briggs briefly reported on the annual *Technical Review Group for the International Criticality Safety Benchmarks Evaluation Project* meeting held in Paris in May 2013, and went through new additions to the 2013 Handbook.

7. Status of ICNC-2015.

Brady-Raap announced the USA will be hosting the next edition of the International Conference on Nuclear Criticality (ICNC-2015) in September 2015 with the location being confirmed in Charlotte, North Carolina. More information on registration will be made available in due course by the organizing committee of ICNC2015.

8. Any Other Business and Date of Next Meeting

The possibility of holding the WPNCS 2014 meetings in conjunction with PHYSOR 2014 in Kyoto, Japan was presented to the committee by Suyama. Holding a full week of meetings after a week-long conference abroad seemed unrealistic mainly for budget and travelling reasons for many participants, but the idea of holding one or two EG meetings in conjunction with Physor-2014 was in principle accepted, however a clear proposal is expected from Japan by the end of 2013.

The next meetings of the WPNCS and associated Expert Groups will take place in September 2014, at NEA, with a possibility to hold some EG meetings in conjunction with PHYSOR 2014 currently being discussed. Exact dates and venues will be announced in due course to participant and through the webpage www.oecd-nea.org/science/wpncs/nextmeeting/

With no other business to discuss, the meeting was adjourned.

List of Actions

1. Action on all delegates - To confirm with NEA the name of official representatives of each member country.

2. Action on all delegates- To submit to NEA if not already done the written National Report for inclusion in the minutes.

ANNEX A
ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT
Nuclear Energy Agency
Nuclear Science Committee

17th Meeting of the Working Party on Nuclear Criticality Safety

NEA Headquarters, Issy-les-Moulineaux
Room B

Friday October 11 2013, 9:00 – 18:00

PROPOSED AGENDA:

1. Welcome and administrative items- *M. Brady-Raap*

2. Review of actions from the previous meetings – *Secretariat*

3. Approval of the summary records of the previous meeting- *All*

4. Feedback from the Nuclear Science Committee Meeting- *J. Gulliford*

5. Nuclear Criticality Safety National Programmes -*All*

6. Reports from the WPNCS Expert Groups :

Advanced Monte Carlo Techniques Expert Group (EGAMCT) – J. Miss (TBC)

Burnup Credit Criticality Expert Group (EGBUC)- M. Brady-Raap

Assay Data for Spent Nuclear Fuel Expert Group (EGADSNF)- I.Gauld

Uncertainty Analyses for Criticality Safety Assessment (EGUACSA)- T. Ivanova

Criticality Excursions Analyses Expert Group (EGCEA) – Y. Miyoshi

International Criticality Safety Benchmark Evaluation Project (ICSBEP) – B. Briggs

8. Status of ICNC 2015- *M. Brady-Raap*

9. Any other business - *All*

10. Date and place of the next meeting - *Secretariat*

11. Adjourn

ANNEX B

WPNCS (Working Party on Nuclear Criticality Safety – Official Delegates present at the 2013 WPNCS meeting.

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