OECD Nuclear Energy Agency NEA

NC STATE UNIVERSITY

Department of NUCLEAR ENGINEERING

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Seventeenth OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark Workshop (LWR-UAM-17)

Lucca, Italy
Wednesday, May 22, 2024
In conjunction with the BEPU 2024 Conference

Hosted by N.IN.E. (Nuclear and Industrial Engineering), Italy

Announcement and Proposed Programme

Background and Purpose of 17th LWR-UAM Benchmark Workshop

The seventeen Light Water Reactor (LWR) Uncertainty Analysis in Modeling (UAM) Benchmark Meeting (LWR-UAM) – LWR-UAM-17 - will be held on May 22, 2024 (track 1), in in Lucca, Italy and is a follow up to the previous workshop. The LWR-UAM-17 meeting will be held in conjunction with the 2024 Best-Estimate Plus Uncertainty (BEPU-2024) international conference as well as with other OECD/NEA Working Party on scientific issues and uncertainty of Reactor Systems (WPRS) meetings/workshops to facilitate co-ordination and sharing of work. The other meetings are being held in three parallel tracks at Lucca, Italy during the same week in order to combine efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis and to make the participation more efficient. The meetings/workshops concerned are:

- *May 19, 2024 (morning)* – COBRA-TF (CTF)-10 a Hands-on Training Session
- *May 19, 2024 (afternoon)* – CTF-10 User Group (UG) Meeting
- *May 20, 2024 (track 1 morning)* – Third OECD/NEA Lead Fast Reactor (LFR) benchmark (LFR-3) workshop – LFR Thermal-Hydraulic (T/H) Stage
- *May 20, 2024 (track 2 morning)* - Third OECD/NEA Fluoride High Temperature (FHR) Reactor Benchmark (FHR-3) workshop
- *May 20, 2024 (track 1 afternoon)* – Third OECD/NEA Lead Fast Reactor (LFR) benchmark (LFR-3) workshop – LFR Neutronics Stage
- *May 20, 2024 (track 2 afternoon)* – Sixth OECD/NEA Rostov-2 VVER-1000 Multi-Physics Transient Benchmark (Rostov2-6*)* workshop
- *May 21, 2024 (track 1)* - Ninth OECD/NEA Sodium Fast Reactor (SFR) UAM Benchmark workshop (SFR-UAM-9)
- *May 21, 2024 (track 2 morning)* - Ninth OECD/NEA Time-Dependent Neutron Transport (C5G7-TD) Benchmark (C5G7-TD-9) workshop
- *May 21, 2024 (track 2 afternoon)* – Fifth Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV-5) workshop
- *May 20*-21 (track 3), 2024 – 2nd OECD/NEA International School on Simulation of Nuclear Reactor Systems (SINUS)
- *May 22, 2024 (track 2 morning)* – Fourth Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulics (T/H) Benchmark workshop (LMFR T/H-4)
- May 22, 2023 (track 2 afternoon) – First OECD/NEA HTGR-TH Benchmark (Based on HTTF Data) workshop (HTGR-TH-1)
- *May 23, 2024 (track 1)* – Fourth OECD/NEA TVA Watts Bar 1 (WB1) Multi-Physics Multi-Cycle Depletion Benchmark (TVA-WB1-4) workshop
- *May 23, 2024 (track 2 morning)* - Summary session with presentations of recently concluded benchmarks: OECD/NEA First Burst-Fission-Gas Release Benchmark (BFGR) and OECD/NEA McMaster Core Thermal-Hydraulics (CTH) Benchmark
- *May 23, 2024 (track 2 afternoon)* – OECD/NEA Task Force Artificial Intelligence & Machine Learning meeting

The OECD/NEA UAM-LWR Benchmark is an international high-visibility benchmark under the auspices of WPRS for uncertainty quantification and propagation in best-estimate coupled code

calculations for design, operation, and safety analysis of LWRs. The benchmark activities are co-ordinated by the North Carolina State University (NCSU) with the following objectives:

a) To determine major uncertainties in modelling and simulation (M&S) of LWR systems under steady-state and transient conditions, quantifying the impact of uncertainties for each type of calculation in the multi-physics analysis:
   - Neutronics (reactor physics) M&S;
   - Thermal-hydraulics M&S;
   - Fuel behaviour M&S.

b) For each of these types of calculation the major sources of uncertainty are determined, arising from:
   - Data (e.g., nuclear data, geometry, materials);
   - Numerical methods;
   - Physical models.

c) To develop and test methods for combining the above sources of uncertainty for each type of calculation so as to yield uncertainty assessment for the coupled multi-physics analyses;

d) To develop a benchmark framework, which combines information from available integral facility and Nuclear Power Plant (NPP) experimental data with analytical and numerical benchmarking. Where available, experimental data will be used to test the individual types of calculation as well as coupled multi-physics simulations.

To summarize, in addition to LWR best-estimate calculations for design and safety analysis, the different aspects of UAM are to be further developed and validated on scientific grounds in support of its performance. There is a need for efficient and powerful analysis methods suitable for such complex coupled multi-physics and multi-scale simulations. The proposed benchmark sequence will address this need by integrating the expertise in reactor physics, fuel performance, thermal-hydraulics and reactor system modelling as well as uncertainty and sensitivity analysis and will contribute to the development and assessment of advanced/optimized uncertainty methods for use in best-estimate reactor simulations.

Reference systems and scenarios for coupled code analysis are defined to study the uncertainty effects for all stages of the system calculations. Measured data from plant operation are available for the chosen scenarios. The proposed technical approach has established a benchmark for uncertainty analysis in best-estimate modelling and coupled multi-physics and multi-scale LWR analysis, which is composed of a series of well-defined problems with complete sets of input specifications and reference experimental data. The objective is to determine the uncertainty in LWR system calculations at all stages of a coupled reactor physics/thermal-hydraulics calculation. Uncertainty propagation is being estimated through the whole simulation process – the benchmark builds a unified framework, which can be used and followed in the future. The full chain of uncertainty propagation from basic data, engineering uncertainties, across different scales (multi-scale), and physics phenomena (multi-physics) are tested on several benchmark exercises for which experimental data are available and for which the power plant details have been released. The implemented principal idea is: a) To subdivide the complex system/scenario into several steps or exercises, each of which can contribute to the total uncertainty of the final coupled system calculation; b) To identify input, output, and assumptions for each step; c) To calculate the resulting uncertainty in each step; d) To propagate the uncertainties in an integral systems simulation for which high quality plant experimental data exists for the total assessment of the

overall computer code uncertainty. The main scope covers uncertainty (and sensitivity) analysis (SA/UA) in best estimate modelling for design and operation of LWRs, including methods that are used for safety evaluations. As part of this effort, the development and assessment of different methods or techniques to account for the uncertainties in the calculations are investigated and reported to the participants.

The general frame of the OECD/NEA LWR-UAM benchmark consists of three phases with different exercises for each phase:

Phase I (Neutronics Phase) – Focused on Standalone Steady-State Multi-Scale Neutronics Calculations

- Exercise I-1: "Cell Physics" focused on the derivation of the multi-group microscopic cross-section libraries
- Exercise I-2: "Lattice Physics" focused on the derivation of the few-group macroscopic cross-section libraries
- Exercise I-3: "Core Physics" focused on the core steady state stand-alone neutronics calculations

Phase II (Core Phase) – Introduces M&S of the Other Physics Phenomena in the Reactor Core and Time Dependence on Different Time Scales

- Exercise II-1: "Fuel Physics": Fuel thermal properties relevant to steady-state and transient performance
- Exercise II-2: "Time-dependent Neutronics": Neutron kinetics and depletion stand-alone performance
- Exercise II-3: "Bundle Thermal-Hydraulics": Thermal-hydraulic fuel bundle performance

Phase III (System Phase) – Introduces Multi-Physics Coupling in the Reactor Core and its Further Coupling with Reactor/Plant System

- Exercise III-1: "Core Multi-Physics" - Coupled neutronics/thermal-hydraulics core performance (coupled steady state, coupled depletion, and coupled core transient with boundary conditions)
- Exercise III-2: "System Thermal-Hydraulics" - Thermal-hydraulics system performance
- Exercise III-3: "Coupled Core-System" - Coupled neutronics kinetics thermal-hydraulic core / thermal-hydraulic system performance
- Exercise III-4: "Comparison of Best Estimate Plus Uncertainties (BEPU) vs. Conservative Calculations"

This benchmark project is challenging and responds to needs of estimating confidence bounds for results from simulations and analysis in real applications. Separate Specifications are being prepared for each phase to allow participation in the full Phase or only in a subset of the Exercises. Boundary conditions and necessary input information are provided by the benchmark team. The intention is to follow the calculation scheme for coupled calculations for LWR design and safety analysis established in the nuclear power generation industry and regulation.

The benchmark activities on Phase I are completed with final specifications and comparative analysis report finalized and published. At the incoming workshop participants' presentations

related to Phase I will be included in the sessions devoted to the Exercise II-2 discussions. The latest version of Specifications on Phase II is v3.0 and is posted on the benchmark website (the link is given below). The latest version of Specification on Phase 3 is v3.1 and is posted on the benchmark website (the link is given below). Ther are also updates on excel submission templates for exercises of Phase II.

The OECD Kalinin-3 Coolant Transient benchmark and OECD/NRC Oskarshamn-2 BWR Stability benchmark have been merged in the Phase III of LWR-UAM benchmark through their uncertainty analysis exercises (phases) along with the OECD/NRC TMI-1 PWR Main Steam Line Break (MSLB), OECD/NRC PB-2 BWR Turbine Trip (TT), and OECD TVA WB1 Multi-Physics Cycle Depletion benchmarks.

The information about the LWR-UAM benchmark is provided at:

https://www.oecd-nea.org/jcms/pl_32175/benchmark-for-uncertainty-analysis-in-best-estimate-modelling-for-design-operation-and-safety-analysis-of-light-water-reactors-lwr-uam

Scope and Technical Content of the Meeting

The topics to be addressed at the workshop include:

- Review and discussion of the final version of specifications and support data for Phase II including templates for submitting participants' results,
- Review and discussion of the latest specifications and support data for Exercise III-1, Exercise III-2, Exercise III-3 and Exercise III-4 of Phase III including templates for submitting participants' results,
- Participants' presentations on their modelling and results for all Phases,
- Presentations on other related activities in uncertainty and sensitivity analysis of LWRs,
- Presentations and discussion of research activity to study and address the problem of heterogeneous void in large LWRs,
- Presentations and discussion on data assimilation and target accuracy assessment,
- Discussion of education activities associated with LWR-UAM: discussion of lessons learned and outcomes of the Second International School on Simulation of Nuclear Reactor Systems (SINUS-2),
- Session on the OECD/NEA Task Force on Doppler Effective Fuel Temperature,
- Defining a work plan and schedule for LWR-UAM activities.

The OECD/NEA Task Force on Doppler Effective Fuel Temperature session will include presentations and discussion on work plan and activities of Task Force on Effective Doppler Feedback Temperature approximations in multi-physics M&S and associated uncertainties.

The LWR-UAM benchmark activities are also related to another meeting to be held within the same week and at the same premises:

- May 23, 2024 (track 2 afternoon) – OECD/NEA Task Force Artificial Intelligence & Machine Learning meeting - presentations and discussion on work plan and activities of Task Force on Artificial Intelligence and Machine Learning for Scientific Computing in Nuclear Engineering including uncertainty quantification and propagation.

The proposed meeting programme is attached as Annex 1.

Organisation of the Meeting

The meeting is organized around the discussion of the LWR-UAM benchmark specifications, preliminary results, participants' concerns, and benchmark-related activities. The participants are requested to present their expertise and experience in benchmark-related modeling, verification and validation, uncertainty quantification/propagation and applications.

Participation in the Meeting

Participation is restricted to individuals from OECD/NEA member country institutions who agree to the benchmark non-disclosure agreement (NDA). Participants are asked to sign and send the corresponding NDA form to wprs@oecd-nea.org.

Benchmark LWR-UAM conditions to release form can be found at:

https://www.oecd-nea.org/upload/docs/application/pdf/2021-07/uam-lwr_conditions_for_release_2020.pdf

Organisation and Programme Committee of the Meeting

An Organisation and Programme Committee has been nominated to make the necessary arrangements for the LWR-UAM-16 meeting and to draw up the final programme, etc.

The members of the Programme Committee are:

Alessandro Petruzzi – Co-Chair, and Local Host
NINE S.r.l., Italy

Gregory Delipei - *Co-Chair*
North Carolina State University, USA

Agustin Abarca
North Carolina State University, USA

Maria Avramova
North Carolina State University, USA

Secretariat: **Oliver Buss**
OECD/Nuclear Energy Agency, France

Proposed Programme of the Meeting

The proposed programme was drawn up by the Programme Committee and is enclosed as Annex 1.

Language of the Benchmark Workshop

The official language of the LWR-UAM-17 meeting is English.

Proceedings of the Meeting

A summary of the LWR-UAM-17 meeting will be published by the programme committee after the meeting. The summary will be distributed free of charge to the participants in the meeting. The presentations will be available free of charge to the participants to download from participants' restricted area after the LWR-UAM-17 meeting.

Contacts and Registrations

The annual benchmark workshops/meetings of the Working Party on Scientific Issues and Uncertainty Analysis of Reactor Systems (WPRS) and CTF UG Meeting and Training will be hosted by NINE S.r.l. in Lucca (Italy). The meetings will take place in three tracks in parallel during the week of May 19 to May 23, 2024, to exchange our results and lessons-learned for the different WPRS benchmark activities and to discuss future activities.

The link to registration page for the WPRS-related workshops/meetings including CTF-10 registration, and overall programme is:

https://www.oecd-nea.org/jcms/pl_89133/wprs-benchmarks-workshops-2024

In addition, there is a link to registration form for the CTF-10 UG Meeting and Training is at NCSU/RDFMG website:

https://www.ne.ncsu.edu/rdfmg/cobra-tf/tenth-ctf-user-group-ug-meeting-and-training/

Workshop Location

The meeting place/venue for the BEPU-2024 conference and the eleven meetings/workshops during the week of May 19 to May 23, 2024 is the Real Collegio, which is located inside the city walls of Lucca. The local information for transportation and hotels is given at:

https://www.nineeng.com/bepu2024/index.php/conference-info/about-the-conference

The schedule for the incoming WPRS Workshops, SINUS-2 school and CTF-10 Meeting and Training is given in the table below (all times in CEST):

The programme and schedule of the meetings is shown below:

Sunday, 19 May 2024	9:00-13:00	CTF UG Training		
	14:00-18:00	CTF UG Meeting		
	Starting at 18:00	Registration & informal networking		
		Track 1	**Track 2**	**Track 3 (SINUS)**
Monday, 20 May 2024	Starting at 8:00	Registration		
	9:00-13:00	Lead-cooled Fast Reactor Benchmark (LFR) - T/H Stage	FHR - Fluoride High Temperature Reactor Benchmark	OECD NEA International School on Simulation of Nuclear Reactor Systems (SINUS)
	14:00-18:00	Lead-cooled Fast Reactor Benchmark (LFR) - Neutronics Stage	Rostov-2 VVER-1000 Benchmark	SINUS

Tuesday, 21 May 2024	9:00-13:00	Uncertainty Analysis in Modelling (UAM) for Design, Operation and Safety Analysis of Sodium-cooled Fast Reactors (SFR-UAM)	C5G7-TD: The Deterministic Time-Dependent Neutron Transport Benchmark C5G7-TD without Spatial Homogenization	SINUS
	14:00-18:00	SFR UAM	Multi-physics Pellet Cladding Mechanical Interaction Validation (MPCMIV) Benchmark	SINUS

		Track 1	**Track 2**
Wednesday, 22 May 2024	9:00-13:00	Benchmark for Uncertainty Analysis in Best-Estimate Modelling for Design, Operation and Safety Analysis of Light Water Reactors (LWR-UAM)	Liquid Metal Fast Reactor Core Thermal-Hydraulics Benchmark (LMFR T/H)
	14:00-18:00	LWR UAM including session on EGMUP Task Force on Doppler effective fuel temperature	HTGR T/H Benchmark based on HTTF Data
Thursday, 23 May 2023	9:00-13:00	TVA Watts Bar Unit 1 Multi-Physics Benchmark	9:00-11:00 Summary presentations of recently concluded benchmarks: - Burst Fission Gas Release (1h) - McMaster CTH (1h)
			11:00-13:00 EGMUP Task Force Artificial Intelligence & Machine Learning
	14:00-18:00	TVA Watts Bar Unit 1 Multi-Physics Benchmark	EGMUP Task Force Artificial Intelligence & Machine Learning

ANNEX 1

OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark (LWR-UAM) – Seventeen Workshop (LWR-UAM-17)

Host Organisation

Hosted by N.IN.E. (Nuclear and Industrial Engineering)

Lucca, Italy

May 22, 2024 (track 1)

PROPOSED PROGRAMME

U01-15: Session code

May 22, 2024 (track 1)

U01. Introduction and opening remarks.

U02. Overview and status of benchmark activities.

U03. Participants' presentations on their modelling and results related to Phase I.

U04. Overview of the final version of Specifications for Phase II, templates for submitting participants' results, support data and studies.

U05. Participants' presentations on their modelling and results for Phase II.

U06. Presentations of related activities and reference analyses to Exercises of Phase II.

U07. Overview of the latest version of Specifications for Phase III, templates for submitting participants' results, support data and studies.

U08. Participants' presentations on their modelling and results for Phase III.

U09. Presentations of related activities and reference analyses to Exercises of Phase III.

U10. Presentations and discussion of research activity to study and address the problem of heterogeneous void in large LWRs.

U11. Presentations and discussion on data assimilation and target accuracy assessment.

U12. Discussion of OECD/NEA Task Force on Doppler Effective Fuel Temperature activities and results.

U13. Discussion of education activities associated with LWR-UAM and SINUS-2 lessons learned and outcomes.

U14. Action items and schedule of benchmark activities - next workshop and plans.

U15. Conclusions and closing remarks.