Sixteen OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark Workshop (LWR-UAM-16)

Bologna, Italy
May 23, 2023 (track 1)

Hosted by ENEA, Italy

Announcement and Proposed Program

Background and Purpose of 16th LWR-UAM Benchmark Meeting

The sixteen Light Water Reactor (LWR) Uncertainty Analysis in Modeling (UAM) Benchmark Meeting (LWR-UAM) – LWR-UAM-16 - will be held on May 23, 2023 (track 1), in Bologna, Italy and is a follow up to the previous workshop. The LWR-UAM-16 meeting will be held in conjunction 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. Nine other meetings are being held in two parallel tracks at Bologna, 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 22, 2023 (track 2 morning) – Ninth COBRA-TF (CTF) User's Group (UG) Meeting (CTF-9) followed by a hands-on CTF training sessions which will be conducted on Monday afternoon, May 22, 2023 and Tuesday morning, May 23, 2023 (track 2);
- May 22, 2023 (track 1 afternoon) – First Burst-Fission-Gas Release Benchmark (BFGR-1) workshop;
- May 23, 2023 (track 1) - Sixteen OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark (LWR-UAM-16) workshop;
- May 23, 2023 (track 2) – OECD/NEA HTGR-TH Benchmark introductory presentation and discussions;
- May 22-23 (track 3), 2023 – OECD/NEA International School on Simulation of Nuclear
- Reactor Systems (SINUS);
- May 24, 2023 (track 1 morning) - OECD/NEA Task Force on Doppler Effective Fuel Temperature meeting;
- May 24, 2023 (track 2 morning) – Fourth OECD/NEA McMaster Core Thermal-
- Hydraulics (CTH) Benchmark (CTH-4) workshop;
- May 24, 2023 (track 1 afternoon) – OECD/NEA Task Force Artificial Intelligence &
- Machine Learning meeting;
- May 24, 2023 (track 2 afternoon – LFR neutronics) – May 25, 2023 (track 2 morning – LFR Thermal-hydraulics) – Second OECD/NEA Lead Fast Reactor (LFR) Benchmark (LFR-2) workshop;
- May 24, 2023 (track 1 afternoon) – May 25, 2023 (track 1 morning) - Eight OECD/NEA Time-Dependent Neutron Transport (C5G7-TD) Benchmark (C5G7-TD-8) workshop;
- May 25, 2023 (track 2 afternoon) – Second Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulics (T/H) Benchmark workshop (LMFR T/H-2);
- May 25, 2023 (track 1 afternoon) – May 26, 2023 (track 1 morning) - Third meeting on OECD/NEA TVA Watts Bar 1 (WB1) Multi-Physics Multi-Cycle Depletion Benchmark (TVA-WB1-3) workshop.
- May 26, 2023 (track 2) - Eight OECD/NEA Sodium Fast Reactor (SFR) UAM Benchmark workshop and First Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulics (T/H) Benchmark workshop (SFR-UAM-8);
- May 26, 2023 (track 1 afternoon) – Fifth benchmark meeting on Rostov-2 VVER-1000 multi-physics transient benchmark (Rostov2-5).

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 coordinated 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. While at the incoming workshops participants' presentations related to Phase I the major neutronics discussions will be focused on Exercise II-2 and Exercises III-1 and III-2. The Specifications on Phase II has been updated to include VVER-1000 experimental test cases for Exercise II-3. The Specification on Phase 3 has been updated to include PWR experimental test case for PWR cycle depletion for Exercise III-1.

The OECD Kalinin-3 Coupled code 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 OECD/NRC PWR TMI-1, OECD/NRC BWR PB-2 TT, and .

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 updated specifications and support data for Phase II including templates for submitting participants' results,
- Review and discussion of the updated specifications and support data for Exercise III-1, Exercise III-2, and Exercise III-3 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,
- Discussion of education activities associated with LWR-UAM: discussion of lessons learned and outcomes of International School on Simulation of Nuclear Reactor Systems (SINUS)
- Defining a work plan and schedule for LWR-UAM activities.

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

  - May 24, 2023 (track 1 morning) - OECD/NEA Task Force on Doppler Effective Fuel Temperature meeting - 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,
  - May 24, 2023 (track 1 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.

The proposed meeting program is attached as Annex 1.

Organization 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

Organization and Program Committee of the Meeting

An Organization and Program Committee has been nominated to make the necessary arrangements for the LWR-UAM-16 meeting and to draw up the final program, etc.

The members of the Program Committee are:

Giacomo Grasso – *Co-Chair, and Local Host*
ENEA, 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 Program of the Meeting

The proposed program was drawn up by the Program Committee and is enclosed as Annex 1.

Language of the Benchmark Workshop

The official language of the LWR-UAM-16 meeting is English.

Proceedings of the Meeting

A summary of the LWR-UAM-16 meeting will be published by the program 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-16 meeting.

Contacts and Registrations

The annual benchmark workshops/meetings of the [Working Party on Scientific Issues and Uncertainty Analysis of Reactor Systems (WPRS)] and the LWR-UAM-16 Benchmark Meeting will be hosted by ENEA in Bologna (Italy). The meetings will take place in two tracks in parallel during the week of 22 May to 26 May 2023 to exchange 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 LWR-UAM-16), overall program, and local information for transportation and hotels is:

https://www.oecd-nea.org/jcms/pl_71612/wprs-benchmarks-workshop-2023

The link to registration page for the CTF-9 UG Meeting and Training is:

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

Workshop Location

The meeting place for the ten meetings/workshops during the week of May 22 – 26, 2023, in three tracks is at the Zanhotel Europa, Bologna, Italy (in-person meeting). As mentioned above the local information for transportation and hotels is given at:

https://www.oecd-nea.org/jcms/pl_71612/wprs-benchmarks-workshop-2023

The program and schedule of the meetings is shown below:

	Track 1	Track 2	Track 3
Monday, May 22	Morning: MPCMIV Afternoon: Burst Fission Gas Release	Morning: CTF UG Afternoon: CTF Training	Morning: SINUS Afternoon: SINUS
Tuesday, May 23	Morning: LWR UAM Afternoon: LWR UAM	Morning: HTGR-TH Afternoon: HTGR-TH	Morning: SINUS Afternoon: CTF Training
Wednesday, May 24	Morning: Task Force on Doppler Effective Fuel Temperature Afternoon: Task Force on AI & ML	Morning: McMaster CTH Afternoon: LFR Neutronics	
Thursday, May 25	Morning: C5G7-TD Afternoon: TVA-WB1	Morning: LFR TH Afternoon: LMFR TH	
Friday, May 26	Morning: TVA-WB1 Afternoon: Rostov-2	Morning: SFR-UAM Afternoon: SFR-UAM	

ANNEX 1

OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark (LWR-UAM) – Sixteen Workshop (LWR-UAM-16)

Host Organization

Hosted by ENEA

Bologna, Italy

May 23, 2023 (track 1)

PROPOSED PROGRAM

U01-13: Session code

May 23, 2023 (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 updates in the 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 updates in the 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. Discussion of education activities associated with LWR-UAM and SINUS lessons learned and outcomes.

U12. Action items and schedule of benchmark activities - next workshop and plans.

U13. Conclusions and closing remarks.