International School on Simulation of Nuclear Reactor Systems (SINUS)

Training the next generation of reactor physicists

The International School on Simulation of Nuclear Reactor Systems (SINUS) provides hybrid, hands-on-training encompassing multiphysics modelling and simulation (M&S) and associated validation, verification and uncertainty qualification (VV&UQ) methodologies. It leverages the comprehensive expertise of the Nuclear Energy Agency (NEA) Nuclear Science Committee (NSC) Working Party on Scientific Issues and Uncertainty Analysis of Reactor Systems (WPRS) and the software distribution capabilities of the NEA Data Bank (DB). Participants engage in a dynamic, hands-on learning experience through self-paced project assignments that introduce them to cutting-edge single- and multiphysics software packages.

The multiphysics challenge

Novel M&S capabilities in nuclear engineering offer comprehensive insights into physical phenomena and present new opportunities for reactor designers. The availability of dependable numerical predictions and complex sensitivity and uncertainty (SU) analyses form the foundation for swift, iterative design processes that lead to heightened safety margins and improved economics for new designs. Additionally, these advanced M&S capabilities yield more comprehensive, well-informed and robust safety assessments of existing reactors to support their long-term operation, power uprates and higher fuel burn-up, which are key economic improvements for the operation of the current fleet of nuclear power plants.

At the nuclear reactor core level, the system behaviour is described by an interplay of different physical phenomena across various temporal and spatial scales, including neutron transport (neutronics), thermal-hydraulics, material behaviour, mechanics, etc. M&S tools incorporating this multiphysics coupling have already been used in current licensing practices.

Source: NCSU, 2019.

Multiphysics coupling mechanisms in LWR core

Novel M&S approaches for reactor physics simulations implement a fully coupled multiphysics approach as achieved in various M&S tools. Current tools include the Consortium for Advanced Simulation of Light Water Reactors (CASL), the Nuclear Energy Advanced Modeling and Simulation (NEAMS) and the Nuclear Reactor Safety Simulation (NURESAFE) platforms, that together yield unprecedented spatial and temporal resolution.

The economic benefits of the best-estimate methodologies and the increased accuracy of novel multiphysics tools, which support the demonstration of accurate safety margins, are obvious. However, the new best-estimate methodology and novel M&S tools create new challenges:

Challenge #1: The multiphysics M&S tools become more complex and require novel approaches for their verification and validation.

Challenge #2: Users' qualification becomes even more critical to analyse the limits and uncertainties of the M&S tools.

Challenges accepted by the Working Party on Scientific Issues and Uncertainty Analysis of Reactor Systems (WPRS)

Under the guidance of the NEA NSC, the WPRS deals with reactor physics, radiation transport and radiation shielding, core thermal-hydraulics (T/H), fuel performance, and associated multiphysics aspects for present and future nuclear power systems. It acts as a platform for international collaboration, sustaining a vibrant community of practice and fostering periodic and synergistic interactions among its participants.

The WPRS studies the M&S of reactor systems and the VV&UQ associated with single and multiphysics phenomena, and thus provides guidance to resolve Challenge #1.

In 2023, the WPRS held the first International School on Simulation of Nuclear Reactor Systems (SINUS), which provides hands-on training in multiphysics simulations and associated VV&UQ to help address Challenge #2.
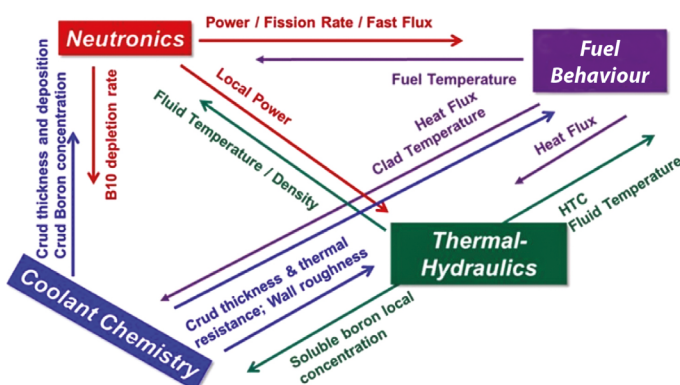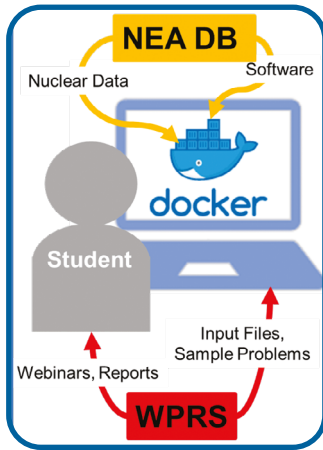
The SINUS school in Bologna, Italy, on 22-23 May 2023.

## The International School on Simulation of Nuclear Reactor Systems (SINUS)

Leveraging NEA expertise and NEA DB and RSICC software distribution capabilities to train a new generation of nuclear experts

SINUS draws upon the extensive multiphysics expertise within the WPRS community. By utilising the software distribution capabilities of the NEA DB and the United States Radiation Safety Information Computational Center (RSICC), it provides unique hands-on training in reactor single- and multiphysics simulations, with a specific focus on state-of-the-art VV&UQ methodologies.

SINUS training schedule

The SINUS training consists of lectures, exercises and project work. A programme of approximately 20 hours of online lectures by experts of the WPRS introduces the participants to the topic and provides training on different M&S tools. During the training, participants engage in a dynamic learning experience through self-paced exercise assignments that introduce them to cutting-edge single- and multiphysics software packages. The state-of-the-art software is provided in a Docker environment distributed by the NEA DB and RSICC and can thus be easily run on the participants' hardware. Next, the participants work in international teams with typically two fellow students on a project assignment and practice the acquired skills.
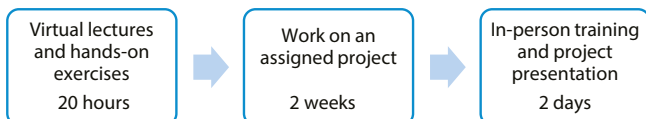

SINUS training scheme

The final stage of the training takes place in person and is scheduled together with the WPRS Benchmarks Workshops. Participants present their project work and network within the international WPRS expert community.

Feedback from the pilot SINUS event

The NEA organised the first SINUS training on 2-23 May 2023. It was jointly developed by North Carolina State University (NSCU), the RSICC at Oak Ridge National Laboratory (ORNL), and the NEA NSC WPRS. The in-person event was hosted by the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) in Bologna, Italy, on 22-23 May 2023. The training in Bologna was supported by an ENEN2plus Project (ENEN#) Mobility Fund.
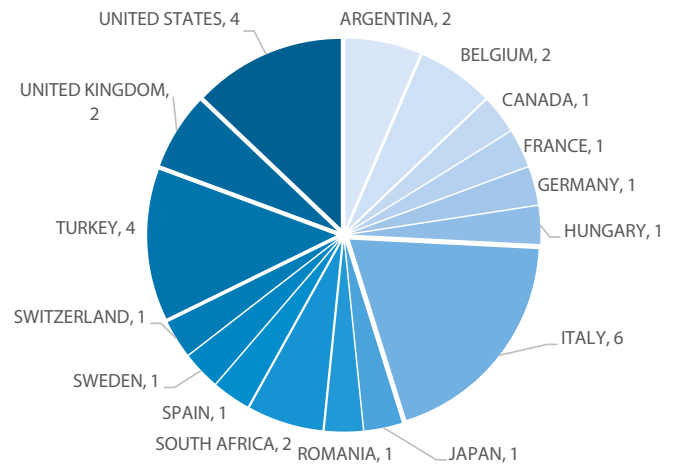
Nationalities of participants in the pilot SINUS event on 2-23 May 2023

The NEA received a total of 64 applications for the pilot SINUS event, and 31 participants from 16 countries were selected to join. Based on an anonymous post-training survey among participants, the overall quality of the course and the international experience were rated as "outstanding" or "excellent".

SINUS trainees' feedback

"   As a nuclear engineer, I found this course to be highly advantageous for my future career. The course was meticulously designed…

"   I had a feeling that lecturers really care and really want us to understand well the content of the course. …The networking opportunity is just brilliant.

Future plans

The NEA plans to organise the SINUS training events on an annual basis. The next SINUS school is scheduled to take place in conjunction with the WPRS Benchmarks Workshops in Lucca, Italy, in May 2024.

Further information

For further information, please contact the NEA by e-mail: wprs@oecd-nea.org or visit http://oe.cd/sinus.