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"Atoms for Peace and Development"

Joint ICTP-IAEA Workshop on Open-Source Nuclear Codes for Reactor Analysis, 7-11 August 2023

IAEA Activities on Computational Tools for Nuclear Reactors Analysis

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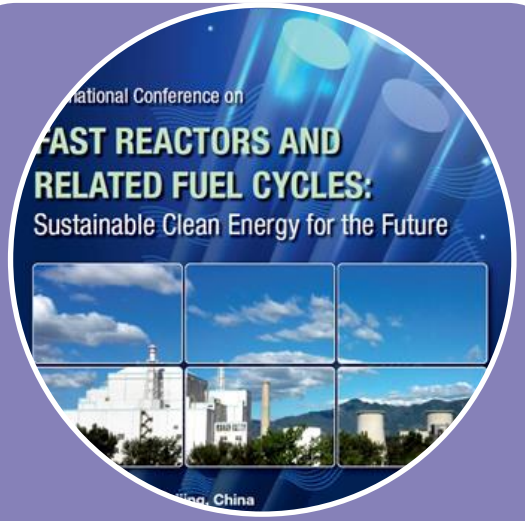
International Atomic Energy Agency

https://www.iaea.org/topics/fast-reactors

email: FR@IAEA.ORG

Main IAEA Activities on Fast Reactor Technology

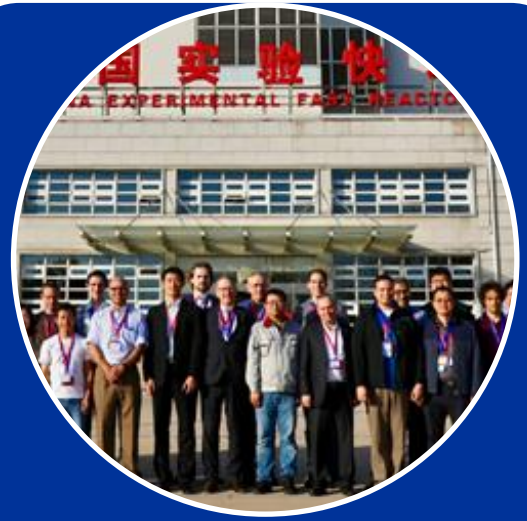


Knowledge Sharing

Publications

Conferences

TMs



Technology Development

Coordinated Research Projects (CRPs)

Capacity Building

Training Courses

Workshops

TECDOCs

Main IAEA Activities on Fast Reactor Technology in 2022 - 2023

- CRPs/Benchmarks/Studies
  - Completed (in publishing)
    - NAPRO (2013 - 2018)
    - PSFR Source Term (2016 - 2020)
  - 3 Ongoing CRPs:
    - CEFR Start-Up Tests (2018 - 2024)
    - FFTF ULOF Test (2018 - 2022)
    - NACIE (2022-2026): Benchmark of Transition from Forced to Natural Circulation Experiment with Heavy Liquid Metal Loop
  - New CRPs proposals (to start in 2023+):
    - PLANDTL: PLANt Dynamics Test Loop Decay Heat Removal Thermal Hydraulics Tests
    - CRP with the S-ALLEGRO facility
    - Modelling of Total Instantaneous Blockage of SFR F/A (Delayed)
    - Benchmark Analysis of STELLA-2 LOHS/LOF Tests
  - TM on Development and Application of Open-Source Modelling and Simulation Tools for nuclear Reactors (Milan, June 2022)
  - TM on State-of-the-art Thermal Hydraulics of Fast Reactors: (ENEA Brasimone, September 2022)
  - TM on the Safety Approach for Liquid Metal Cooled Fast Reactors and the Analysis and Modelling of Severe Accidents (March 2023- with NSNI)

- FR22- International Conference on Fast Reactors and related fuel cycles (April 2022)
- Technical Working Group on Fast Reactors
  - 55th TWG-FR Meeting (Virtual), May 2022
  - 56th TWG-FR Meeting (Vienna), June 2023
- Joint IAEA-GIF Workshops on LMFR Safety
  - 10th GIF-IAEA Workshop on LMFR Safety (2022)
  - 11th GIF-IAEA Workshop on non-WCR Safety (2023)
- Basic Principles SFR Simulator
  - Ready for Distribution to Member States
- Training Courses and Workshops
  - Webinar on Repurposing Sites of Retired Fossil Plants with Advanced Nuclear Reactors (May 2022)
  - Webinar Series on Multiphysics Modelling of Nuclear Reactors using OpenFOAM (Aug-Sep 2022)
  - Regional Workshop on Advances in Modelling & Simulation of Thermal Hydraulics in LMFRs, India (Nov 2022)
  - Joint ICTP-IAEA Workshops on the Physics and Technology of Innovative Nuclear Energy Systems, Trieste (Dec 2022)
  - Joint ICTP-IAEA Workshop on Open-Source Nuclear Codes for Reactor Analysis, Trieste (Aug 2023)

What is ONCORE?

Open-source Nuclear Codes for Reactor Analysis

The Open-source Nuclear Codes for Reactor Analysis (ONCORE) initiative is an IAEA-facilitated international collaboration framework for the development and application of open-source software to support research, education and training in the field of Nuclear Science and Engineering.

Institutions and individuals participating in ONCORE can collaborate in, and benefit from, the development of open-source software in the field of nuclear science and technology.

ONCORE Objectives

- Build and preserve knowledge in the field of open-source software and open data and facilitate the exchange of information within the nuclear science and technology community
- Conduct a survey on existing open-source software and open data and help make them widely accessible
- Identify best practices for open-source software development, verification, and validation
- Assess features, gaps and opportunities for integration of already developed open-source software
- Facilitate sharing of reference solutions, standard benchmark problems, and data
- Promote the individual tools and platform in education and research environments
- Organize education and training activities
- Promote the ONCORE initiative and broaden engagement among the IAEA Member States

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Open-source Nuclear Codes for Reactor Analysis (ONCORE)

The Open-source Nuclear Codes for Reactor Analysis (ONCORE) initiative is an IAEA-facilitated international collaboration framework for the development and application of open-source multi-physics simulation tools to support research, education and training for the analysis of advanced nuclear power reactors. Institutions and individuals participating in ONCORE can collaborate in, and benefit from, the development of open-source software in the field of nuclear science and technology.

An international network of research and academic institutions is creating a common platform in the area of *advanced reactor experiments and high-fidelity multi-physics nuclear simulation techniques for open-source code development and validation.* The work focuses on three major areas: modelling and

Access to
Members' Area

Related Stories

IAEA Designates Swiss Ecole Polytechnique Federale de Lausanne as Collaborating Centre

https://www.iaea.org/topics/nuclear-power-reactors/open-source-nuclear-code-for-reactor-analysis-oncore

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IAEA | Open-source Nuclear Codes for Reactor Analysis

Open-source Nuclear Codes for Reactor Analysis

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Open-source Nuclear Codes for Reactor Analysis

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https://nucleus.iaea.org/sites/oncore

- Collaborative development
- Code submission (guidelines)
- Expert group to support
- Training courses
- Useful resources

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Home
Download Codes
VSOP
STACY
HCP
Discussion Forums
VSOP Forum
STACY Forum
HCP Forum
Expert Group

HTGR- Code Package

Background:

The efforts made since 2015 have led to the official transfer of the High Temperature Reacto Germany to the IAEA. This include the VSOP99, STACY and the HCP HTR code packages. been obtained and the codes are free for distribution to the IAEA Member States. The intere include (just to name a few) Canada, China, Egypt, India, Indonesia, Japan, Jordan, Russia and United States.

Status of the codes:

1. The VSOP99/11 code has been used extensively for HTR pebble-type design and safety analysis. It represents the last release and has

Registered User Area

Currently the registration is open to people willing to access HTGR code package.

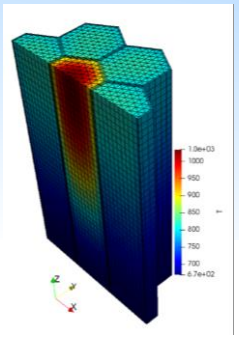
Register to Access HTGR Code Package

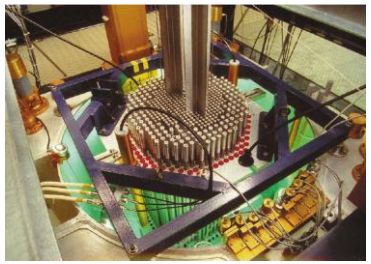
The contents of Registered Users Area are restricted to registered users of the ONCORE. The registration is completed as follows:

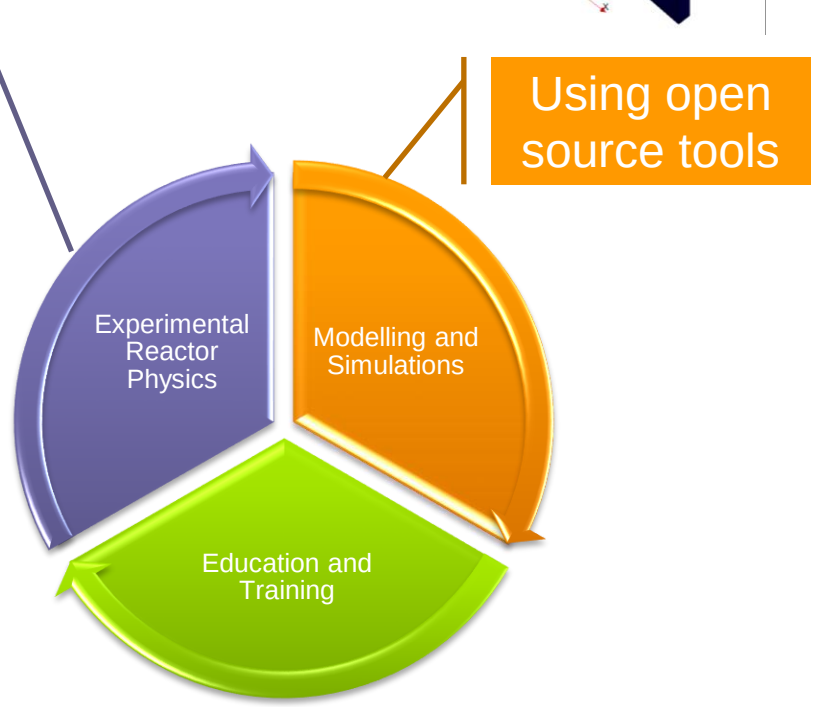
- Go to http://nucleus.iaea.org and fill the form available in the upper right corner, by clicking on "Register".
- An email will be sent to you shortly after your registration. Click on the link mentioned in the email to confirm your registration.
- Once your account is activated, please fill out this form
- Your request will be reviewed by the ONCORE team. As soon as your request is accepted you will receive an email notification.
- Additionaly, if you also need access to source code, please write an email to oncore@iaea.org with detailed explanation of the expected use (this will be done only after your request is approved).

ONCORE Platform

- Common platform in the area of advanced reactor experiments and high-fidelity multi-physics nuclear simulation techniques for open-source code development and validation
- Links to 35+ Open source tools
  - Neutronics
  - Thermal-hydraulics, system analysis, containment
  - Structural mechanics
  - Multi-physics applications and libraries
  - Data processing, optimization, UQ, pre-post processing
  - Application frameworks
- 2 tools hosted and distributed by ONCORE
  - VSOP99/11: HTR pebble-type design and safety analysis
  - STACY: V/HTR safety analyses for the quantification of fission product release from the fuel







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IAEA Designates Swiss Ecole Polytechnique Federale de Lausanne as Collaborating Centre

Chirayu Batra, IAEA Department of Nuclear Energy
Elisabeth Dyck, IAEA Department of Nuclear Energy

JUN
12
2019

Mikhail Chudakov, IAEA Deputy Director General and Head of the Department of Nuclear Energy (right) with EPFL's Vice President for Research, Andreas Mortensen (left) and Andreas Pautz, Head of EPFL's Laboratory for Reactor Physics and System Behaviour (middle) after signing the cooperation agreement, Vienna, 12 June 2019. (Photo: S. Krikorian/IAEA)

Related Storie


New IAEA Centre in Training f Infrastruc


Argentina Commiss Collabora

Related Reso

Collaborating Ce
Ecole Polytechni Lausanne (EPFL)
Nuclear power r
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IAEA

- Cooperation agreement signed on 12 June 2019:
  - The IAEA designated the Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, as an IAEA Collaborating Centre to support IAEA Member States in increasing their modelling and simulation capabilities in the field of advanced reactors.

> "Education and training are very important to prepare the next generation of nuclear workforce. The creation of such high performance simulation platforms with modern computational tools will attract many young professionals.
>
> — Mikhail Chudakov, IAEA Deputy Director General, Head of the Department of Nuclear Energy

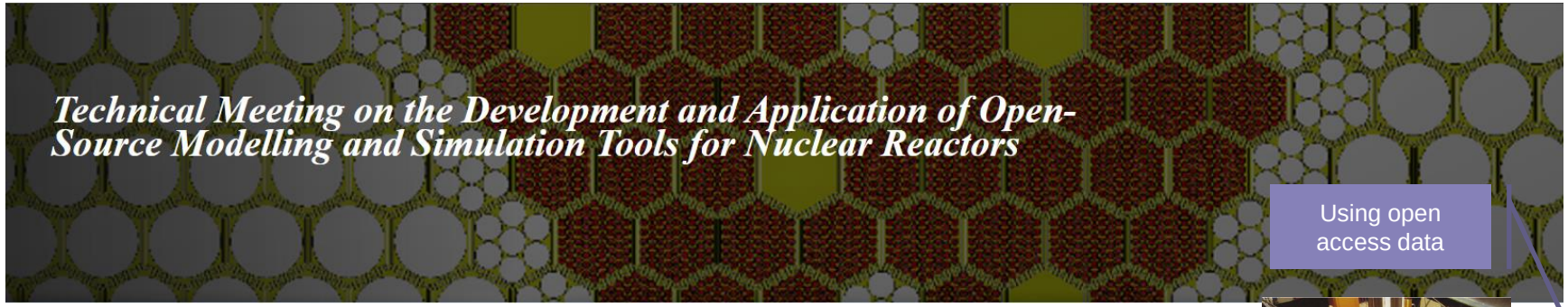
ONCORE: Major Past and Future Events

Date	Title
Jun 2022	**Technical Meeting on Development and Application of Multi-Physics Modelling and Simulation on Nuclear Reactor Using Open-Source Tools** – will be followed by publication of Technical Report Series.
Aug-Oct 2022	**Webinar Series on Multiphysics Modelling of Nuclear Reactors using OpenFOAM** - 12 lectures focused on theoretical background, physical and mathematical models and numerical simulation methods implemented in the family of the OpenFOAM codes as well as practical recommendations, guidelines and examples of inputs and applications, connected to e-learning course.

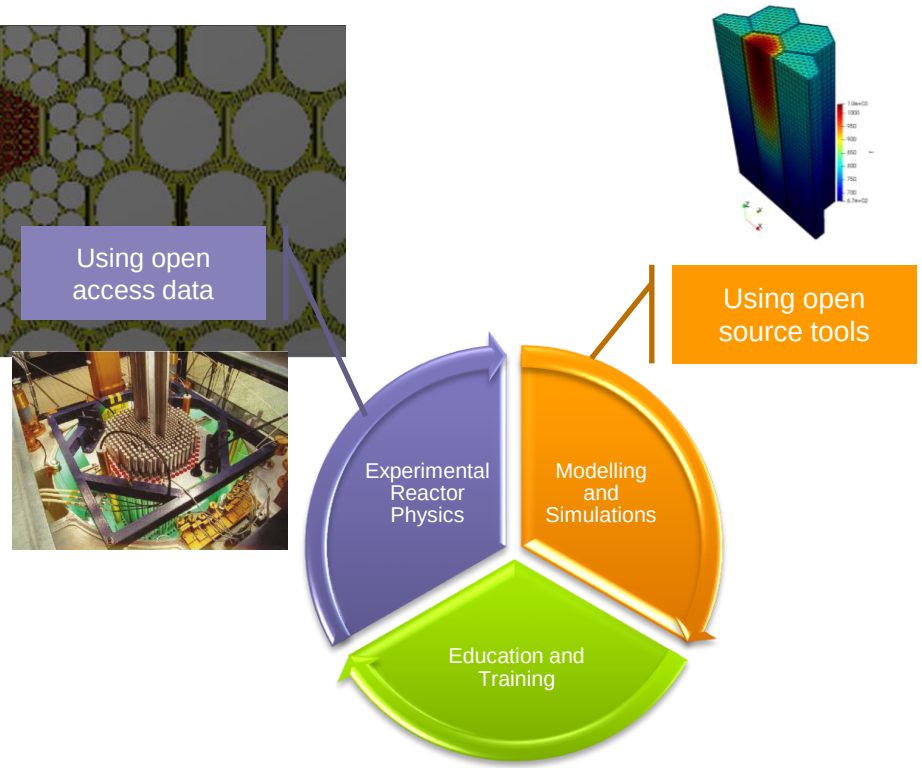
Date	Title
August 2023	**Joint ICTP-IAEA Workshop on Open-Source Nuclear Codes for Reactor Analysis**

Technical Meetings on

Development and Application of Open Source Modelling and Simulation Tools for Nuclear Reactors



20-24 June 2022
Milano, Italy



Technical Meeting on Development and Application of Multi-Physics Modelling and Simulation on Nuclear Reactor Using Open Source Tools

- 20 - 24 June 2022 in Milan, Italy
- Objective was to share and discuss recent developments in the area of multiphysics modelling and simulation of nuclear reactors using open-source software and open-access data to support research, development, education and training in nuclear science and technology
- Included live workshops on several open-source tools such as OpenMC, Moose, ARMI and OpenFOAM
- Particiapnts presented work on several aspects ranging from motivations, experiences, and challenges for the open-source approach, advanced application of open-source tools to nuclear engineering, recent developments in open-source tools to discussion about best practices in nuclear open-source projects and open-source software for education and training
- Technical Report Series publication in progress, expected release in Q4 2023.

- https://conferences.iaea.org/event/247/?view=standard_numbered

Technical Meeting on Development and Application of Multi-Physics Modelling and Simulation on Nuclear Reactor Using Open Source Tools

Motivations and Challenges of Open-Source Software for Nuclear Reactors

Motivation from user perspective: free to use, distribute and modify; exposed source code; transferable skills; supported by a large global community; from developer perspective: potential to build on work from others

Challenges: usability and protection of the intellectual property; switching from an established commercial code to a newer open-source; time investment; potential costs come from training, updates, QA services; the transition from a single group lead project to a multi-developer, multi-institution project; heavy reliance on a single expert, or small group; crucial role of validation

Best Practices in Open-Source Software Projects for Nuclear Applications

Use of version control and tagged releases of code and documentation; use of automated continuous integration (CI) for quality assurance; writing of documentation involving guide on start-up, tutorials, topical narrative, code-embedded documentation, etc.; publishing of useful examples; adding a Python API to the code to encourage interoperability; giving contributors ownership; provide clear guidelines and documentation; eliminating main issues of intellectual property and licensing.

The Role of Open-Source Software in Education and Training

Adequate training in the use of the software helps to grow the number of skilled users; many forms available: webinars, workshops, tutorials, online courses and forums; consistent materials and latest version of the code necessary; facilitating the sharing of solvers and exercises among different institutions; providing software resources like github/gitlab and other discussion forums

Webinar Series on Multiphysics Modelling of Nuclear Reactors using OpenFOAM

OpenFOAM* is a well-known open-source toolbox for industrial-level computational fluid dynamics (CFD), but also a library for the finite-volume discretization and parallel solution of Partial Differential Equations (PDEs) for nuclear-related applications.

Directly supports the education and training part of the ONCORE initiative.

The Webinar Series provided the audience with up-to-date information about the modelling possibilities provided by OpenFOAM and OpenFOAM based codes, its strengths and challenges as well as practical guidelines, thus allowing for more informed decisions about the opportunity to employ OpenFOAM, or existing OpenFOAM-based tools, for one's own applications. It has also served as an entry point for further autonomous learning and using of these tools.

12 lectures in the series covering:

- Overview of using OpenFOAM as a multi-physics library for nuclear reactor analysis
- Brief introduction to the use of finite-volume methodologies
- Basics of Partial Differential Equations (PDEs)
- Problem definition
- Geometry and mesh generation
- Introduction to OpenFOAM's source code and object-oriented programming
- ContainmentFOAM tool for system-scale CFD analysis of containment atmosphere pressurization, H2/CO mixing and mitigation.
- GeN-Foam tool as multi-physics solver in nuclear reactor design and safety analysis
- OFFBEAT tool, a solver for fuel behavior analysis in nuclear reactors. As a multi-dimensional code, it allows studying the evolution of the fuel in 1-D, 2-D or 3-D, and it can simulate both transient and steady-state conditions.
- GeN-ROM, a data-driven model-order reduction tool for nuclear applications based on GeN-Foam

Recordings of all Lectures available here: https://elearning.iaea.org/m2/course/view.php?id=1286

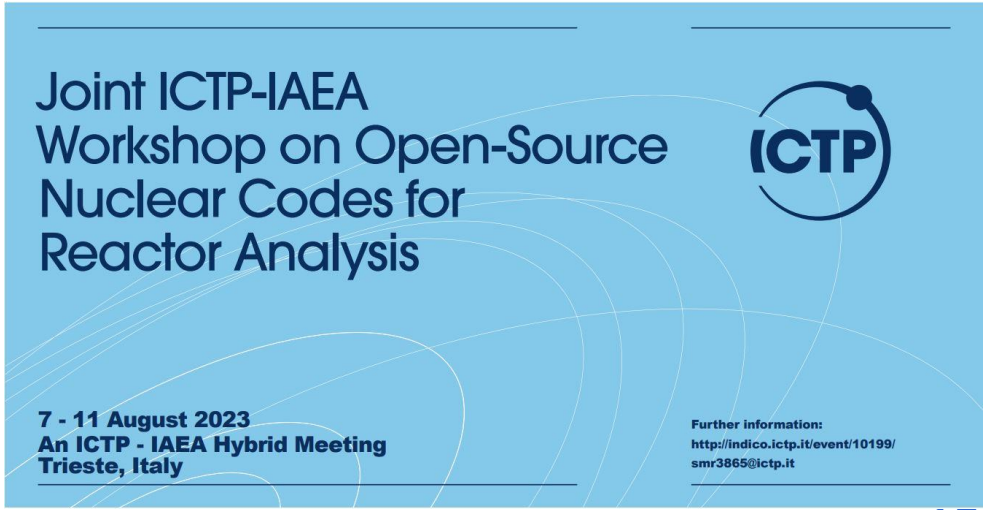
Joint ICTP-IAEA Workshop on Open-Source Nuclear Codes for Reactor Analysis

7-11 August 2023 in Trieste, Italy

This workshop offers a comprehensive journey in cutting-edge computational techniques for nuclear reactor analysis, providing an in-depth understanding of reactor neutronics, thermal hydraulics and system analysis at different scales. Participants will be led through the essential stages required to conduct engineering-level multi-physics simulations.

General overview, theoretical background and practical exercises will be offered for

- **OpenFOAM** and its derivatives for CFD simulation of multi-physics and multi-scale problems
- **GenFOAM** for core thermal hydraulics, neutron transport and structural mechanics modelling
- **Offbeat** for fuel performance simulation
- **ContainmentFOAM** for severe accidents simulation
- **OpenMC** Monte-Carlo neutron transport
- **ARMI** Advanced Reactor Modelling Interface
- Introduction to **OpenMC for Fusion**



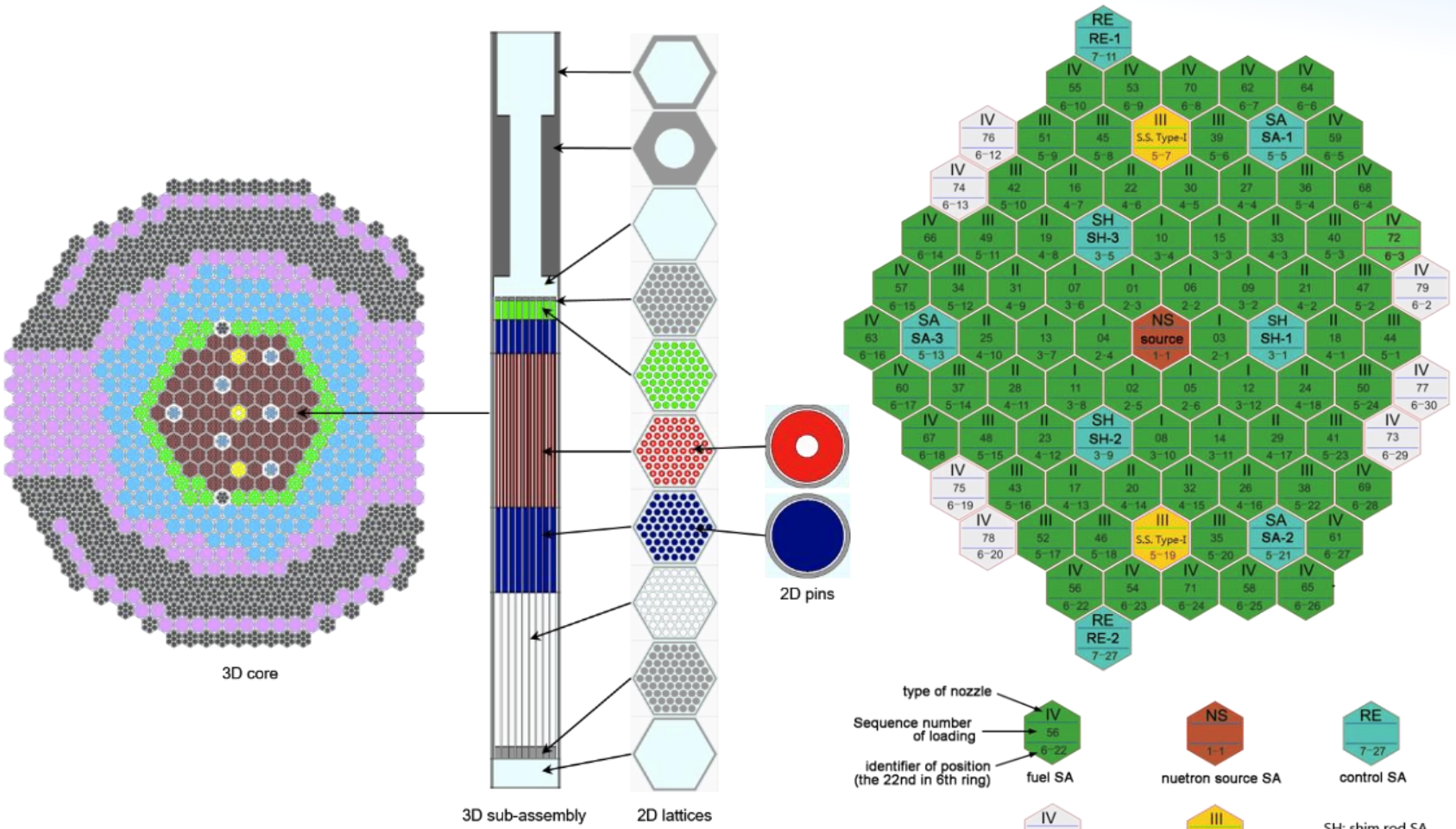
CRP: **Neutronics Benchmark of CEFR Start-Up Tests**
Training Course Series

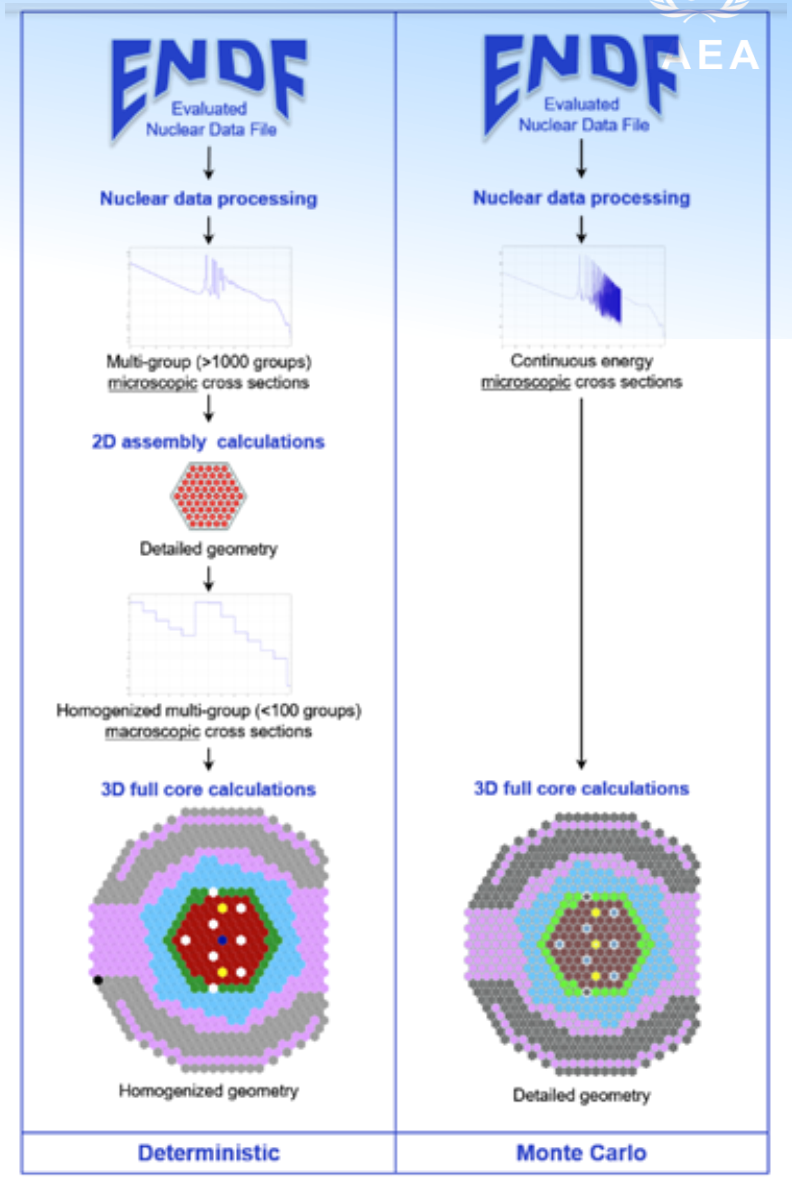
Training Course Series Documents
- Comprehensive Guidance and how-to perform MC simulations
- with SERPENT-2 and Open-MC
- Freely available IAEA Series of documents for capacity building
- Template for future CRP adaptations

Performing Neutronics Benchmark Calculations
- Intended for students or early career nuclear engineers.
- Can easily be implemented and used in classrooms.
- Also provides a valuable template for continuing benchmarking opportunities.

➢ In Publishing

IAEA Training Course Series: Fundamentals of neutronics simulations of a fast reactor based on IAEA's benchmark of CEFR Start-up Tests





ICTP-IAEA Workshop on Open-Source Nuclear Codes for Reactor Analysis

IAEA Training Course Series:
Fundamentals of neutronics simulations of a fast reactor based on IAEA's benchmark of CEFR Start-up Tests

#	2D axial region		OpenMC input
	Content	Snapshot	

0	Outside		`c_FU_OUT = openmc.Cell( name='c_FU_OUT')`
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			`c_FU_OUT.fill = u_FU_HEA`

1	Head		`c_FU_HEA = openmc.Cell( name='c_FU_HEA')`
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			`c_FU_HEA.fill = u_FU_HEA`

2	Upper shield		`c_FU_USH = openmc.Cell( name='c_FU_USH')`
			`c_FU_USH.region = -pz_FUEL_USH & +pz_FUEL_UCN`
			`c_FU_USH.fill = u_FU_USH`

3	Upper connector		`c_FU_UCN = openmc.Cell( name='c_FU_UCN')`
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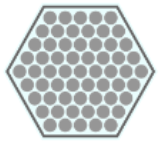
			`c_FU_UCN.fill = u_FU_UCN`

4	Top end plug		`c_FU_TEP = openmc.Cell( name='c_FU_TEP')`
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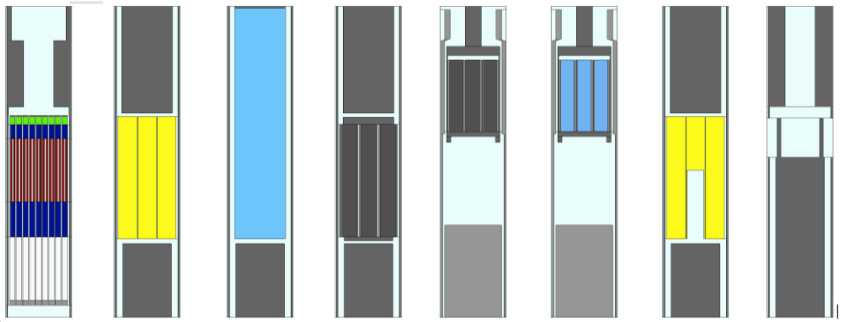
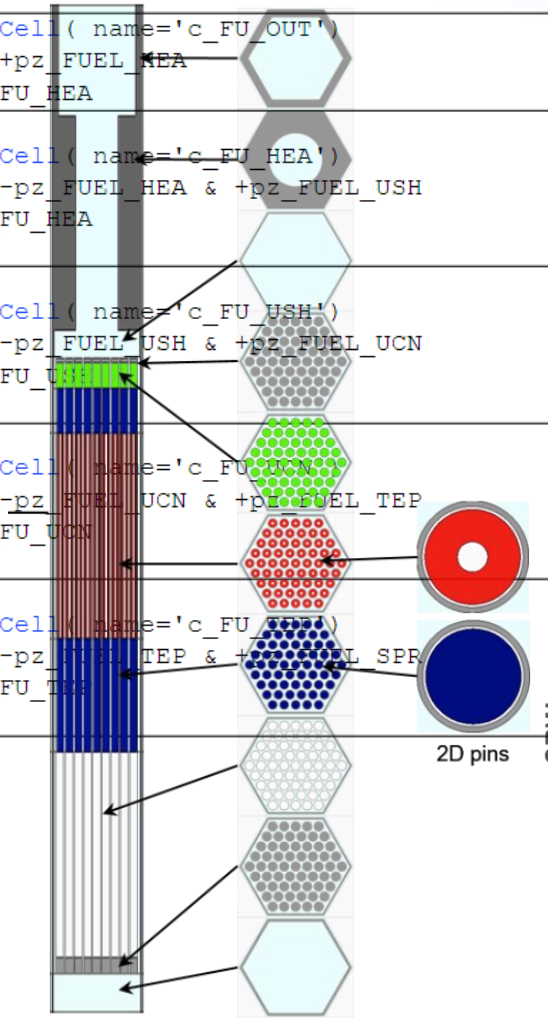
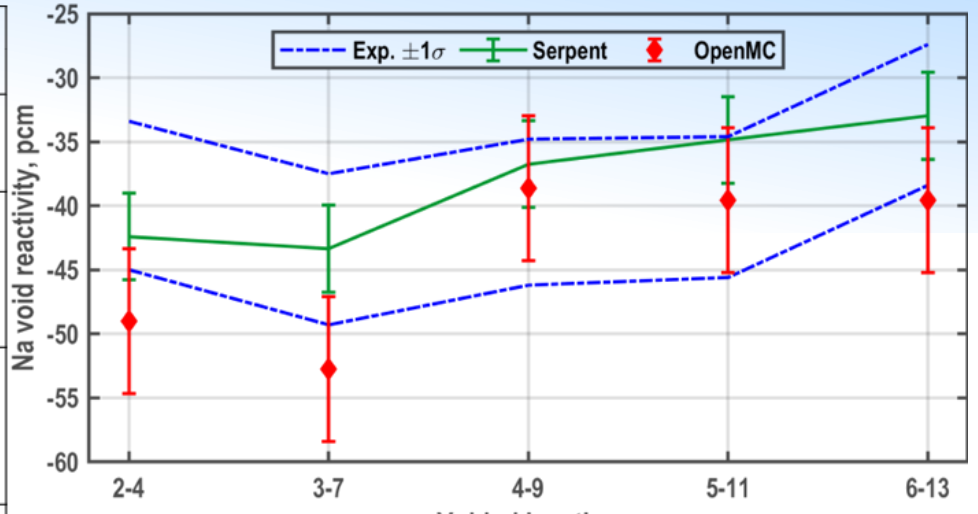
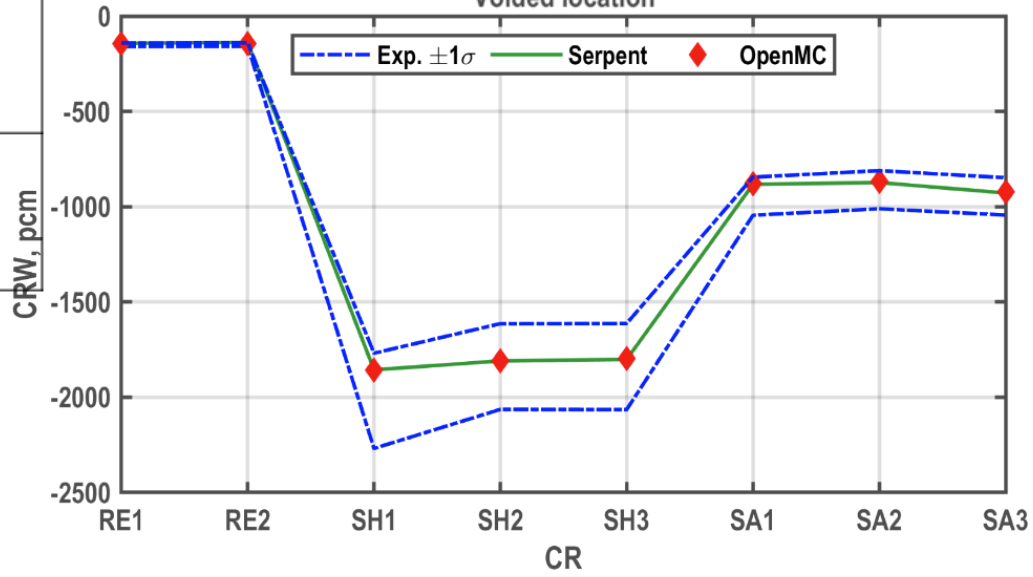
			`c_FU_TEP.fill = u_FU_TEP`

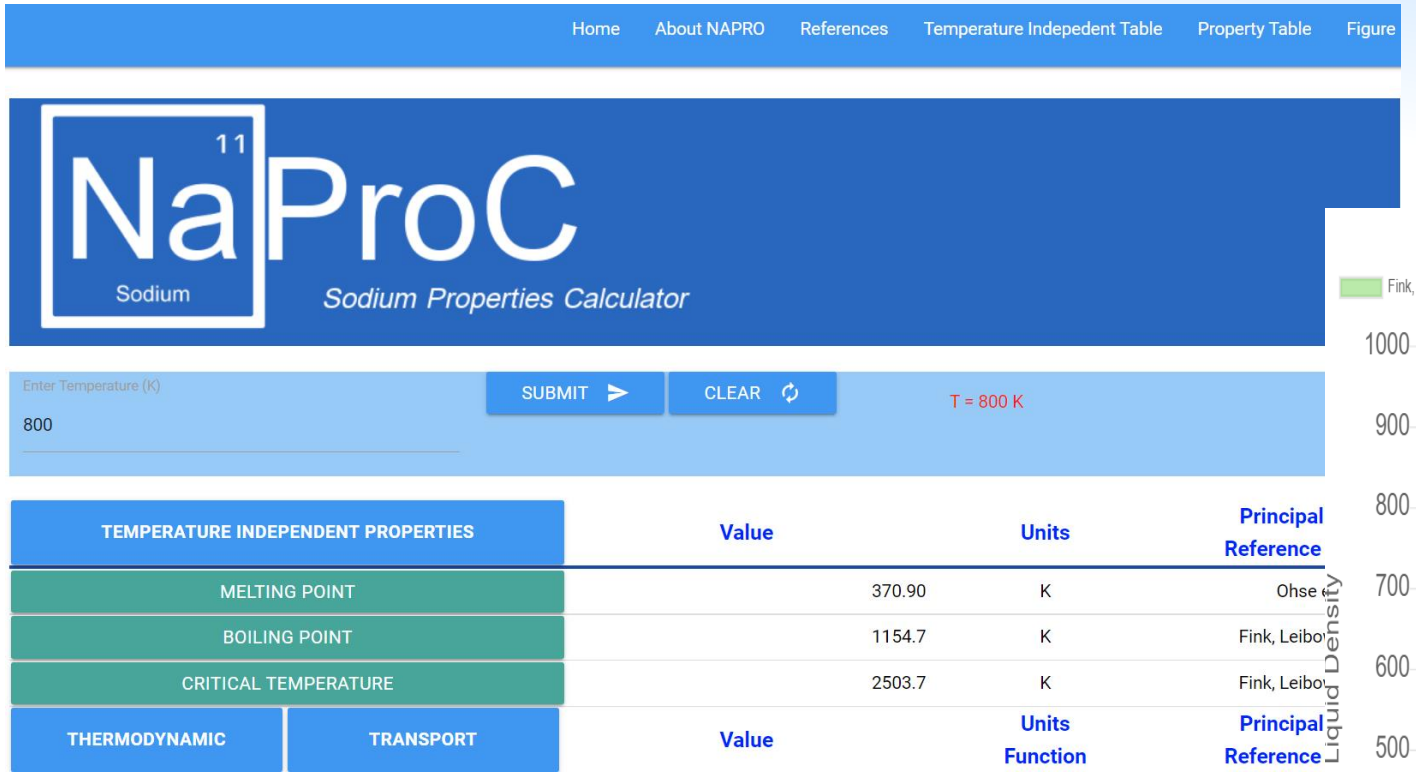


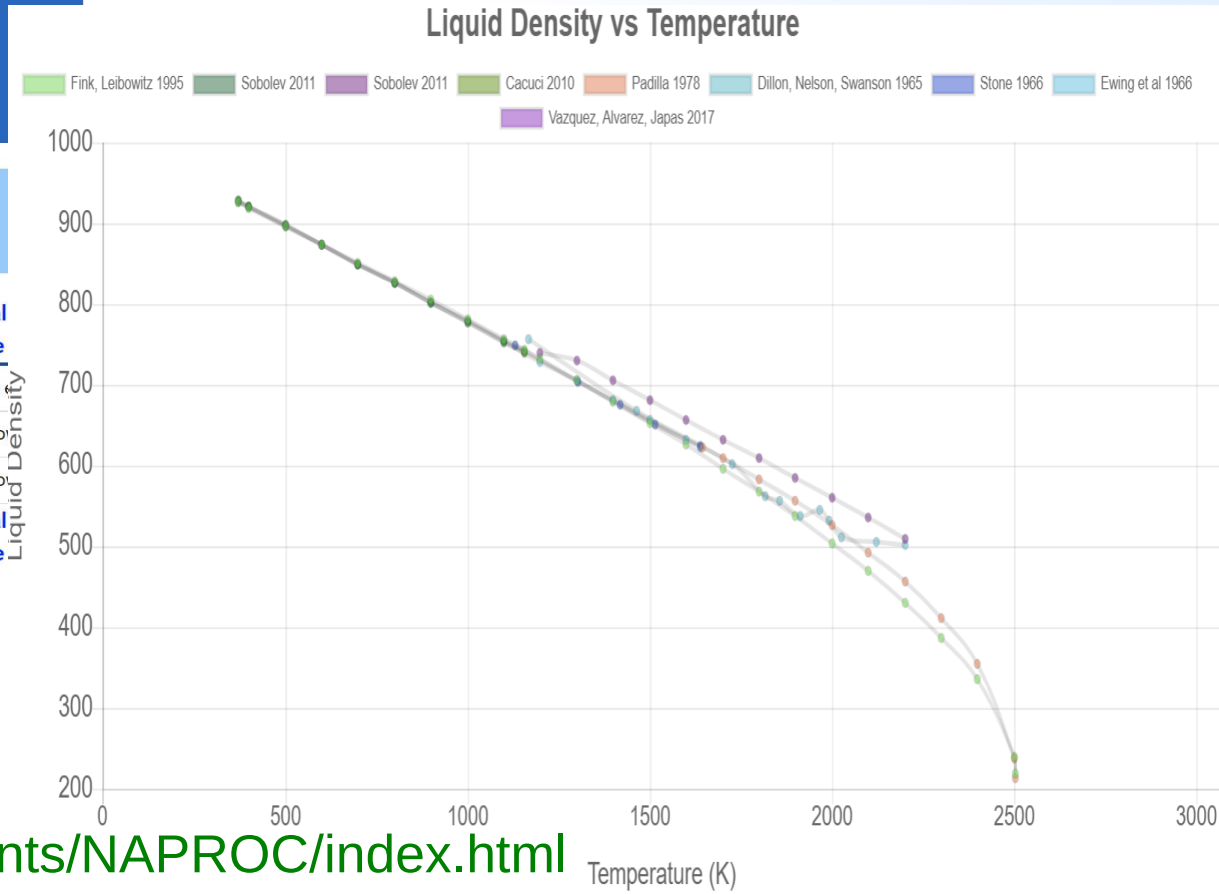






NAPRO: Sodium Properties Calculator

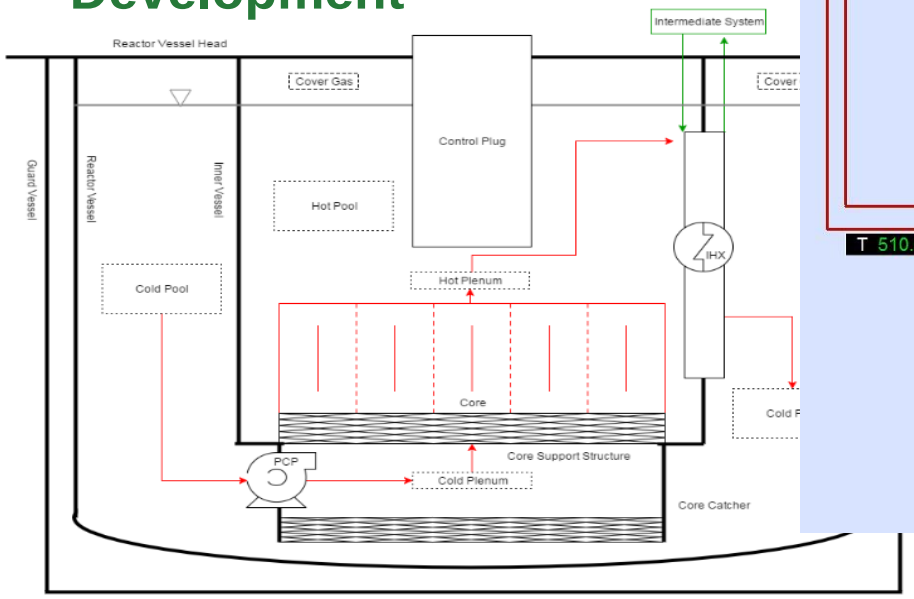


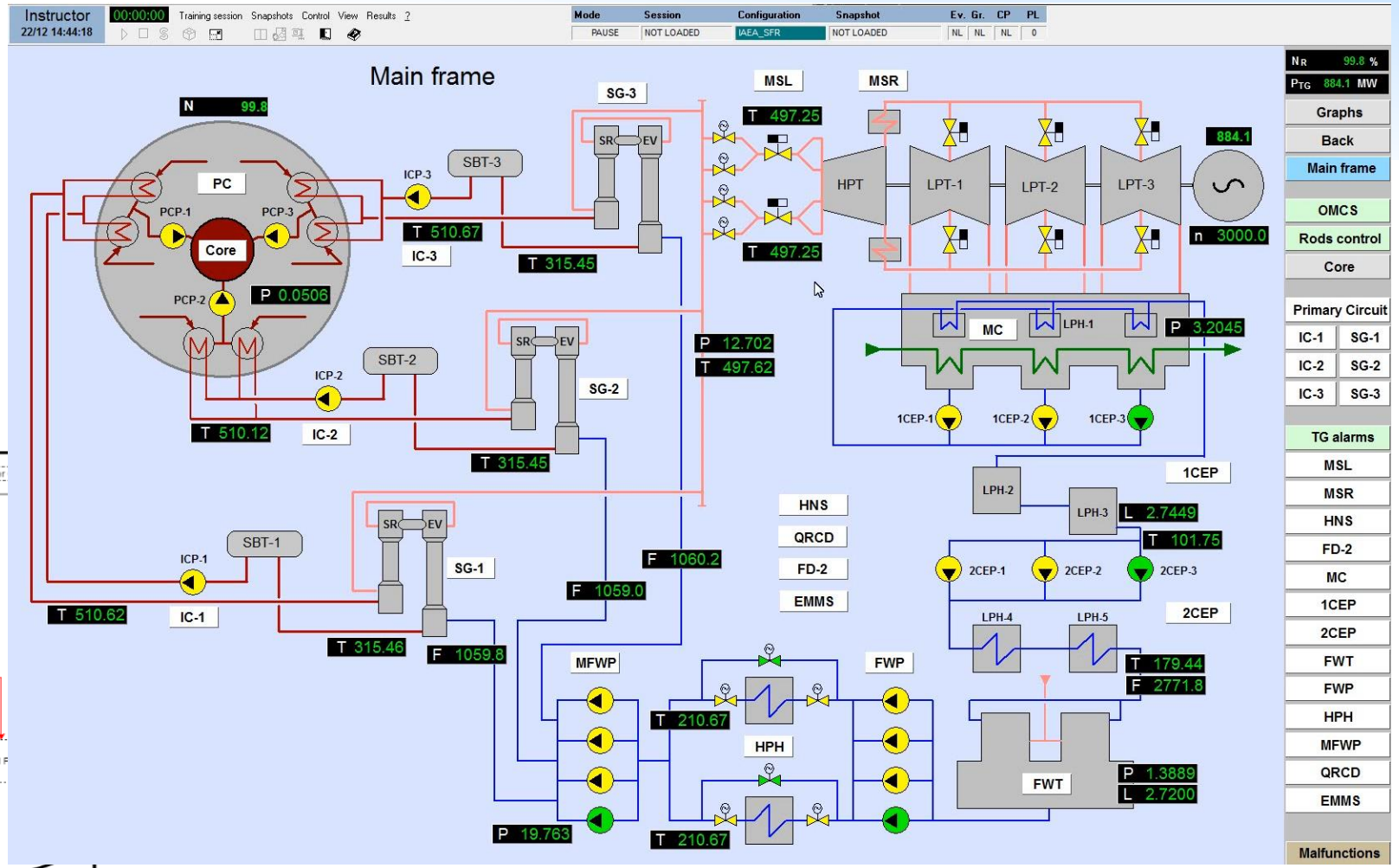


https://nucleus.iaea.org/sites/fr/Shared%20Documents/NAPROC/index.html

SFR Educational Simulator

- Pool type sodium cooled fast reactor simulator for education and training
- **2023: Ready Distribution to Member States**
- **Exercise Manual under Development**





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Thank You!

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