H2020 McSAFER: High-Performance Advanced Methods and Experimental Investigations for the Safety Evaluation of Generic Small Modular Reactors

SNETP Governing Board Nr. 7

V. H. Sanchez-Espinoza, H. Suikkanen, V. Valtavirta, M. Bencik, S. Kliem, C. Queral

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This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945063.

Content

- Technical and scientific approach
- Partners, budget
- Work packages
- Numerical tools
- Remaining R&I gaps

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Technical Goals & scientific approach

Technical goals:

- Advance the safety research for water cooled SMR
  - Perform key experiments relevant for SMR-safety (core, helical HX) at EU-facilities (COSMOS-H, MOTEL, HWAT)
  - Develop, improve, validate simulation tools for safety evaluations of SMRs
  - Demonstrate advantages of advanced (multiphysics /multiscale) tools compared to legacy ones
- Apply simulation tools to four SMR-designs (F-SMR, CAREM, NuScale, SMART)

Scientific approach:

- Combine experimental investigations with numerical tools for safety
- Consider different SMR-designs:
  - Natural circulation: CAREM, NuScale
  - Forced convection: F-SMR, SMART
  - Core design: square (F-SMR, SMART, NuScale) and hexagonal (CAREM) fuel assemblies
  - Etc.

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Partners and Budget

Partners: 13

- R&D: CEA, VTT, HZDR, UJV, JRC KA, CNEA
- **Universities:** LUT, UPM, KIT, KTH
- **Industry:** Jacobs, TRACTEBEL, PEL

Budget:

- Total: 4 045 133.75 €
- EC-contribution: 95 %

  (3 995 982.50 €)
- In-Kind: 5 %

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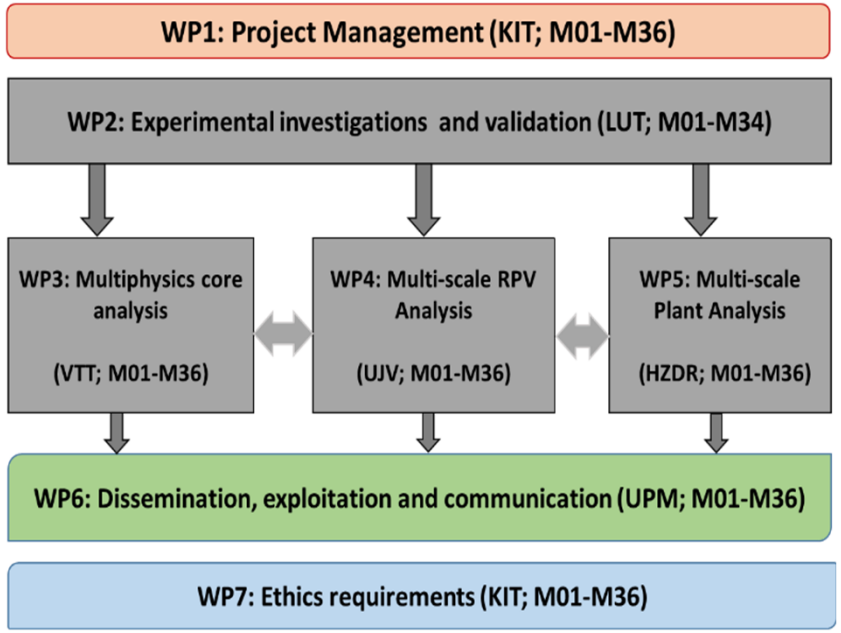
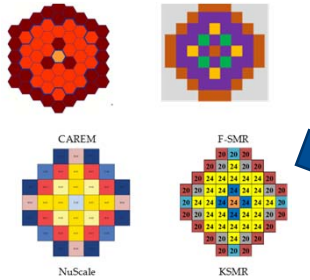
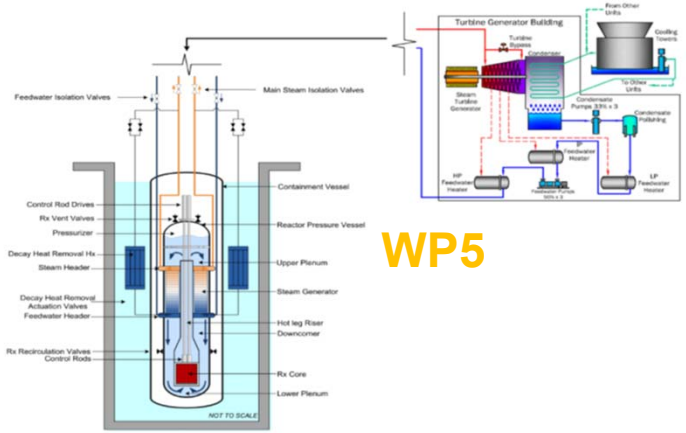
McSAFER: Work Packages, Interactions







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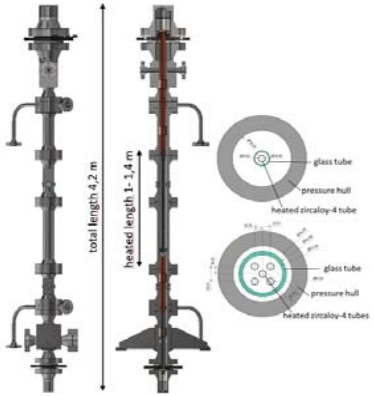
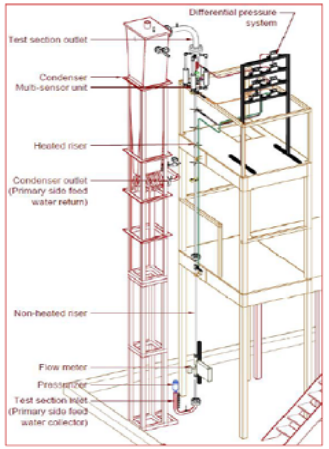
WP2: Key Experimental Investigations & Validation

- Validation matrix: CFD, subchannel, and system thermal hydraulics codes



COSMOS-H (KIT)

MOTEL (LUT)



HWAT (KTH)

- Code validation

Codes	COSMOS-H		
	KIT	LUT	UJV
CFD	CFX	OpenFOAM	CFX
SubCH	SCF		VIPRE
SysTH	TRACE		RELAP3D

Codes	MOTEL				
	KIT	LUT	UJV	UPM	TBL
CFD	CFX		FLUENT		
SubCH			VIPRE		COBRA-TF
SysTH		APROS		TRACE	

Codes	HWAT	
	KTH	UPM
CFD	OpenFOAM	
SubCH		
SysTH	GOTHIC/TRACE	TRACE

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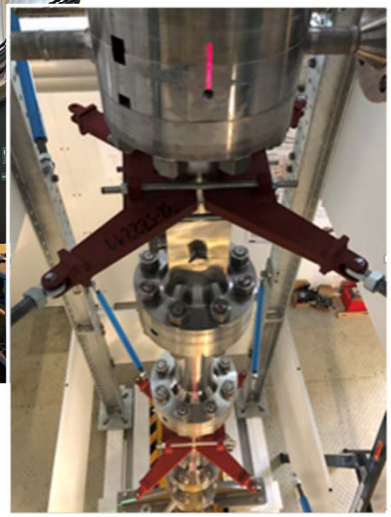
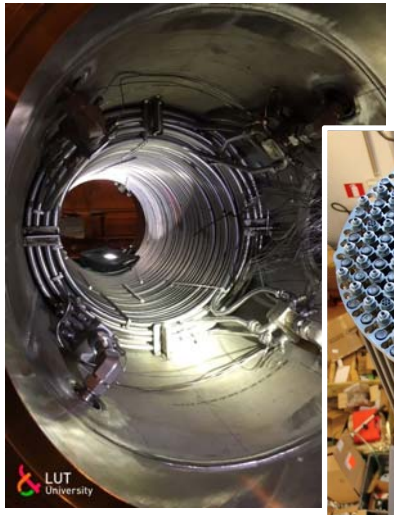
WP2: Key Experimental Investigations & Validation

- Test setups and instrumentation have been prepared and the first experiments at the test facilities and preparation of calculation models is underway.



Installation of the COSMOS-H test section (KIT)



MOTEL steam generator and core modules (LUT)

Multisensor probe unit of the HWAT facility (KTH) →

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McSAFER: WP-3,-4 and-5: McSAFER Numerical Tools

Core analysis (Static /transient)

- Traditional with system code and point kinetics
  - **RELAP5, ATHLET, TRACE**
- 1D system code + 3D nodal diffusion
  - **TRACE/PANTHER**
  - **TRACE/PARCS**
- Low order transport + subchannel codes
  - **PARCS-SP3/Subchanflow (SMART)**
  - **APOLLO3/FLICA (F-SMR)**
  - **WIMS/ARTHUR (NuScale)**
  - **DYN3D-SP3/Subchanflow (NuScale)**
- High-fidelity MC + subch + TM codes
  - **SERPENT2/Subchanflow/TU**

- 1D system TH code + PK
  - **TRACE**
  - **ATHLET**
  - **RELAP5-3D**
- 3D system TH-code + Subchannel code
  - **TRACE/Subchanflow**
  - **TRACE/ARTHUR**
- 3D system TH + CFD code
  - **TRACE/SCF/OpenFOAM (TrioCFD)**
  - **ATHLET/OpenFOAM (CFX)**
  - **ATHLET/FLUENT**

- 1D system TH code + 3D nodal diffusion
  - **TRACE/PARCS (KIT)**
  - **TRACE/PANTHER (TRACTEBEL)**
  - **TRACE/ANTS (VTT)**
  - **ATHLET/DYN3D (HZDR, UJV)**
- 3D system TH-code + Subchannel code + 3D nodal diffusion
  - **TRACE/PARCS/SCF (KIT)**
  - **TRACE/WIMS/ARTHUR (JACOBS)**
- 3D system TH code + 3D nodal diffusion + CFD code
  - **TRACE/PARCS/OpenFOAM (KIT)**
  - **ATHLET/DYN3D/OpenFOAM (HZDR)**
  - **TRACE/ANTS/OpenFOAM (VTT)**
  - **ATHLET/FLUENT/DYN3D (UJV)**

WP3 Scenarios:

- **REA: NuSCALE / SMART**
- **Cold water insertion: CAREM / F-SMR**

WP4 Scenarios:

- **NuSCALE: Boron Dilution**
- **SMART: ATWS**

WP5 Scenarios:

- **NuSCALE: MSLB**
- **SMART: MSLB**

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Remaining R&I Gaps (will be concretized at project end)

- SMR safety-relevant experimental investigations
  - Natural circulation tests in representative geometries for different designs
  - Heat transfer & pressure drop tests for ATF-cladding material candidates (subcooled boiling, void fraction, DNB)

- Multiphysical core physics methods
  - Innovations to improve economics keeping high safety for operational flexibility
  - Advantages of BF-core may need innovative control rod systems, reduce reactivity swing over cycle, assure sufficient shutdown margins at BOC and EOC
  - Multi-group transport solvers to account for harder spectrum, highly heterogeneous and highly leaky core (axial, radial)
- Multiscale / multiphysics safety methods
  - Foster use of CFD for RPV thermal hydraulics combined with 3D core TH with 2Phase flow models (porous-media codes may be intermediate solution)
  - Improve multiscale coupling e.g. of system TH /CFD codes (robustness, flexible coupling, convergence)
  - Increase experimental data base for validation → especially for projects with natural circulation

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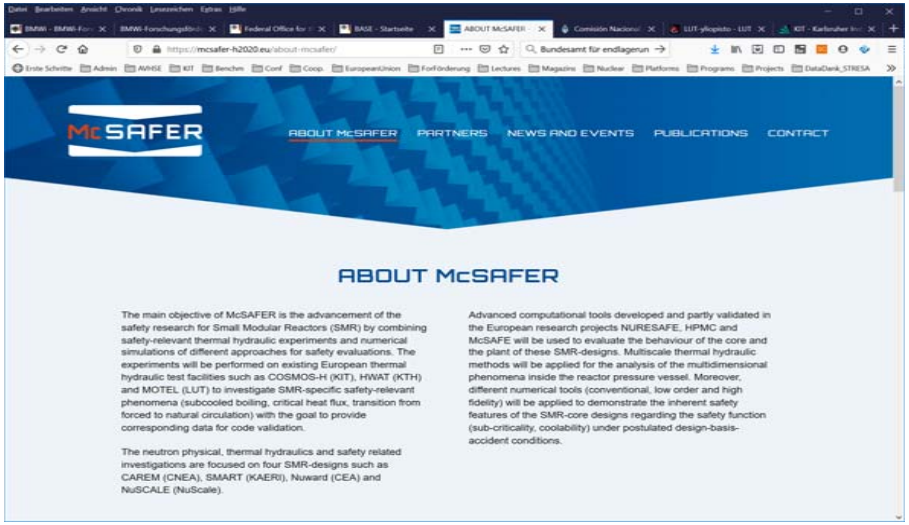
McSAFER Coordinator

Contact:
Victor.sanchez@kit.edu
Handy: +49 15201547532
KIT CN Karlsruhe



Visit website: www.mcsafer-h2020.eu

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Back-Up Slides

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McSAFER Education & Training, Dissemination

- Training courses:
  - First training course on SMR Technologies: January 25-27.2021: UPM
    - 194 participants
  - **Upcoming event: Second training course on neutronics and thermal hydraulics for SMR (March 2022): LUT**
    - See link: **https://mcsafer-h2020.eu/news-and-events/**
  - MOOC course on Multiphysics simulations applied to SMR (march 2023): UPM
- Mobility program
  - 9 fellowships **to be assigned for mobility of young researchers**
    - **See:** **https://mcsafer-h2020.eu/news-and-events/**
    - Still available budget

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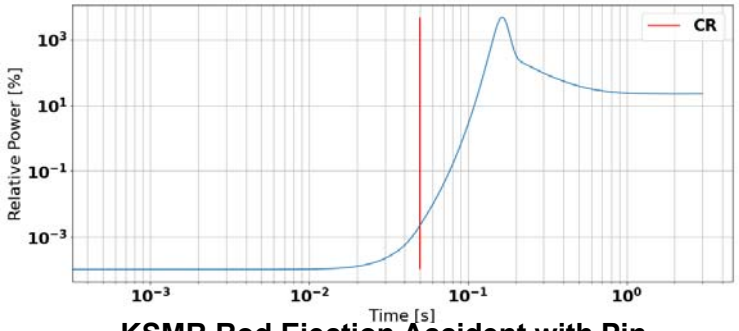
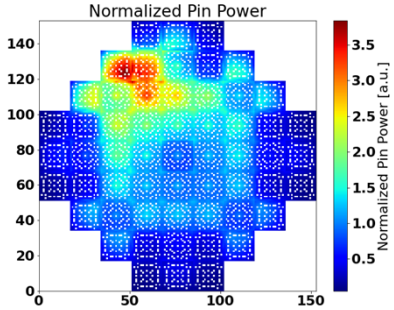
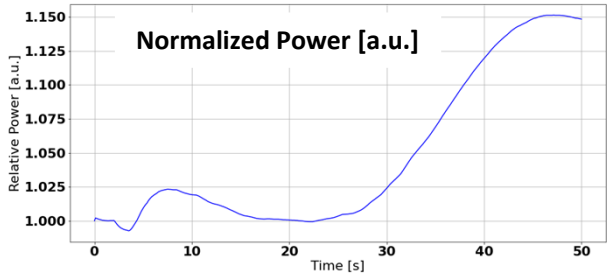
KSMR and CAREM Transient Analysis with PARCS/SCF

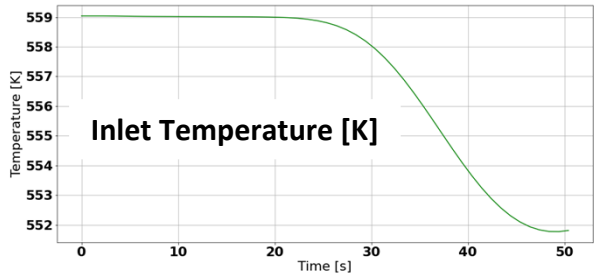


KSMR Rod Ejection Accident with Pin Power Reconstruction at power peak



KSMR REA: Relative power evolution [%]





CAREM Cold Water Transient: Power and core inlet temperature evolution

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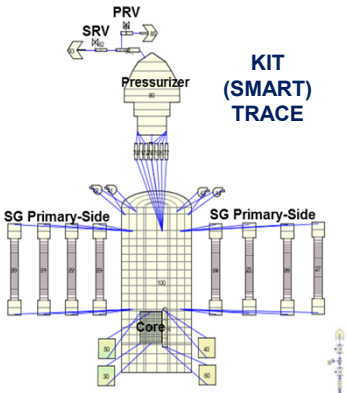
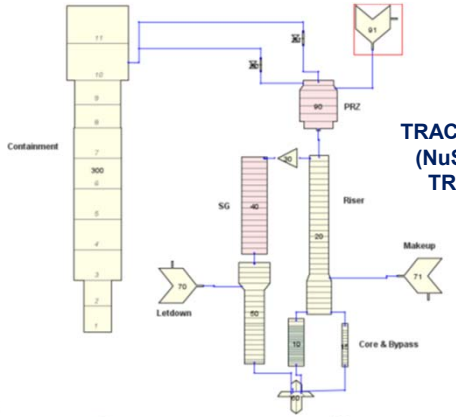
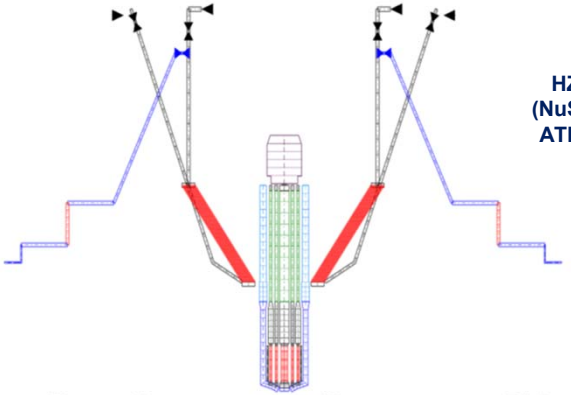
McSAFER: WP4 Multiscale RPV Thermal Hydraulic Analysis



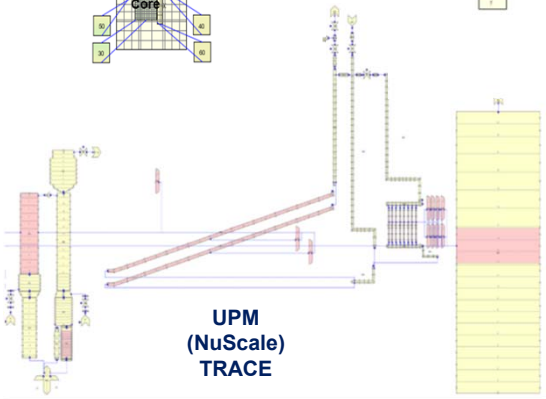
KIT
(SMART)
TRACE



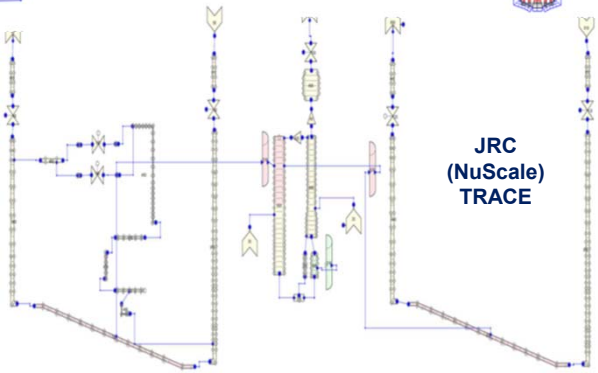
TRACTEBEL
(NuScale)
TRACE



HZDR
(NuScale)
ATHLET

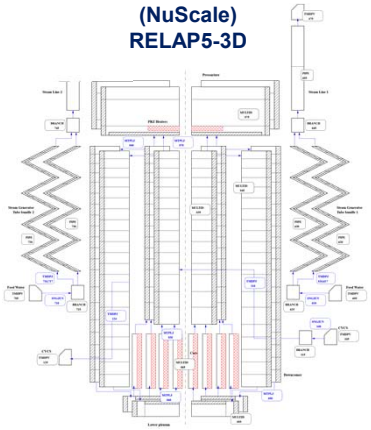


UPM
(NuScale)
TRACE



JRC
(NuScale)
TRACE

UJV
(NuScale)
RELAP5-3D



1D and 3D system TH code models

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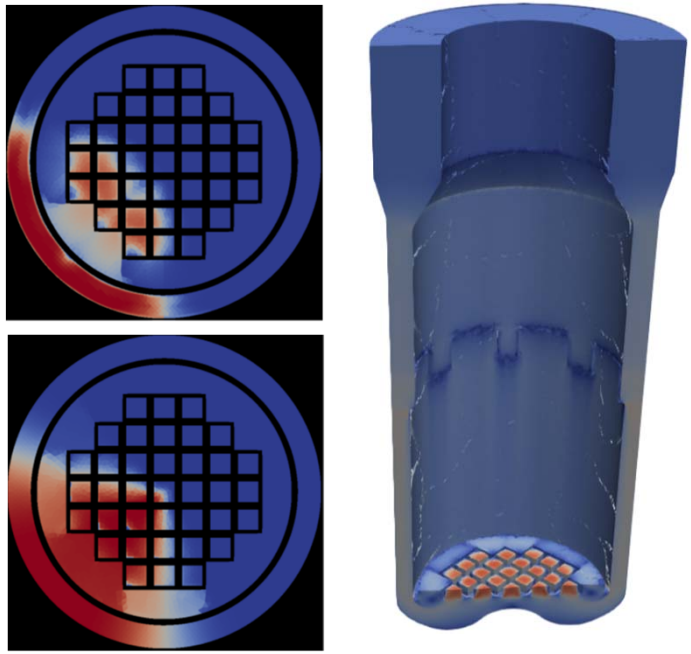
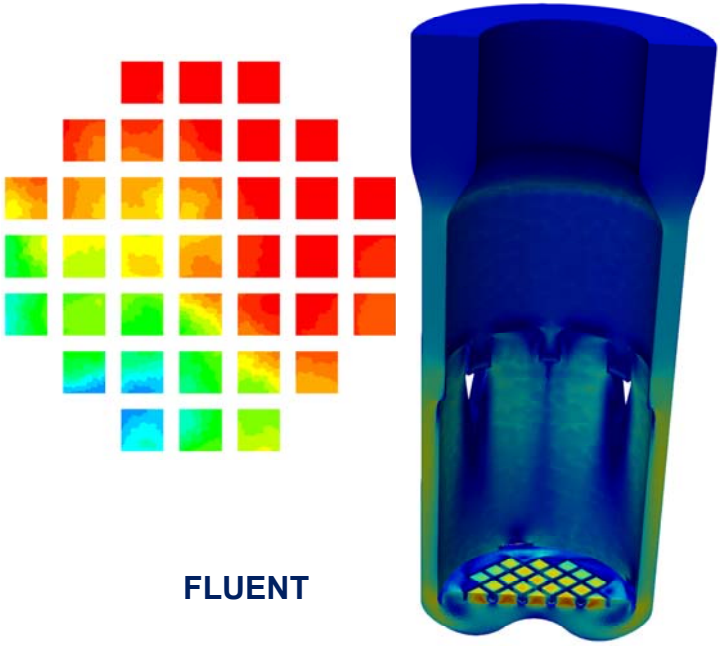
McSAFER: WP4 Multiscale RPV Thermal Hydraulic Analysis



OpenFOAM / TrioCFD



FLUENT

Mixing Scalar Test in NusSale

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