

# Towards geometric multi-scale coupling in preCICE

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<sup>1</sup>Technical University of Munich

Department of Informatics

Chair of Scientific Computing in Computer Science (SCCS)

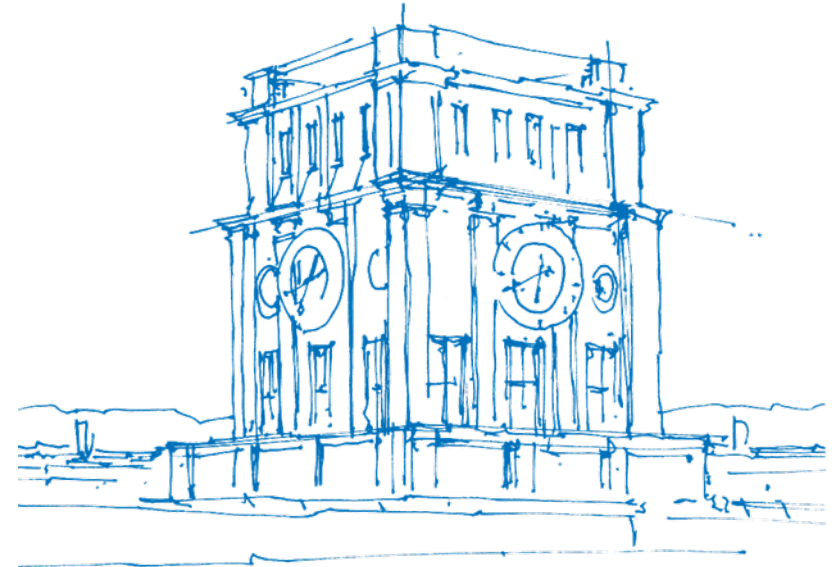
<sup>2</sup>University of Stuttgart

Institute for Parallel and Distributed Systems (IPVS)

Chair of Usability and Sustainability of Simulation Software

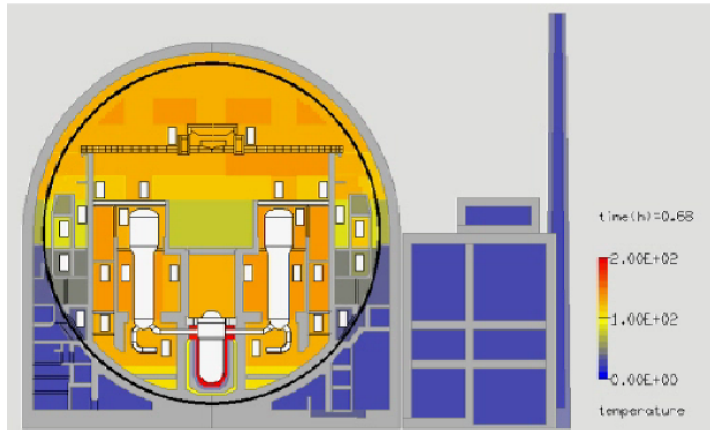
ECCOMAS Young Investigators Congress 2021

July 7, 2021 (online)

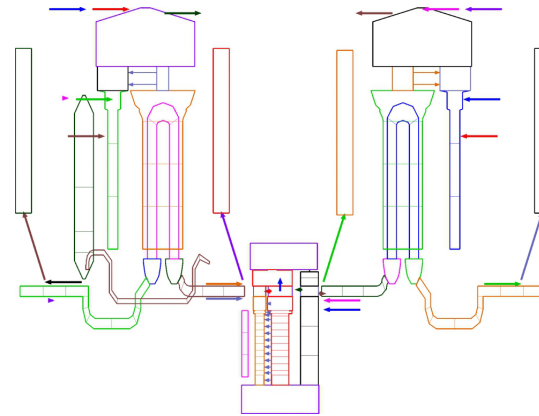
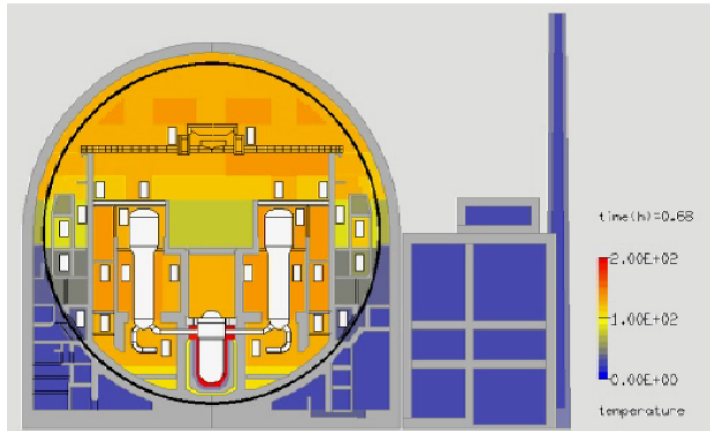


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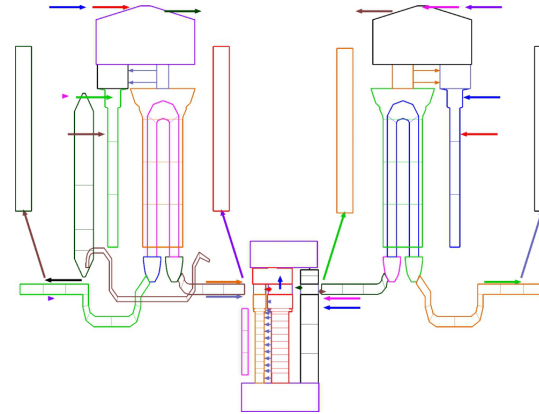
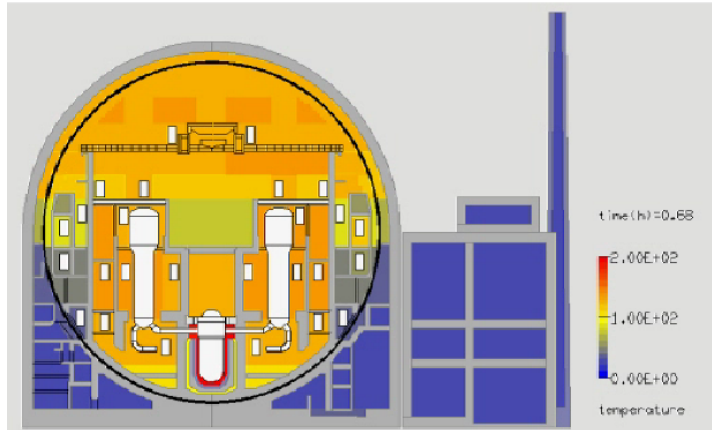
## How would you simulate a nuclear reactor?



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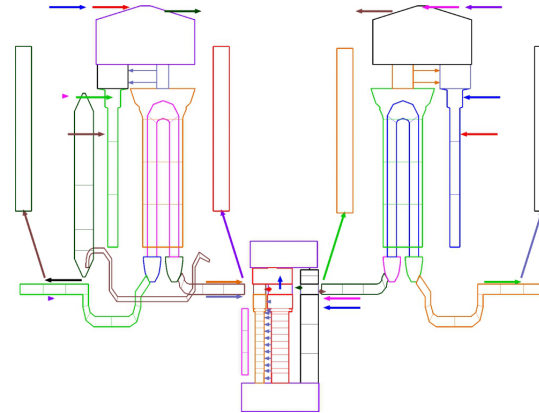
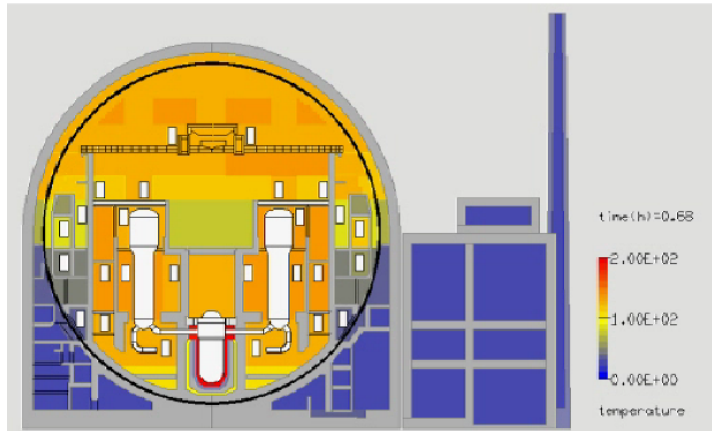


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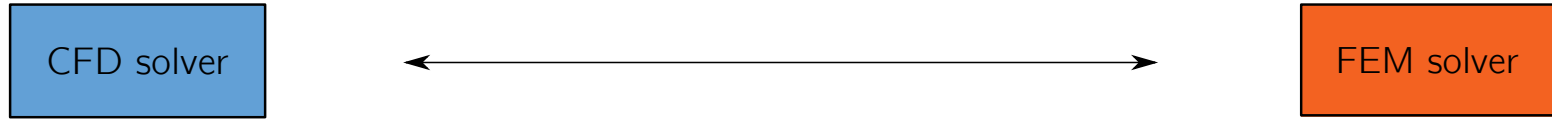
What if we could integrate higher dimension models? (in a plug-and-play way)

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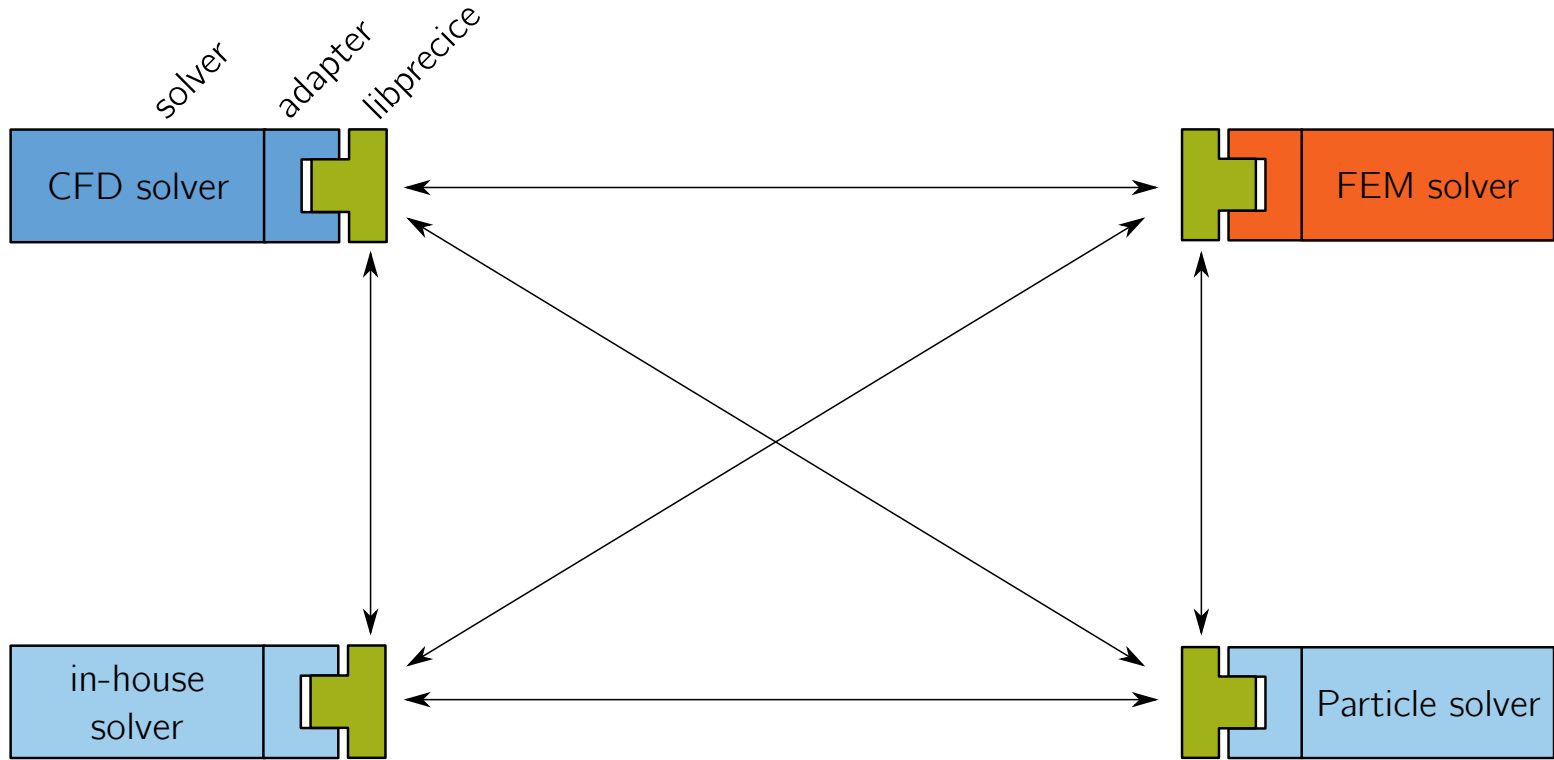


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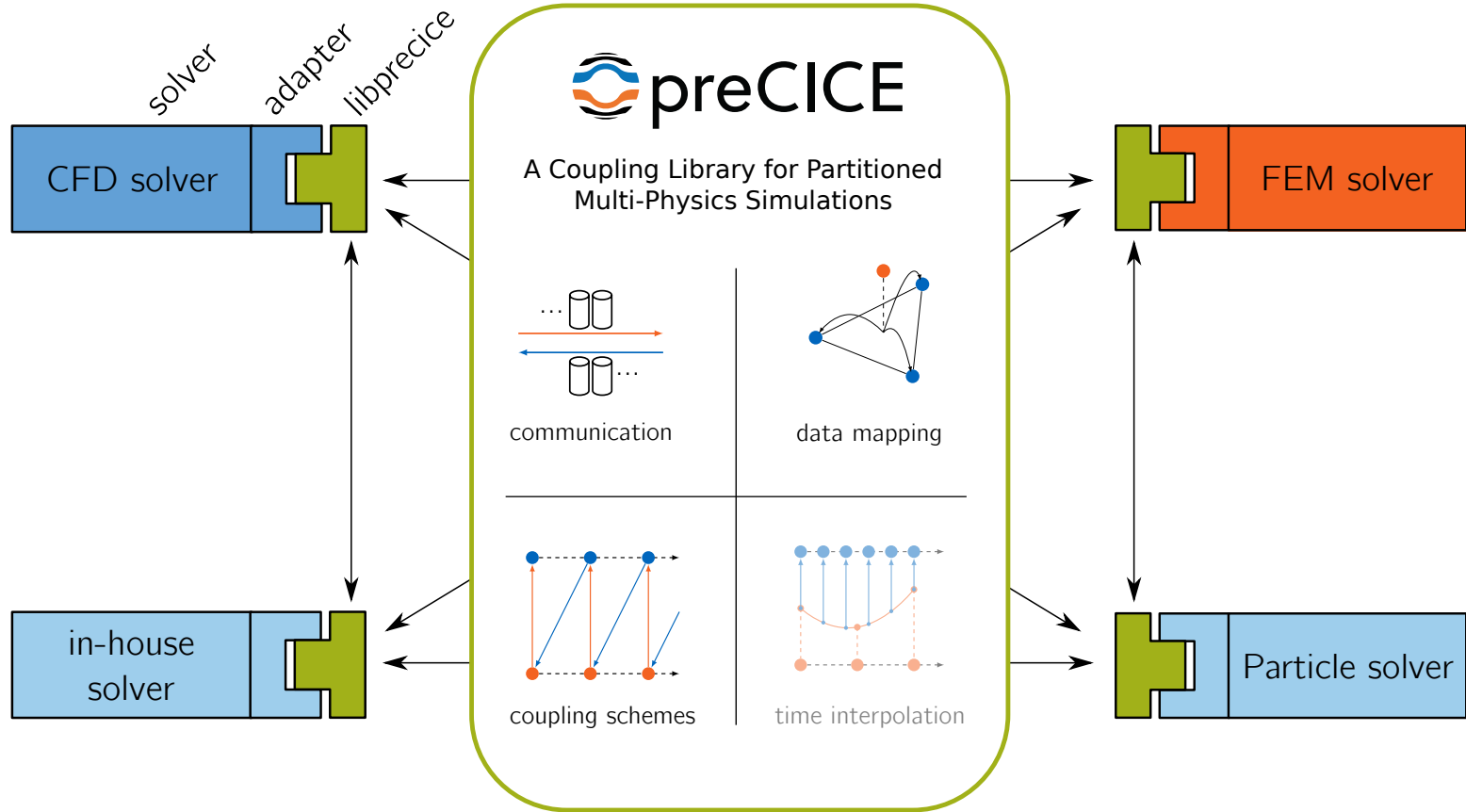


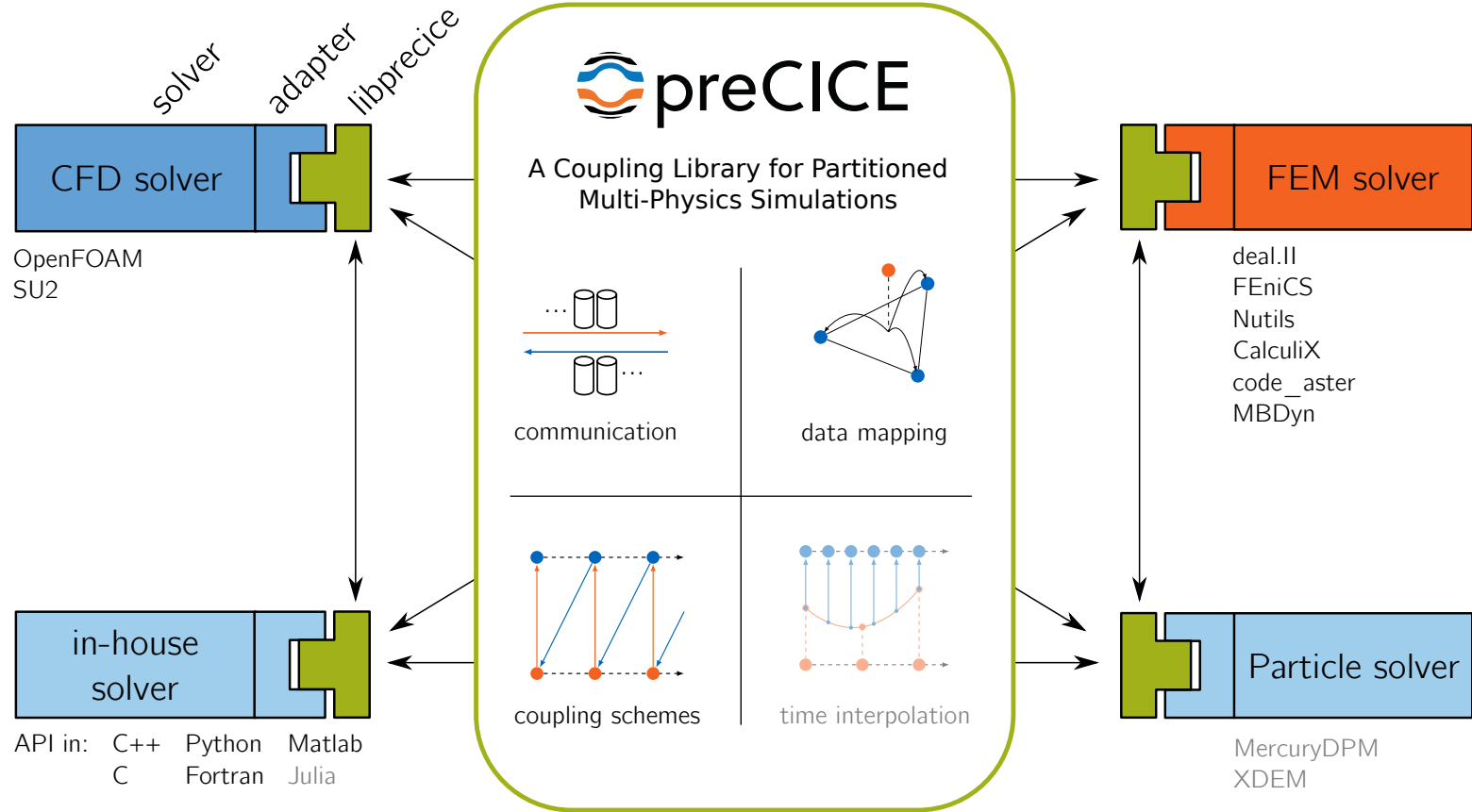




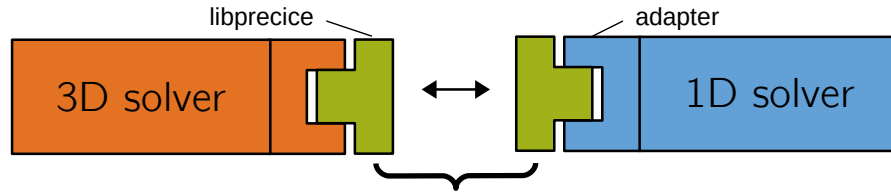




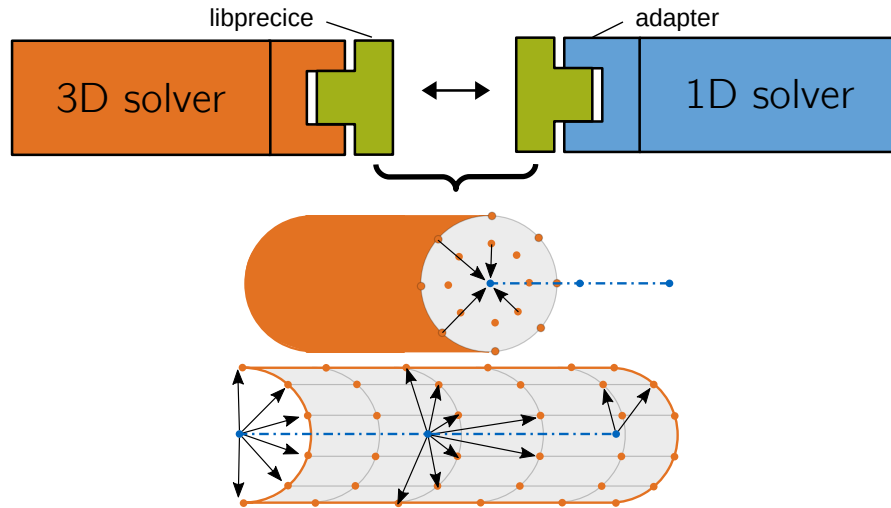




# Geometric multi-scale coupling



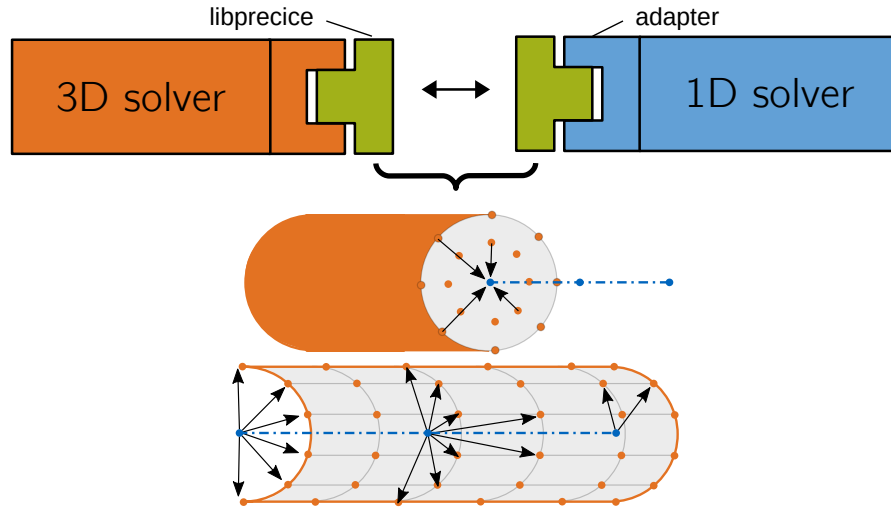
# Geometric multi-scale coupling



Mapping types:

- *axial -vs- radial*
- *collect -vs- spread*

# Geometric multi-scale coupling



Research questions:

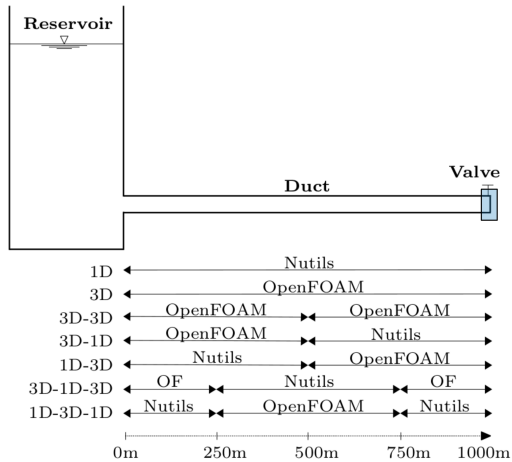
- How to **generate** missing information? (e.g. velocity components)
- How to **reduce** information?
- How to **convert** information? (e.g. velocity vs mass flux)
- How to implement this in a **general** way in preCICE?  
→ What are common **use cases**?

Mapping types:

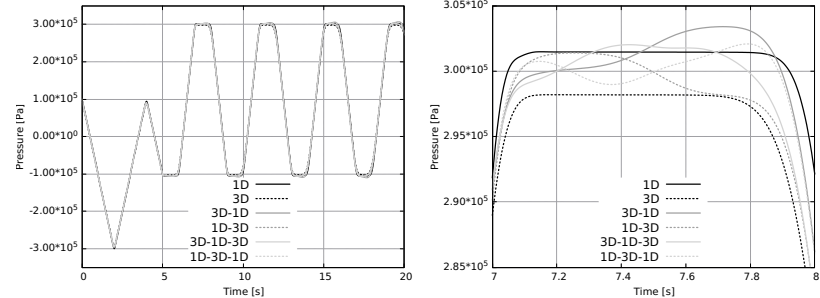
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G. Chourdakis, B. Uekermann, G. van Zwieten, H. van Brummelen (2019). Coupling OpenFOAM to different solvers, physics, models, and dimensions using preCICE. 14th OpenFOAM Workshop, Duisburg.

# Prototype: water hammer (1D-3D fluid-fluid coupling)



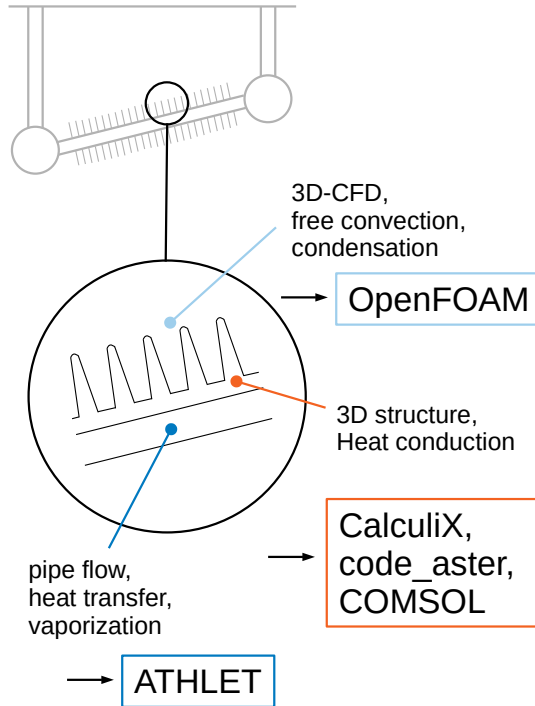
1D single-phase flow in a pipe, opening-closing valve, axial mapping



G. Chourdakis, B. Uekermann, G. van Zwieten, H. van Brummelen (2019). Coupling OpenFOAM to different solvers, physics, models, and dimensions using preCICE. 14th OpenFOAM Workshop, Duisburg.

**Proof-of-concept:**  
feasibility, workbench for developing methods.  
OpenFOAM + Nutils ([www.nutils.org](http://www.nutils.org), Python),  
mapping directly in preCICE

# Prototype: nuclear reactor cooling (1D-3D FF, CHT)



## 1D two-phase flow in pipes

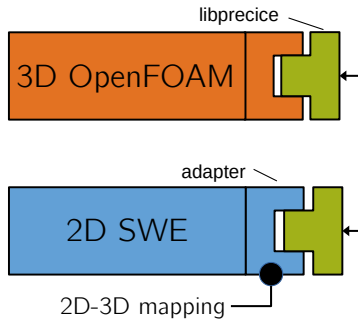
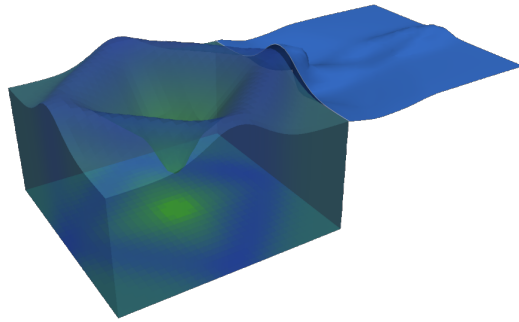
- + 3D flow in critical regions → axial 1D-3D mapping
- + 3D heat transfer in solids → radial 1D-3D mapping

## Long-term goal:

replace several existing coupling systems with a sustainable approach.

J. Herb (2014). *Coupling OpenFOAM with thermo-hydraulic simulation code ATHLET*. 9th OpenFOAM Workshop, Zagreb.

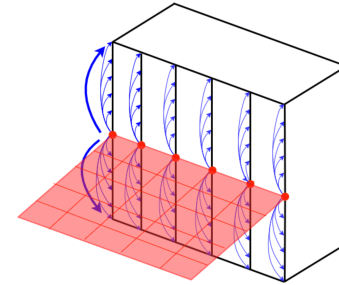
# Prototype: tsunami near coast (2D-3D FF)



2D-3D two-phase flow

- 2D flow in large regions, shallow-water equations
- 3D flow in critical regions, Navier-Stokes equations

→ axial 2D-3D mapping



**Idea:**

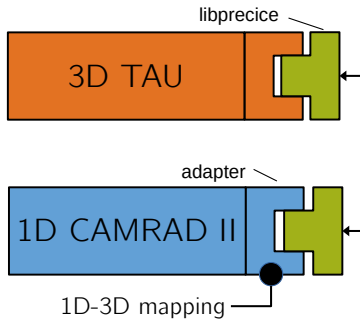
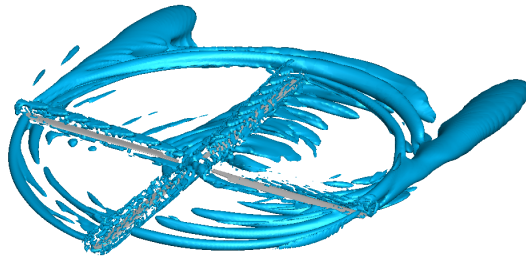
the same approach should work for more than 1D-3D  
(see also 2D-3D in fractures, 5D-6D in plasma fusion)

F.J. Espinosa Pelaez (2020). *A flexible approach to 2D-3D coupling of a Shallow-Water Equation solver to OpenFOAM.*

Master's Thesis. Technical University of Munich.



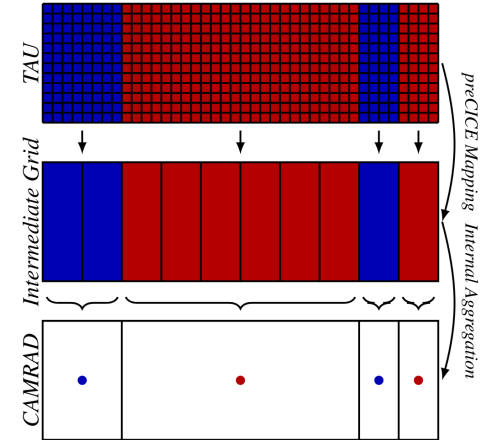
# Prototype: helicopter blades (1D-3D FSI)



1D-3D FSI

- 1D helicopter blade shape (CAMRAD II)
- 3D flow around the blade (DLR TAU)

→ radial 1D-3D mapping



Q. Huang, A. Abdelmoula, G. Chourdakis, J. Rauleder, B. Uekermann (2021). *CFD/CSD Coupling for an Isolated Rotor using preCICE*. Proceedings of the ECCOMAS WCCM 2020.

# People

## Core team:

- **Technical University of Munich, SCCS** (since < 2008)
  - [Gerasimos Chourdakis](#) → [this talk](#)
  - Benjamin R uth
  - Fr d ric Simonis
- **University of Stuttgart, SGS** (since 2013)
  - Miriam Schulte (head)
  - [Kyle Davis](#) → [see talk here at 18:30](#)
  - Amin Totounferoush
- **University of Stuttgart, US3** (since 2021)
  - Benjamin Uekermann (head)
  - Ishaan Desai
  - David Schneider

- + student assistants
- + external contributors on GitHub
- + alumni



# Funding preCICE



Research Software  
Sustainability



Bundesministerium  
für Wirtschaft  
und Energie



EXC 2075  
SimTech



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 754462

# Summary






**Ongoing work:** Currently prototypes for fluid-fluid coupling (1D-3D, 2D-3D) and FSI

**Challenges:** How to generate / reduce / convert information

**Goal:** General implementation in preCICE

**Contact me:** I am looking for use cases for geometric multiscale coupling

`gerasimos.chourdakis@tum.de`

 [precice.org](https://precice.org)  
 [github.com/precice](https://github.com/precice)  
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 preCICE



See also poster: Gerasimos Chourdakis, Qunsheng Huang, Francisco Javier Espinosa Pelaez, Fabian Weyermann, Benjamin Uekermann:

*Geometric multi-scale coupling prototypes with preCICE*. SIAM CSE21, SIAM, 2021

G. Chourdakis | Towards geometric multi-scale coupling in preCICE | YIC 2021