LONKERO

Developing the working arms of Kraken, the next generation computational framework for reactor design and licensing analyses

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Background for LONKERO

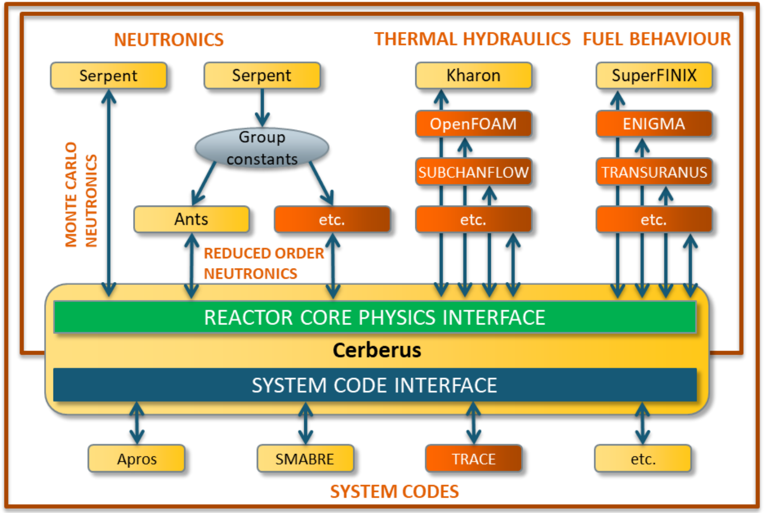
- Historically the independent deterministic safety analyses for Finnish reactors have been conducted by Finnish organizations using Finnish reactor analysis tools.
- Many of the tools currently in use were originally developed in the 80’s and 90’s educating a whole generation of experts into the field of reactor analysis.
- The aging of both tools and expertise leads to challenges.
- New reactor types (e.g. small modular reactors) are expected to enter the market

“*It is expected that by the end of 2022 we will have available […] a new validated set of analysis codes and tools that are ready for the applications to follow […]*”

SAFIR2022 Framework Plan, Objectives of the research on Reactor safety

LONKERO and Kraken

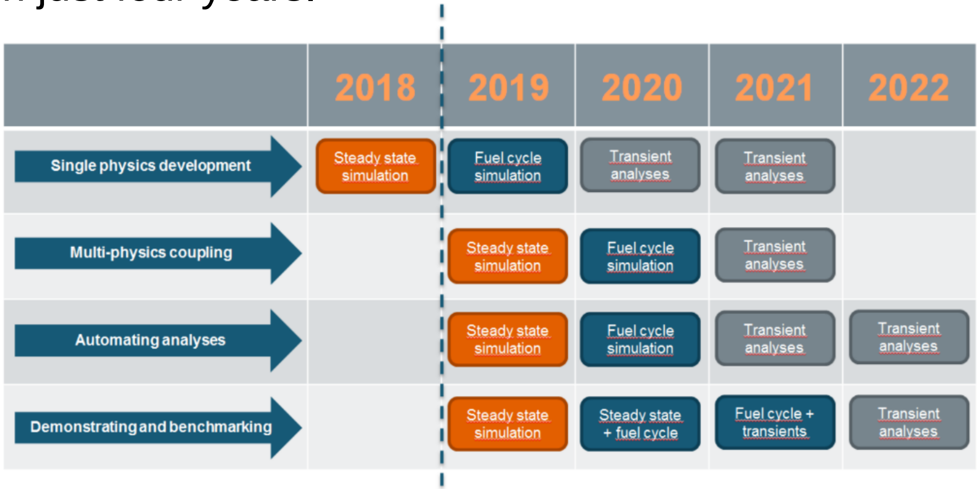
- LONKERO kickstarts the construction of both the next generation reactor analysis framework, **Kraken**, and the expertise to use it for the years to come.
- Kraken combines novel Finnish solvers such as Serpent, FINIX and Ants into a reactor simulator capable of operating cycle and transient analyses with and without plant level feedback.



A schematic representation of the plans for the completed Kraken framework. Finnish solver modules developed at VTT are shown in yellow, while potential state-of-the-art third party solvers to be coupled are shown in orange.

LONKERO and Kraken

- At the start of 2019, the individual solvers were available in various states of development, but the coupling of them into a usable reactor simulator needed to start from scratch.
- Main goal of LONKERO: Build a transient capable reactor simulator that can be applied to safety analyses in just four years.



A high level overview of the four year plan for the development, demonstration and benchmarking of the Kraken framework.

VTT

Development goals for Kraken

Kraken aims to be

- **Capable**: Can evaluate fulfilment of design bases according to YVL-guides and NUREG-0800.
- **Usable**: Offers a reasonable user interface while automating the routine parts of analyses.
- **Modular**: Allows cross-verification of single physics solvers even in coupled transients.
- **Alive**: Maintains source-code level expertise of the different parts of the framework.
- **Excellent**: Uses state-of-the-art and beyond-the-state-of-the-art approaches whenever possible.

Kraken is intened both as a

- **Safety analysis tool**, able to conduct Finnish deterministic safety analyses in the future, and
- A **research and design tool** that can be applied to reactor core related research problems including the design of new reactor concepts.

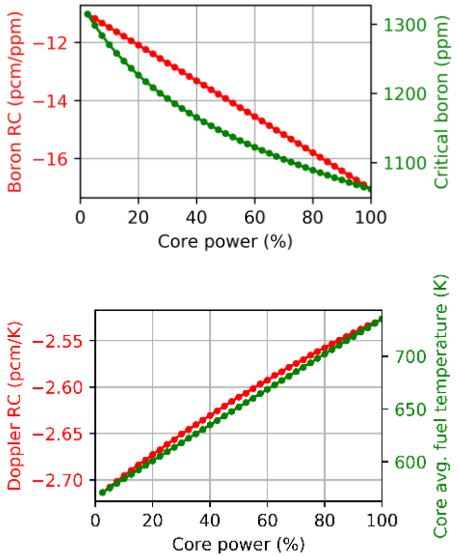
VTT

LONKERO 2019

- Establishing the basic solver modules.
- Establishing a coupling between the solvers.
- Demonstrating the **capability** and **modularity** at steady state:

	CZP			HZP			HFP		
	Ants	**Serpent**	**A–S**	**Ants**	**Serpent**	**A–S**	**Ants**	**Serpent**	**A–S**
RB1	861	874	–13	1974	2012	–38	2084	2221	–137
RB2	2094	2092	+2	2218	2161	–57	2290	2285	+5
SB3	2592	2597	–5	3547	3559	–12	3612	3697	–85
SB4	2592	2596	–4	3547	3560	–13	3612	3703	–91

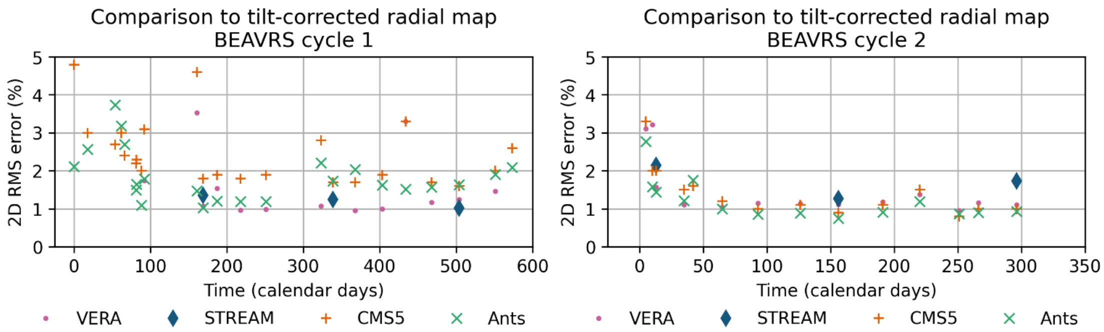
Using high-fidelity solver to verify reduced order solver performance also in coupled calculations: Control rod group worths in an SMR core evaluated by Ants and Serpent based coupled calculation sequences in cold-zero-power (CZP), hot-zero-power (HZP) and hot-full-power (HFP) conditions.



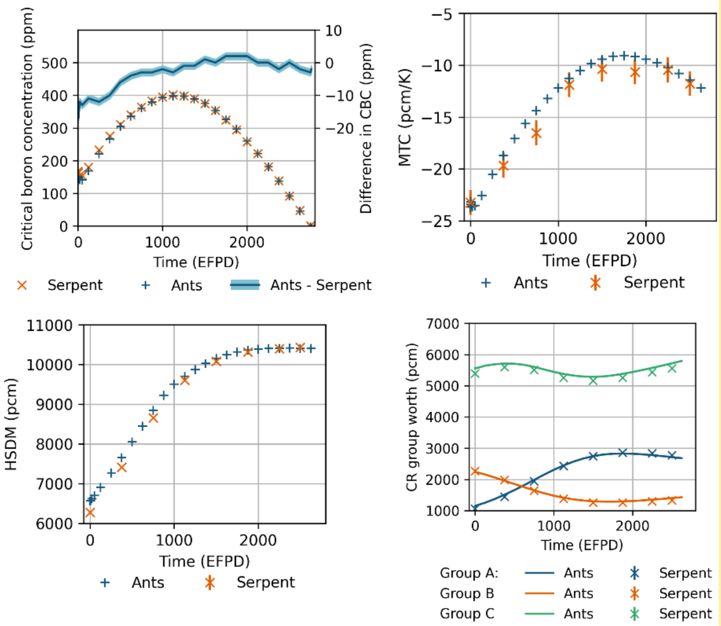
Evaluating licensing relevant data:
Two reactivity coefficients calculated with Ants-Kharon-SuperFINIX for the SMR core at various power levels:
Top: Boron reactivity coefficient (red) and critical boron (green).
Bottom: Doppler reactivity coefficient (red) and core average fuel temperature (green).

LONKERO 2020

- Extending the solvers and coupled solution to operating cycle analyses.
- Constructing a reactor core simulator for operating cycle analyses.
- Demonstrating the **capability**, **usability** and **modularity** of the core simulator in operating cycle analyses.
- Beginning the validation of the framework for operating cycle analyses.



Validation: 2D RMS errors when comparing calculated results to measured detector maps during the two operating cycles of the BEAVRS benchmark. Various industry and scientific leaders and Kraken (Ants).



Automatic evaluation of licensing relevant data during the simulation of an SMR operating cycle. Verification by switching one physics from reduced order solver (Ants) to a high-fidelity one (Serpent), while Kharon and SuperFINIX models are kept constant

Top left: Boron letdown curve.

Top right: Moderator temperature reactivity coefficient.

Bottom left: Instantaneous hot shutdown margin.

Bottom right: Control rod group worths.

LONKERO 2021-2022

- The project moves to transient analyses.
- Time-dependent solutions for the individual solvers and reactor simulator as a whole implemented in 2021.
- Demonstration of **capability**, **usability** and **modularity** in transient simulations in 2022.
- Beginning of validation of Kraken for transient analyses in 2022.

beyond the obvious

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