INL/MIS-22-69011-Revision-0



# Coupled Multiphysics Earthquake Simulation of MSRs

September 2022

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Changing the World's Energy Future


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**September 2022**

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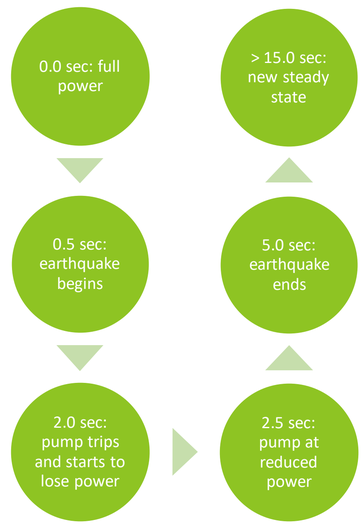
# Coupled Multiphysics Earthquake Simulation of MSRs

**Chandrakanth Bolisetti[a], Guillaume Giudicelli[b], Abdalla Abou-Jaoude[a], Paolo Balestra[c], Mauricio Tano[c]**

[a]Advanced Reactor Technologies and Design, [b]Computational Frameworks, [c]Thermal Fluids

## Background

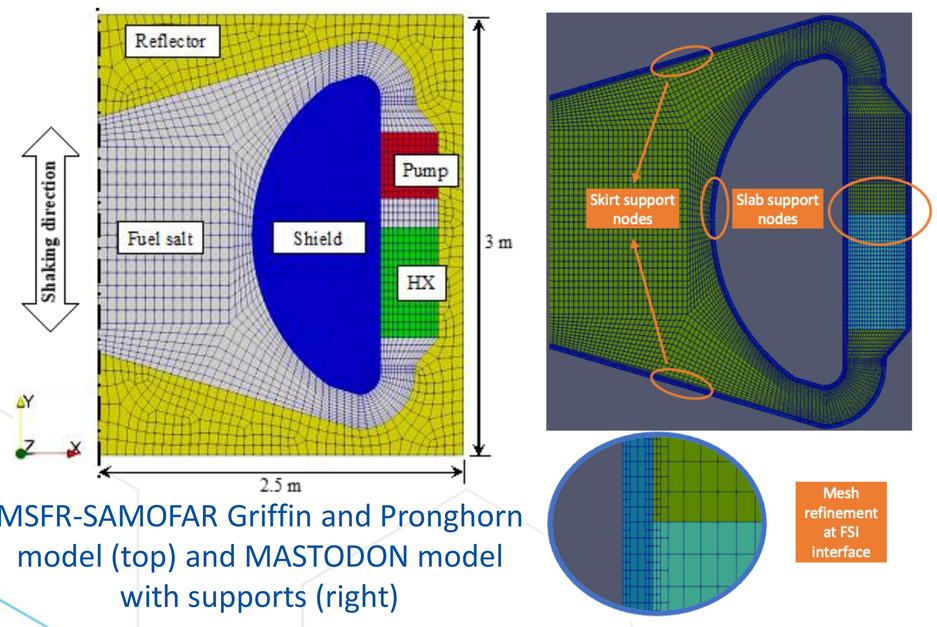
- Earthquakes affect numerous nuclear power plants around the world and safe earthquake design requires that the physics of reactors subjected to earthquakes is well understood.
- This project attempts to understand the physics of **molten salt reactors** (MSRs) subjected to earthquakes using coupled multiphysics tools in MOOSE.
- A **beyond-design-basis scenario** of an unprotected pump trip (ULOFA) during an earthquake is analyzed.



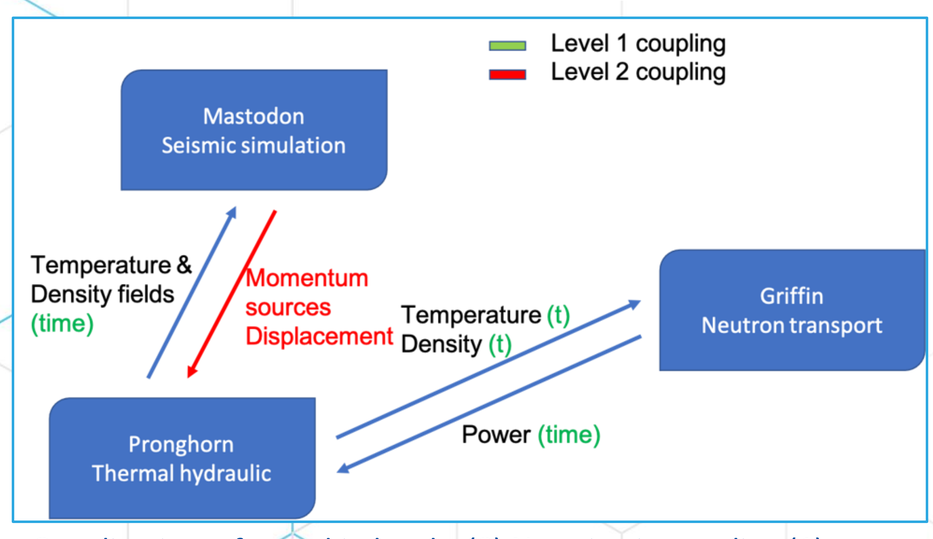

## Reactor model and coupling scheme

Three MOOSE apps are used:
- Griffin: neutronics
- Pronghorn: thermal hydraulics
- MASTODON: seismic acoustic fluid-structure interaction

Unique simulation challenges:
- multiphysics, time scales, moving meshes
- Such a coupling has never been done before → **only possible in MOOSE**




MSFR-SAMOFAR Griffin and Pronghorn model (top) and MASTODON model with supports (right)




Coupling is performed in levels: (0) No seismic coupling (1) one-way seismic coupling and (2) two-way multiphysics coupling

## Publications

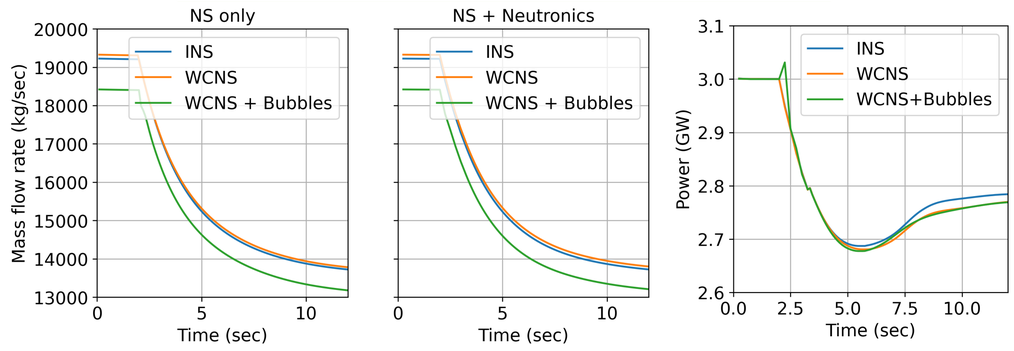
Kim et al (2021). "Coupled Multiphysics Seismic Simulations of Molten Salt Reactors", Transactions: ANS Winter Meeting, Washington, D.C., November 2021.

Bolisetti et al (2022). "Coupled Multiphysics Seismic Simulations of Molten Salt Reactors", Transactions: ANS Winter Meeting, Phoenix, AZ, November 2022.

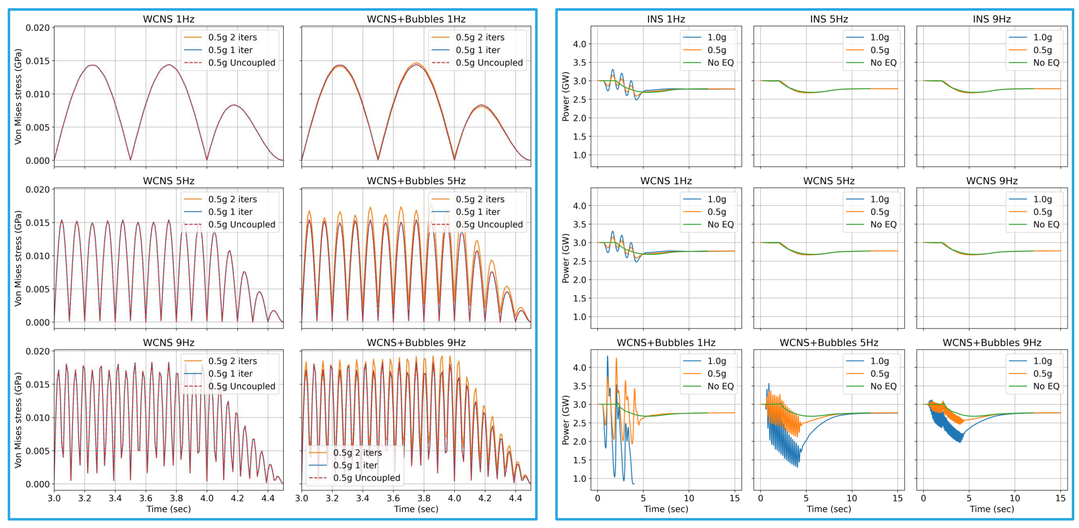
Bolisetti et al (2022). "Coupled Multiphysics Seismic Simulations of Molten Salt Reactors", *International Journal of Energy Research*, *under preparation*.

## Earthquake + ULOFA Results

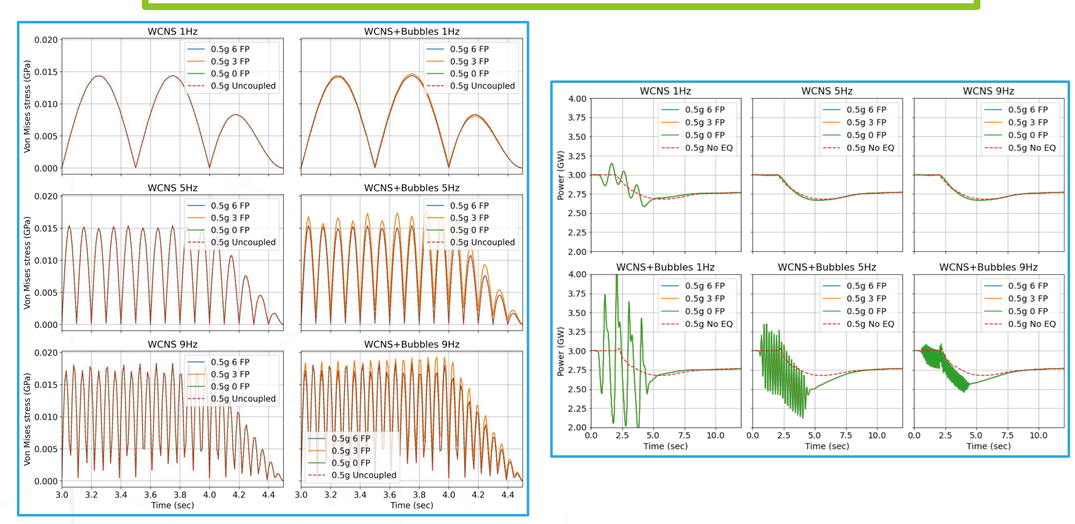
### Level 0 – no earthquake: loss of flow accident




### Level 1 coupling : MASTODON -> Pronghorn + Griffin




### Level 2 coupling : MASTODON <-> Pronghorn + Griffin




| Observations | Implications |
|---|---|
| Earthquakes can cause considerable power perturbations, especially at low frequencies (i.e., 'slow' shaking) | Traditional thinking is that low frequencies are safe – this research shows that it *may not* be. |
| Power perturbations are very sensitive to bubbles in the core. More research is needed to evaluate the bubble formulation and estimate bubble fraction. | Reactivity control mechanisms that rely on bubbles and maintenance protocols to remove fission gas bubbles should be evaluated for earthquakes. |
| Coupling effect of reactor vessel stress is limited, but more research is needed to evaluate temperature effects on stress (not modeled here) | Reactor vessel may be designed without considering this neutronics and TH feedback (for earthquake-resistance purposes) |
| Coupling effect is limited to 1-2 Picard iterations | Few Picard iterations might be enough to evaluate seismic coupling |

## Future plans

- Seek additional funding opportunities from industry and institutional partners of the INL
- Using such coupled simulations to evaluate natural circulation, reactivity control mechanisms through gas injection, impact of technologies such as seismic isolation, etc

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