Molten Static Salt (MOSS) Reactor

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Motivation

Currently in the United States, one of the most problematic outcomes of the nuclear power industry is what to do with spent nuclear fuel. It is highly toxic and will exist for thousands of years. We propose a solution where we take the spent nuclear waste from current reactors and repurpose it to burn off the long-lived actinide byproducts. Using a fast spectrum reactor, the heavy elements can be fissioned into short-lived products that are more easily managed.

Designing a next-generation reactor concept is critical to the evolution of the nuclear industry. Closing the fuel cycle by reprocessing waste is an environmentally sound practice to reduce heavy metal strip mining, and it allows for the generation of green energy that can meet net zero carbon emission demands.

Background

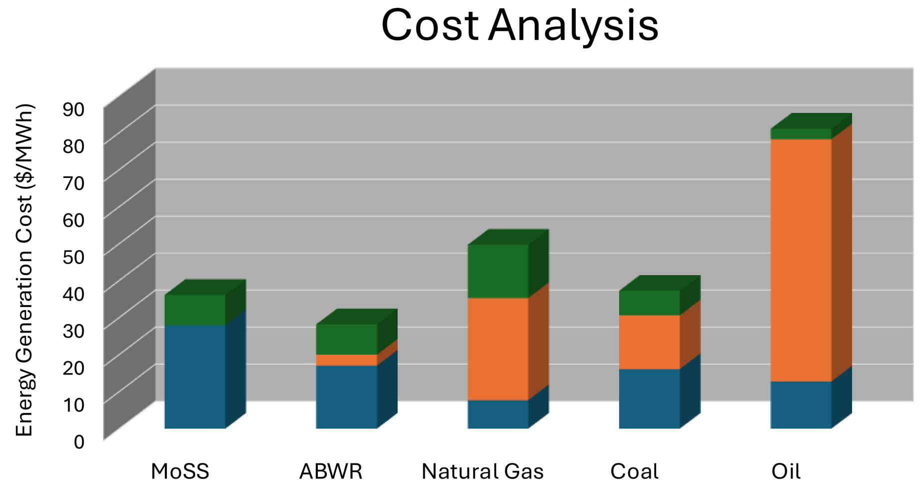
Several companies have begun investigating fast spectrum salt reactors to burn nuclear waste. The proprietary SSR-W Reactor design by Moltex Energy has recently been approved for construction in Canada. It uses waste from Canadian heavy-water reactors to produce energy. However, it uses a much lower plutonium concentration fuel, meaning that its waste burning capabilities may be limited.

Our group has adopted their plan for static salt fuel tubes as they provide a barrier to accidental radioactive releases and limit damaging radiation to control systems on the reactor periphery. Using fuel tubes also ensures a consistent geometry and can provide better reactivity control in the event of coolant leaks

Economics

- Energy generation cost is significantly lower than fossil fuels
- Fuel fabrication and transportation costs will be charged to companies for recycling nuclear waste (0$ net cost)
- 8.5¢/kWh profit using electricity rate from Georgia Power

Cost Analysis

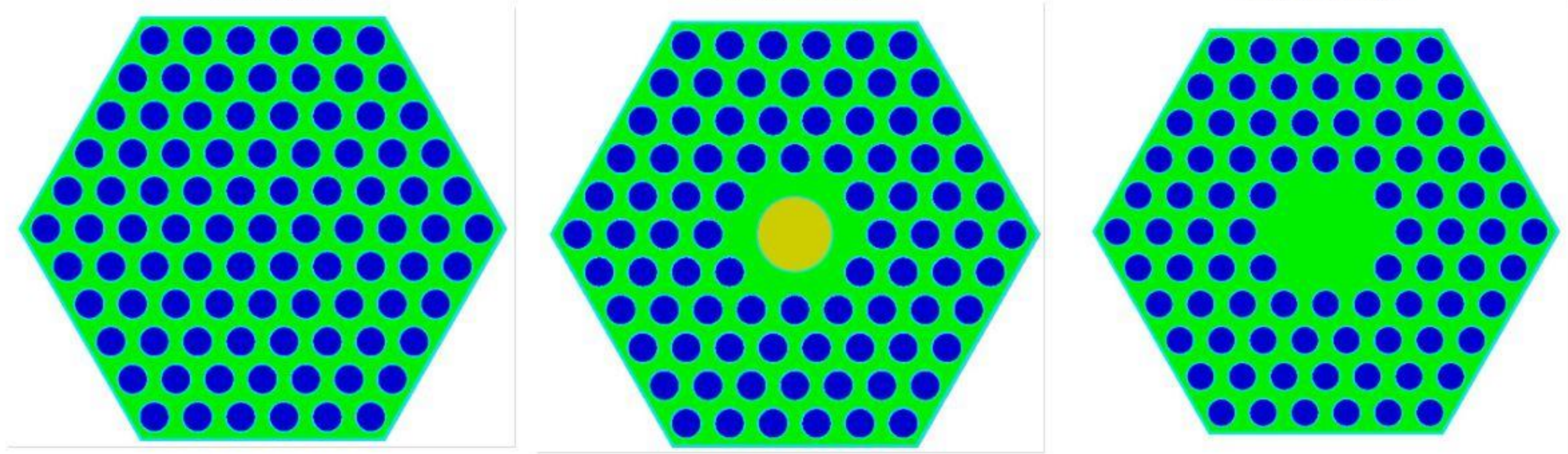


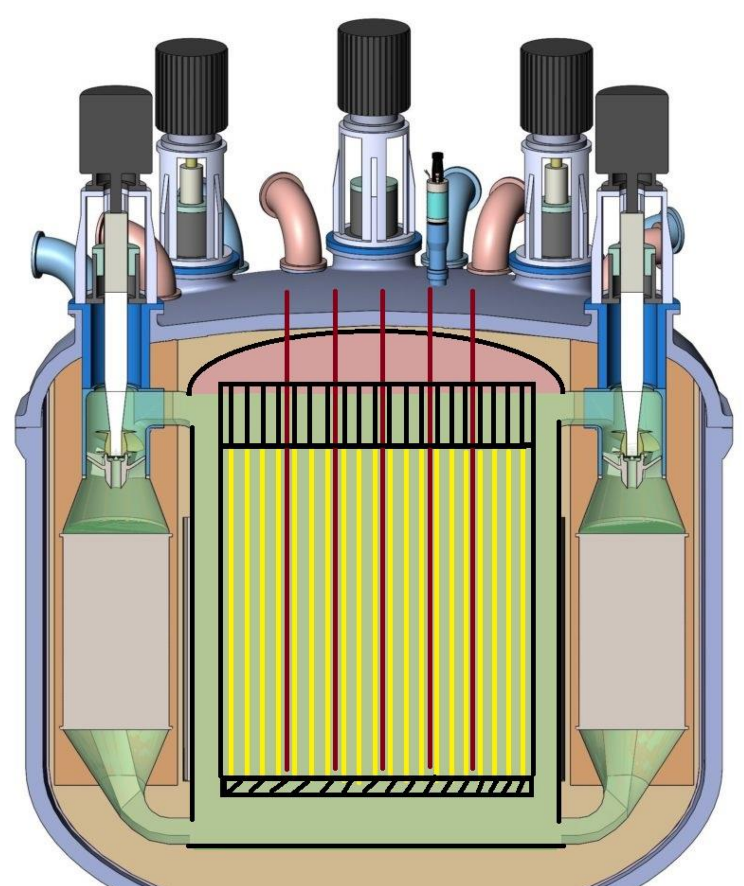
Design

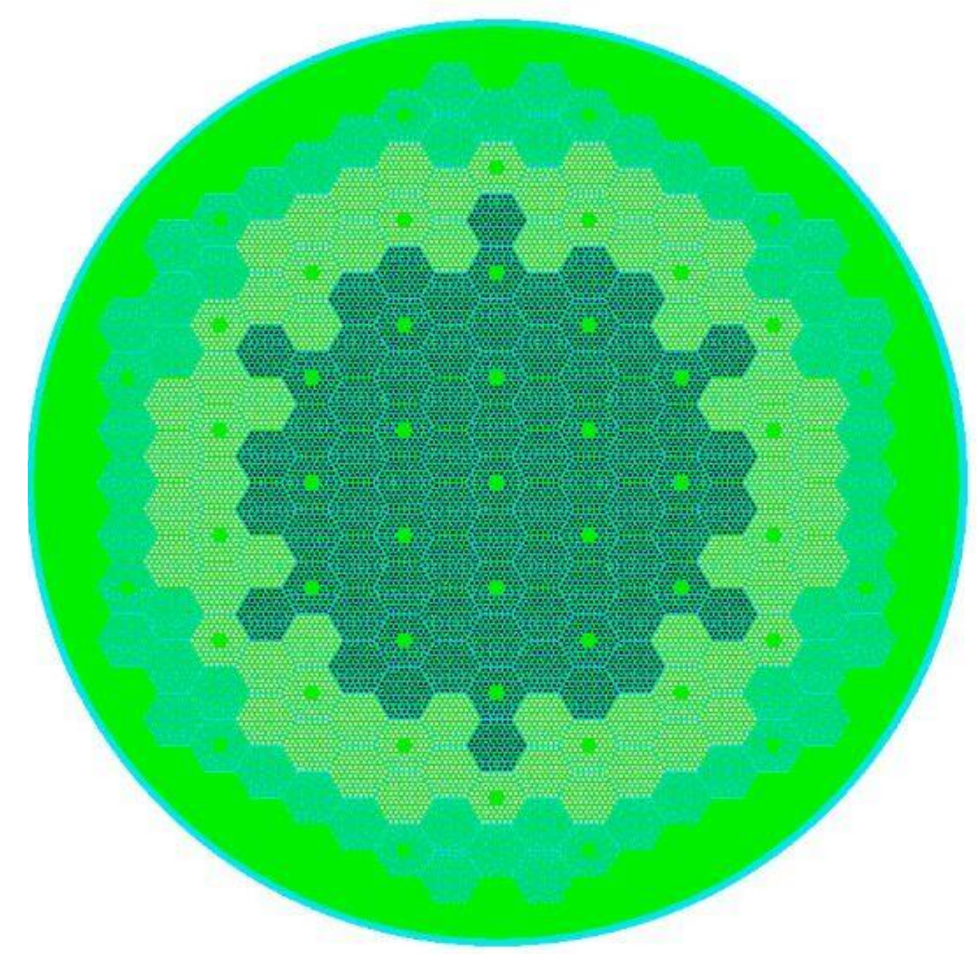
Filled Assembly
91 fuel rods

Control Rod Assembly
84 fuel rods

Empty Guide Tube Assembly
84 fuel rods







211 Assemblies
18858 Total Fuel Rods
37 Control Rods

Salt Optimization

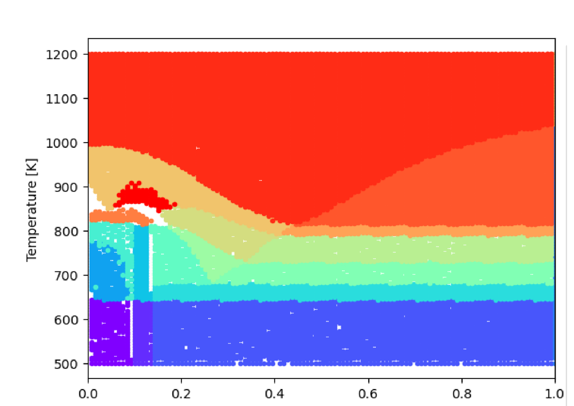
- **Fluoride** coolant and **Chloride** fuel salt
- The optimal salt composition depends on operating conditions/objectives
  - Maximize coolant **heat transfer coef.**
  - Maximize fuel **thermal conductivity**
  - Maintain reasonable **melting points**

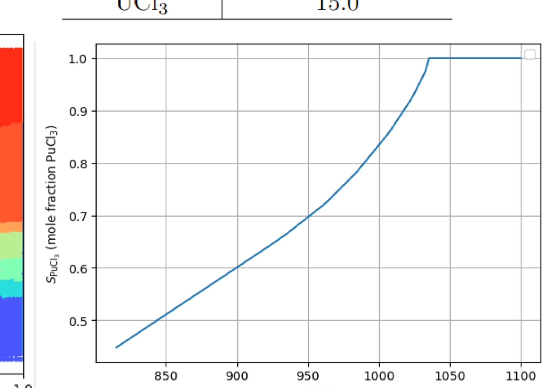
Coolant Salt

Endmember	Mole Fraction (%)
NaF	13.2
ZrF_4	3.2
KF	41.09
LiF	41.77

Fuel Salt

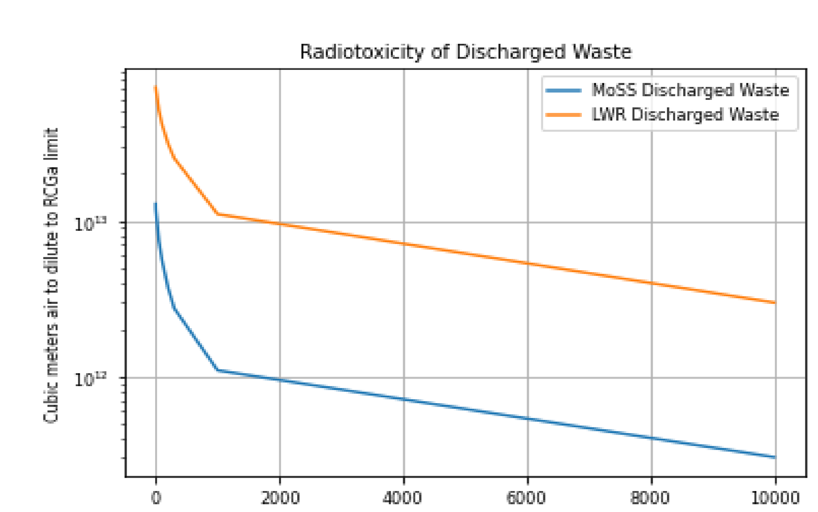
Endmember	Mole Fraction (%)
NaCl	25.0
KCl	14.1
$ZrCl_4$	5.9
$PuCl_3$	39.8
$NdCl_3$	0.2
UCl_3	15.0





Radiotoxicity Reduction

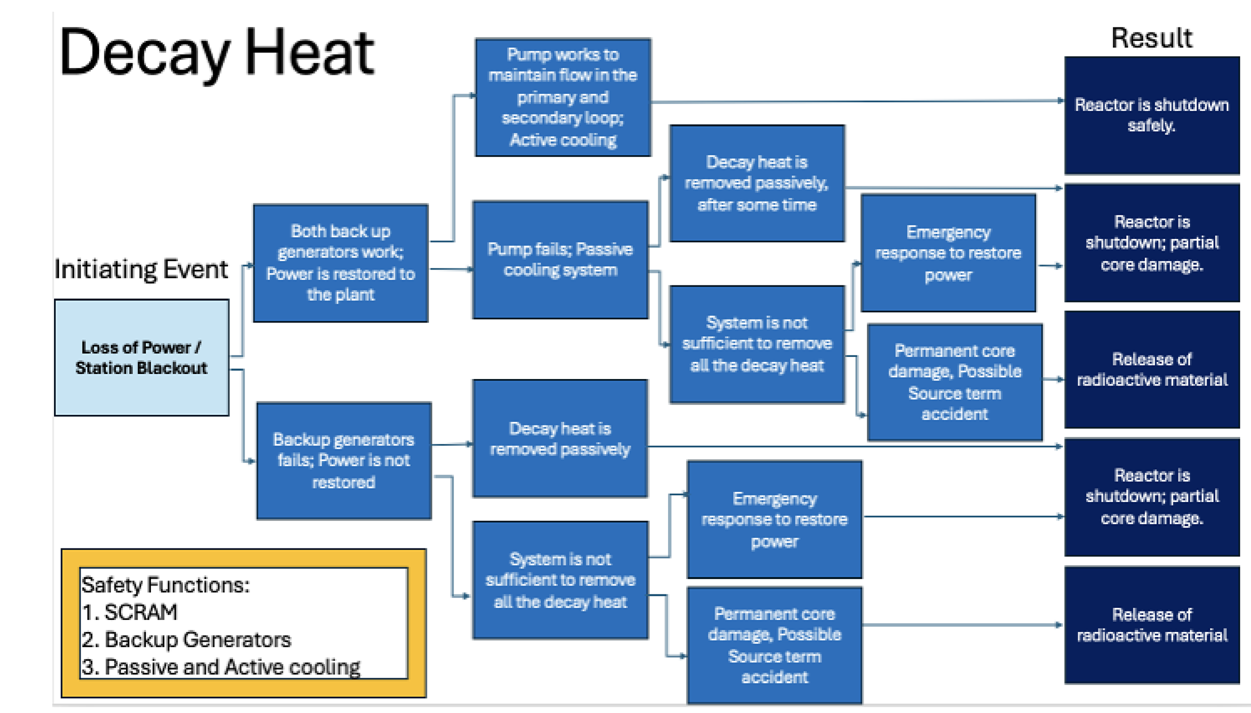
- Decreased by 82% at shutdown, 89& after 300 years
- Fission products decay to under natural uranium toxicity after ~200 years



Safety

Event Tree Analysis

- Identify the possible sequences of events that could lead to accidents.
- Assess the probability of each sequence of events occurring.
- Evaluate the potential consequences of each .
- Identify weaknesses within the safety systems.
- Facilitate the safety measures and emergency response plans.



Regulations

1. Venting of Radioactive Gases
   40 CFR 190.10
   40 CFR 61.92
2. Radioactivity in the Coolant
   10 CFR 50.36a
   10 CFR 20.1301

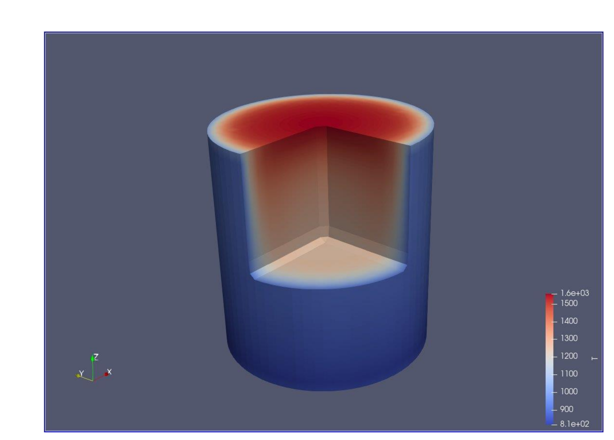
Safety Mechanisms:

- Redundancy in Safety functions (detectors, monitors, operators)
- Passive and Active Cooling
- Exclusion of Freeze Plugs

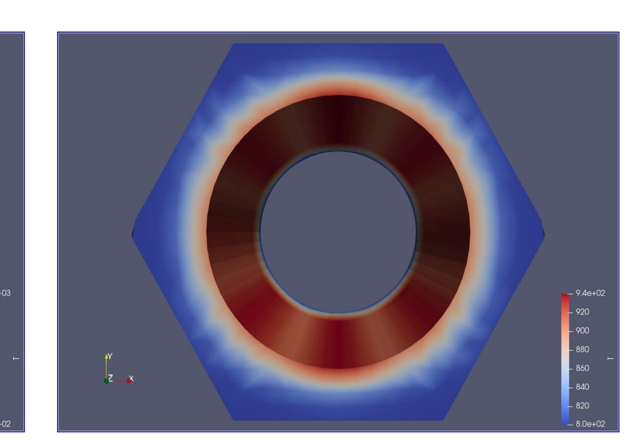
Fuel & Thermohydraulics

- Fissile fuel salt components derived from Three Mile Island spent nuclear fuel. Approximately 20% Pu-239, 10% U-238, and 25% Actinides by weight.
- 5.5 mm outer clad radius 4.9 mm fuel radius
- Boron carbide control rods 12.4 mm radius, 13 mm clad radius
- At an average of 100 kW/L specific power, the reactor generates 426 MW of thermal energy, or approximately 170 MW of electricity.

CFD Temperature Profiles



Fuel Salt



Coolant Salt

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