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A Novel Stationary Molten Salt Reactor Design for Spent Nuclear Fuel Burning

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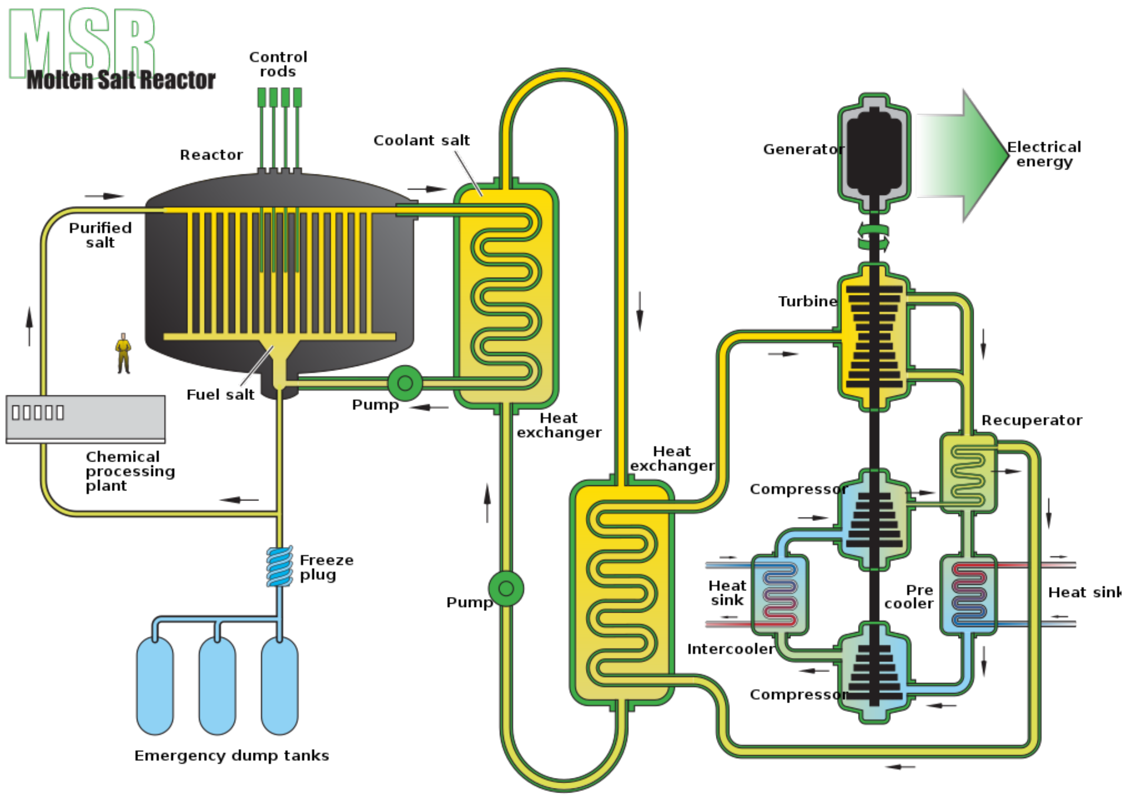
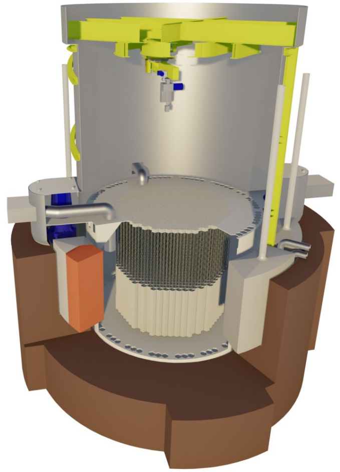
Conventional MSR Designs

- MSR designs are limited by spatial constraints
- Fuel dissolved in salt lessens overheat concern
- Loss of 1st barrier in current LWR designs

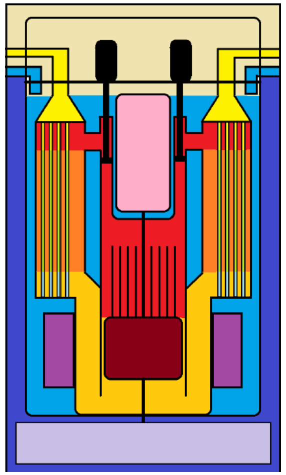


Stationary MSR Concepts

- Moltex SSR-W: salt contained within assemblies
- Aristos Power Hard Spectrum Reactor (HSR) - scalable SMR
- BYU Molten Salt Micro Reactor (MSMR)
- VCU Inverted SSR concept

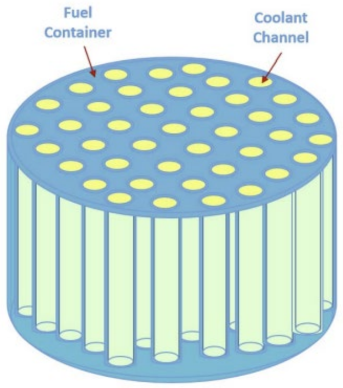


Moltex SSR-W



Aristos HSR

BYU MSMR



VCU Inverted SSR

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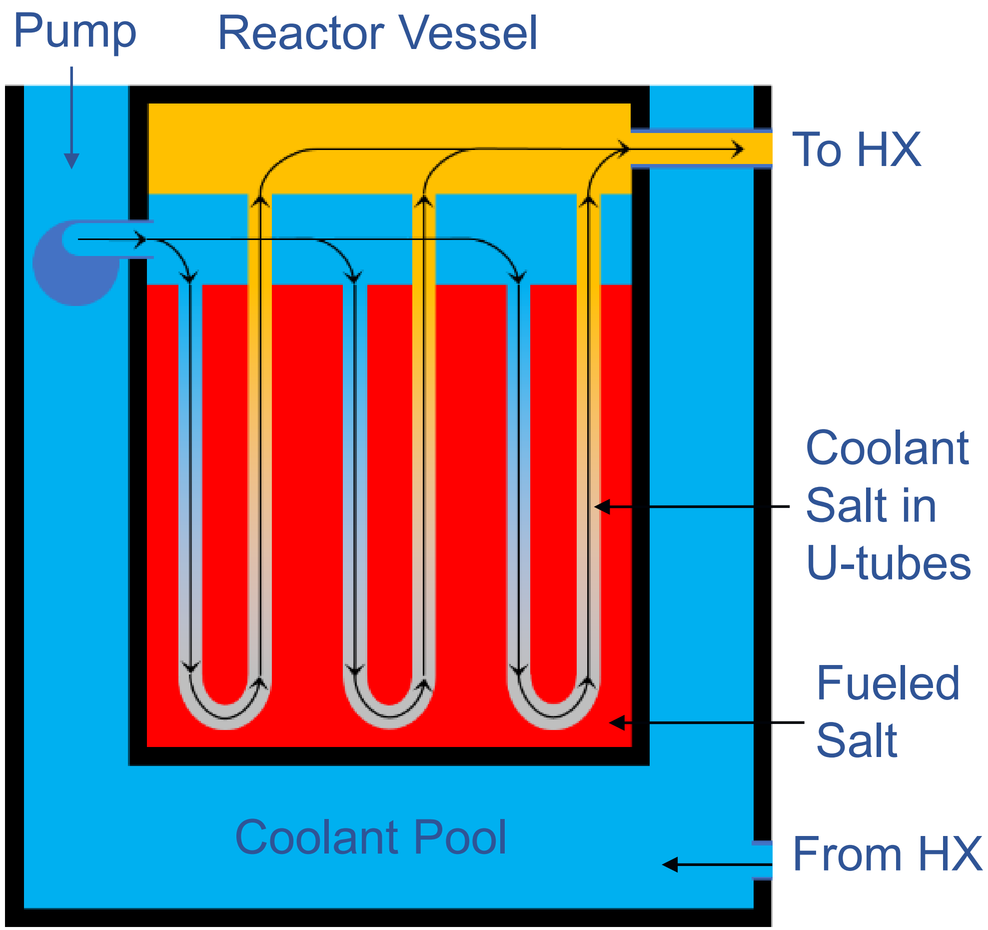
Our Idea – UTSSR (U-Tube SSR)

- Fast spectrum to facilitate burning of long-lived actinides
- Fueled salt basin cooled by u-tube array
- Reactor to sit in pool of coolant salt which will serve to compensate as additional layer of protection



Reactor Design Parameters

- Core designed to generate minimal heat
- Fast neutron spectrum to create excess neutron leakage for burning Actinides
- Hexagonal array of u-tubes

Parameter	Value
Thermal power	300 MW
Effective fuel height	2.50 m
Core diameter	2.50 m
Inlet temperature	650 ºC
Outlet temperature	700 ºC
Mass flow rate (total)	2514.7 kg/s
Coolant tube diameter	0.8 cm
Coolant tube pitch	1.25 cm
Number of U-tubes	11922
Coolant tube thickness	1.0 mm

Materials Selected for the Design

- Chlorine will be enriched to 95% ^{37}Cl to reduce neutron capture cross section
- FLiBe was selected as coolant salt for its thermal conductivity
- Hastelloy-N is resistant to corrosion from fluoride salts

Material	FLiBe	Hastelloy-N	$PuCl_3$-NaCl
Thermal Limit	1430 ºC	1300 ºC	1550 ºC

Component in Fuel	Atom Percent
Sodium Chloride	60%
Spent Nuclear Fuel Trichloride	30%
Reactor Grade Plutonium Trichloride	10%

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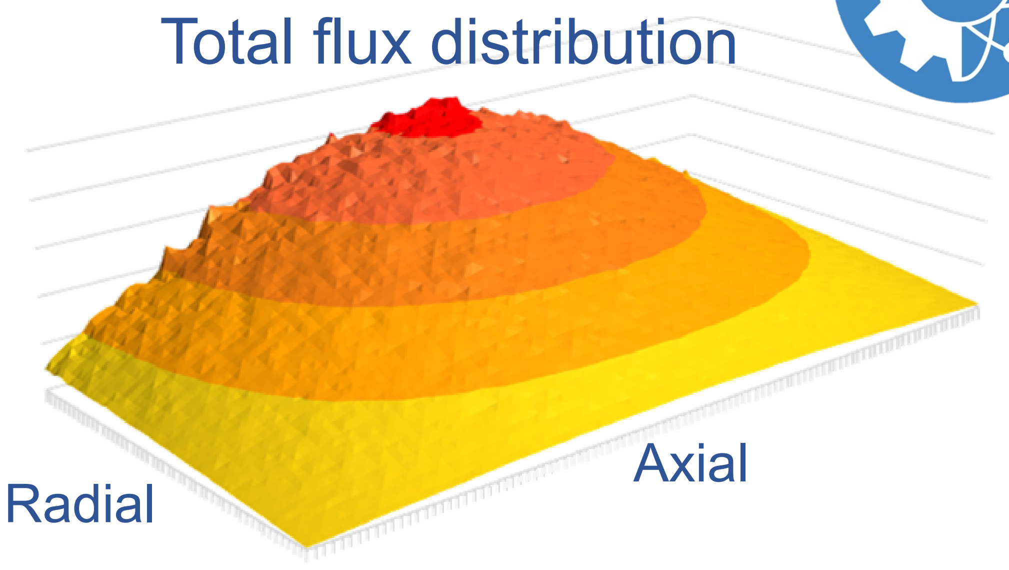
Preliminary T/H Performance

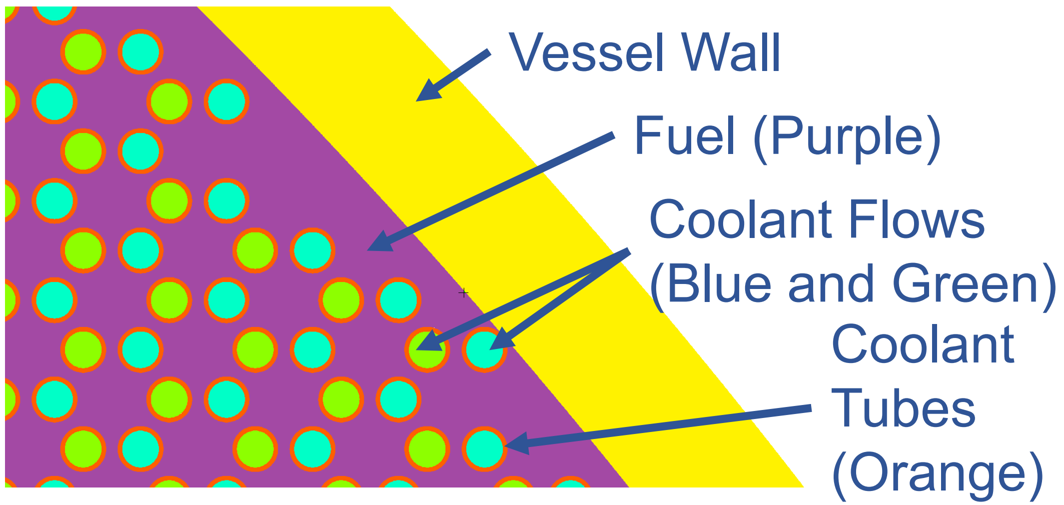
- Analytical T/H models were used to predict both the thermal and fluid behavior of the core
- Temperature limits were defined by material properties
- Gnielinsky correlation was used for Nusselt Number for the estimation of the heat transfer coefficient

Parameter	Value
Reynolds Number	6105.5
Prandtl Number	11.93
Nusselt Number	59.27
HTC	8150 W/m^2-K
Max Centerline Temp.	1462.0 ºC
Max Tube Temp.	824.4 ºC
Max Coolant Temp.	750.7 ºC
Coolant Velocity	2.165 m/s
Coolant Pressure Loss	304.19 kPa
Friction Factor	0.0356

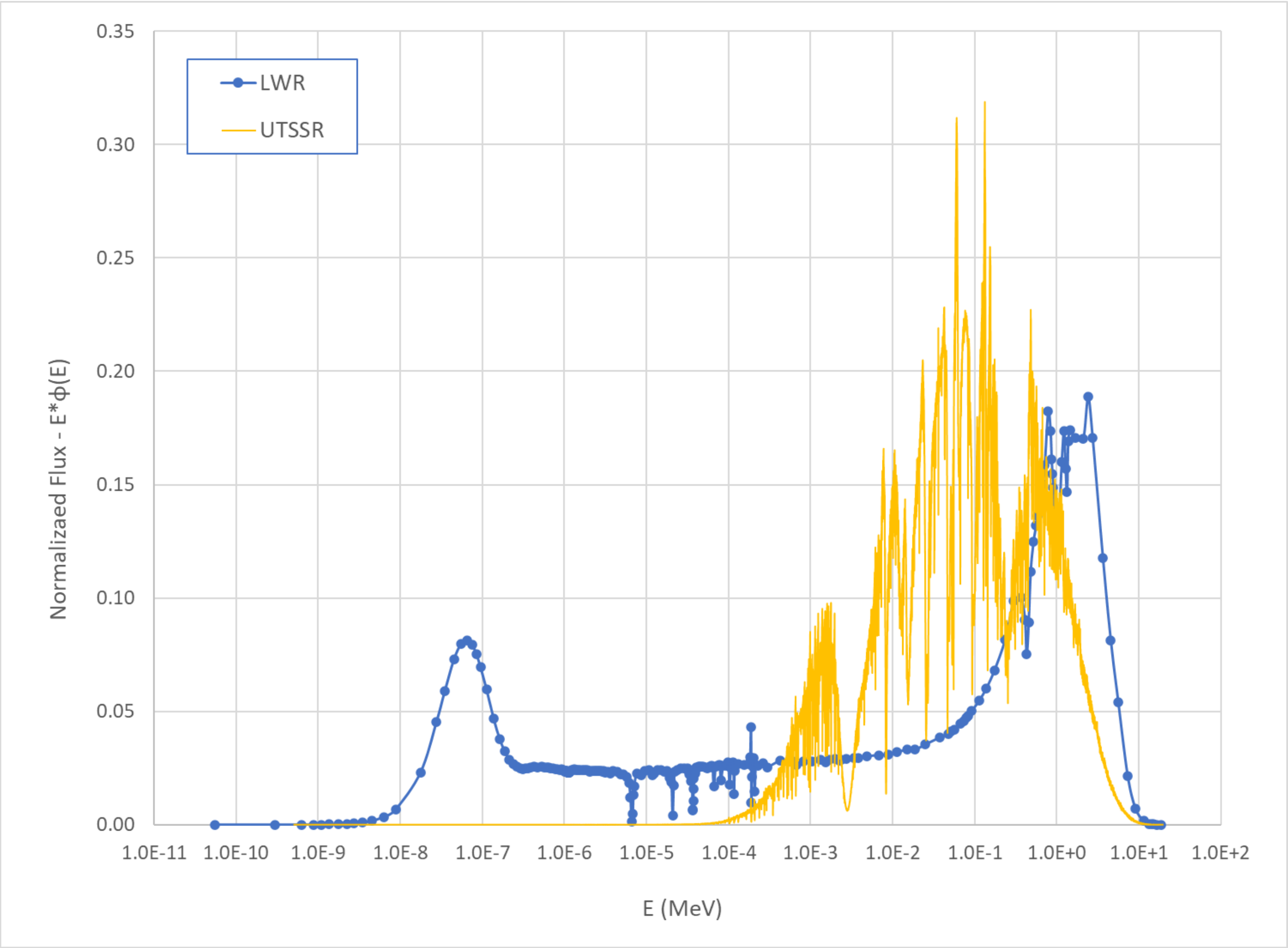
Neutronics Modelling

- A Monte-Carlo N-Particle (MCNP) model was used to ensure the reactor as designed would achieve criticality.
- Tallies based on neutron energy and core location were used to generate energy flux spectrum and map.
- $k_{\text{eff}} = 1.01518 \pm 0.00048$





Energy Spectra of UTSSR



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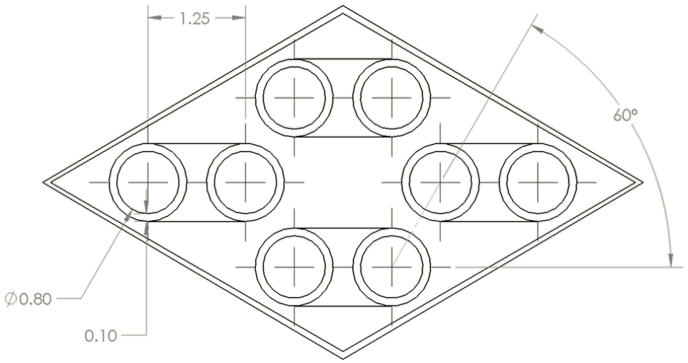
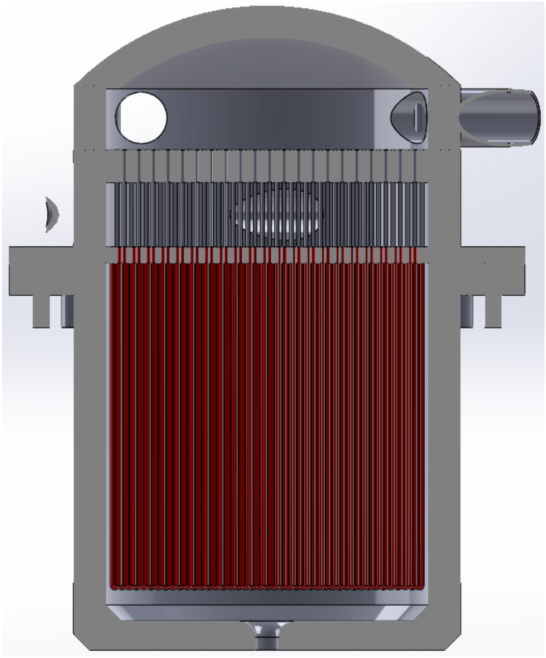
CAD Modelling

- SOLIDWORKS model based on dimensions from analytical solver.
- Single channel dimensions kept adjustable for parameter changes.
- Full core model based on older tube dimensions but retains core features.





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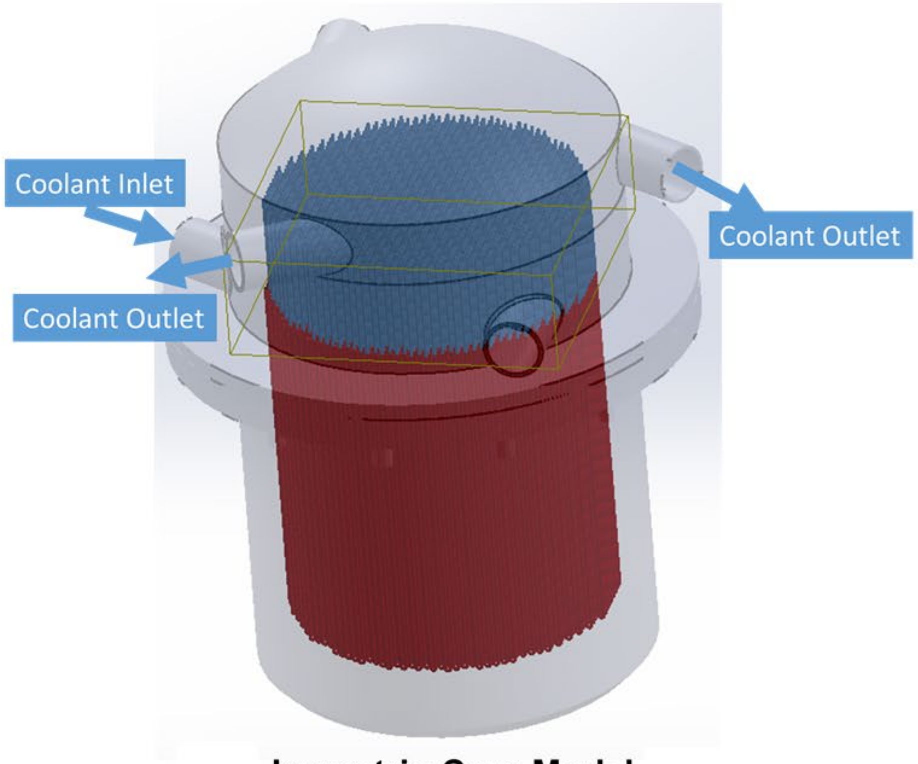
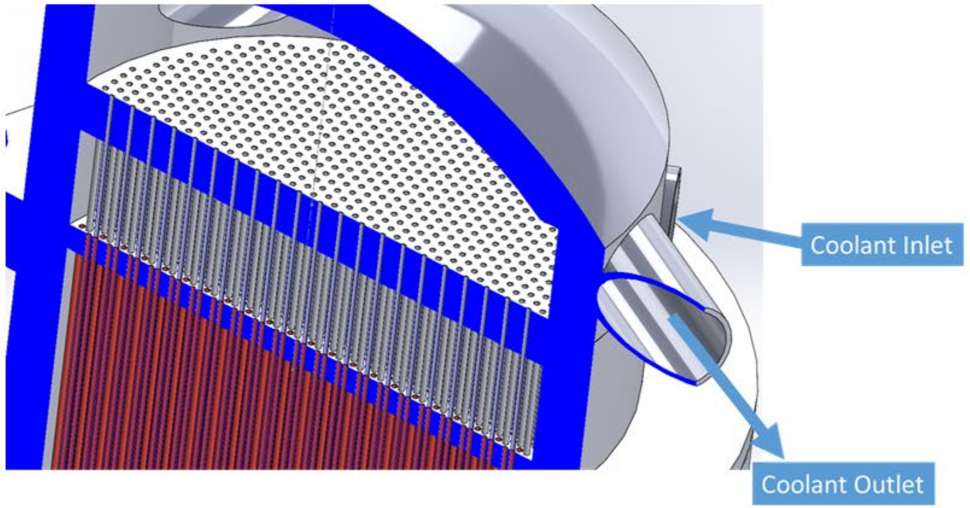
More CAD Diagrams of the Reactor



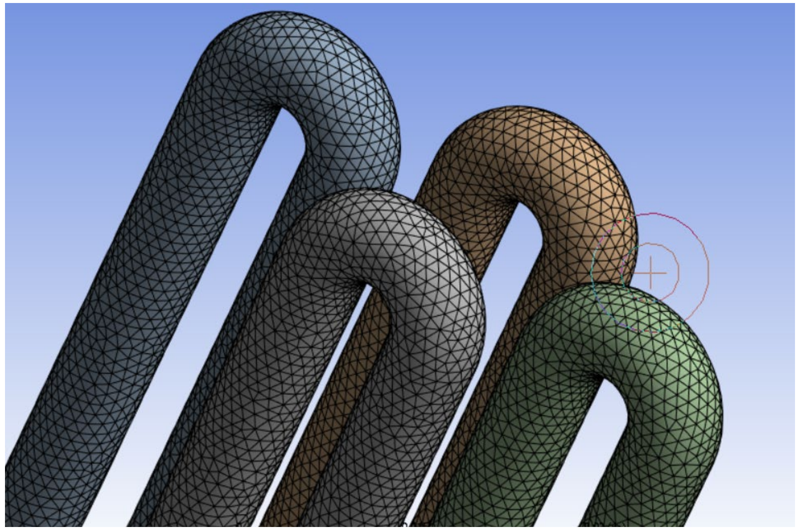
Isometric Core Model

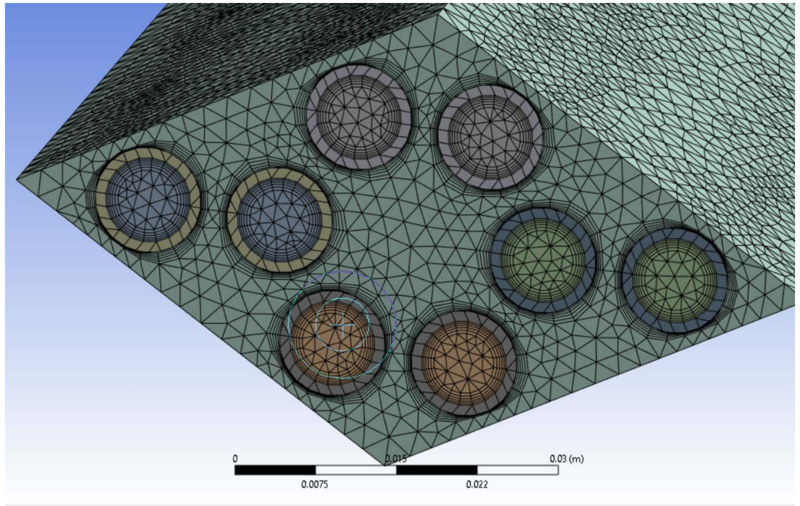


Coolant Plenum Cross Section

ANSYS Meshing

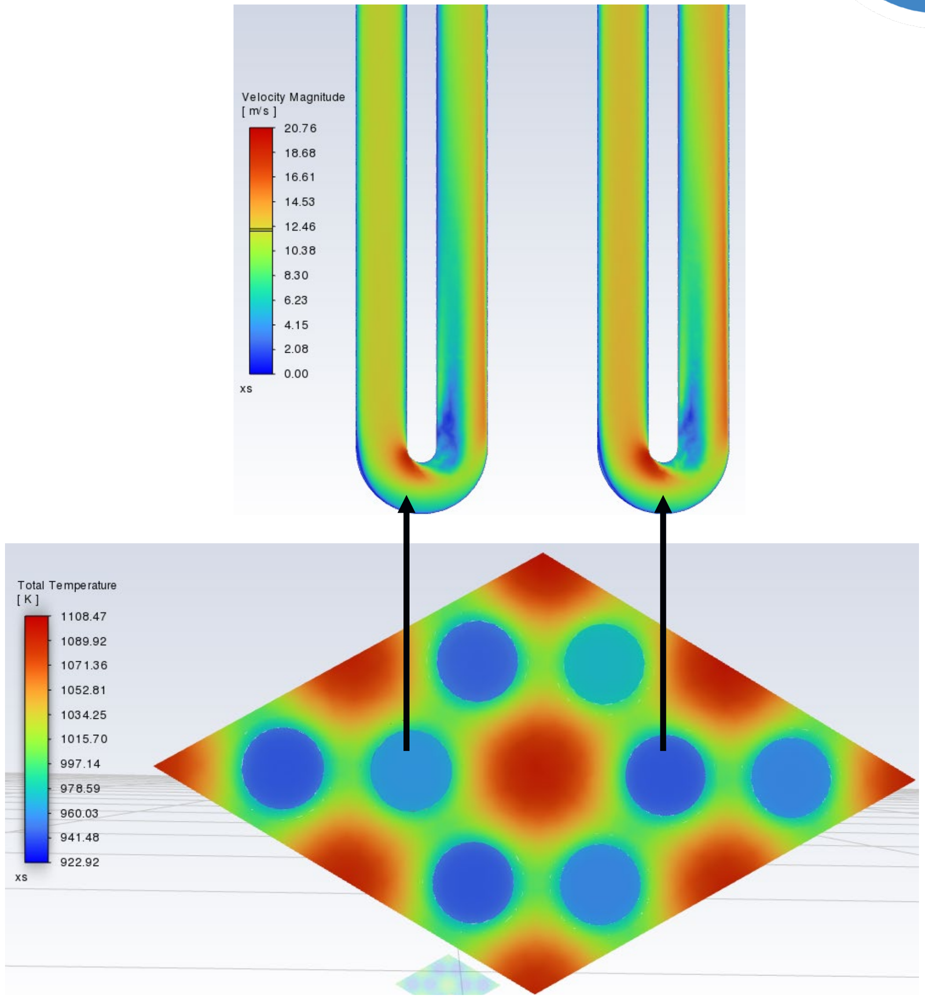
- Imported geometry from SOLIDWORKS
- Tetrahedral mesh totaling nearly 12M elements.
- Inflation in coolant and near tube walls





Flow and Temperature Distribution

- Volumetric heat generation generated from flux profile from MCNP
- Centerline fuel temperature was 835 °C.
- Coolant speed was higher than expected.
- Pressure drop in the tube was within expected tolerances.



Conclusions and Future Work

- UTSSR design was optimized for a balance between neutronics and heat transfer capability
- Preliminary results have shown with neutronically and thermodynamically feasibility to the UTSSR design
- Current thermohydraulic model iteration uses static fluid (no free convection)
- Single channel model uses adiabatic bounds
- U-tubes are small and may require structural analysis

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- VCU HPC computing facility is utilized in the calculations.

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Questions?