

# Molten Salt Fuel Version of Laser Inertial Fusion Fission Energy (LIFE)



Presented by  
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# Molten Salt LIFE Option

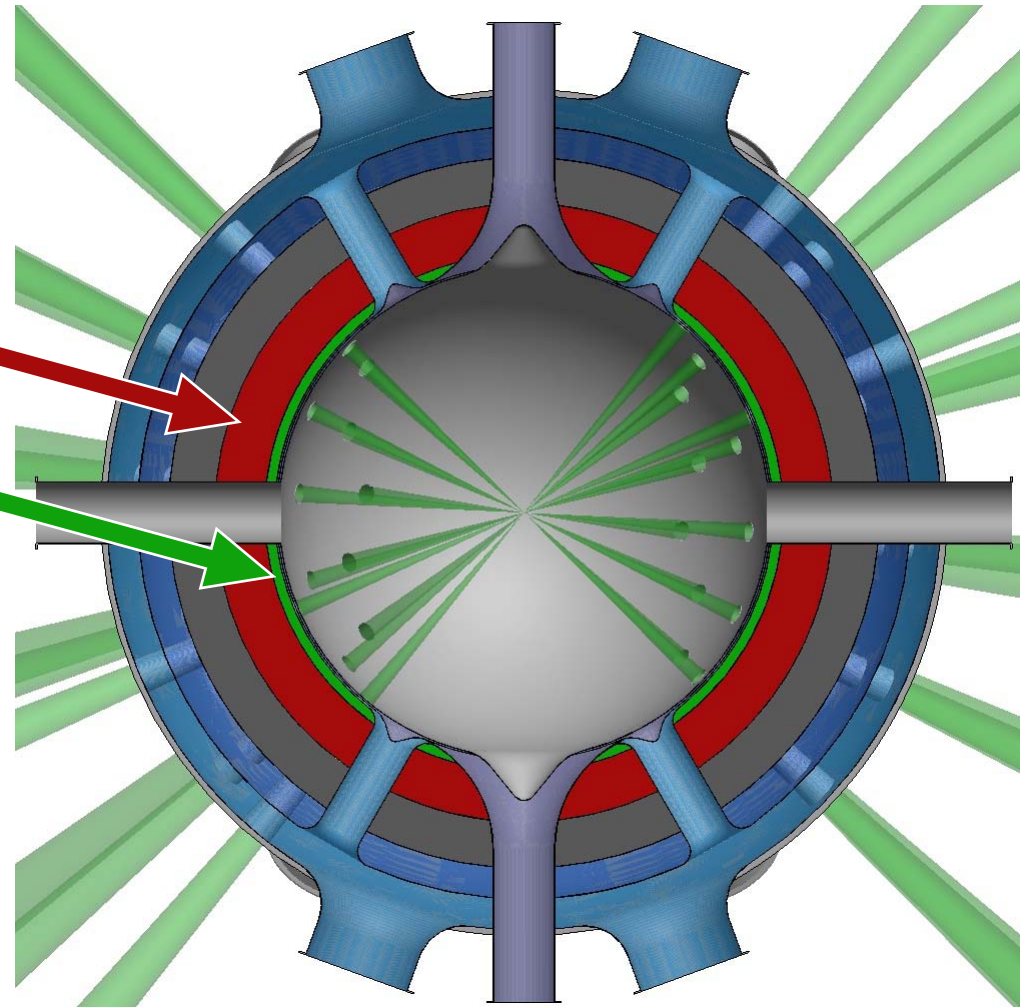
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- **Why molten salt for LIFE?**
- **Pu solubility**
- **Mixed thorium and uranium molten salt**
- **Fission product removal**
- **Materials compatibility**
- **Recommendations and conclusions**

# The solid fuel pebbles would be replaced with molten salt containing $\text{UF}_4$ and/or $\text{ThF}_4$



- Replacement solid-fuel pebbles, with molten salt composed of  $\text{LiF} + \text{UF}_4 + \text{ThF}_4$
- Neutron multiplier



# Liquid fuel is an alternative choice for burning fertile fuels

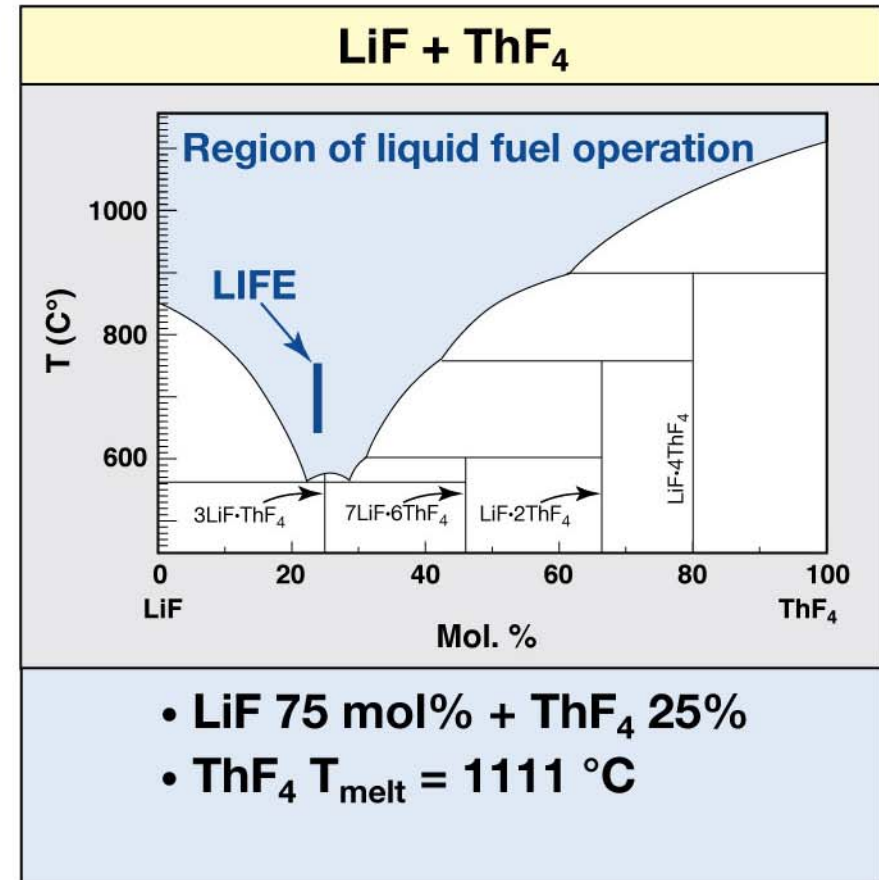
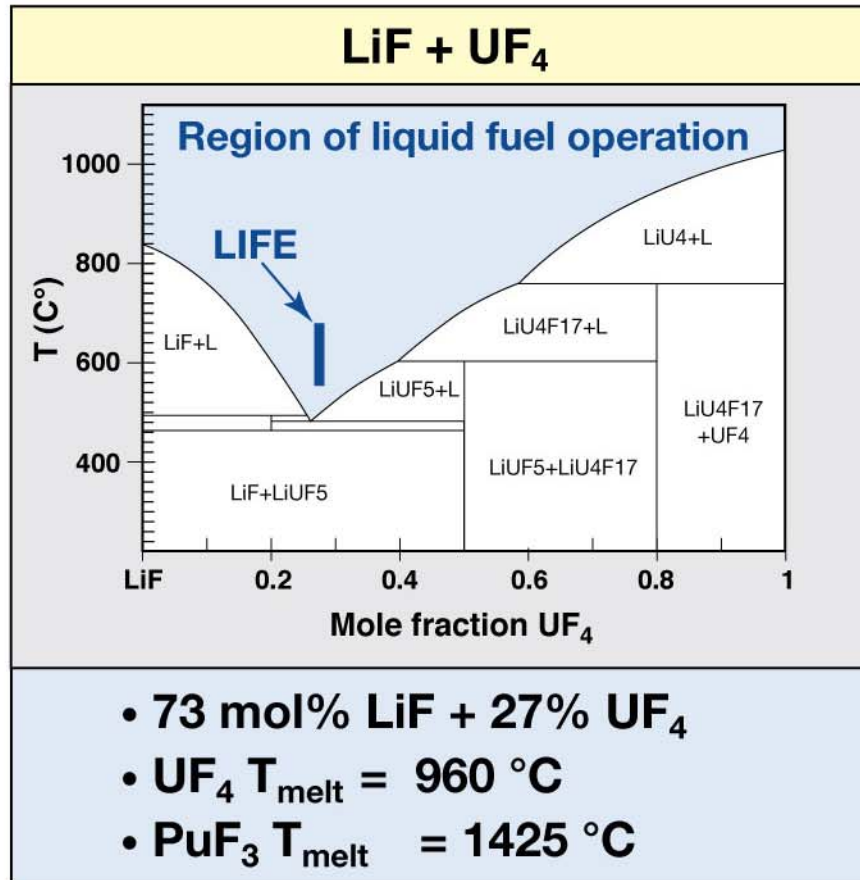
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- **Liquids can have higher fusion gain**
  - **Fission products are continuously removed**
  - **Steady-state power operation is possible**
- **Liquids do not have radiation damage or thermal-mechanical constraints**



# Liquid fission fuel options for LIFE

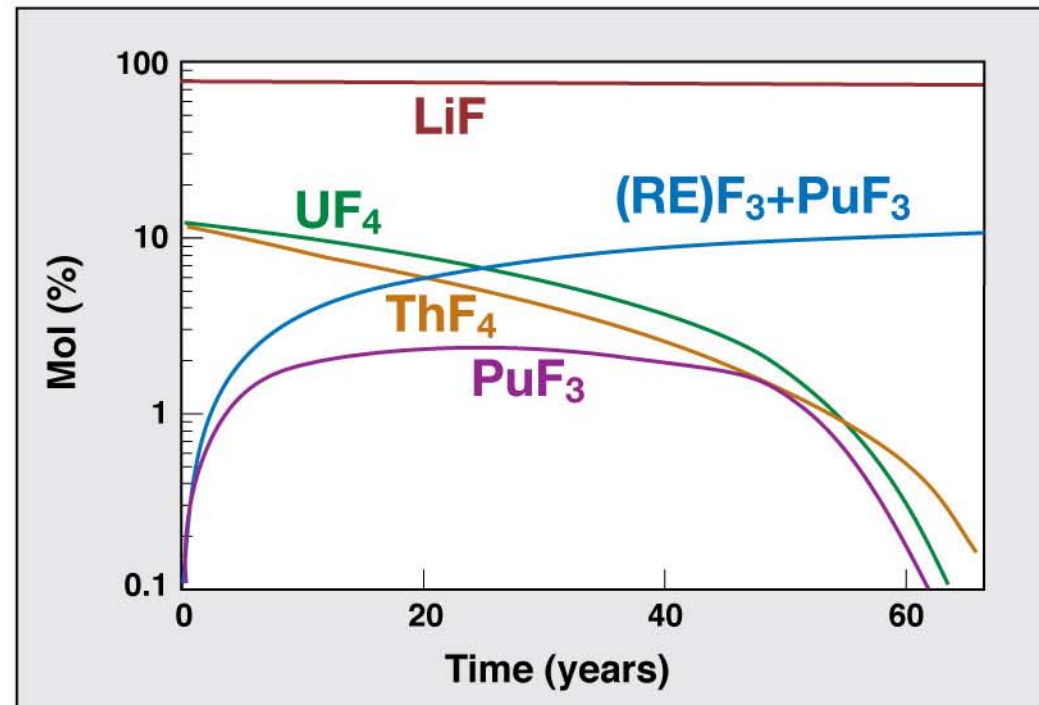


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# As uranium and thorium burn down, plutonium and rare-earths build up



- Rare-earth fluorides  $(RE)F_3$  behave like Pu and will limit solubility of  $PuF_3$
- We must remove the  $(RE)F_3$

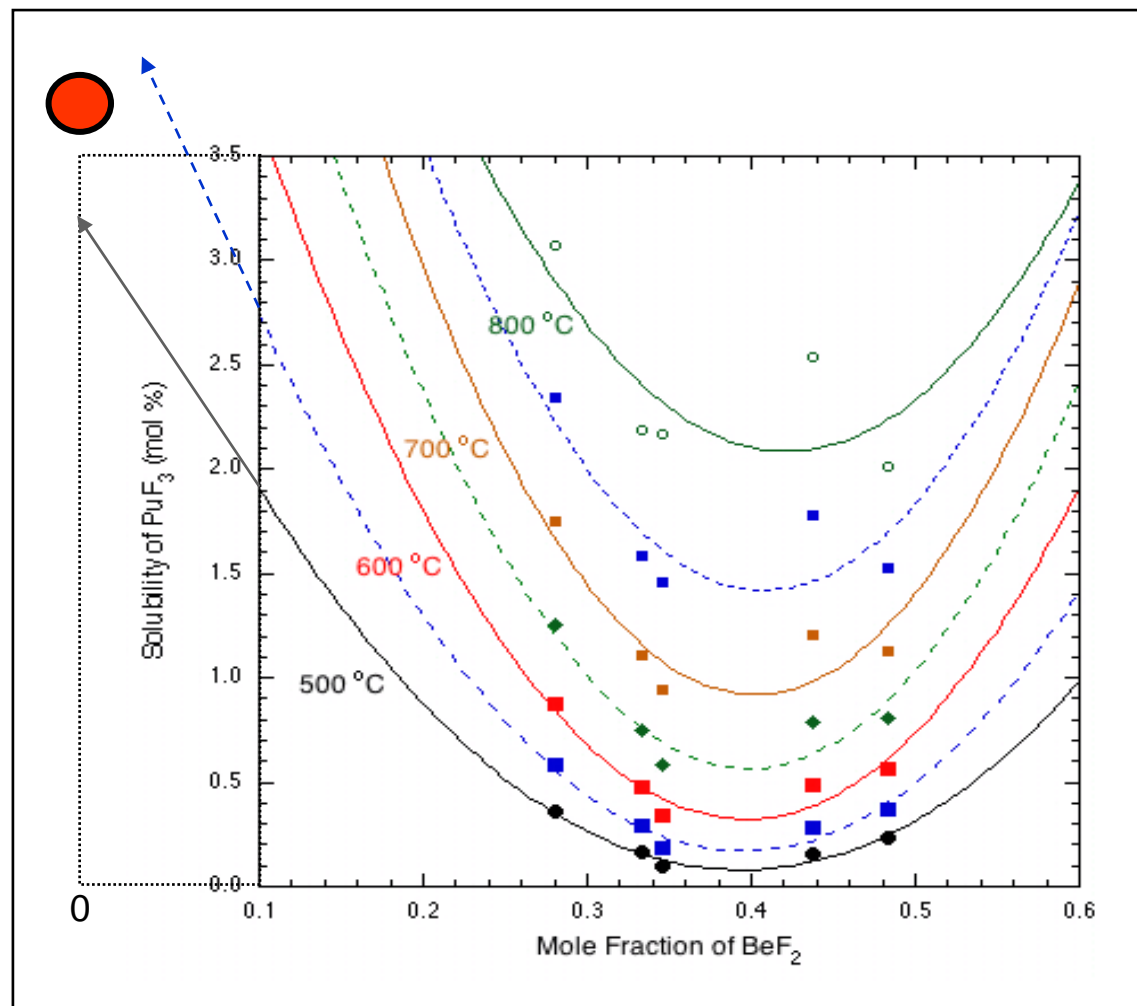


Is 2 mol%  $PuF_3$  soluble at  $>550^\circ C$ ?

# Data suggest 2 mol% PuF<sub>3</sub> is soluble above 550°C



- Available Pu solubility data is for BeF<sub>2</sub> salts
- Extrapolation suggests Be-free salts may have solubility >3.5% at 550°C

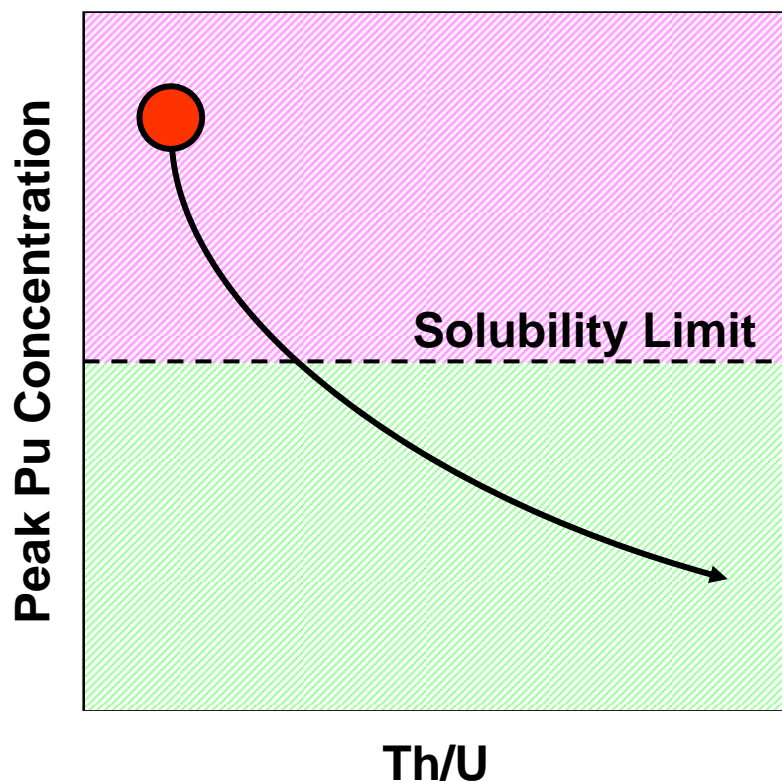


**Planning experimental campaign to determine solubility**

# Plutonium concentration is easily controlled through addition of thorium



- Thorium and produced  $^{233}\text{U}$  compete for thermal neutrons
- This reduces plutonium production



Composition	Peak Pu (%)
$76\text{LiF} + 24\text{UF}_4$	4.3
$76\text{LiF} + 12\text{UF}_4 + 12\text{ThF}_4$	2.0
$76\text{LiF} + 6\text{UF}_4 + 18\text{ThF}_4$	1.2



# Fission products are easily removed from the molten salt fuel

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- Volatile fission products removed: Kr, Xe, T<sub>2</sub>
  - Removal in minutes via gas sparging
- The insoluble noble and semi-noble metals removed: Zn, Ga, Ge, As, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, and Sb
  - Removal in hours via centrifugation and filtration with bypass flow

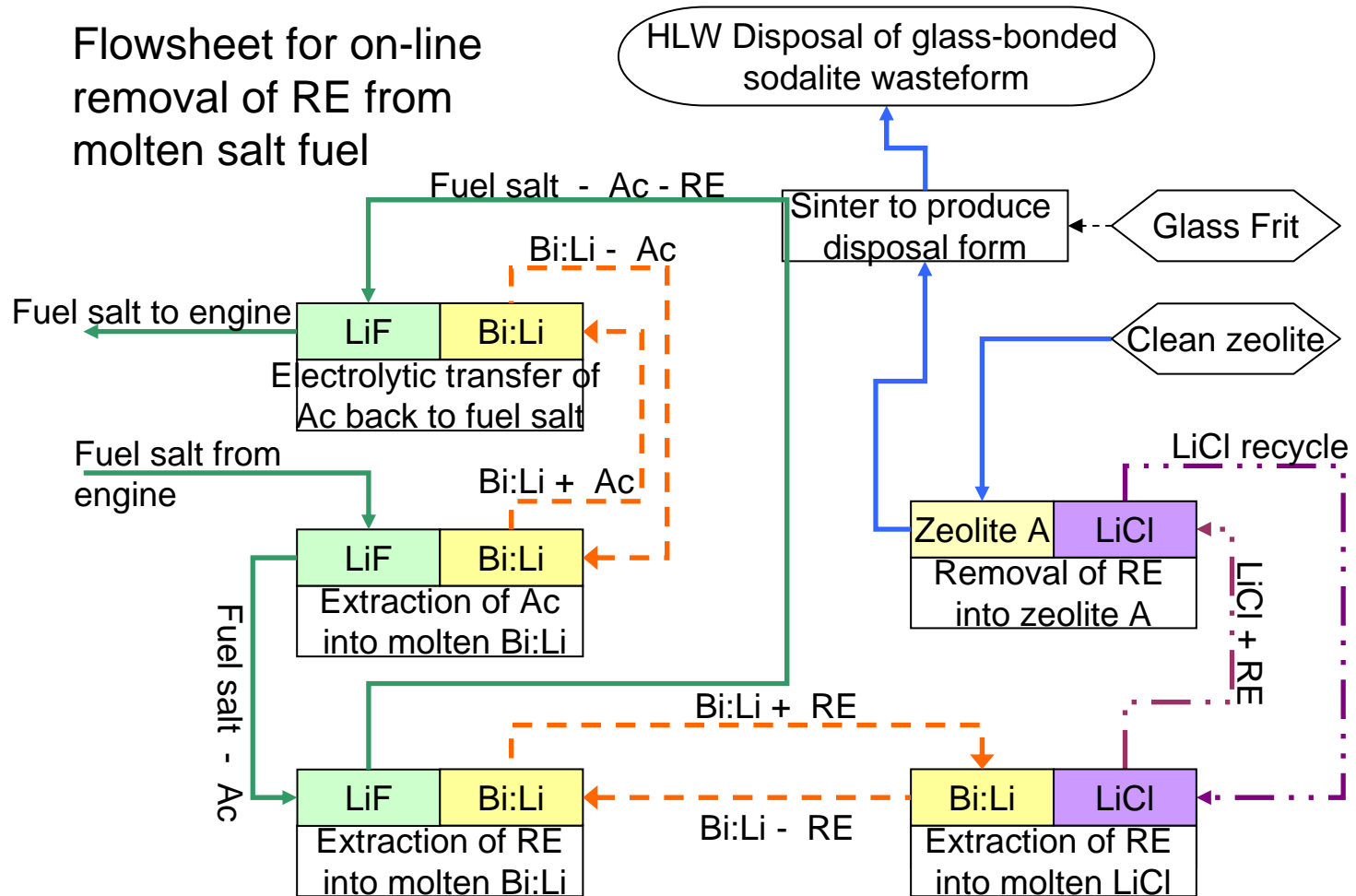
**Removing fission products reduces parasitic neutron capture and increases overall system gain by 30-100%**



# Conceptual flowsheet for RE removal process

RE = rare-earth elements

Flowsheet for on-line removal of RE from molten salt fuel



# Corrosion resistant structural material are required

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- **Candidate structural materials include:**
  - **ODS ferritic steel for temperature below 750°C**
  - **Steel surfaces coated with tungsten, molybdenum, etc.**
  - **Nickel alloys, such as hastelloys may be used in low neutron flux regions (piping and heat exchangers)**

# A molten salt fuel is the ultimate 'segmented blanket'

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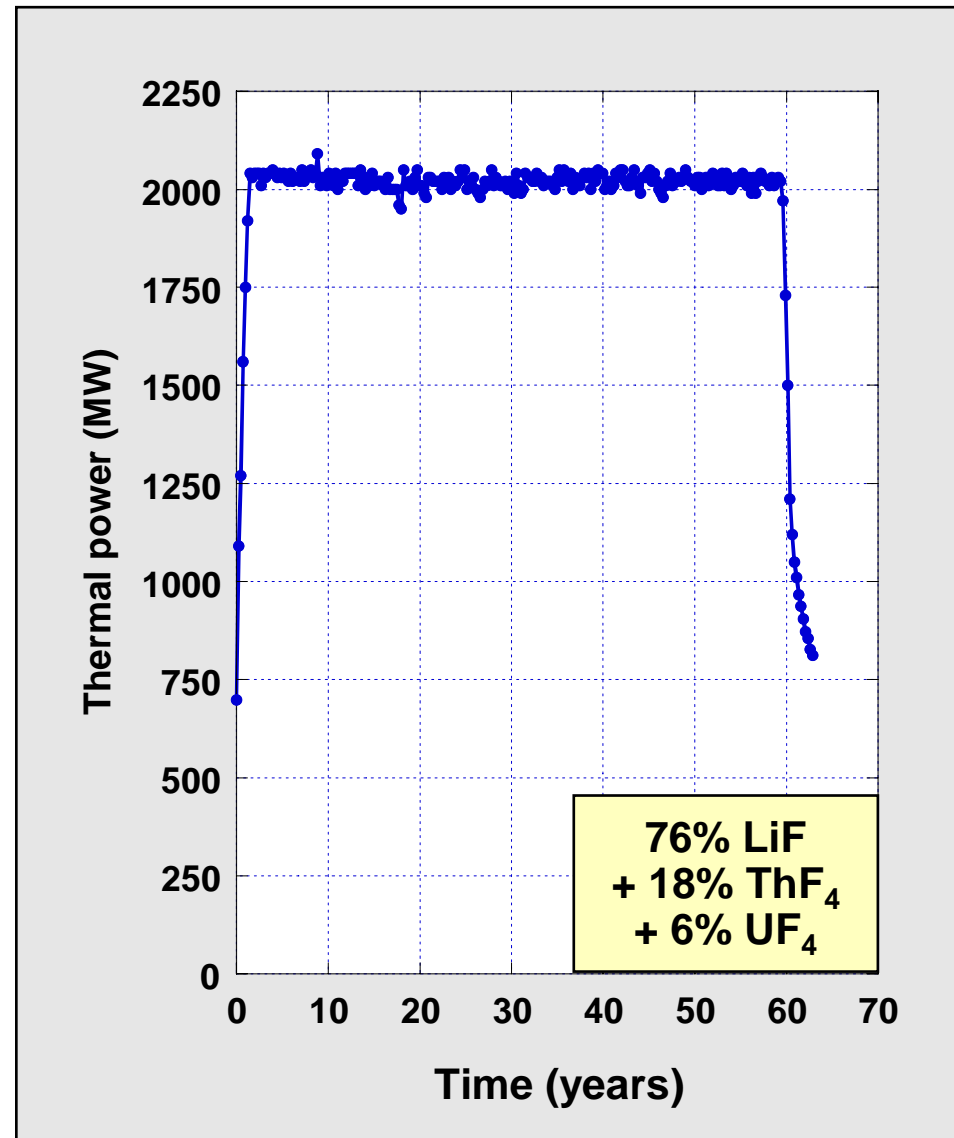
- As  $(RE)F_3$  are produced and then removed, the salt would move off of the eutectic composition
- Therefore,  $UF_4$  and  $ThF_4$  should be replenished:
  - Maintains salt thermal properties
  - Salt stays on flat portion of power curve indefinitely (steady-state)
- Since fertile material depletion never occurs, tritium production never falls
- System makes more tritium than needed; this can be traded for additional fission gain

**By replacing fertile material as it gets depleted, molten salt fuels should achieve gains of 8-10**

# A molten salt would be an attractive option for burning fertile fuels



- Extended time at full power output
- Shortened incineration phase



# **Additional work is needed for the molten salt fuel option for LIFE**

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- **Complete system point design**
- **Design rare-earth fission product removal system**
- **Study plutonium solubility**
- **Assess structural material**
- **Address salt freeze-up and Pu solubility at lower temperatures**

**Molten salt fuels improve LIFE performance in several ways**

