Licensing approach and initial safety studies for the LIFE Power Plant

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The LIFE power plant design presents attractive safety characteristics

- Runaway reaction is **not possible**
- **Low** residual decay heat: no need for active cooling
- **Low** and **segregated** tritium inventory
- In case of off-normal conditions the plant transitions **passively** to safe state
- Initial design basis accidents assessment shows off-site dose < 1 rem: **no need for public evacuation**
- **No need for “safety class”** structures, systems or components (SSCs)

Current US regulatory framework is being used to develop LIFE licensing strategy

- DOE Fusion Safety Standards developed to provide safety requirements and guidance for **experimental** fusion facilities
- It is expected that transition to **commercial** fusion power will be regulated under NRC space
- NRC 2009 memorandum (SECY-09-0064) confirms that the Commission asserts jurisdiction over commercial fusion energy, however…

> "The staff should wait until commercial deployment of fusion technology is more predictable before expending significant resources to develop a regulatory framework for fusion technology"

- **LIFE will provide such demonstration of commercial deployment feasibility of fusion technology**

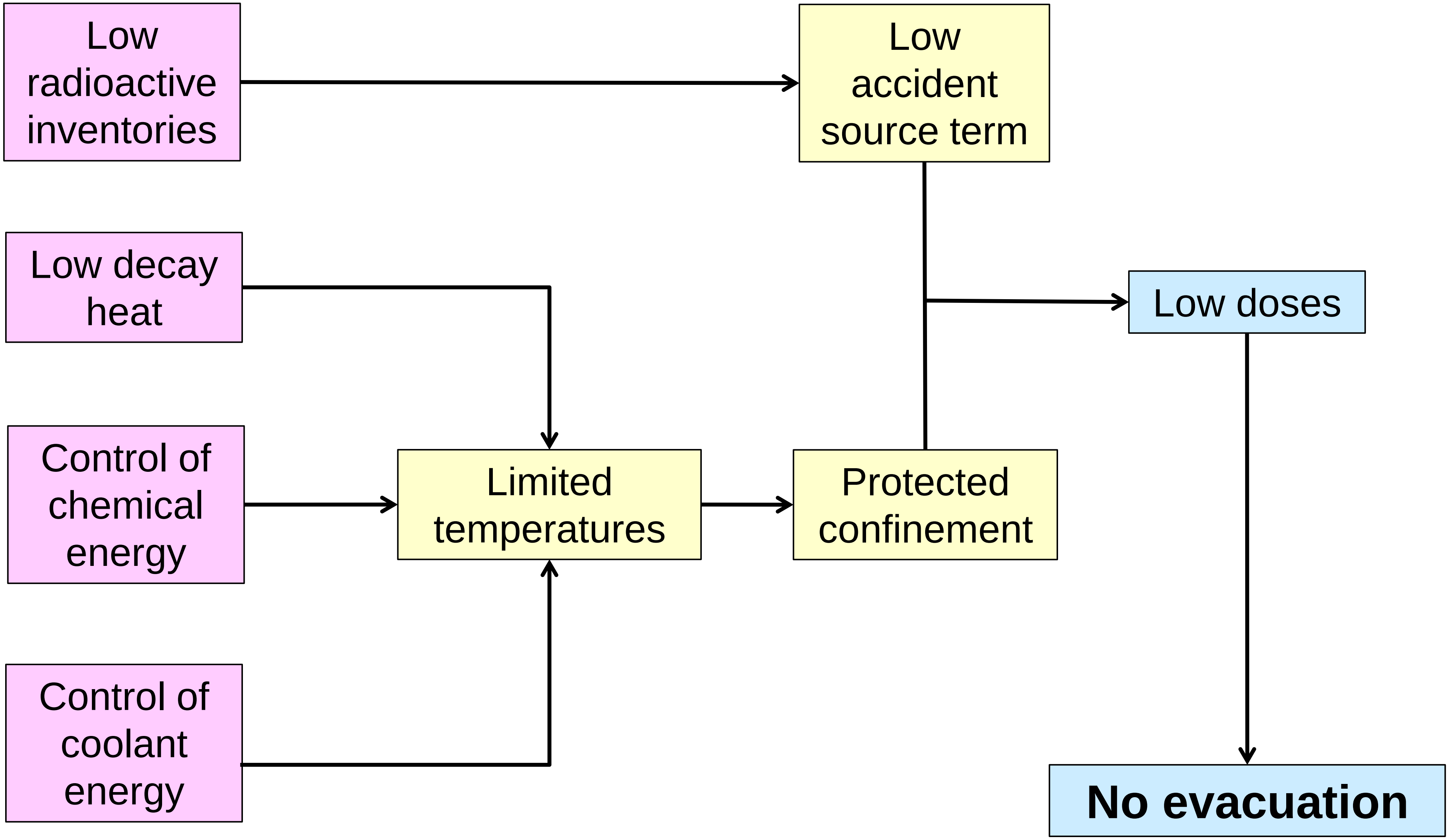
Fusion's favorable safety characteristics should allow for simplified licensing

- Licensing guidance indicates that **risk-informed, performance-based** approach could be most appropriate
- **10CFR50/52** regime applied to LWRs **not applicable** (too prescriptive, plus very different safety hazards and requirements)
- Preliminary scoping of NRC regulations indicates that **10CFR70 might provide the roadmap** for future licensing of fusion facilities
- Although Part 70 is generally used for **fuel cycle facilities**, similar requirements could be applied at the discretion of the NRC
  - ***Example 1:*** GE Laser Enrichment Facility, Wilmington, NC, under 10CFR70 for test demonstration prior to full scale commercial
  - ***Example 2:*** Mixed oxide fuel (MOX) facility, Savannah River Site, first-of-a-kind facility licensed under modified version of 10CFR70

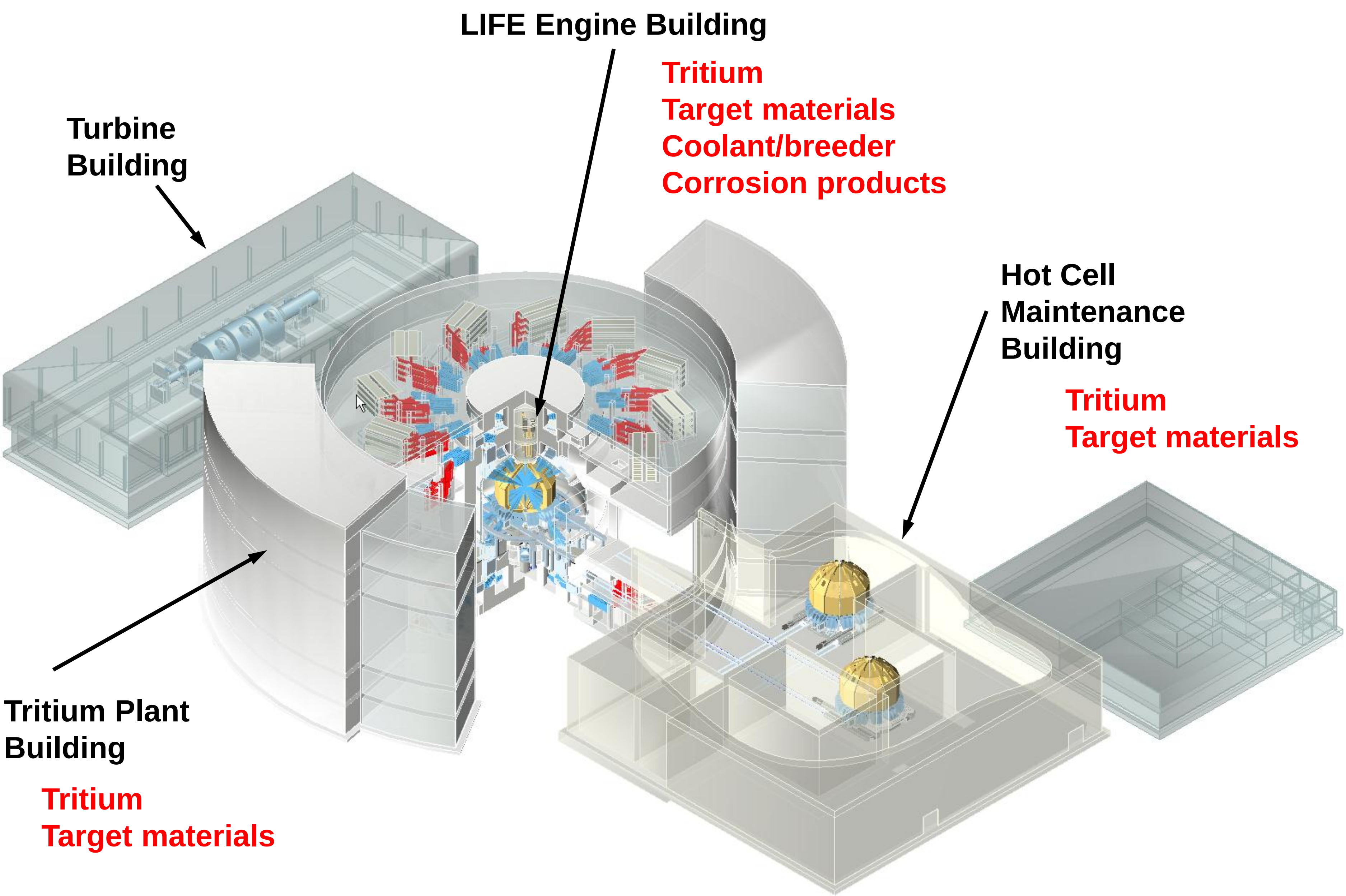
DOE Fusion Safety Standards provide general safety requirements for fusion facilities

- to **protect workers, public and environment** from hazards
- to ensure that **exposure** to hazards within the premises and due to release of hazardous material from the premises is **ALARA**
- to **prevent accidents** with high confidence
- to ensure accident **consequences are bounded** and likelihood small
- to demonstrate **no need for public evacuation** in any event
- to **minimize radioactive waste** hazards and volumes to ALARA

Requirements are met through safety design considerations from early design stages

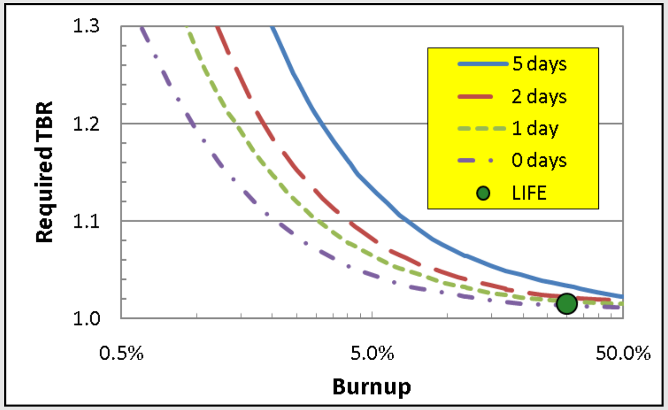


A hazards assessment has been completed to identify potential release pathways

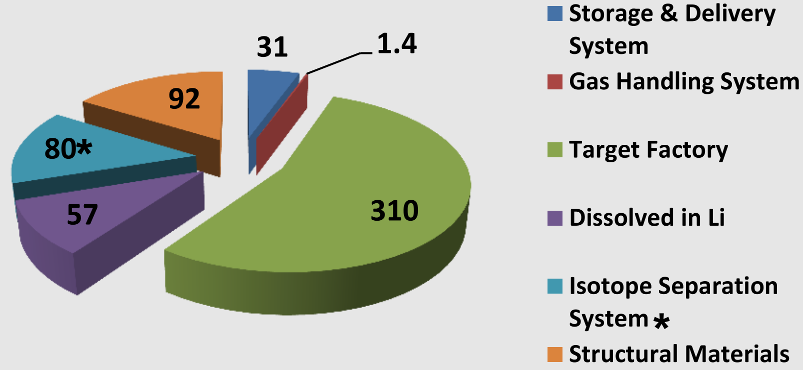


LIFE fuel cycle expected to allow for site inventory < 600 grams for GW plant

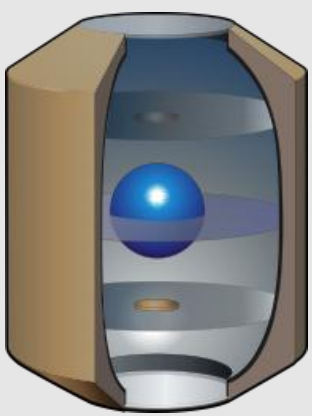
High burnup results in low TBR requirement for reasonable storage times (Abdou 1986)



More than 50% of the plant's T inventory (307 g) resides in the target factory

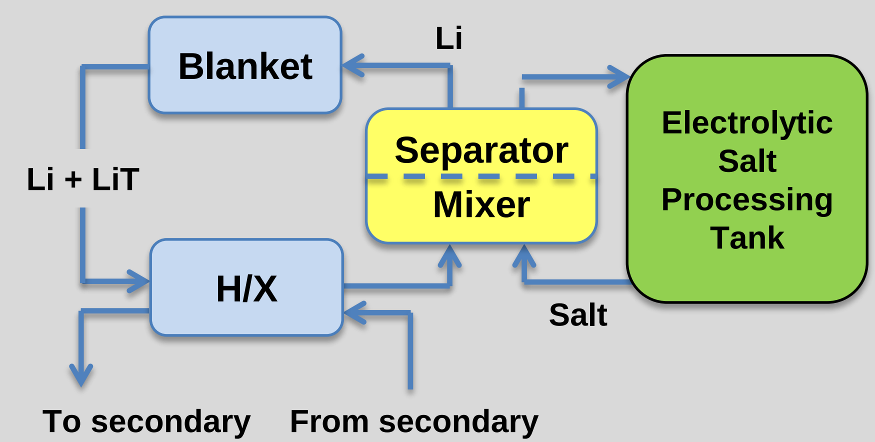


LIFE targets each contain only ~ 0.7 mg of tritium



- Tritium throughput is ~ 1 kg/day
- 288 g/day is burned
- 294-426 g/day can be bred in the blanket
- A new plant can be supplied with T inventory every week

T recovery from Li (demonstrated in 1974) is compact; limits inventory to ~60 g



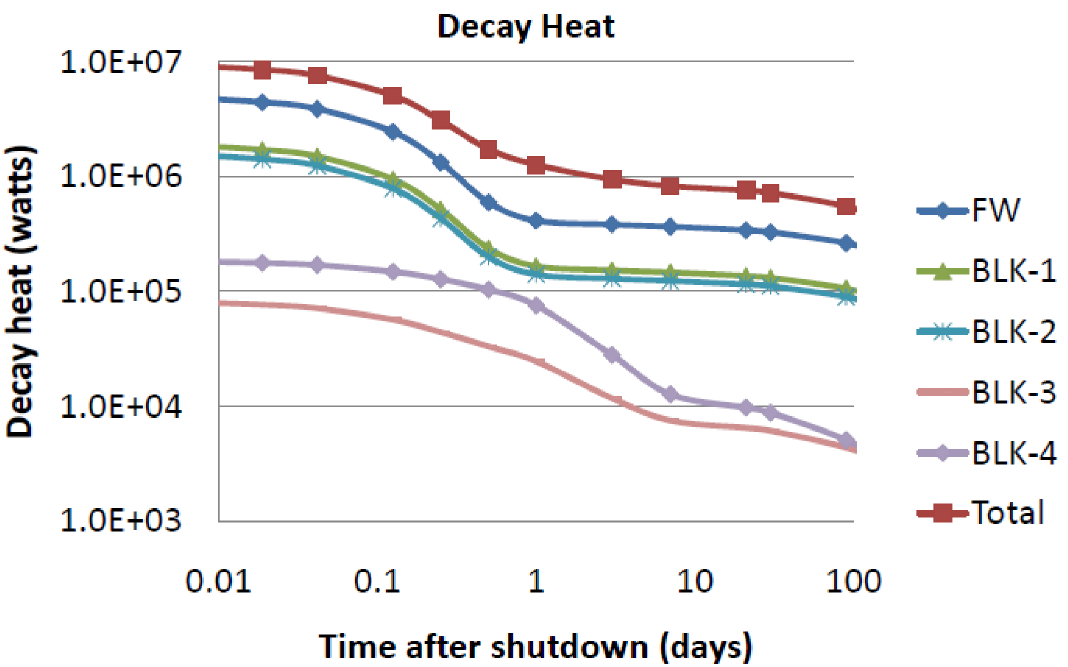
Liquid lithium is the candidate primary coolant for LIFE point design

- **Advantages:**
  - — Low ρ provides low hydrostatic and stresses
  - — Excellent Tritium breeding:
    - – Obviates need for Be multiplier
    - – Enables large open solid angle
  - — Good heat transfer properties
  - — Very low Tritium permeation
  - — Good corrosion performance
  - — Low neutron activation

EBR-II sodium-cooled reactor operated for 30 years at Idaho National Laboratory

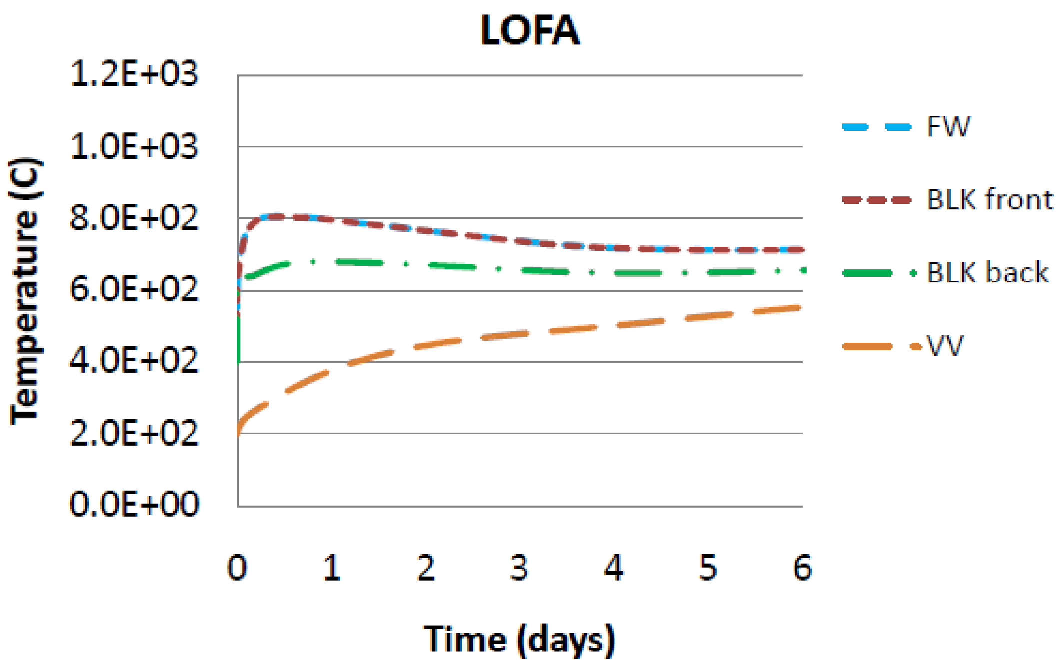
- **Challenges:**
  - — Chemical reactivity: fire hazards are well known and can be controlled
  - — Tritium extraction: partially demonstrated (Maroni et al.), integrated test needed to ensure efficient recovery, low coolant inventory

Preliminary accident analysis of LIFE engine: loss of flow accident



- We have completed activation calculations for a 6-m radius, Li cooled chamber, assuming 1-yr FW lifetime
- Blanket cooling channel includes a W skin to allow for high T operation
- Figure shows decay heat at shutdown

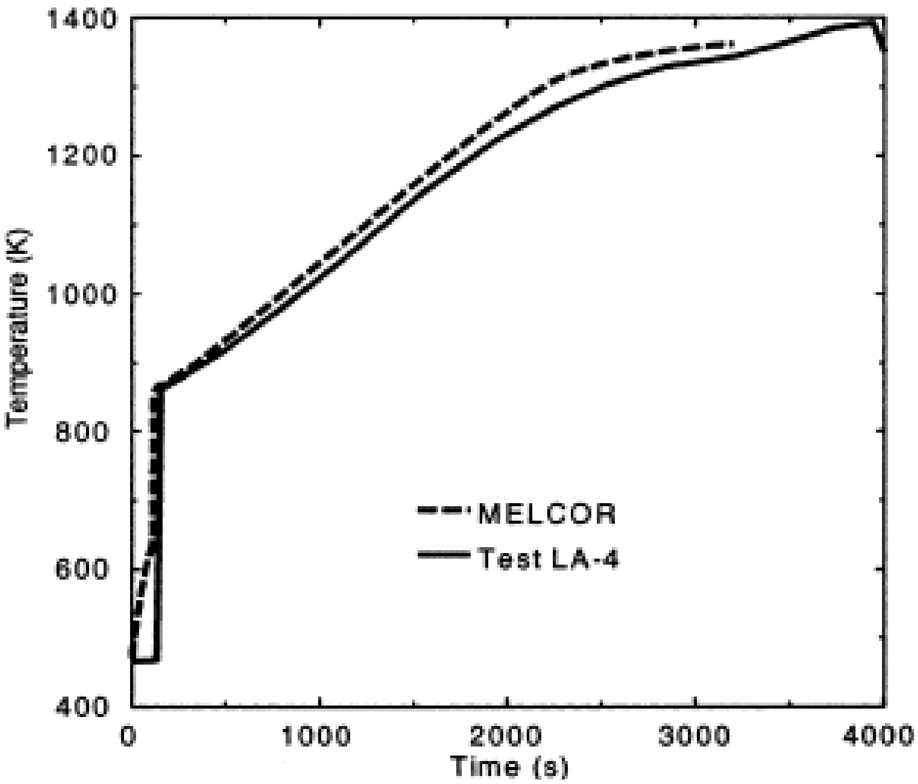
- 1-D heat transfer model shows moderate T increase under assumption of total loss of flow
- Engineered passive cooling (i.e., natural circulation) would further limit accident temperatures



Thermal-hydraulics assessment of Li fires

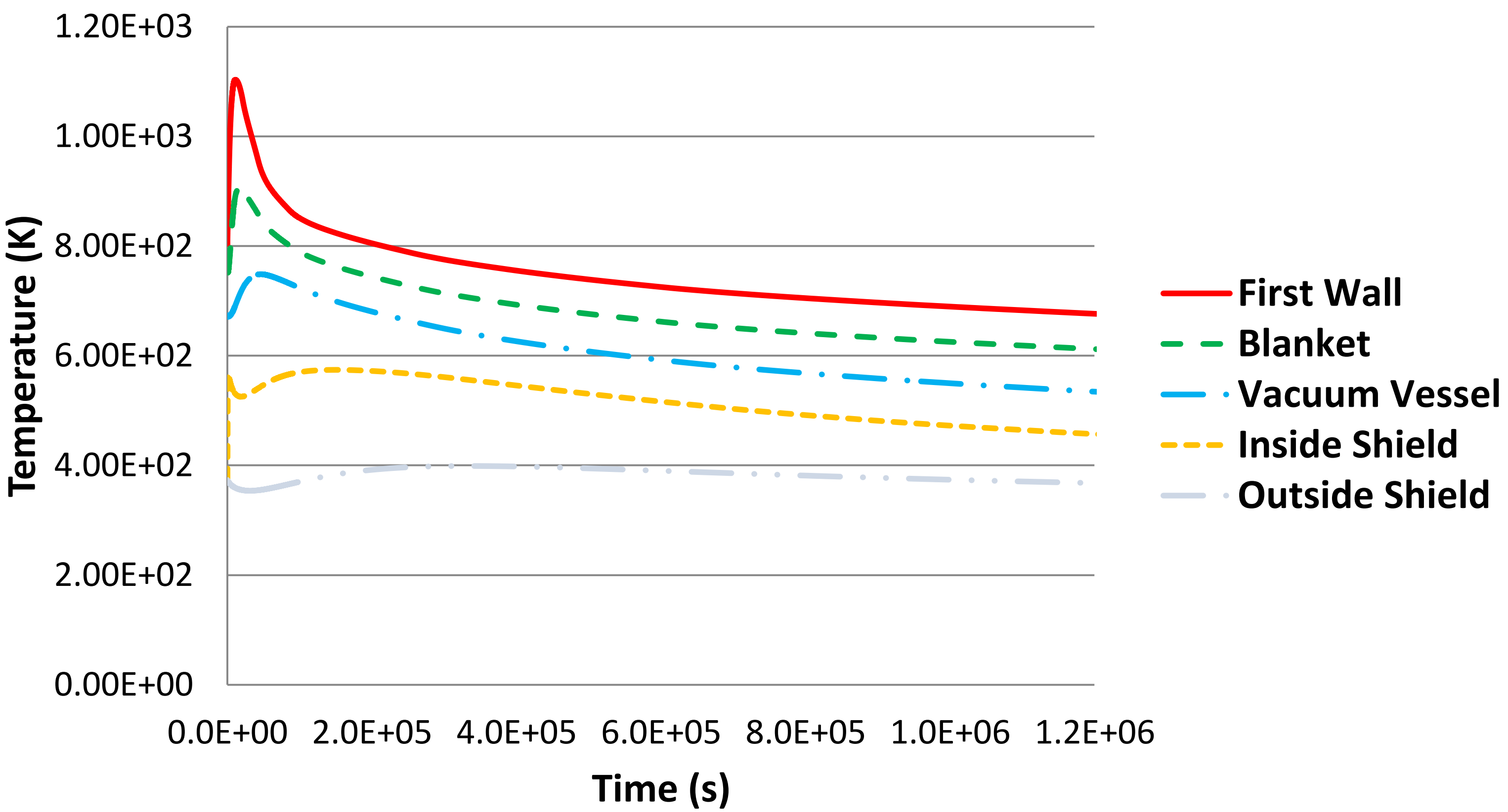
- Idaho National Laboratory experts modified the MELCOR thermal-hydraulics code to predict the consequences of lithium spill accidents
  - introduced EOS for Li, new subroutine computes the critical mass flow
  - reaction rate assumption adopted for this model is similar to that adopted for the LINT code (thermal equilibrium)

- Lithium-air reaction tests at the HEDL used to benchmark new MELCOR capability gave good agreement (B.J. Merrill : *Fusion Engineering and Design* 54 (2001) 485–493)



Initial assessment of lithium fire: ex-vessel loss of coolant with air ingress

- We have used a simple MELCOR model to assess consequences of a large lithium spill with air ingress in the engine room (initially filled with Argon)
- Initial results show dose < 1 rem achievable: non-evacuation criteria



Conclusions

- Initial hazards analysis indicates that **simplified licensing** based on risk-informed, performance-based approach might be most appropriate for LIFE (similar to 10CFR70 requirements)
- In case of off-normal conditions, the facility transitions **passively** to safe state
- Initial assessment of accidents sequences show that **non-evacuation limit** is achievable with no need of safety class SSCs and a limited number of safety significant SSCs
- Additionally, unmitigated release scenarios show potential for **reduced facility seismic design criteria** compared to fission power plants
- **Ongoing work** is being devoted to identification of initiating events and analysis of accident sequences


LIFE