SOLVING ENERGY CHALLENGES
THROUGH SCIENCE

Versatile Test Reactor Core Design and Fuel Selection

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NATIONAL ACADEMY OF SCIENCES

Note: Information regarding site location is **preliminary**. The decision for site location is determined via DOE acquisition processes that have not yet been completed.

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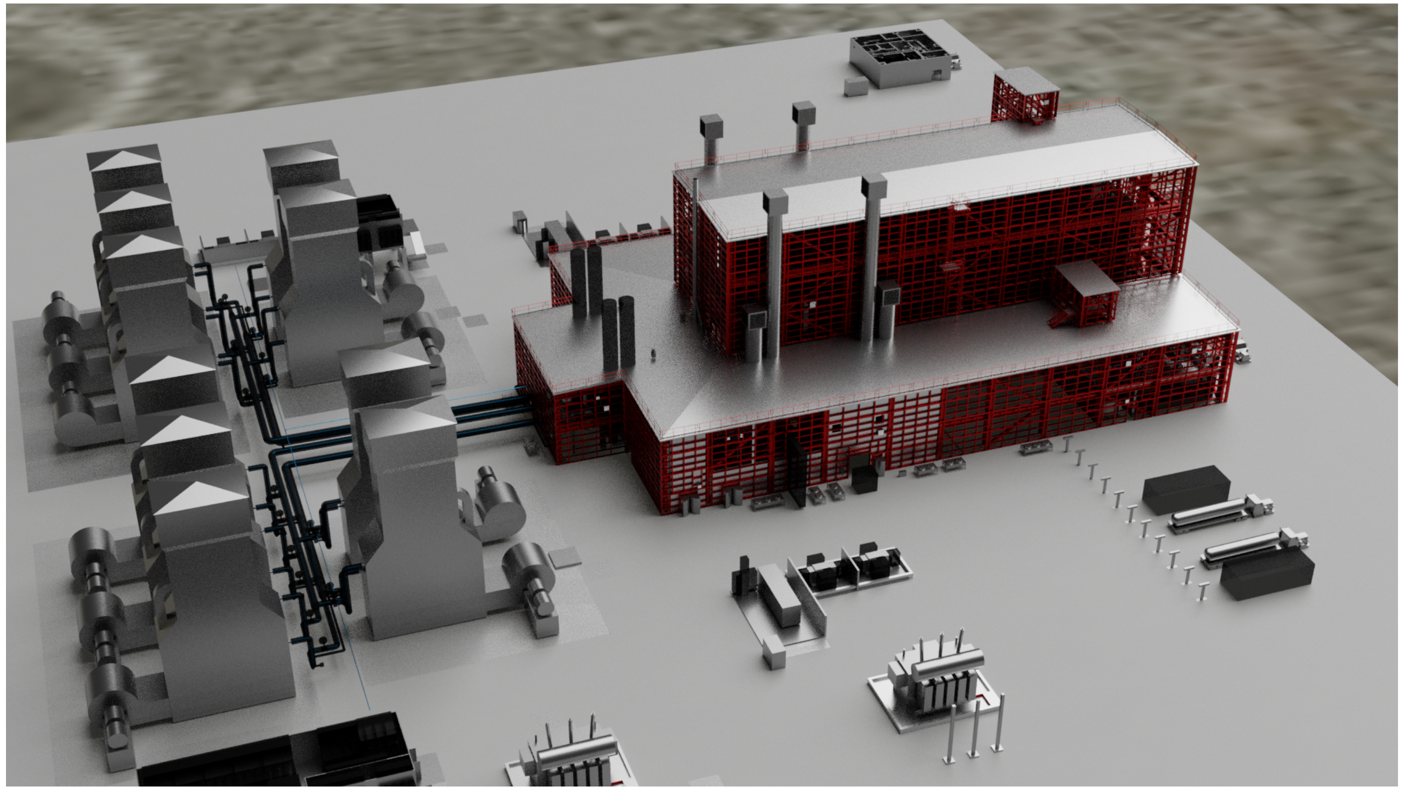
Key Performance Objectives

Parameter	Target
High fast neutron flux	≥ 4 x 10^{15} n/cm^2-s
High fast fluence	≥ 30 dpa/yr
Large in-core test volume	≥ 7 L (multiple locations)
Representative testing height	0.6 ≤ L ≤ 1 m
Flexible test environments	Rabbit & Loops (Na, Pb, LBE, He, Salt)
Advance instrumentation and sensors	In-situ, real time data
Experiment life cycle	Proximity to existing infrastructure
Driver fuel life cycle management	Utilize existing facilities as much as possible



REFERENCE TECHNOLOGY

- Mature Technology: Sodium-cooled pool type reactor with inherent and passive safety
- Metallic alloy fuel
- No electricity production

Reactor Building Overview

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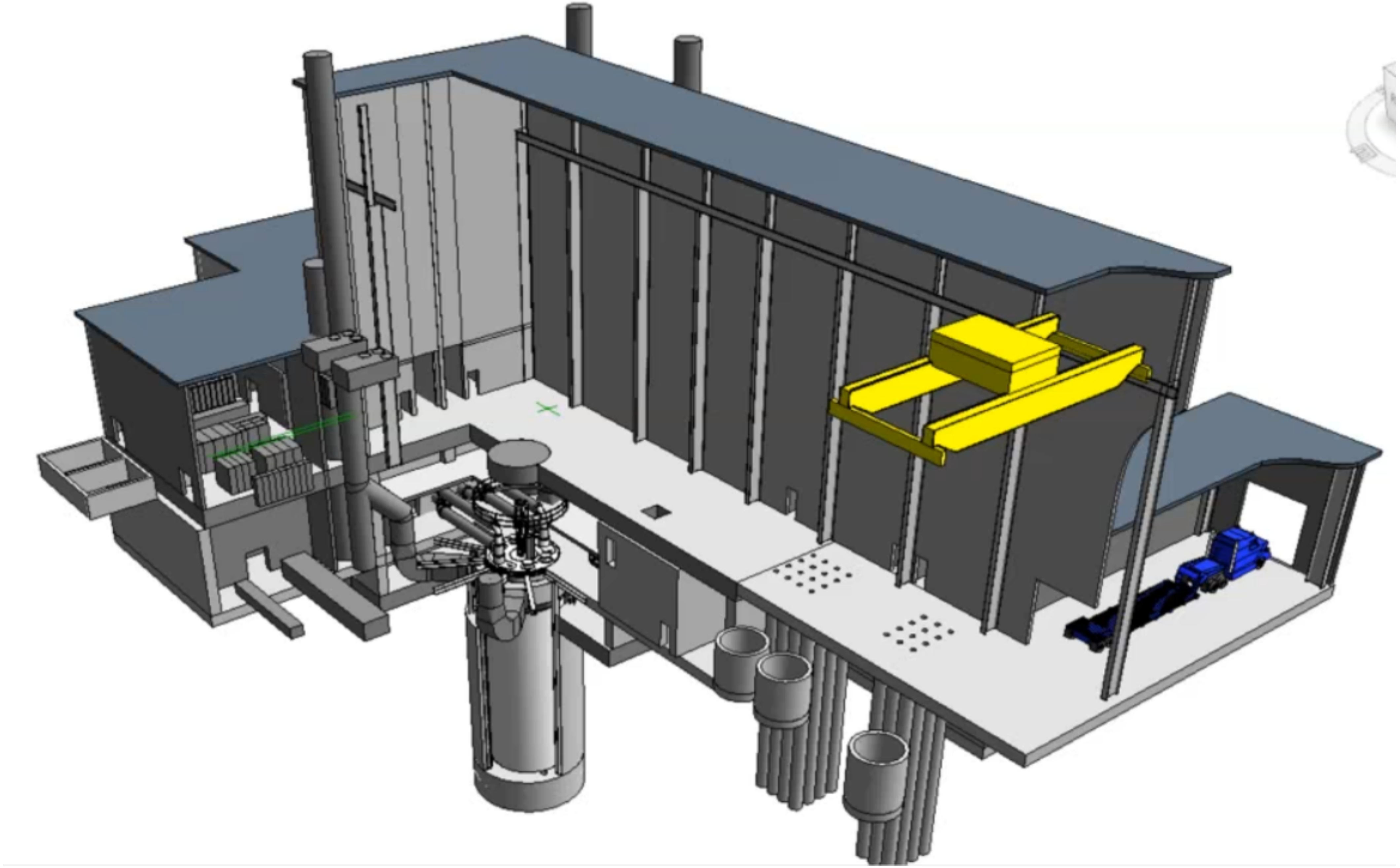
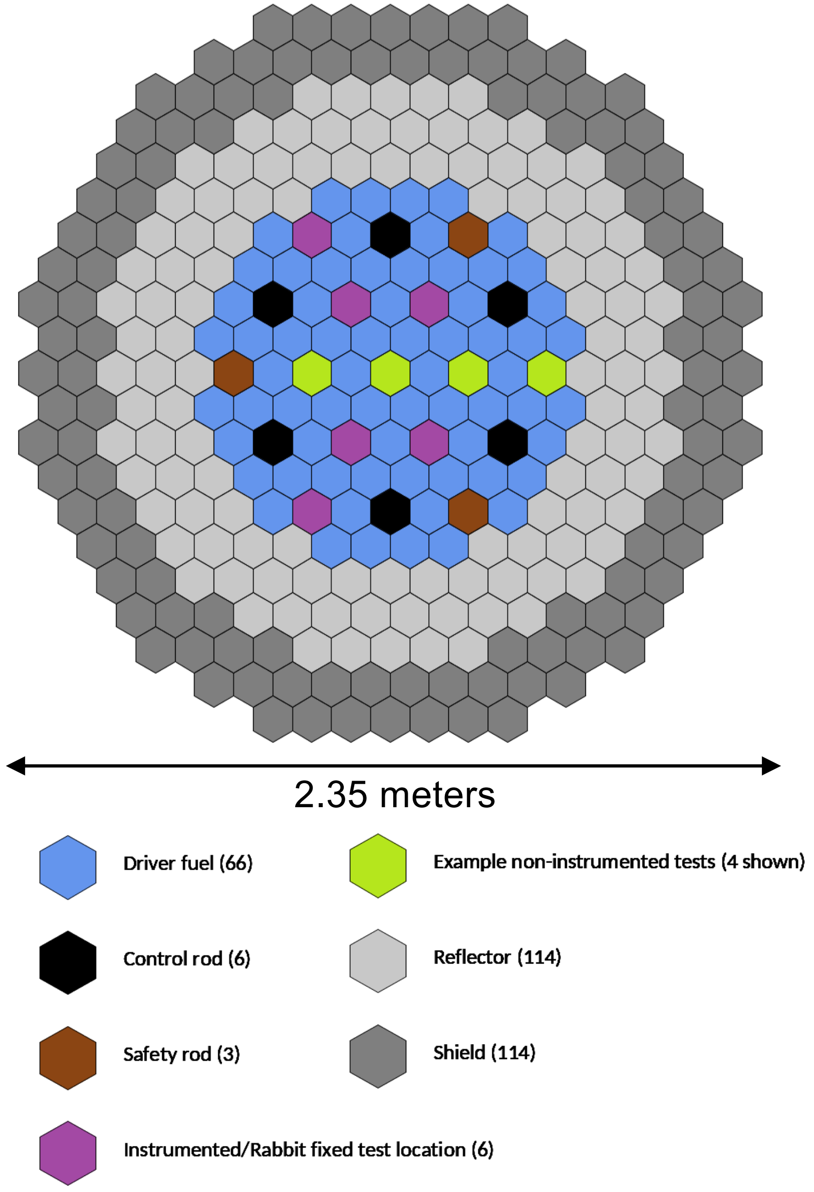
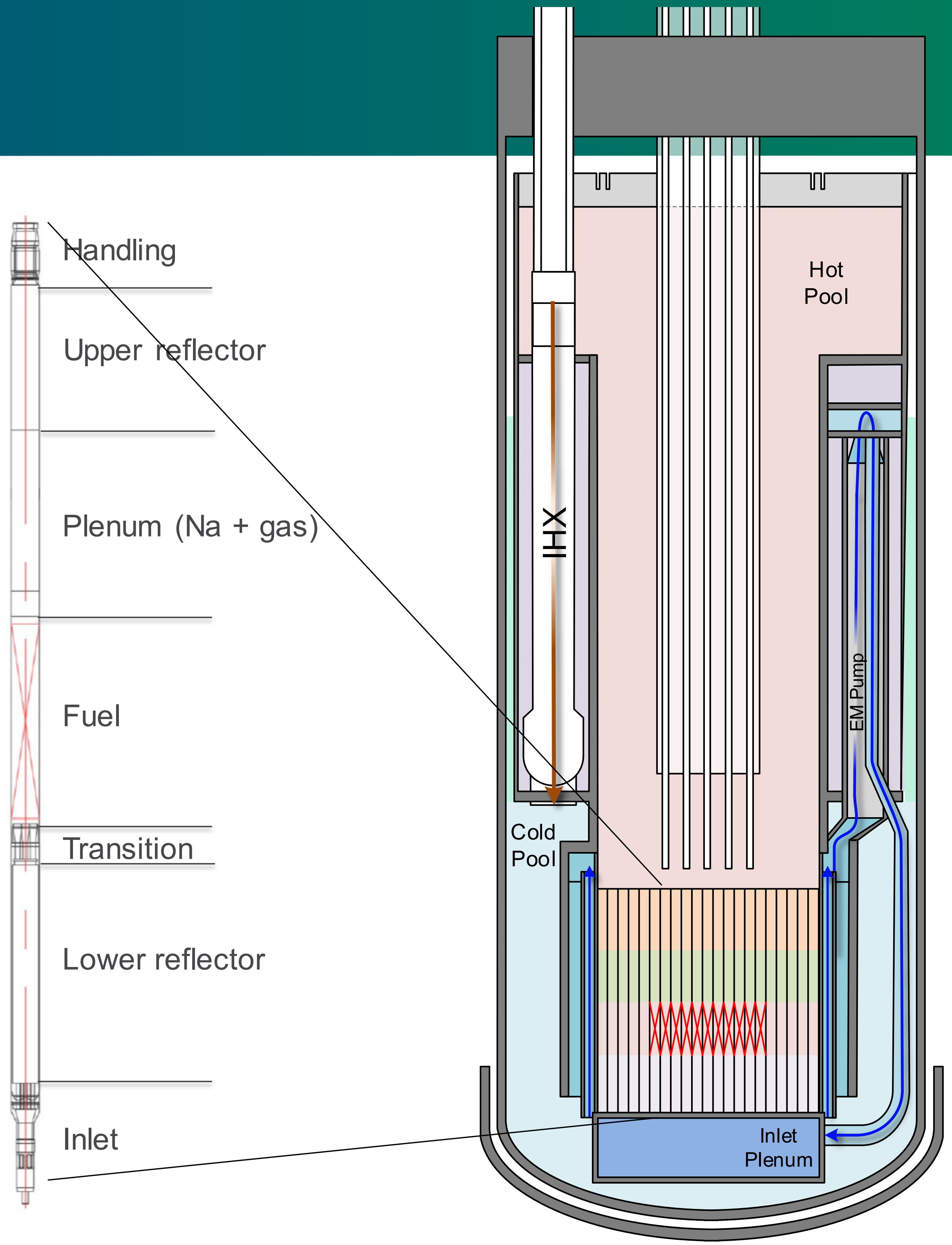


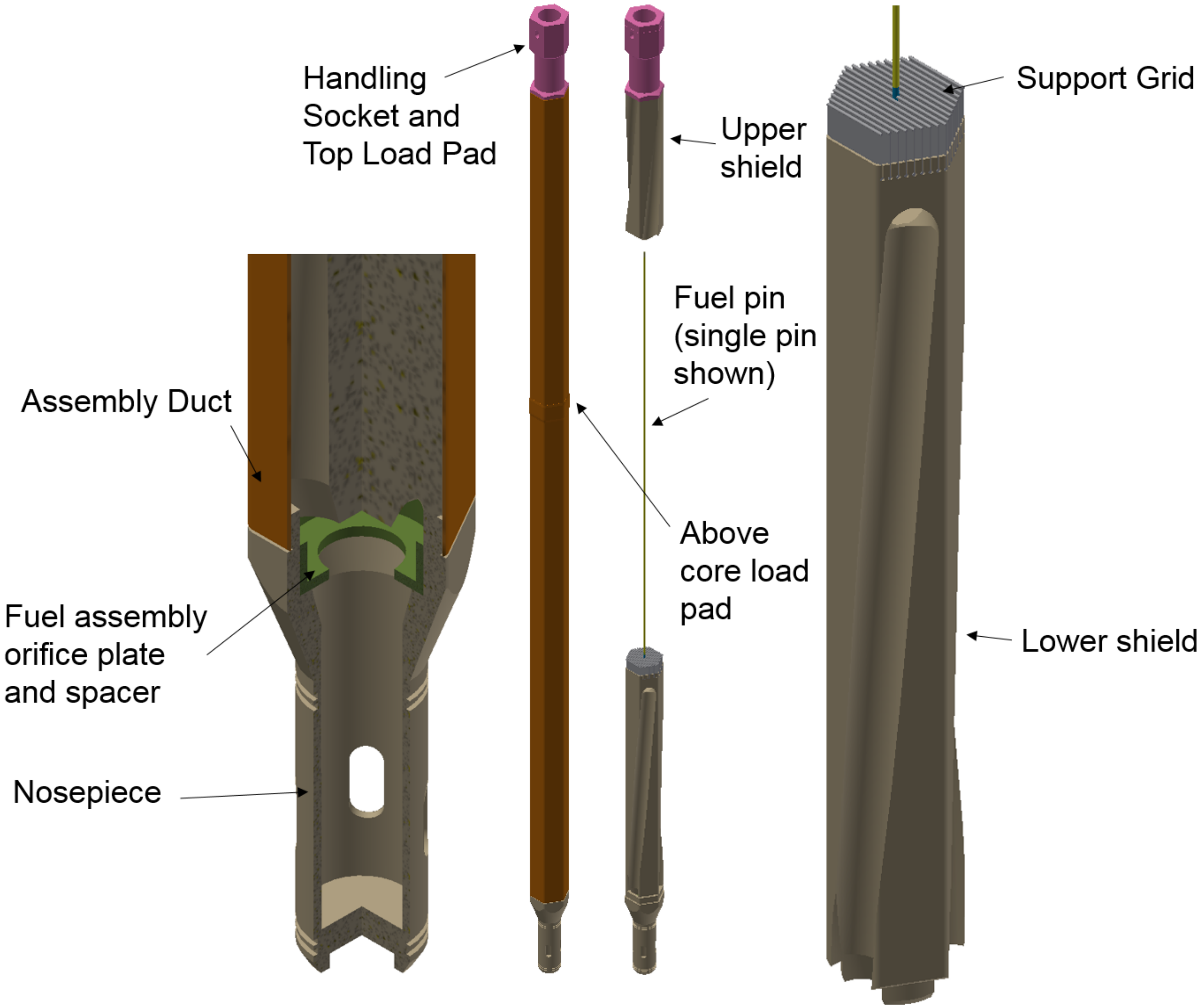
Reactor Core and Vessel





Reactor Parameters

Parameter	Value
Core thermal power	300 MW
Fast flux	≥ 4 x 10^{15} n/cm^2-s
Flexible test environment	Rabbit & Loops (Na, Pb, LBE, He, Salt); multiple non-instrumented test locations
Core diameter	2.35 m
Assembly Length	3.85 m
Fuel zone length	0.8 m
Pins per assembly	217
Core fuel load	66 fuel assemblies (~2600 Kg HM) Ternary metal fuel U-20Pu-10Zr
Operating mode	3 100-day cycles/year, 20-day refuel
Fuel assemblies/year	~45 (~1800 Kg HM)
Discharge burnup	53/61 GWd/MT (avg/peak)



Design Considerations

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- High flux achieved with compact core and high power density
- Fuel pin specifications based on accumulated experience to establish high confidence in fuel performance
  - Cladding thickness and pin diameter
  - Power density, temperatures, dimensions, burnup, fuel composition are within the area of confidence
- Fuel height determined based on:
  - Coolability/pumping power, fuel performance, flux characteristics
- Cycle length determined based on feedback from experimenters
  - Can be adjusted without adversely impacting reactor performance
- Impact of fission product build-up is small in fast reactors
  - Reactivity loss does not limit burnup

Selection of Sodium-bonded Metallic Fuel as Reference Concept

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- High fissile density of metallic fuel offers more core design options for achieving test reactor performance targets and preferred reactor size
  - Flux and spectrum
  - Better accommodation of a variety of fissile feed materials
- Extensive US experience with metallic fuels is adequate to support authorization of a startup core
- Simple, compact, economical fuel fabrication relative to other fuel forms
- Multiple US companies currently pursuing advanced reactor designs call for use of metallic fuels

Driver Fuel Considerations

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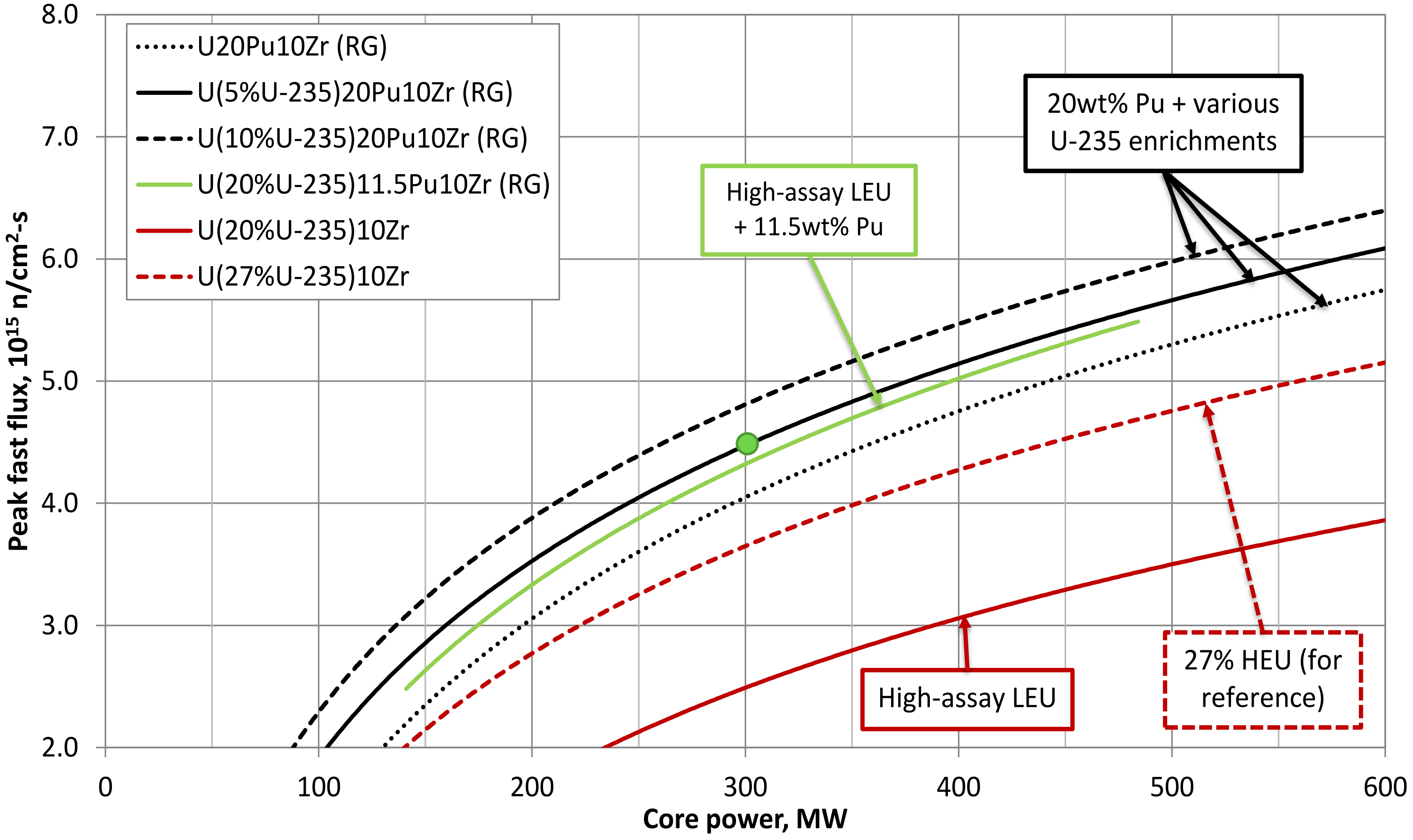
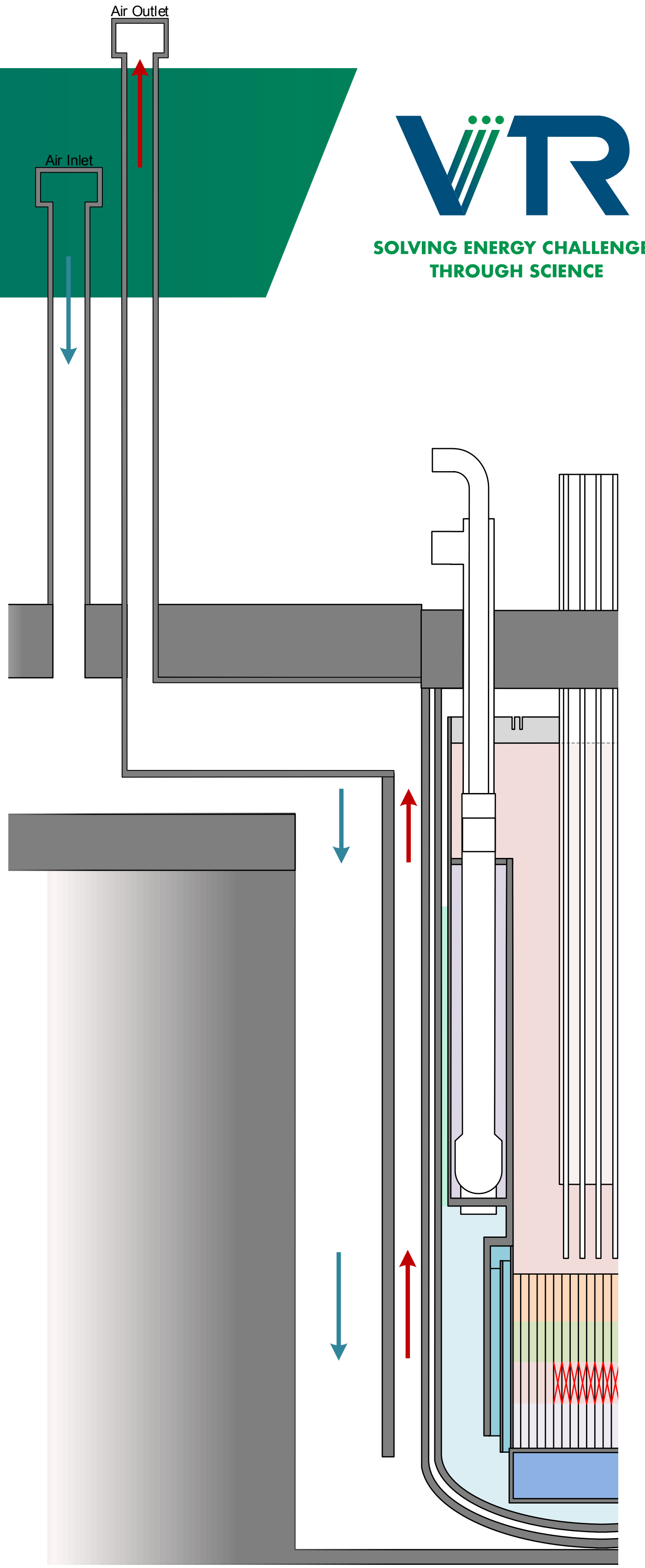
- Types Evaluated:
  - High Assay Low Enriched U
  - U-Pu-Zr
  - High Enriched U (for reference only)
- U-Pu-Zr selected
- Possible Pu Sources
  - Excess Pu stockpiles
  - DOE-NE inventories
  - International sources
- Possible fabrication locations:
  - INL (Materials and Fuels Complex)
  - Savannah River Site (K-Area)
- NE/NNSA MOU signed to organize transfer of excess plutonium



Core power versus peak neutron flux for multiple fuel options

VTR Safety Attributes

- Low-pressure primary pool and low-pressure secondary coolant system
  - No LOCA concern, no need for coolant injection
  - Guard vessel (and guard pipes) to maintain coolant inventory
- Liquid-metal sodium coolant
  - ~100 times more effective heat transfer medium compared to water
  - Wide margin to boiling (~400°C)
  - Compatible with structural components and metallic fuels
- Proven fuel safety performance via EBR II metal fuel
- Inherent safety with net negative reactivity feedback provides long grace period for action, if needed
- Passive decay heat removal system driven by natural circulation



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Questions?

Supplemental Slides

Conceptual Assembly

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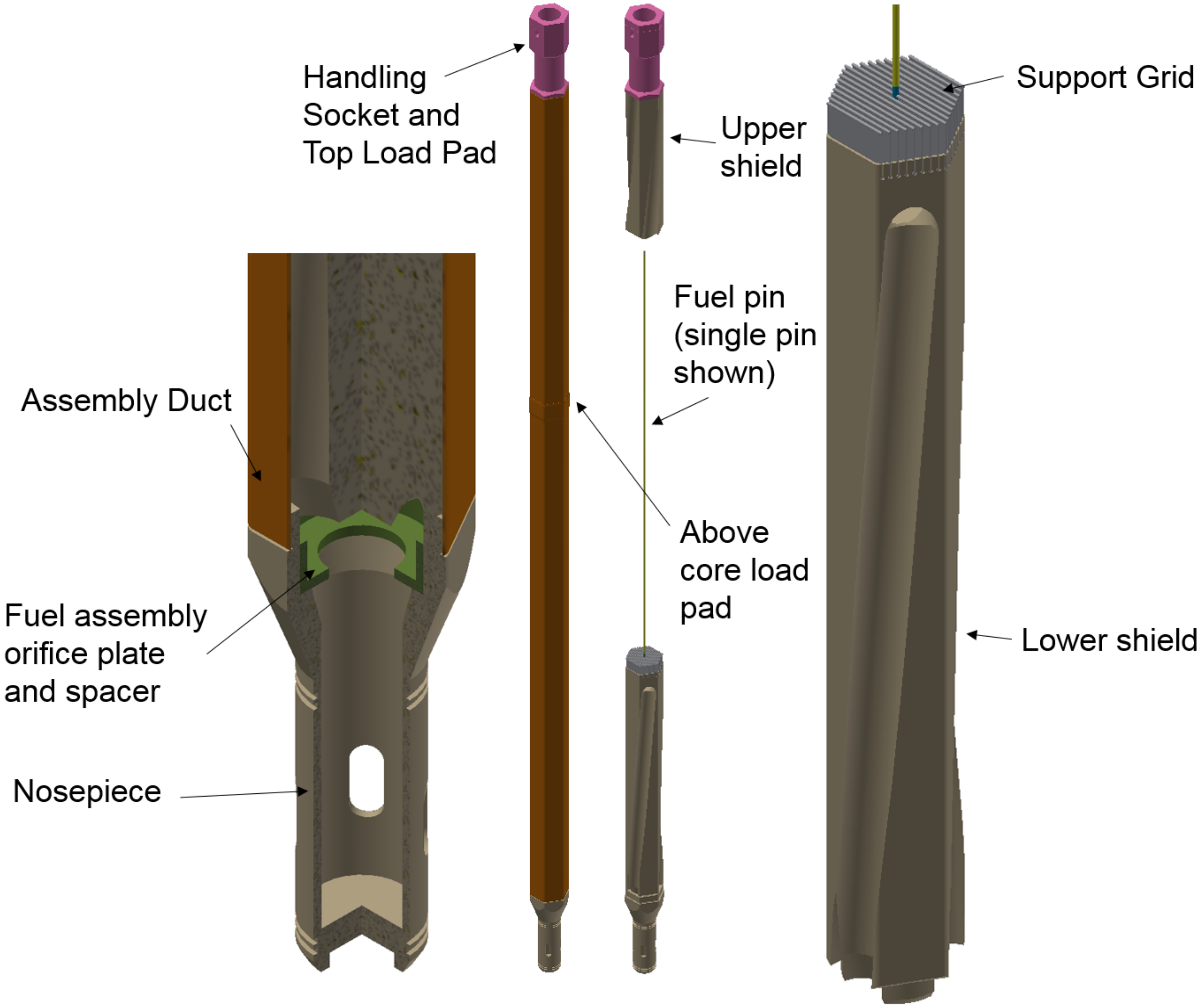
Driver Fuel Conceptual Design



Reflector and Shield Conceptual Designs

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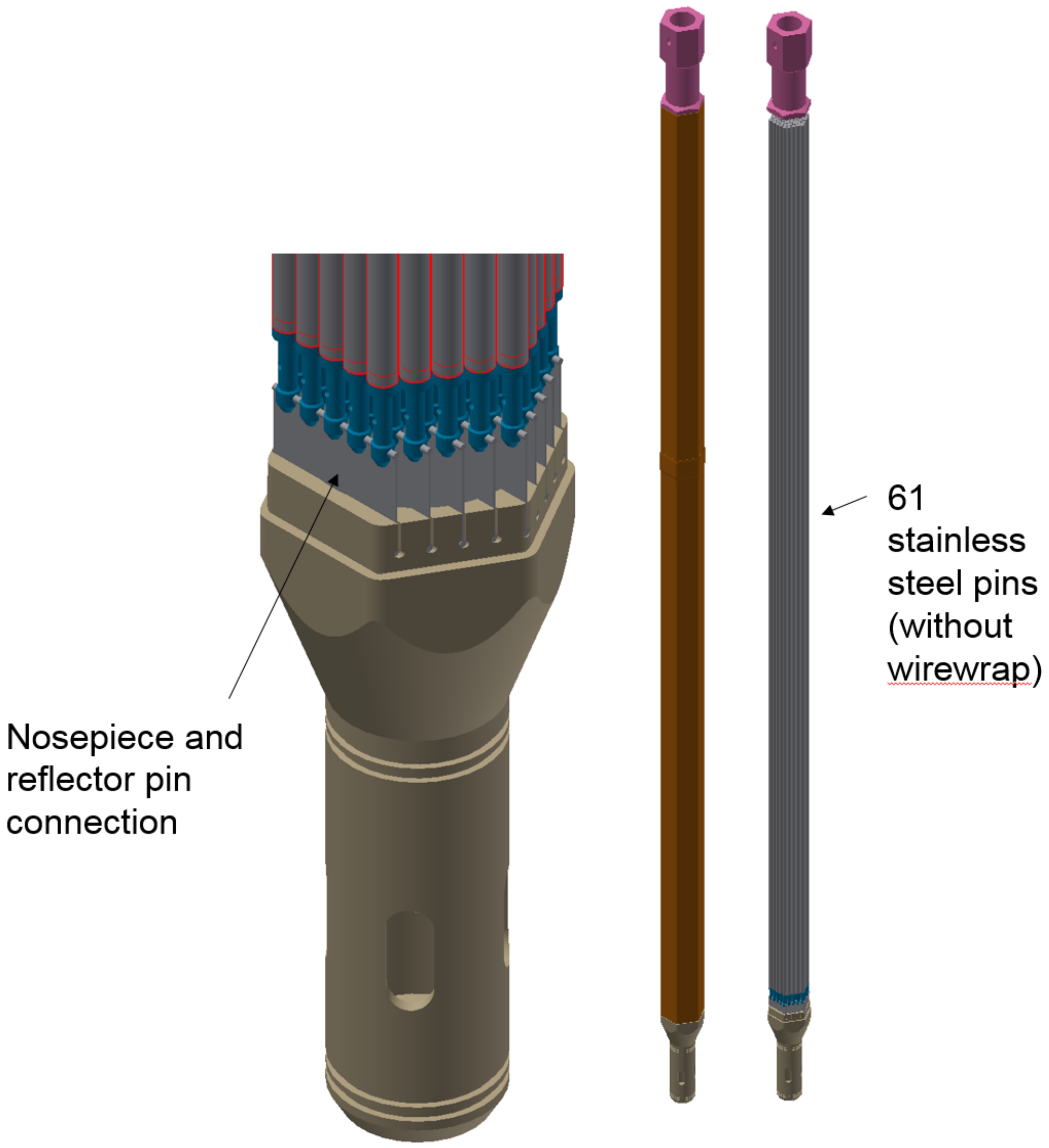
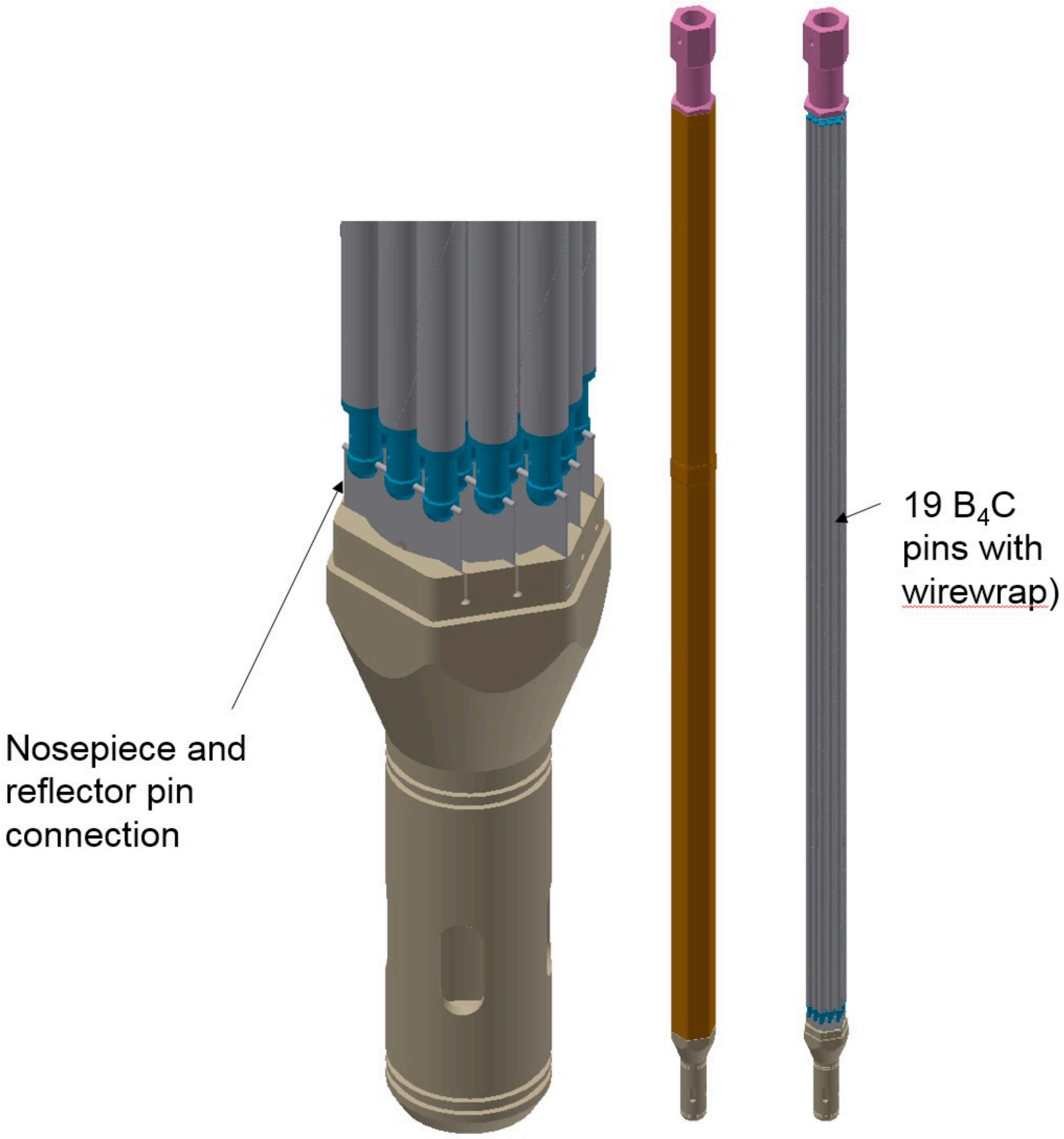
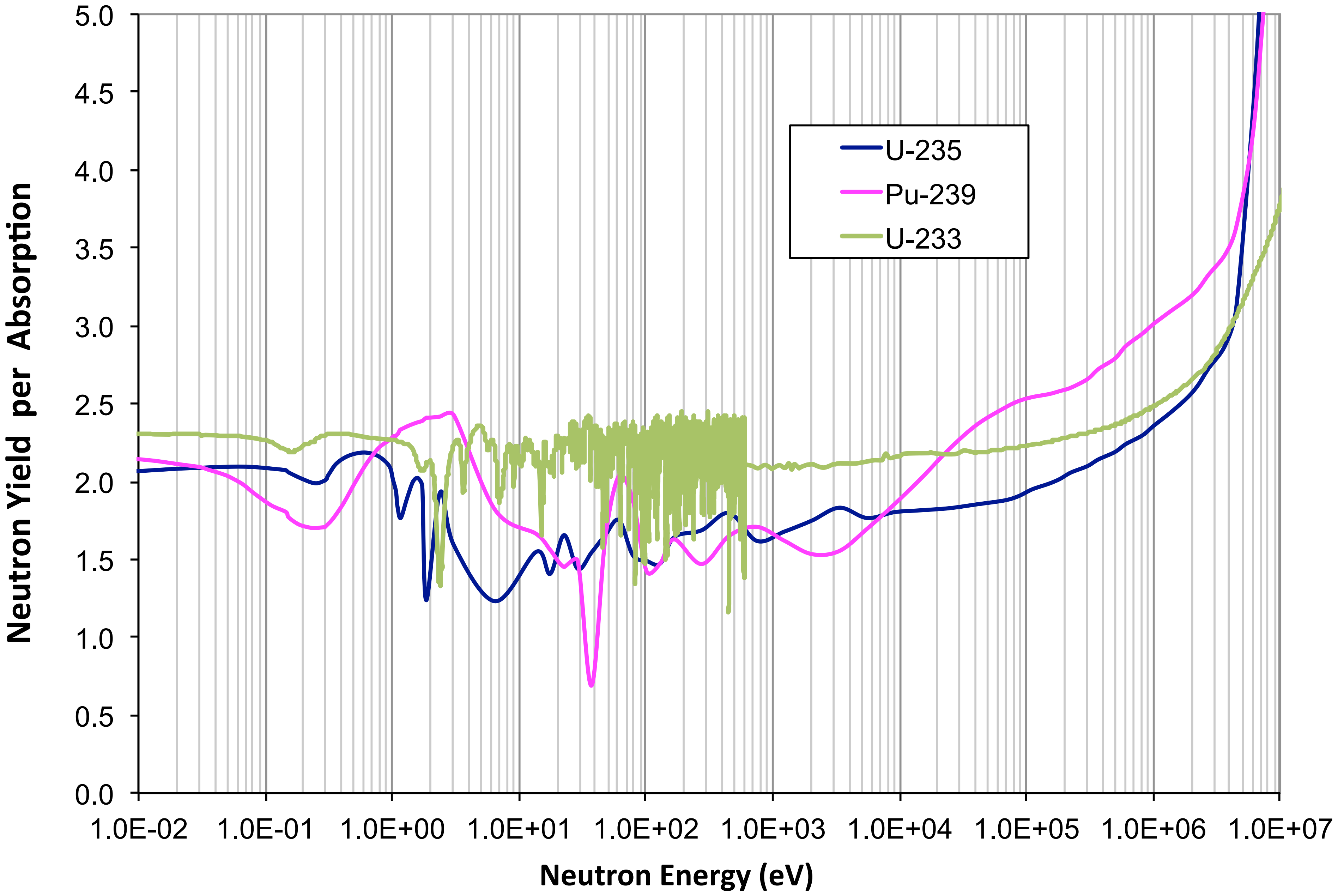
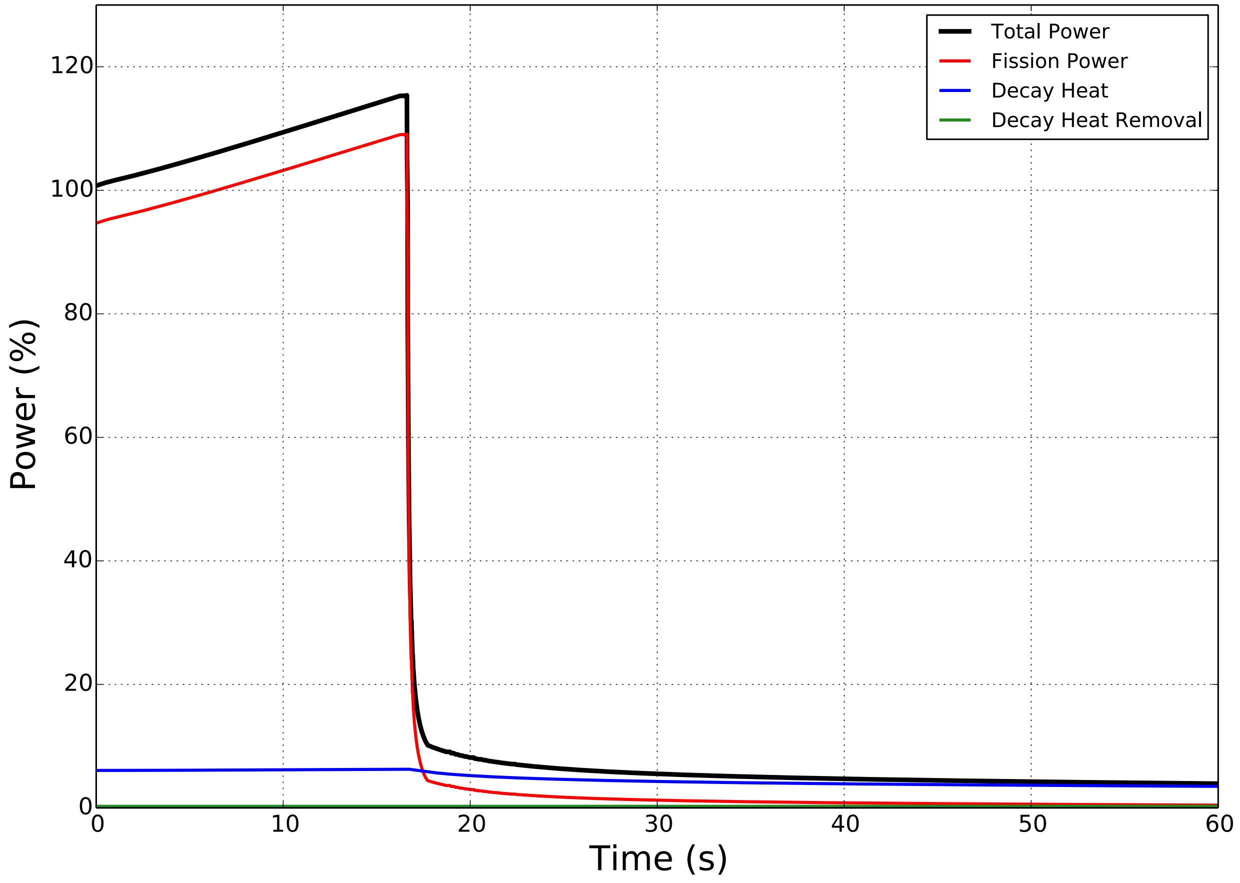


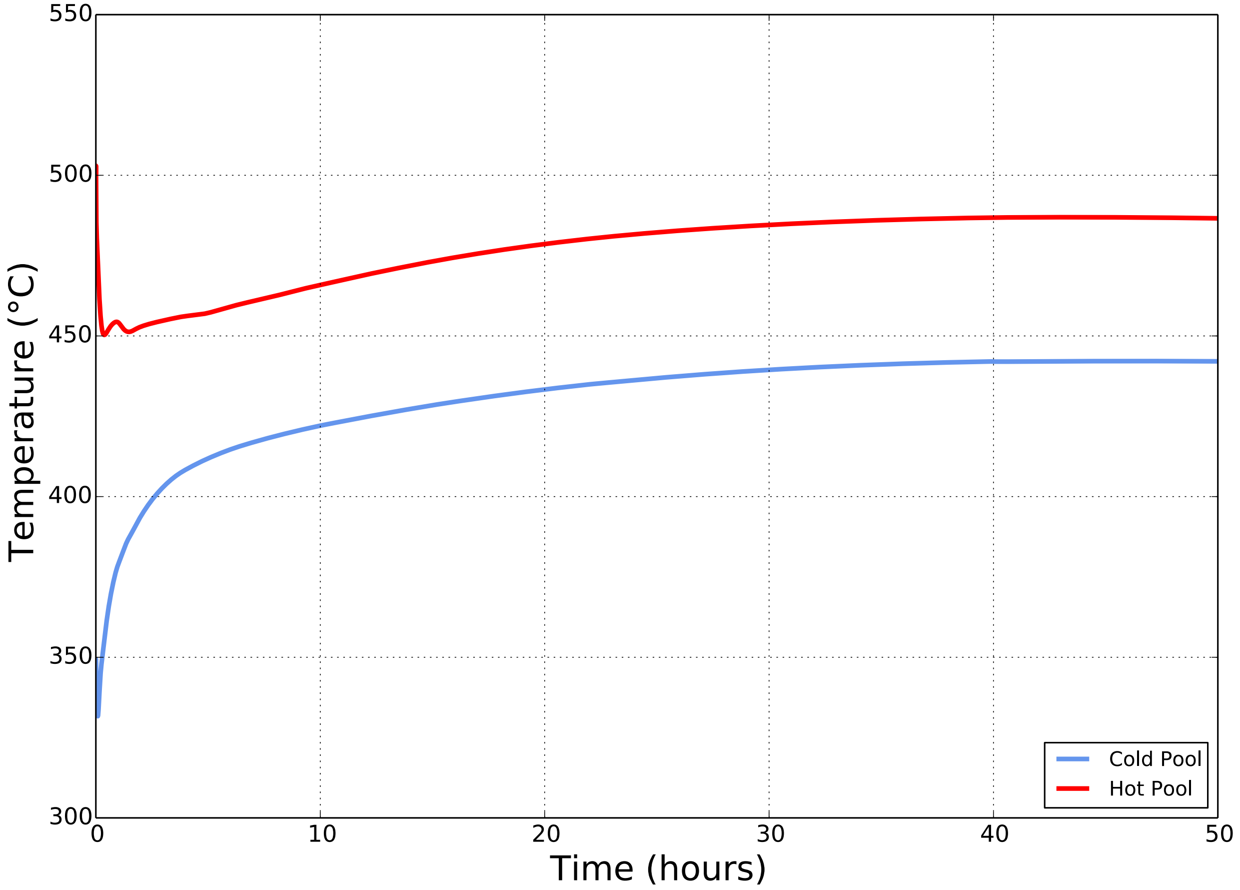


Fast Spectrum Neutron Economy



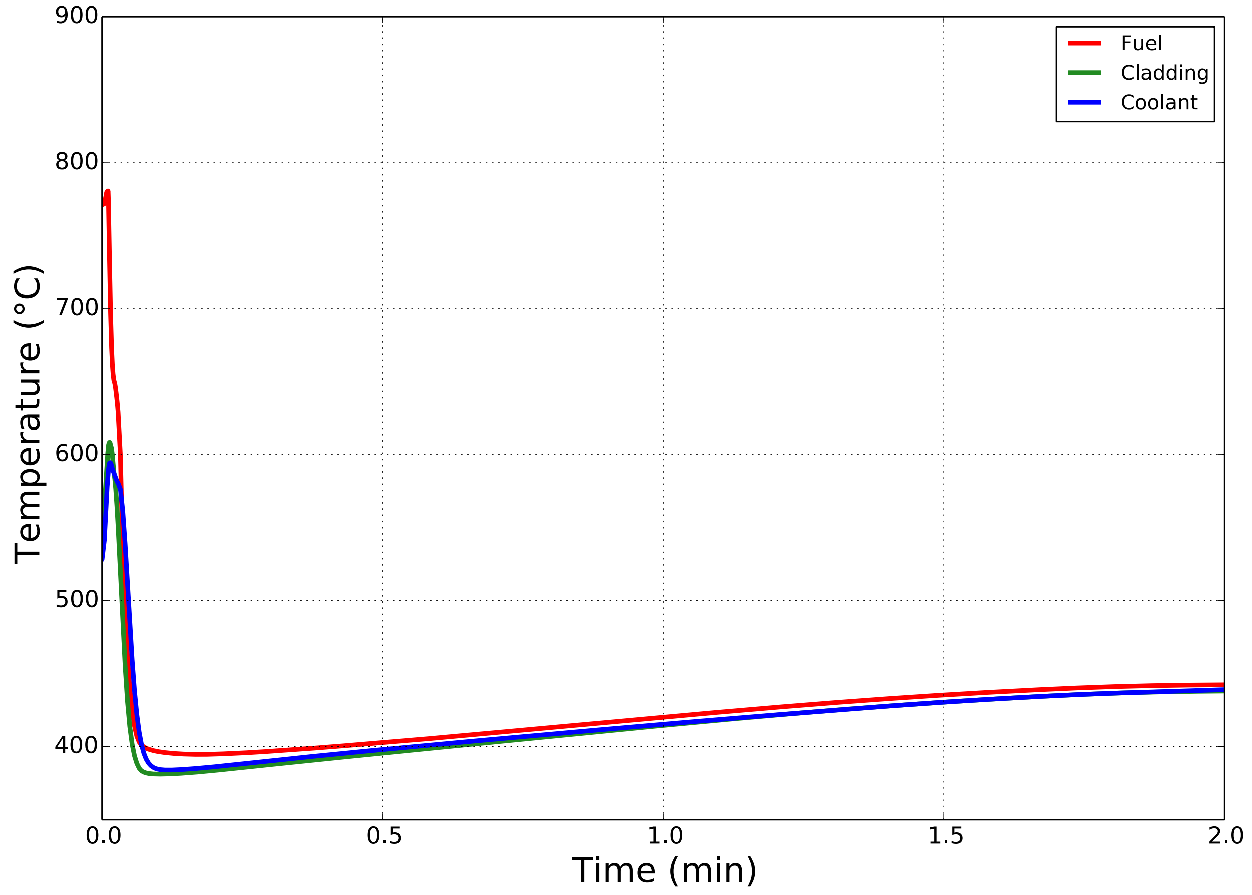
Protected Transient Overpower

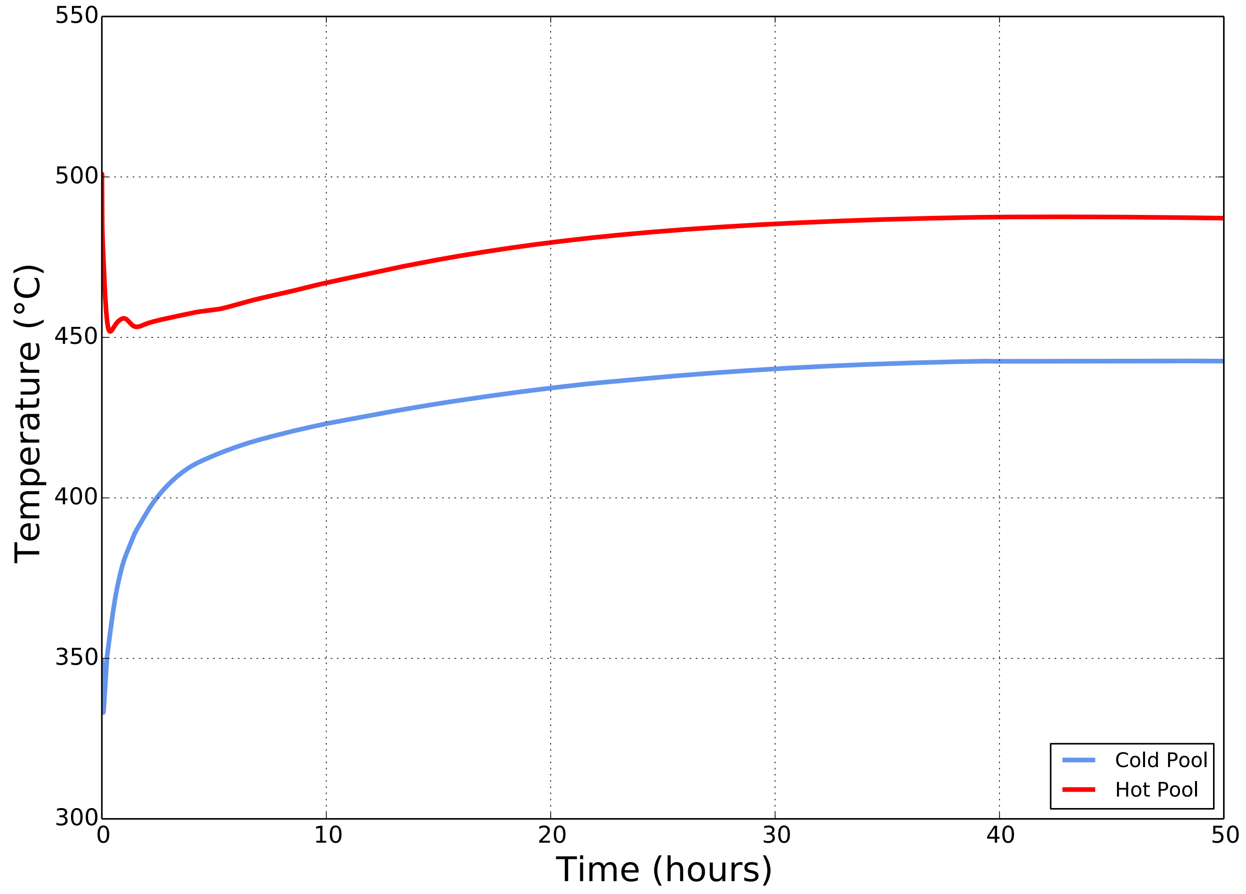




- Complete withdrawal of a control rod at beginning of cycle
- Overpower triggers scram, primary and secondary pumps trip
- Normal heat rejection pathway is lost, transition to natural circulation
- Passive RVACS heat removal only

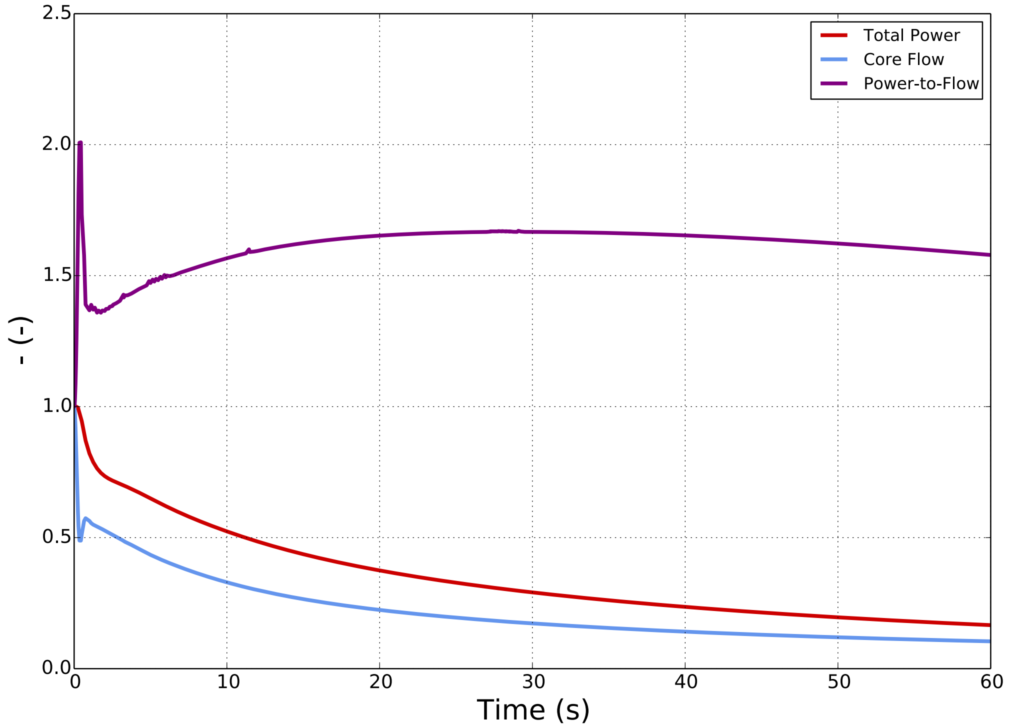
Protected Station Blackout

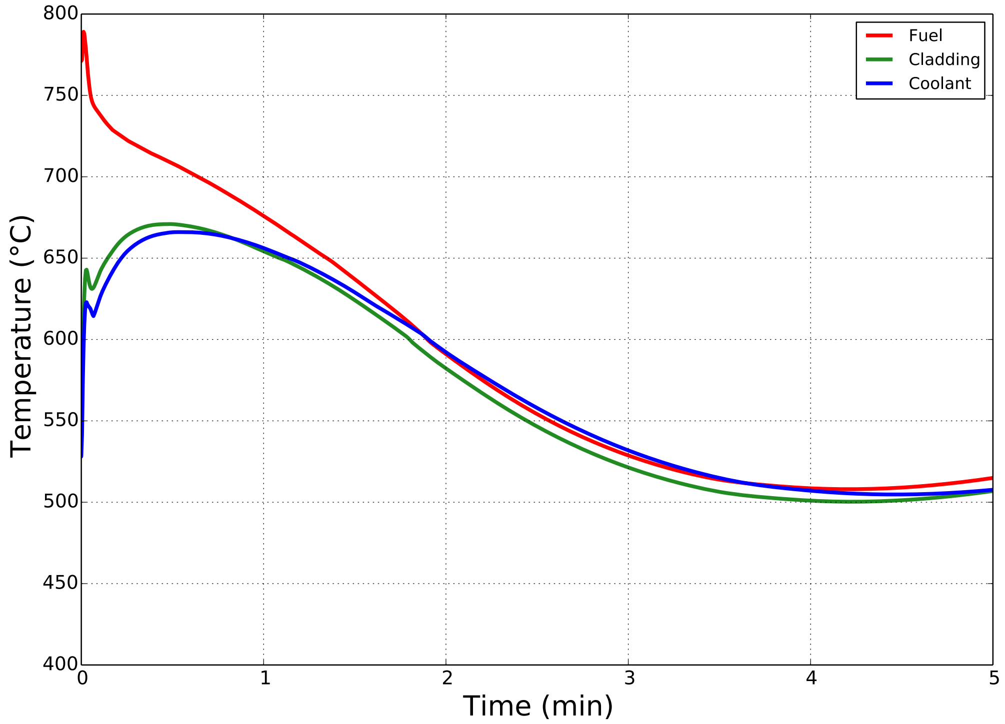


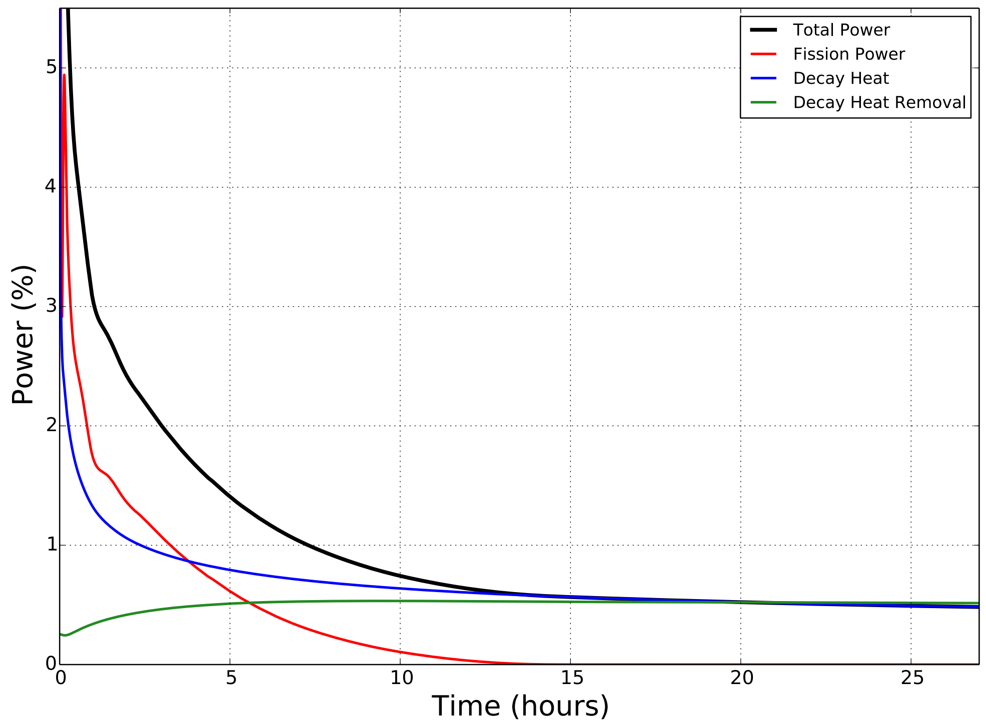


- Loss of off-site station power, primary pump coast-down
- Power/flow mismatch triggers scram
- Normal heat rejection pathway is lost, transition to natural circulation
- Passive RVACS heat removal only

Unprotected Station Blackout







- Loss of off-site station power, primary pump coast-down
- Power/flow mismatch, reactor protection system fails to trigger scram
- Normal heat rejection pathway is lost, transition to natural circulation
- Passive RVACS heat removal only