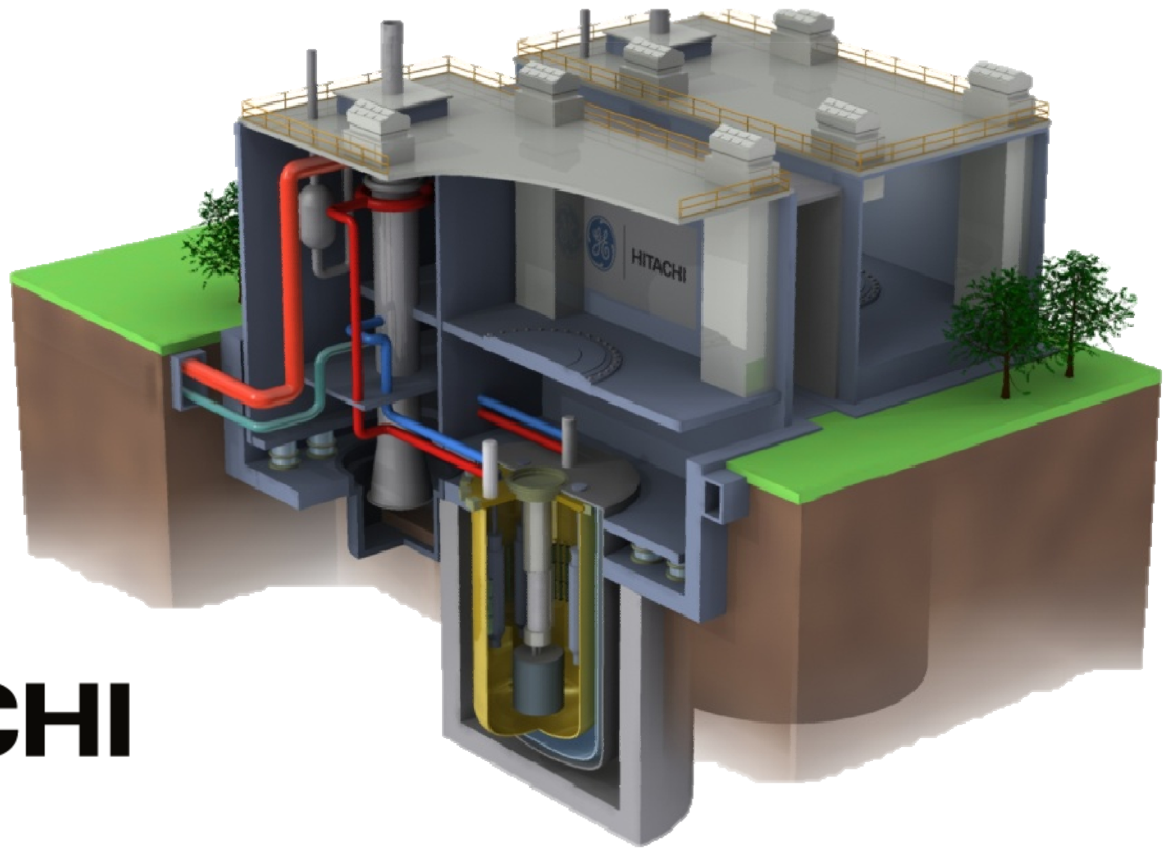
GE Hitachi Nuclear Energy

PRISM Fueling Options

Brian Triplett



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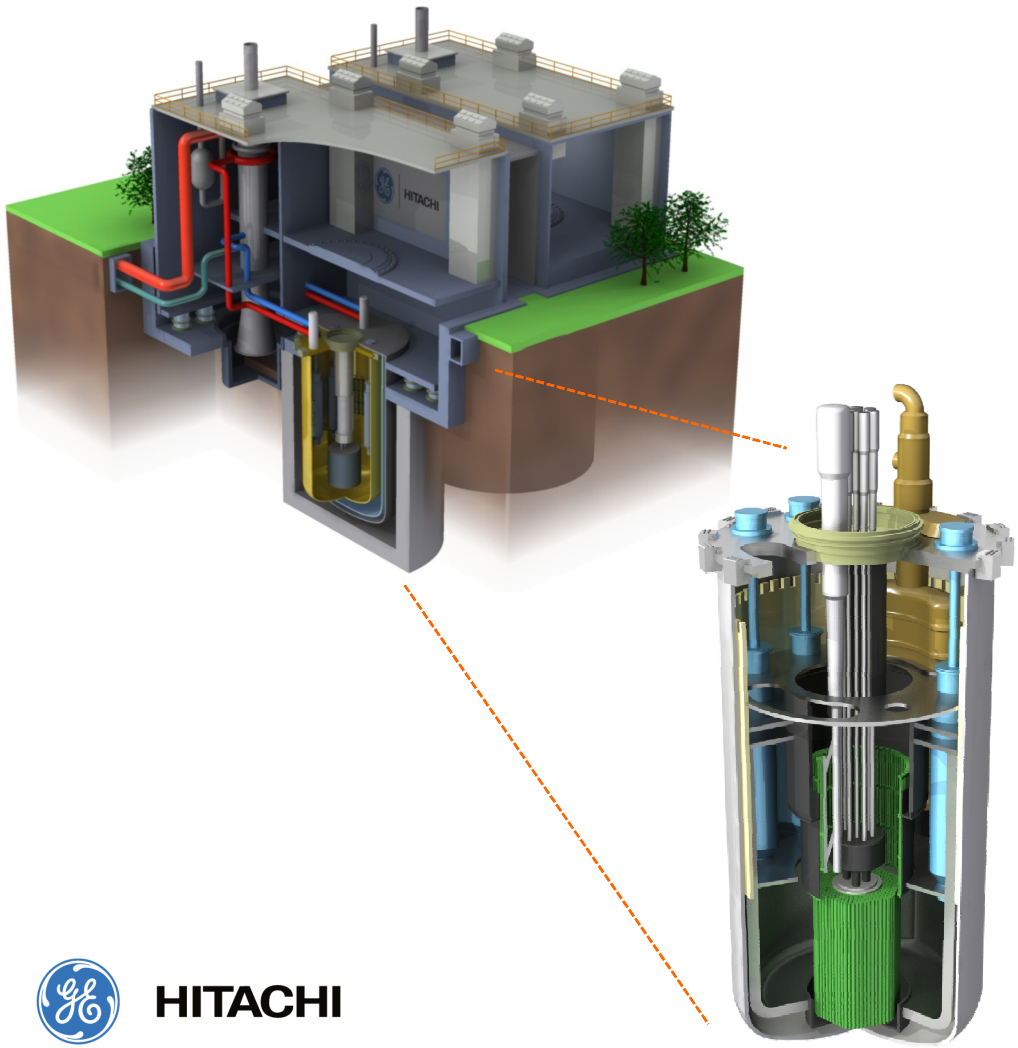
Power Reactor Innovative Small Module (PRISM)



- Modular nuclear reactor which uses recycled used nuclear fuel (UNF) as fuel
- Sodium cooled fast reactor that can be operated in breeder, breakeven, or burner configuration
- 311 MWe (840 MWth) per reactor
  - Two reactors per T-G
  - Modular plant allows for scaling to power requirements
- Metal-fueled, pool-type sodium fast reactor
- Features passive-safety and digital controls
- Modular components allow for factory fabrication

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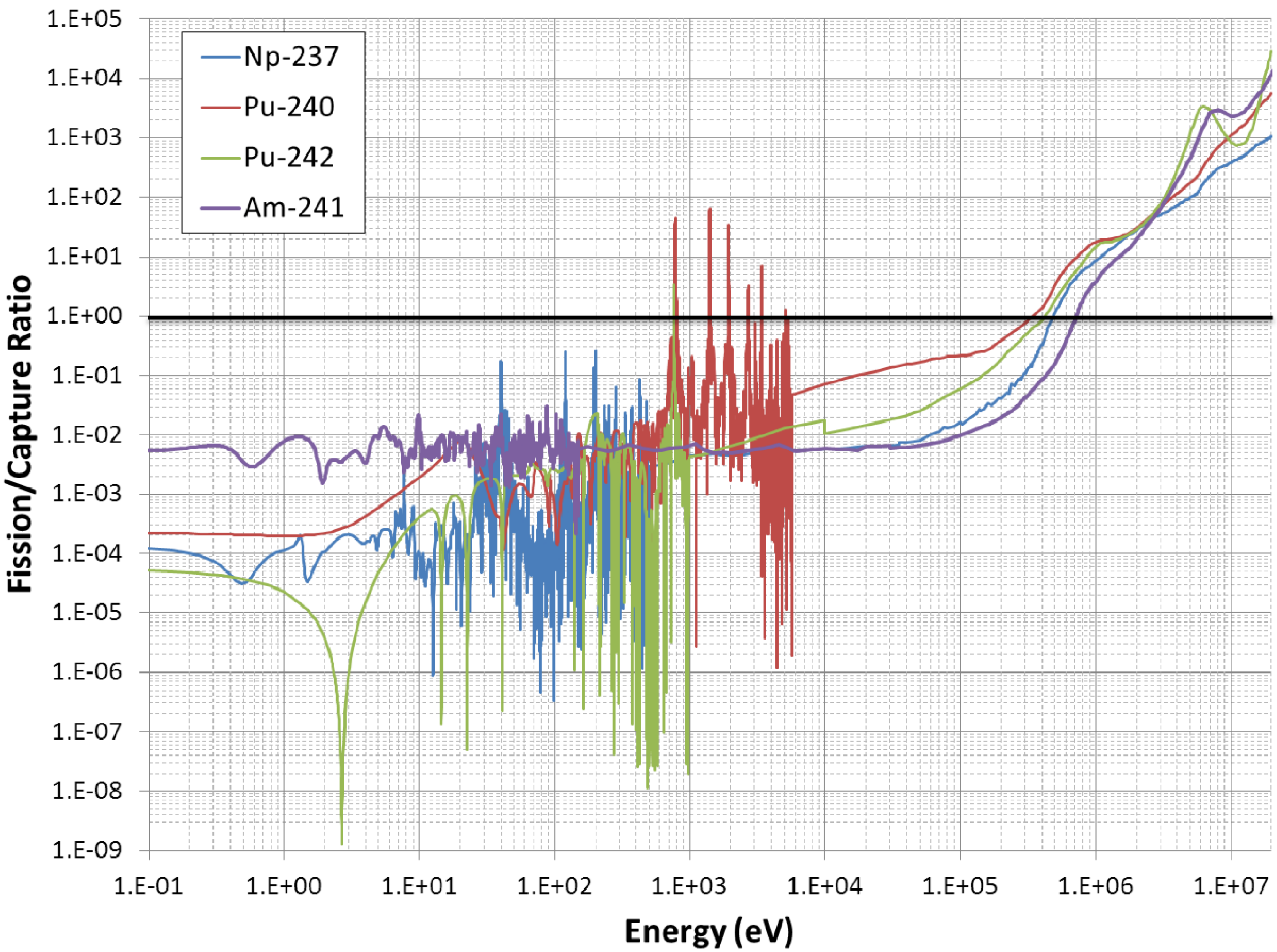
Why a Sodium Fast Reactor?



Transuranics will fission more often than capture at fast energies

SFR Fuel Options

	Metal U-20Pu-10Zr	Oxide UO_2-20PuO_2	Nitride UN-20PuN	Carbide UC-20PuC
Heavy Metal Density, g/cc	14.1	9.3	13.1	12.4
Melting Temperature, °C	1075	2725	2760	2300
Thermal Conductivity, W/cm-°C	0.16	0.023	0.26	0.20
Operating Centerline Temperature @ 40 kW/m ; (T/T_{melt})	785 (0.75)	2085 (0.75)	725 (0.3)	750 (0.35)
Fuel-Cladding Solidus, °C	725	1400	1125	1115
Thermal Expansion, 1/°C	17E-6	12E-6	10E-6	12E-6
Heat Capacity, J/cm-°C	0.17	0.34	0.26	0.26

Want

- High HM Density for high neutron efficiency
- High T_{melt} and low T/T_{melt}
- High solidus temperature for safety margins
- Low heat capacity to limit energy release in accident

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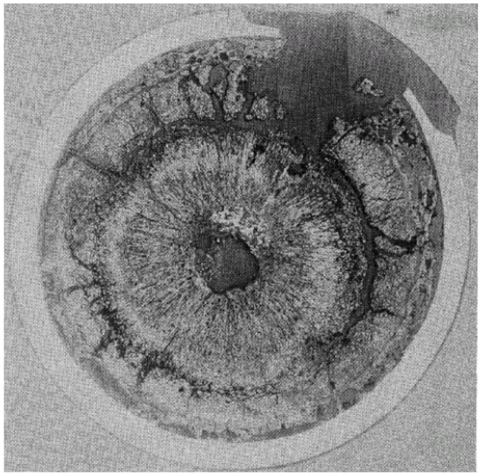
Metal Fuel Safety Performance

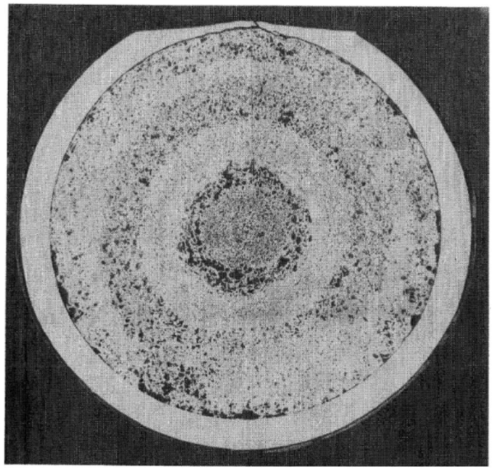
- Shutdown Heat Removal Tests (SHRT) and Inherent Safety Tests (IST) at EBR-II (1984-1986)
  - Natural Convection Decay Cooling
  - Loss of Flow without SCRAM
  - Loss of Heat Sink without SCRAM
- No fuel failures resulted from tests
- Reactor reached safe condition without active safety systems
  - Low energy content of metal fuel
  - Negative feedbacks
  - Large sodium pool for heat dissipation
- PRISM transient analysis shows similar performance for unprotected loss of flow and heat sink
- Superior performance with cladding breach in metal fuel

Oxide



9 at% burnup

Metal



12 at% burnup

Metal Fuel Database

- Most significant metal fuel experience from EBR-II
  - Initially fueled with U-5Fs*
  - Converted to U-10Zr core in 1980s
  - Planned to convert to U-Pu-Zr in 1990s, shutdown prior
- Significant database created in EBR-II
  - > 120,000 pins U-5Fs (qualified for burnups up to 8 at%)
  - > 13,000 pins U-10Zr (qualified for burnups up to 10 at%)
  - > 600 pins U-Pu-Zr (15-20 at% burnup in experiments)
- Irradiation experiments in FFTF
  - > 1000 U-10Zr pins
  - 37 U-Pu-Zr pins
- TREAT transient fuel limits testing
  - U-10Zr and U-19Pu-10Zr fuel taken to ~4x nominal power to determine failure limits

EBR-II

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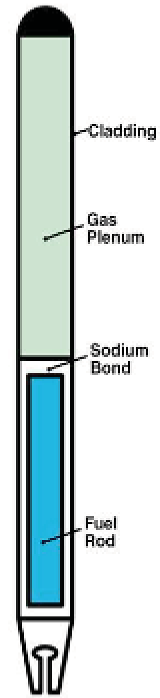
*Fissium = 2.4 wt% Mo, 1.9 wt% Ru, 0.3 wt% Rh, 0.2 wt% Pd, 0.1 wt% Zr, 0.01 wt% Nb

TRU Fuel Qualification

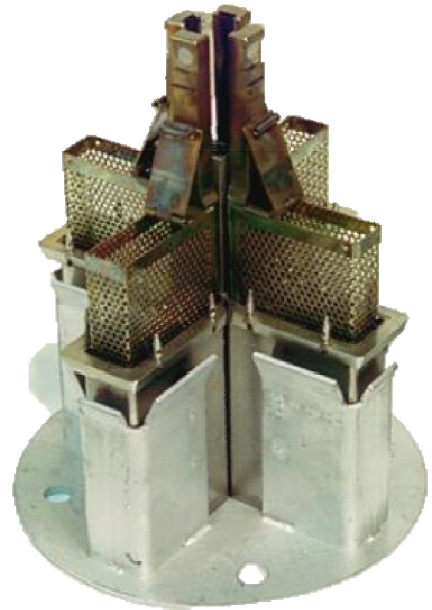
- X501 experiment at EBR-II irradiated U-20.2Pu-9.1Zr-1.2Am-1.3Np for 339 effective full power days
- METAPHIX experiment irradiated U-19Pu-10Zr-5MA(-5RE) to 12 at% burnup (>100,000 MWD/MTU)
  - Practically no change in material properties (elasticity, thermal conductivity, etc) versus non-TRU control fuel
  - Pyroprocessing of samples planned by CRIEPI
- Current experiments FUTURIX-FTA and at ATR being performed up to 30 at% burnup
  - Many combinations of U, Pu, Np, Am, RE, Zr irradiated to various levels
  - Irradiation and Post-Irradiation Examination in progress



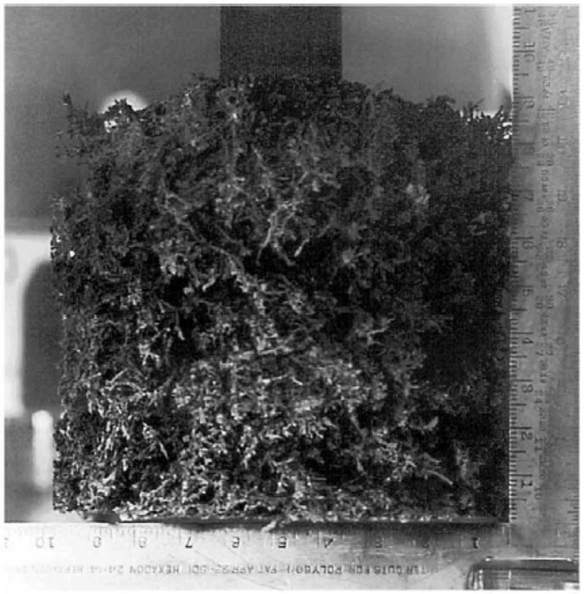
Initial results show feasibility of TRU bearing fuels up to 20 at% burnup

Metal Fuel Fabrication

- Metal fuel used to successfully demonstrate the viability of a closed fuel cycle in EBR-II by 1969
  - 35,000 fuel pins irradiated, processed, remotely refabricated, and returned to core
  - Melt refining process employed
  - Did not recycle Pu from fertile blankets
- ANL electrometallurgical demonstration in 1990's with EBR-II fuel
  - 100 driver assemblies (410 kg of HEU) processed in Mark IV electrorefiner
  - 25 blanket assemblies (1,200 kg of DU) processed in high throughput Mark V
  - Original proposal was to include Pu/TRU demonstration
  - Only U processed based on revised environmental impact statement



Anode Basket



Cathode with fuel

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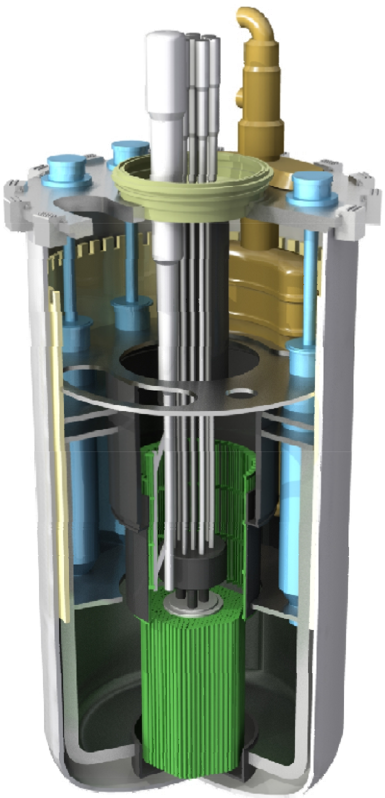

U-Zr	Qualified in EBR-II Used as startup fuel
U-Pu-Zr	Qualification in demonstration core to replace U-Zr as driver fuel
Pu-TRU-Zr	Qualification in demonstration core for TRU consumption mission

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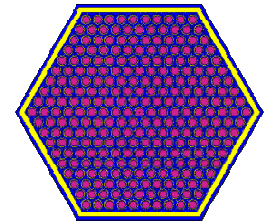
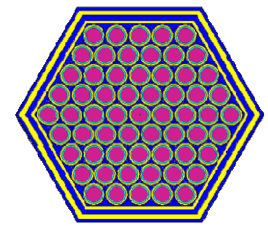
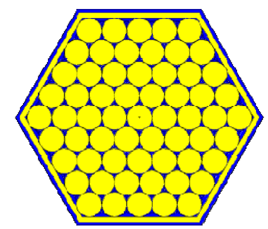
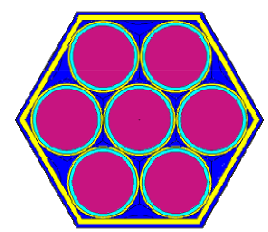
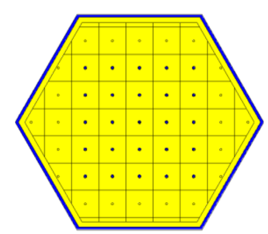
Summary

- Metal fuel is integrated into the overall design of PRISM
  - Improved safety performance
    - Low heat content → Less decay heat
    - High thermal conductivity → Lower operating temperatures
  - Compatible with sodium coolant
  - Coupled readily with electrometallurgical recycling
- Significant experience with metal fuel
  - Binary U-Zr fuel as EBR-II driver fuel
  - Significant testing of U-Pu-Zr and U-Pu-TRU-Zr fuel
  - Fuel/cladding limits evaluated at TREAT

Conclusion

Much more is known about fast reactor fuel performance and fabrication today than was known about thermal reactor fuel when LWRs began commercial production