POWERPOINT 3

SODIUM-COOLED FAST REACTORS – GENERATION IV SYSTEMS

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Presentation to Joint Committee on Energy
State Capitol, Little Rock, Arkansas
28 August 2017

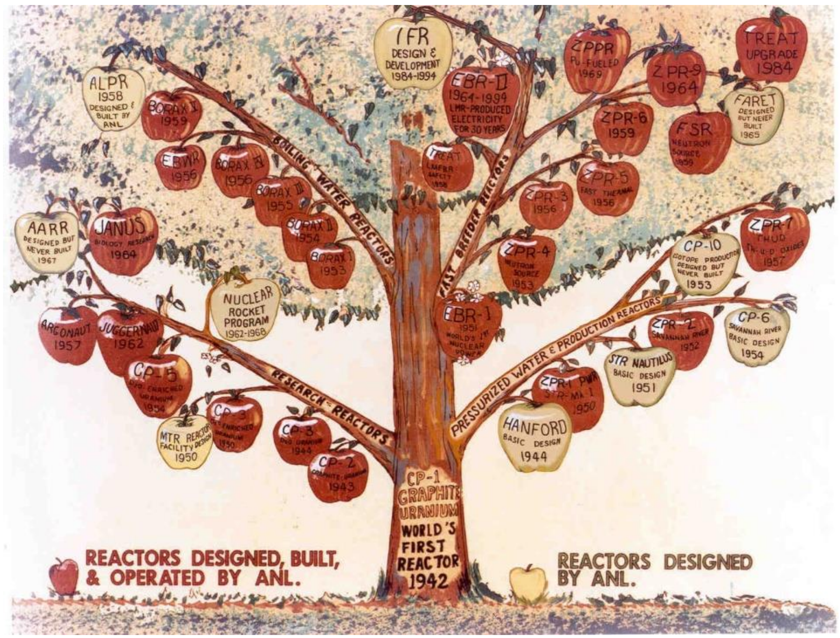
A VITAL PART OF THE DEPARTMENT OF ENERGY NATIONAL LABORATORY SYSTEM

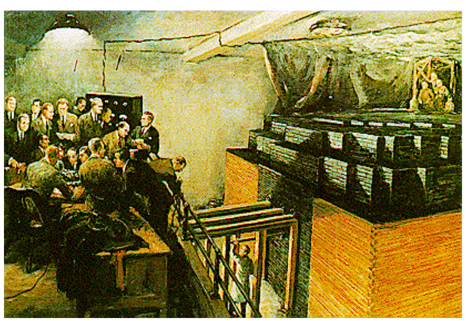
Argonne National Laboratory

- **Founded 1943 by the University of Chicago**
- **Designated national laboratory in 1946**
- **Operated for DOE by UChicago Argonne, LLC**
  - $735 M Budget (FY 2016)
  - 3300 employees, 7200 facility users, 460 students, 300 postdocs, 250 joint faculty
  - Collaborate with over 600 agencies, private companies, and institutions worldwide
  - 1500 acre site
- **Conduct multi-disciplinary research in basic and applied science**
- **Build/operate major national user facilities**
- **Pioneered most civilian nuclear technologies used worldwide**

ARGONNE'S NUCLEAR PROGRAM BUILDS ON PIONEERING ACHIEVEMENTS

- **Seminal work on reactors and fuel cycle technologies**
- **Our mission today is to advance the safe, secure use of nuclear energy and management of nuclear materials**
  - **Incorporating S&T advances in the development, design, and operation of nuclear energy systems**



GENERATIONS OF NUCLEAR REACTORS

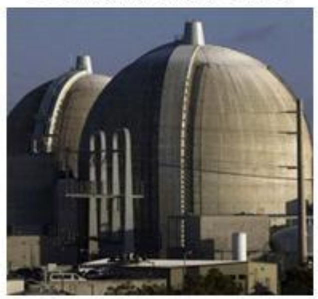
Generation I

Early Prototypes

- Shippingpor
  t
- Dresden
- Fermi I
- Magnox

Generation II

Commercial Power



- PWR, BWR
- CANDU
- VVER
- AGR

Generation III

Advanced LWRs

- ABWR
- AP600
- System
  80+
- CANDU 6

Generation III+

Evolutionary Designs

- ESBWR
- AP1000
- EPR
- APWR
- ACR1000

Generation IV

Revolutionary Designs

- FR
- HTR
- MSR

1950 1960 1970 1980 1990 2000 2010 2020 2030

Gen I | Gen II | Gen III | Gen III+ | Gen IV

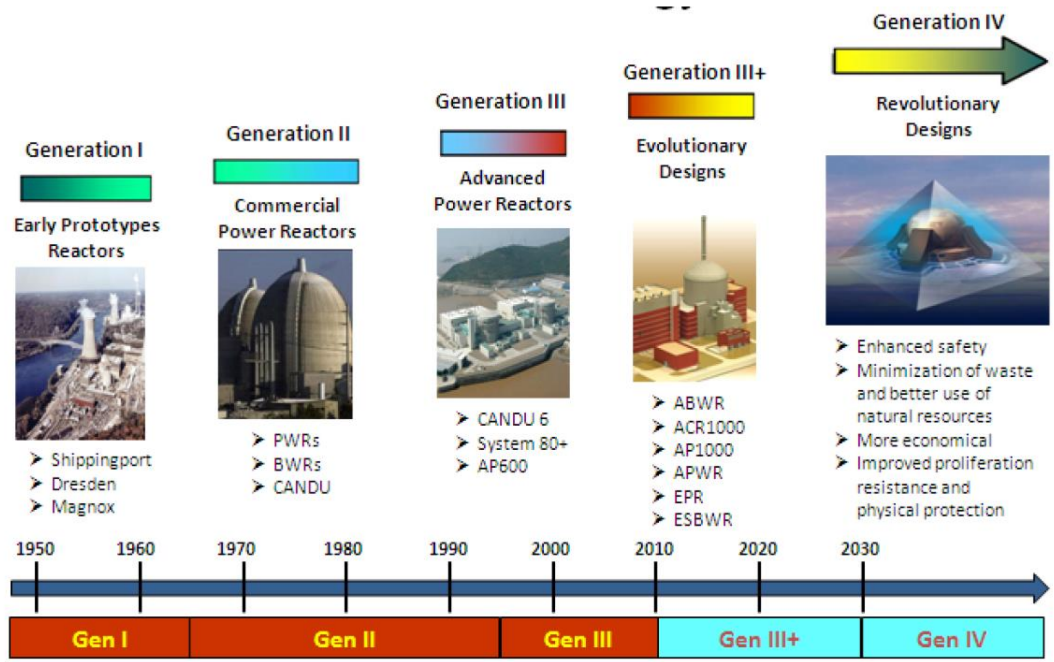
GENERATION IV NUCLEAR SYSTEMS

Goals – Developed during Technology Roadmap (US DOE 2002)

- SUSTAINABILITY
  - Effective Fuel Utilization
  - Fuel Cycle Impact on Environment – Waste minimization
- ECONOMICS
  - Life-cycle cost advantage
  - Financial risk comparable to other sources
- SAFETY AND RELIABILITY
  - Excel in safety and reliability
  - Very low likelihood and degree of reactor core damage
  - Eliminate need for offsite emergency response
- PROLIFERATION RESISTANCE AND PHYSICAL PROTECTION
  - Increase assurance of unattractiveness and least desirable route for diversion of material
  - Increased physical protection

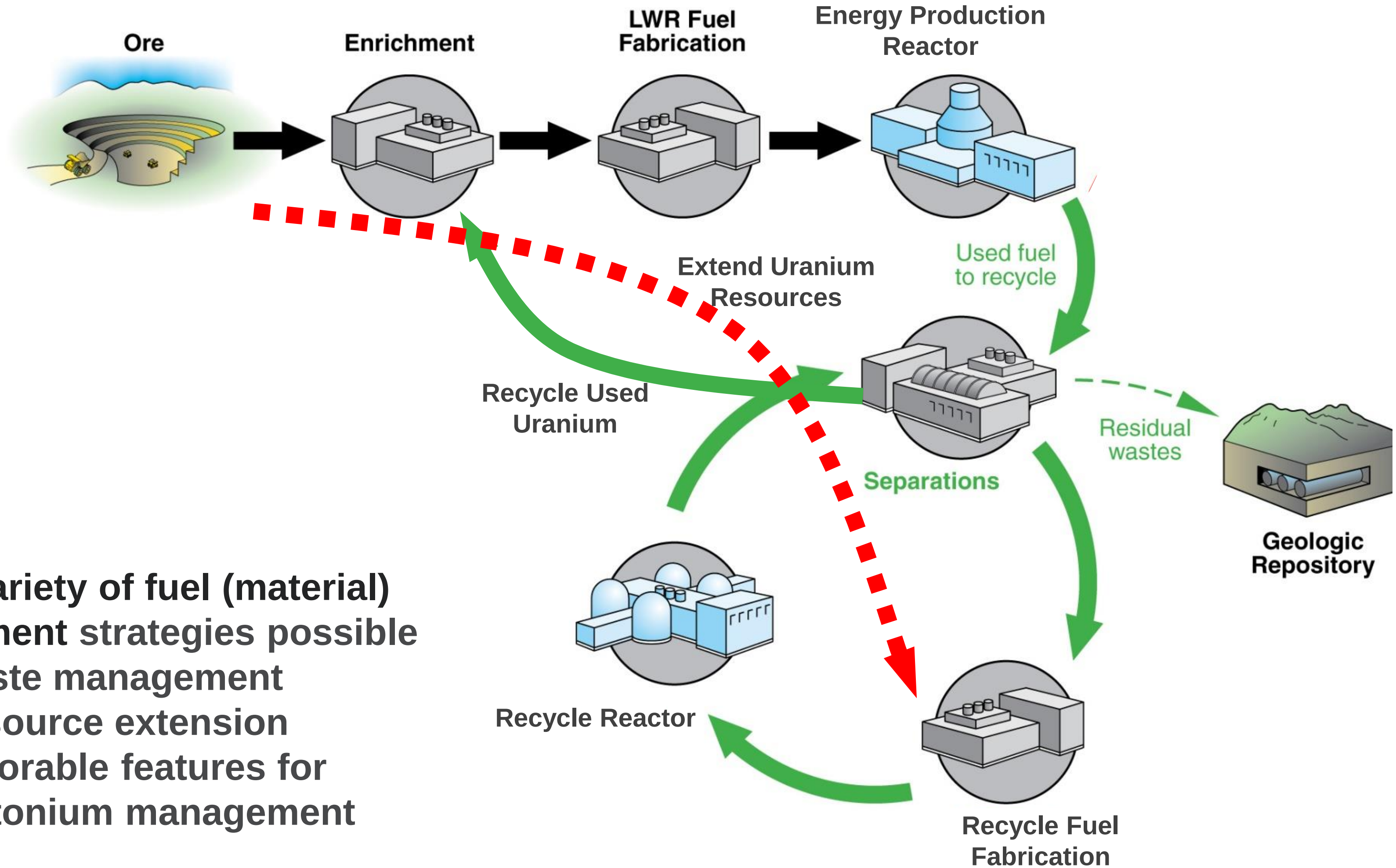
GENERATION IV NUCLEAR SYSTEMS

- **Six Generation IV Systems considered internationally**
- **Often target missions beyond electricity**
  - High temperature energy products
  - Fuel cycle benefits



System	Neutron spectrum	Coolant	Outlet coolant Temp. °C	Fuel cycle	Size (MWe)
VHTR (Very high temperature reactor)	thermal	helium	900-1 000	open	250-300
SFR (Sodium-cooled fast reactor)	fast	sodium	550	closed	30-150, 300-1 500, 1 000-2 000
SCWR (Supercritical water cooled reactor)	thermal/fast	water	510-625	open/closed	300-700 1 000-1 500
GFR (Gas-cooled fast reactor)	fast	helium	850	closed	1200
LFR (Lead-cooled fast reactor)	fast	lead	480-800	closed	20-180, 300-1 200, 600-1 000
MSR (Molten salt reactor)	Epithermal/fast	fluoride salts	700-800	closed	1 000

FUEL MANAGEMENT IN FAST REACTORS

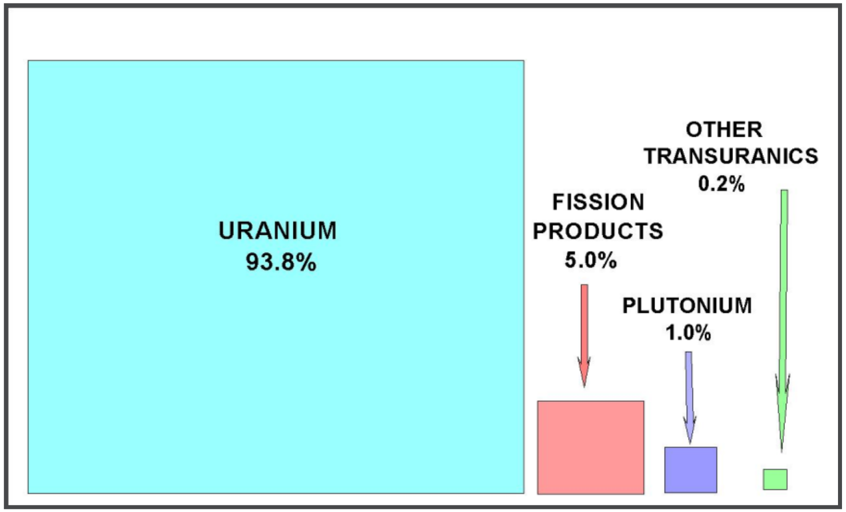


A wide variety of fuel (material) management strategies possible

- Waste management
- Resource extension
- Favorable features for plutonium management

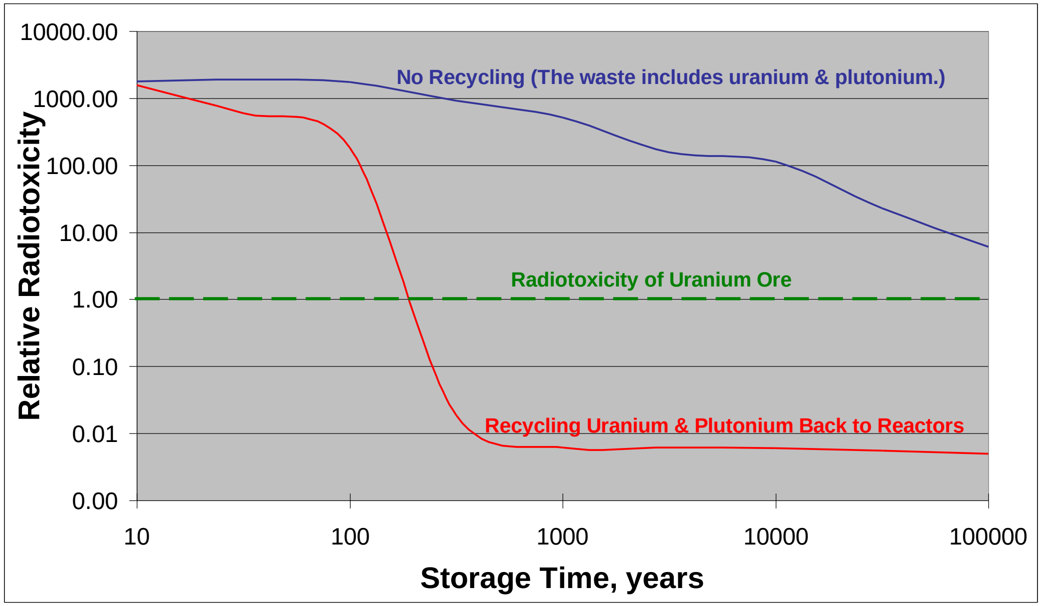
FUEL MANAGEMENT IN FAST REACTORS

Used Light Water Reactor Fuel



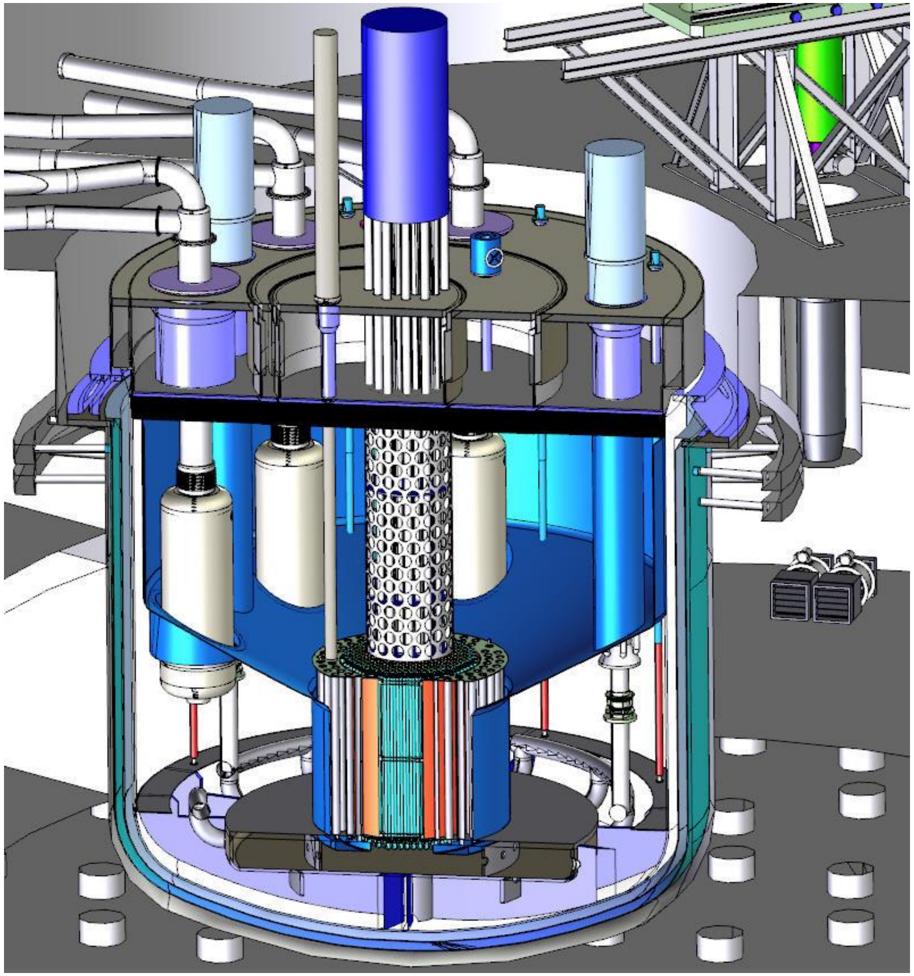
- Uranium, plutonium and other transuranics can be used as fuel in fast reactors
- Uranium resource utilization is improved by a hundred-fold as compared to current commercial reactors

- Recycling reduces radiotoxicity of waste
- Repository siting will be easier
- Optimize repository utilization



SODIUM-COOLED FAST REACTOR (SFR)

- Fuel Cycle Applications
- Inherent Safety
- Multiple small modular designs



- Considerable experience in several countries with experimental, prototype and demonstration SFRs
  - Russia, China, US, France, Japan, India, others – current and previous experience

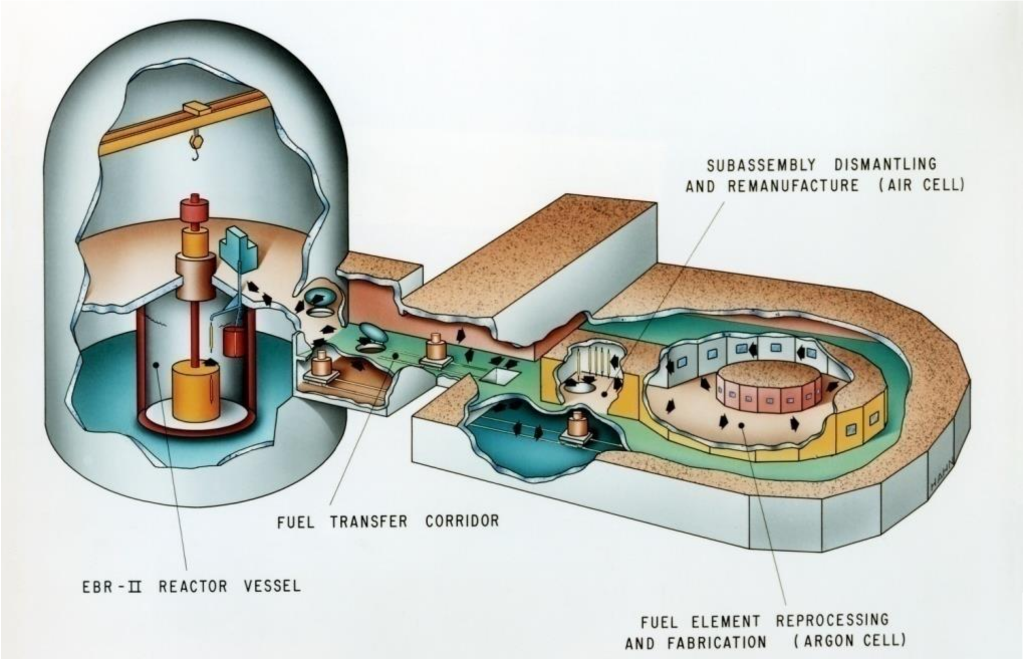
SODIUM COOLED FAST REACTORS - SAFETY

- Superior heat transfer properties of liquid metals allow:
  - Low pressure operation – no “pressure vessels” needed
  - Designed to prevent loss of coolant
  - Enhanced natural circulation for heat removal

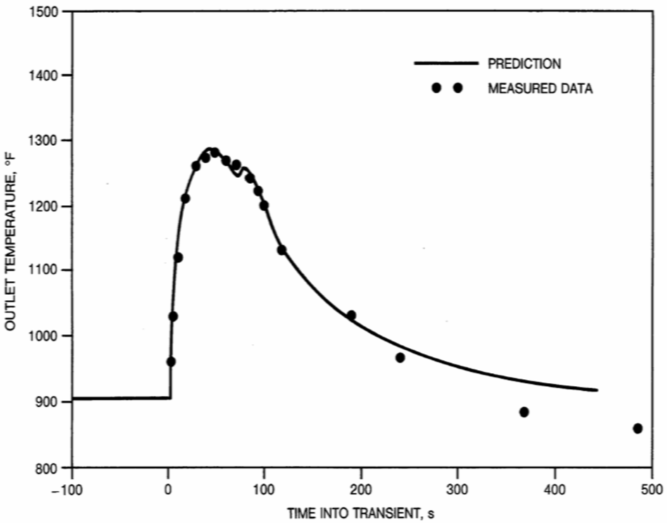
- Inherent safety design
  - Designed to provide feedbacks to prevent fuel damage during transients
    - Loss of heat removal
    - Loss of flow (circulation pumps)
  - Transient response is such that as temperature increases, power is reduced and reactor reaches safe condition
  - Demonstrations performed (EBR-II and FFTF)

- Passive Safety Features
  - Multiple paths for passive decay heat removal envisioned
    - Natural circulation systems
    - Response time

SODIUM-COOLED FAST REACTORS - SAFETY



- Reactor technology and associated fuel cycle developed with EBR-II
- Key safety tests conducted and demonstrated inherent safety

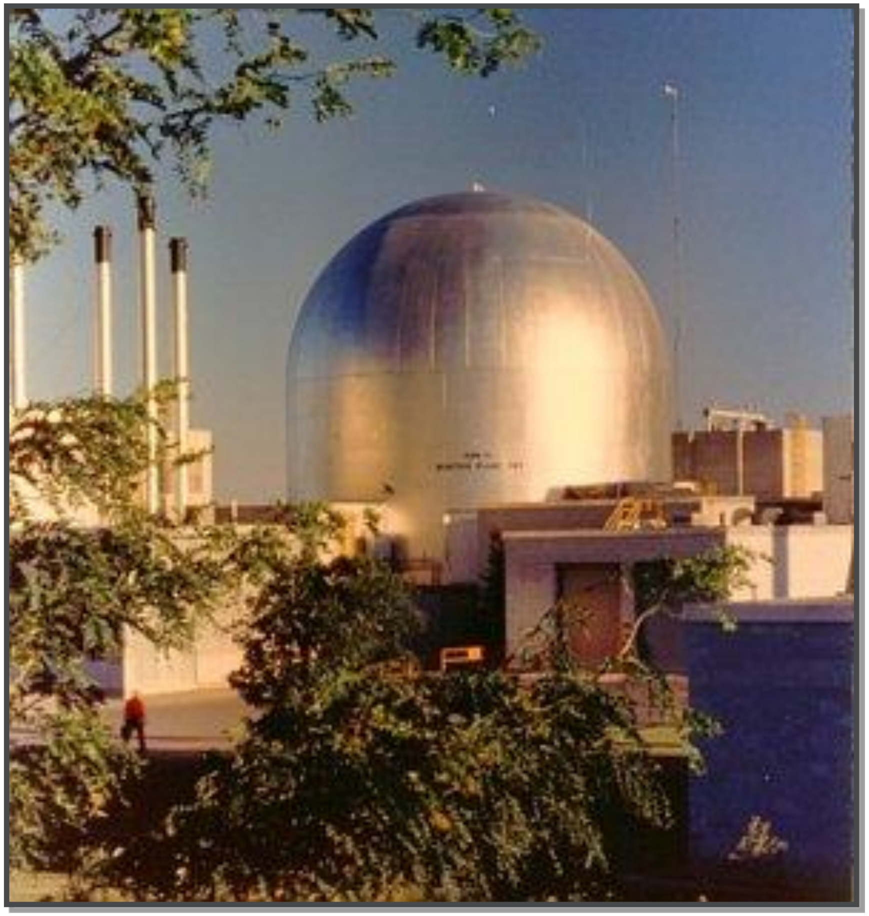


- Inherent safety
  - Reactor shuts itself down safely under transients
- Passive Safety
  - Decay heat removal with natural circulation systems; no electricity required

EXPERIMENTAL BREEDER REACTOR II

- EBR II design features
  - Metal alloy fuel with inherent safety features
  - Pool-type design with heat transfer system components in cold pool, serving as a massive heat sink
  - Unique configuration minimizing thermal stresses on major primary system components
    - Most of the sodium inventory at reactor inlet temperature

- 30 years of successful and safe operation
  - High capacity factors approaching 80% even with an aggressive testing program
  - Maintenance techniques were proven
    - Very low exposure to personnel
    - Excellent safety record
    - Sodium management demonstrated
  - Over 150,000 metal fuel pins irradiated up to 20% burn-up without failure
  - Fuel reprocessing demonstrated with 35,000 metal fuel pins reprocessed



ACKNOWLEDGEMENT

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