



# Requirements for and Development of U.S. Transmutation Fuels



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# Fast-Spectrum Transmutation Fuel Development



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- **Overall objectives are to:**
  1. Develop a fuel that will support the system mission, including requirements for safety and recycle compatibility
  2. Provide performance and safety data that will support licensing of a first-of-a-kind unit
- **Accomplished through operation of an integrated system demonstration (using a demo unit)**
  - Sustained operation with a core load of reference fuel (per a fuel specification)
  - Requires a safety case for operation with reference fuel



# Fuel Development Objectives Formulated to Support Demo Operation



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- **Fuel Performance**
  - Development of a suitable fuel design (or designs) and specification for the service conditions particular to the technology
  - Evaluation of irradiation performance over anticipated and selected steady-state and off-normal conditions
  - Establish limiting conditions of operation, including burnup limits
- **Fabrication**
  - Development and demonstration of economic and viable fuel fabrication processes in conformance with fuel specification
- **Development and validation of predictive performance models and integration into a predictive code for safety analyses**
- **Characterization of fuel (and cladding) material properties and behavior to support physical understanding of relevant phenomena**



# Transmutation Fuel Functions



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- **Position the materials to be transmuted into the neutron flux of the reactor**
- **Provide for efficient heat generation and removal for economic energy production**
- **Provide a barrier to the release of fission products or other radionuclides**
- **Provide a convenient unit for insertion of fresh fuel and targets into the reactor and for removal and handling of spent fuel**



# Requirements for Fast-Spectrum Transmutation Fuels



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- **Normal Operation:** failure rates, operating conditions, endurance of operational (anticipated) transients
- **Safety and Off-normal Performance:** intended to ensure operators maintain control of nuclear reaction and that hazardous radionuclides are contained
- **Composition:** based on fuel cycle requirements as well as safety and economic performance
- **Burnup and Exposure:** driven by performance and economic objectives, but limited by requirements for failure rates and safety
- **Processing and Fabrication:** driven by economics and mission requirements (e.g., actinide losses)

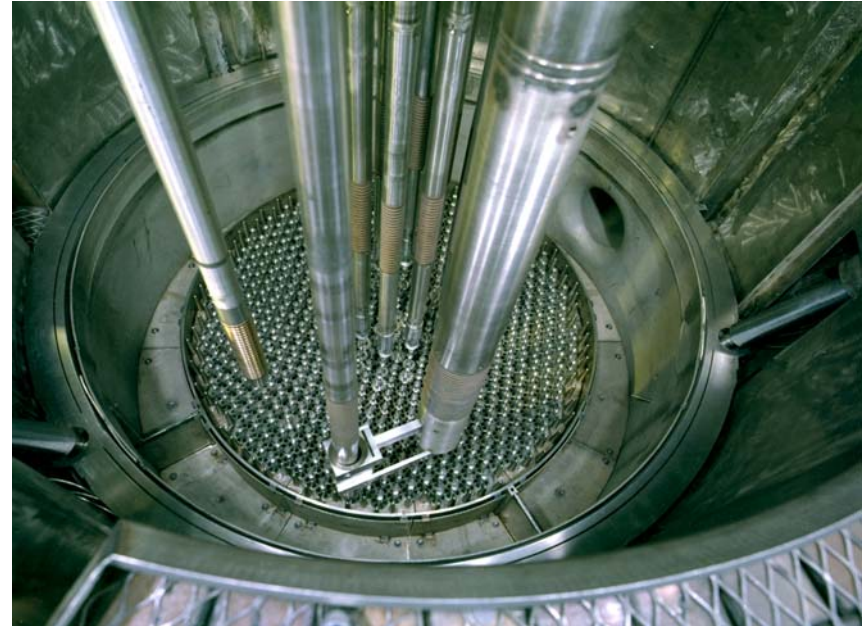


# Irradiation Testing is



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- **In general, irradiation testing used for:**
  - Identifying potential performance issues with a fuel type of design
  - Establishing limiting conditions of operation
  - Assessing consequences of off-normal events
  - Qualifying a fuel design for production and operation



- **Important test parameters include:**
  - Fuel, cladding, and coolant temperatures; Neutron flux and spectrum
  - Coolant chemistry
  - Implications for “rod power” & time-dependent fast neutron damage and fuel microstructure/morphology evolution



# Fuel Development



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- Can characterize fuel development into 4 phases
  - Lead to establishment of a reference design, specification, and licensing basis
1. Fuel Candidate Selection
  2. Concept Definition and Feasibility
  3. Design Improvement and Evaluation
  4. Fuel Qualification and Demonstration



# Fuel Development Phase 1: Fuel Candidate Selection



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- **Objective:** Based on previous experience, select fuel forms and concepts that appear capable of meeting mission needs.
- **Selection criteria include:**
  - *Consideration of experience with similar fuel types*
  - *Suitability of established fabrication techniques*
  - *High-burnup capability of analogous or similar fuels*
  - *Acceptable safety-related behavior of analogous or similar fuels*
  - *Expected compatibility with cladding material(s) and coolant*
  - *Compatibility with proposed recycle technology*
  - *Expected cost of fabrication*
- **U.S. selections for fast-spectrum systems: metal alloy and nitride; other alternates**



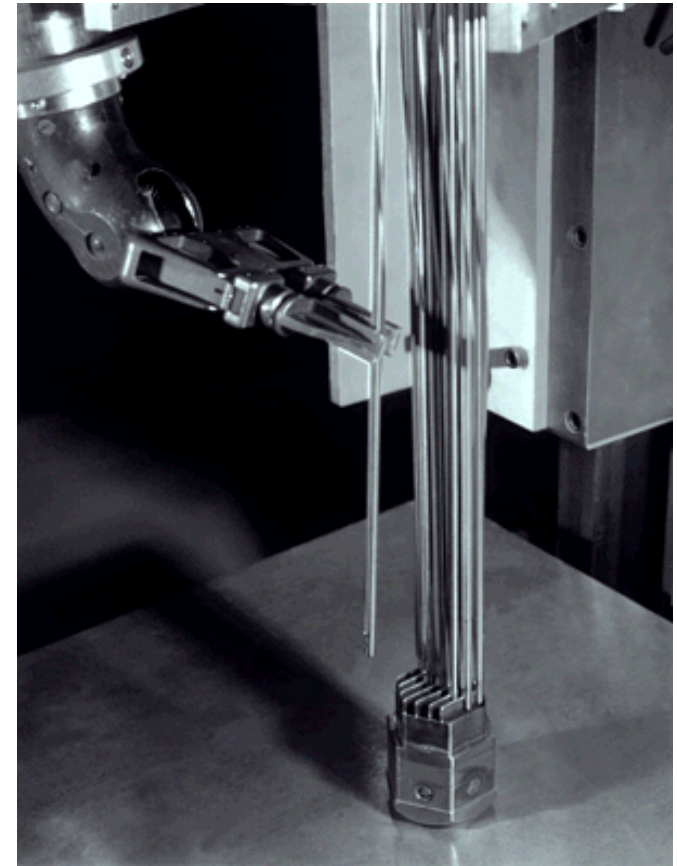
# Fuel Development Phase 2: Concept Definition and Feasibility



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**Objective: Establish a reference  
concept & design**

- **Determine fabricability**
- **Determine and assess key  
properties**
- **Use scoping irradiation tests to  
assess phenomena envisioned to  
impact feasibility and fuel  
lifetime**



# Fuel Development Phase 3: Design Improvement and Evaluation



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## Objectives:

- Optimize the fuel design for economics, performance and safety
- Produce a Fuel Specification and a Fuel Safety Case for a reactor core of the specified fuel
- Establish predictive fuel performance code (or codes)
- **Develop of engineering-scale fabrication processes and equipment**
- **Acquire fuel properties and their variance with composition or processing variances**
- **Irradiation Testing to:**
  - Determine sensitivity of performance to fuel design and fabrication variances and to operating conditions
  - Establish burnup limits and safety margins for various operating conditions (normal and off-normal)
- **Develop predictive fuel behavior models and predictive codes**



# Fuel Development Phase 4: Fuel Qualification and Demonstration



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## Objectives:

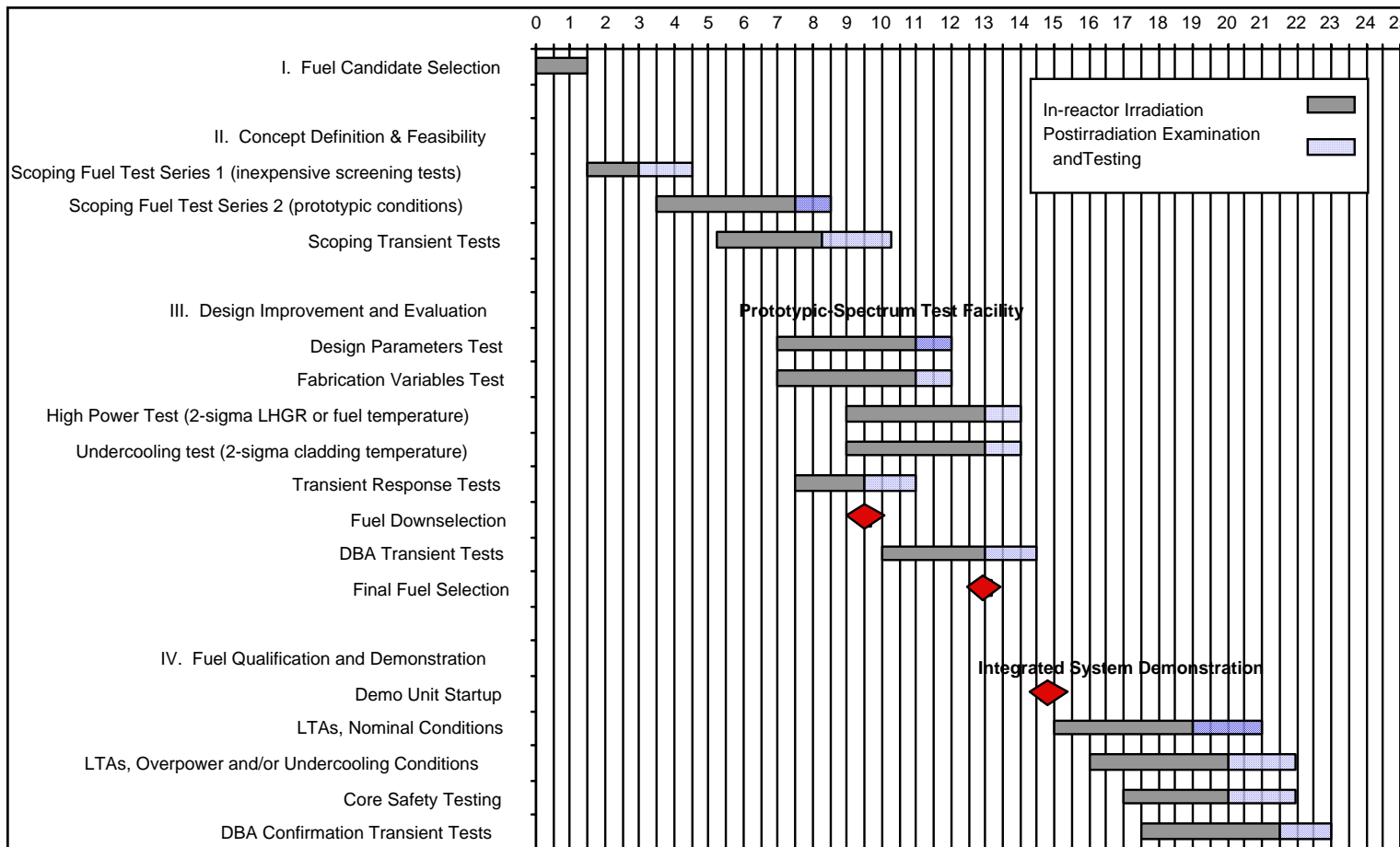
- Qualify production-line fuel as the driver fuel for a demonstration reactor
  - Demonstrate the safety and reliability of a core of that fuel through successful operation of the demonstration reactor
  - Validate predictive fuel performance code (or codes)
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- **Demonstrate of fuel fabrication in conformance with Fuel Specification**
  - **Demonstrate, through lead test assembly irradiation, that fuel and fuel assembly behavior is within the bounds of the Fuel Safety Case**
  - **Accumulate of reactor performance data and operating experience with a core of fuel to support licensing of first-of-a-kind unit**



# Conceptual Irradiation Test Schedule



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# Conclusions



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- **Development of a fuel for a given mission, such as transmutation, requires understanding of the function of the fuel and what is required of the fuel from the operating system**
- **A fuel development program requires activities that develop, assess and document a fuel design, fuel properties, fuel fabrication, and in-service fuel performance.**
- **Irradiation testing is an important part of the development program, and requires careful consideration of test conditions.**
- **A four-phase development program has been outlined, which would, under optimistic conditions, support completion of an Integrated System Demonstration within 25 years**

