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Advanced Reactor Technologies–Instrumentation, Control, and Human-Machine Interface (ICHMI) Technology Area Overview

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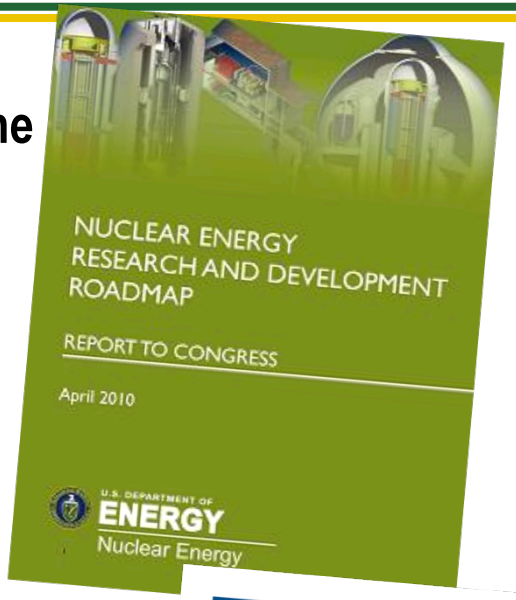
ICHMI Technology Area Focus is on Achieving Goals and Resolving Challenges for Advanced Reactors

- DOE-NE R&D Objective #2 [Develop improvements in the affordability of new reactors…] establishes the primary goal for ART ICHMI research
  - ICHMI is the equivalent of the central nervous system for nuclear power plant and contributes significantly to
    - Achieving cost-competitiveness
    - Ensuring safety
    - Enabling licensability for operation
- Advanced Reactor Concepts TRP Report lists some ICHMI-related technical issues requiring resolution to establish an Advanced Reactor Licensing Framework
  - Multi-module control
  - Staffing of smaller units or modules
- ICHMI R&D specifically targets challenges associated with unique operational and process characteristics of advanced reactor concepts



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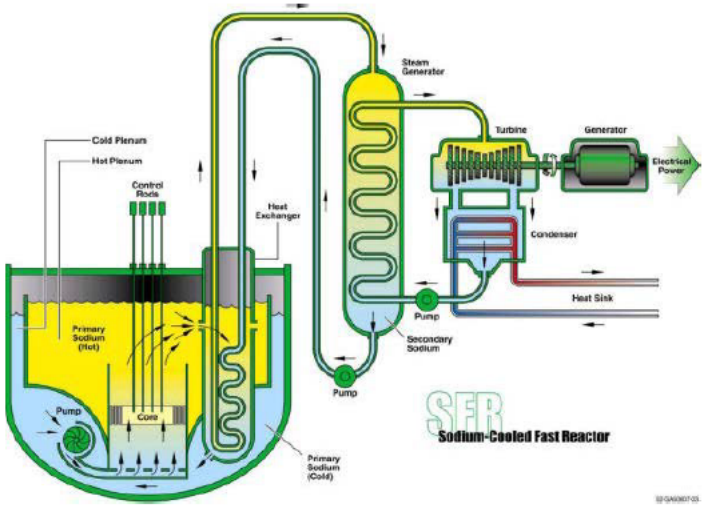
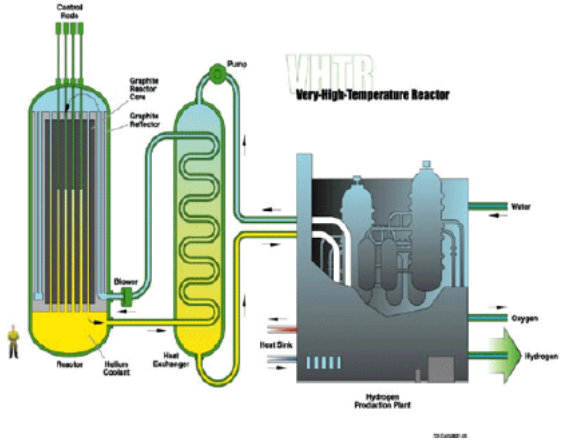
DOE Established Advanced Reactor Technologies (ART) Program in FY15

- Advanced Small Modular Reactors
- Advanced Reactor Concepts
- Next Generation Nuclear Plant



- Advanced Reactor Technologies



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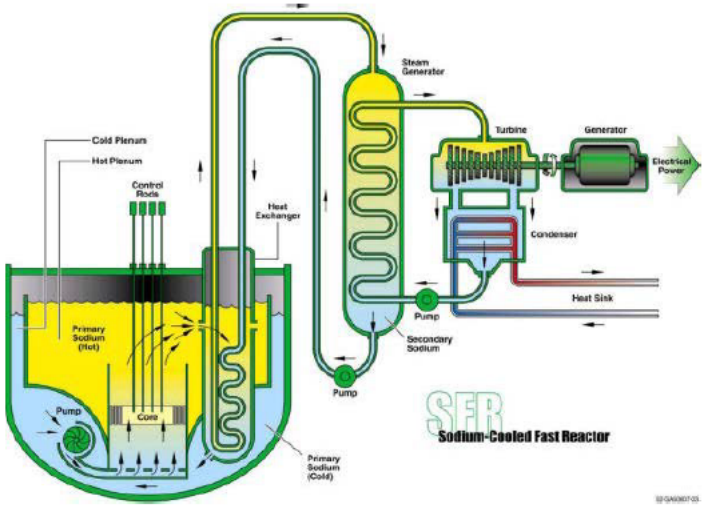
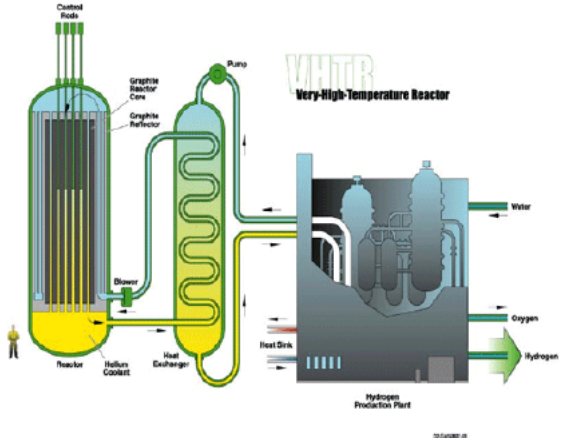
ICHMI R&D Priorities Were Adapted for Transition from AdvSMR to ART

- **Research priorities**
  - Address technology gaps (e.g., sensors)
  - Resolve key technical and licensing issues

Sensors	↑
O&M Efficiency/Staffing	↓
Automation	↓
Diagnostics/Prognostics	↔



- **Key research targets [Observability and Operability]**
  - Environment, architecture, and dependability for critical measurements and in-vessel monitoring
  - High-fidelity condition determination and incipient failure detection to support extended operation
  - Flexible, robust automation for non-traditional operation (multi-unit, integrated energy systems), including off-normal conditions and events
  - Optimized human resource utilization for safe and cost-effective operations and maintenance



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Ten ART ICHMI Projects Continued in FY15

- Johnson Noise Thermometry for Drift-Free Temperature Measurements
- Key Technology Demonstration for Under Sodium Viewing (Waveguide Transducer Assembly)
- Under-Sodium Viewing (Submerged Transducer Assembly)
- Prototypic Prognostic Technique Demonstration for Advanced Reactor Passive Components
- Supervisory Control of Multi-Modular Advanced Reactor Plants
- Enhanced Risk Monitors with Integrated Equipment Condition Assessment
- Impact of Active Control on Passive Safety Characteristics of Advanced Reactors
- Modeling Tools for Dynamic Behavior Simulations of Advanced Reactors
- Operational Concepts for Advanced Reactors
- Framework for Human-Automation Collaboration

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FY-15 ART ICHMI Accomplishments

- **Johnson Noise Thermometry for Drift-free Temperature Measurements (AT-15OR230103)**
  - Field demonstration at HFIR cooling pond completed and second compact JNT system prototype developed for offsite demonstration at SNL sCO2-Brayton Cycle loop
  - Demonstrated self-calibration capability in laboratory testing
- **Key Technology Demonstration for Under Sodium Viewing (AT-15AN230101)**
  - Integrated brush-type ultrasonic waveguide transducer (BUWT) and phased array (PA) techniques
  - Tested HT submergible ultrasonic transducer #1 in sodium with potential in-situ defect detection sensitivities of 0.5 mm in both width and depth
- **Undersodium Viewing (AT-15PN230102)**
  - Developed submersible, matrix phased-array, transmit-receive longitudinal (TRL) 10x3(x2) engineering test unit (SN3) for testing and evaluation

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FY-15 ART ICHMI Accomplishments (cont)

- **Prototypic Prognostic Technique Demonstration for Advanced Reactor Passive Components (AT-15PN230104)**
  - Developed component-level (Bayesian) prognostics health management framework for passive components
  - Conducted in-situ, real-time ultrasonic measurements of 316 SS under high-temperature (~650C) creep to investigate diagnostic and prognostic indicators for true-state characterization and remaining life assessment
- **Supervisory Control of Multi-Modular Advanced Reactor Plants (AT-15OR230202)**
  - Developed deterministic decision-making tools and expanded capabilities of probabilistic decision algorithms
    - Developed component level decision-making capabilities based on complex fault trees
    - Established framework to combine insights from the probabilistic module (individual decision alternatives) with deterministic evaluations (i.e., plant status, diagnostics, simulation results, etc.)

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FY-15 ART ICHMI Accomplishments (cont)

- **Enhanced Risk Monitors with Integrated Equipment Condition Assessment (AT-15PN230105)**
  - Demonstrated ERM capability to account for dynamically updated component conditions when computing safety and non-safety/economic risk metrics
- **Impact of Active Control on Passive Safety Characteristics of Advanced Reactors (AT-15AN230201)**
  - Evaluated safety consequences related to operator errors or control system failures (based on reference LMR) and assessed impact of enhanced passive safety characteristics (e.g., inherent feedbacks) for advanced SFR
  - Developed methodology for treating multiple control system failures and performed transient analysis to evaluate plant safety response

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FY-15 ART ICHMI Accomplishments (cont)

- **Modeling Tools for Dynamic Behavior Simulations of Advanced Reactors (AT-15OR230203)**
  - Completed multiple unit reactor architecture for ALMR concept and incorporated HTR modules into library
  - Advanced Reactor Modeling Tool interface capabilities established to support web-based collaboration
- **Operational Concepts for Advanced Reactors (AT-15IN230204)**
  - Developed Work Domain Analysis Methodology and completed example WDA for generic SFR
- **Framework for Human-Automation Collaboration (AT-15IN230205)**
  - Performed pilot studies on human-automation collaboration based on four defined scenarios, including faults to be injected, to represent different levels of automation

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Future Targets for ICHMI R&D Emphasize Observability

- High-sensitivity, high-temperature fission chamber
- Gamma thermometer (in-core power)
- In-vessel flowmeter (e.g., ultrasonic)
- Optical measurement technology
- In-vessel integrity monitoring
- Prognostic sensors and *in situ* inspection/NDE techniques

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Eight ART ICHMI Projects are Scheduled for FY16

- Johnson Noise Thermometry for Drift-Free Temperature Measurements
- Technology Demonstration for Under Sodium Viewing (Waveguide and Submerged Transducer Assembly)
- Technology Demonstration for Under-Sodium Viewing (Submerged Transducer Assembly)
- Measurement Technologies for Prognostic Indicators for Advanced Reactor Passive Components
- Supervisory Control of Multi-Modular Advanced Reactor Plants
- Enhanced Risk Monitors with Integrated Equipment Condition Assessment
- High Temperature Fission Chamber
- Sensor Technology Assessment for Advanced Reactors

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ICHMI Research Addresses Advanced Technology Development

- ICHMI research advances state of the technology for addressing critical ICHMI needs to ensure technology needs for Advanced Reactors are resolved
- ICHMI research priorities focus on Observability technologies for combined Advanced Reactor Technologies Program (Fast Reactors, High Temperature Reactors)
  - Emphasize gap resolution for Observability technologies [sensing, inspection and prognostics research]
  - Conclude Operability research focused on longer term, more generic issues
  - Identify future research targets to proceed with addressing technology gaps