U.S. DEPARTMENT OF ENERGY | Office of Nuclear Energy

## DOE Office of Nuclear Energy
## Nuclear Technology Research and Development (NE-4)

# SPECIAL PURPOSE APPLICATIONS


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National Universities Consortium Workshop

Idaho National Laboratory

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NTRD
Nuclear Technology Research & Development

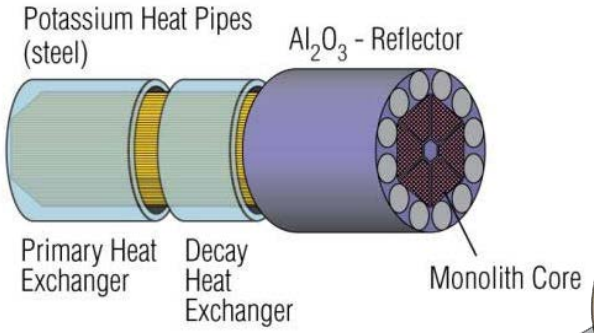
# ART Special Purpose Applications Program

"Special Purpose Applications" is a technical area under the Advanced Reactor Technologies (ART) program that was established in FY18 to:

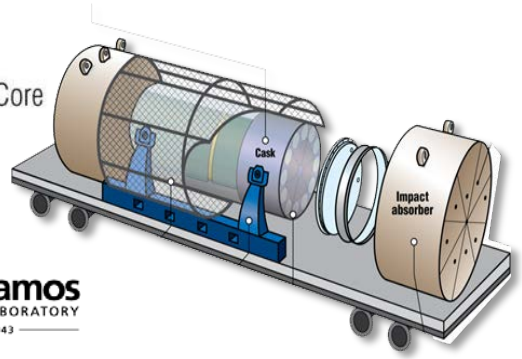
- Develop and demonstrate technologies and manufacturing approaches that will enable the near term deployment of Megawatt class, very small modular reactors (vSMR) (<20 MWt) for non-traditional applications
  - Development areas include core structural materials, heat exchangers, power conversion systems, reactor control and shutdown system

Key features and use-cases:

- Defense application
  - Uninterrupted mobile power without cyber vulnerabilities
  - Heat and power to support various operational needs
- Commercial application
  - Support for remote communities, mining sites, etc.
  - Features similar to defense applications, but with emphasis on economics



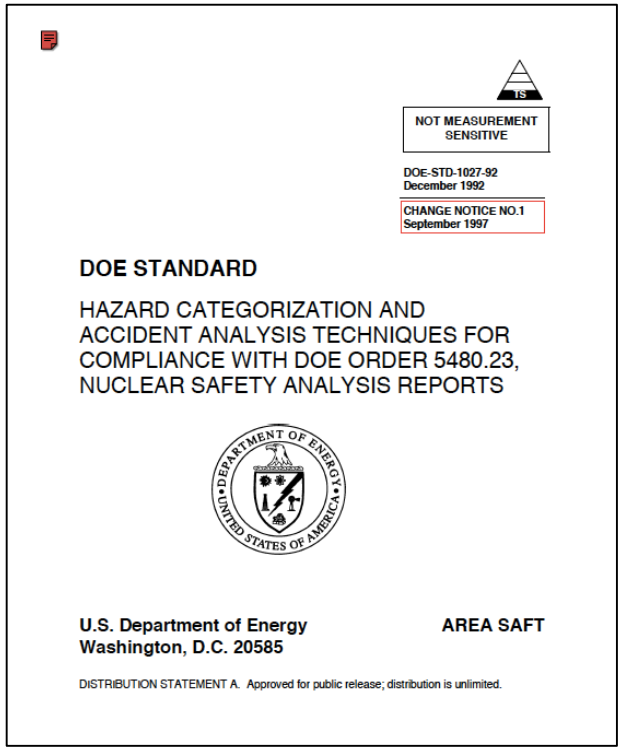

Example of a proposed heatpipe-cooled vSMR concept



# Definition of a "Micro" Reactor

- **Definition:** A "micro reactor" or "special purpose reactor" is designed to produce <20 MWt* while ensuring that the system is factory manufacturable, is transportable (via truck, rail, or aircraft), and maintains neutronic simplicity (e.g. external controls) that can enable safe operation under semi-autonomous or autonomous operation.

**Note that the limit of <20 MWt allows for classification of microreactors as Hazard Category 2 per 10 CFR 830, DOE-STD-1027.*


NOT MEASUREMENT SENSITIVE

DOE-STD-1027-92
December 1992

CHANGE NOTICE NO.1
September 1997

DOE STANDARD

HAZARD CATEGORIZATION AND ACCIDENT ANALYSIS TECHNIQUES FOR COMPLIANCE WITH DOE ORDER 5480.23, NUCLEAR SAFETY ANALYSIS REPORTS

U.S. Department of Energy
Washington, D.C. 20585

AREA SAFT

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# Current R&D Objectives

- Conduct fundamental R&D to reduce uncertainty and risk in the design and development of vSMRs
- DOE-funded R&D is selected to support technology maturation that is broadly applicable to multiple vSMR concepts to ensure that concepts can be licensed and deployed to meet specific use-case requirements
- Key R&D areas include (as they specifically apply to this class of reactor):
  - Advanced manufacturing (AM) for components and systems
  - Heat exchanger design and PCU integration
  - Moderator options (e.g. high temperature hydride development)
  - Instrumentation and control
  - Unique licensing challenges (e.g. transportation, semi-autonomous control, AM materials)

# Industry Activities

- Multiple developers currently working in the micro reactor space:
  - Gas cooled:
    - HolosGen
    - UltraSafe Nuclear Corporation
    - StarCore Nuclear
    - U-Battery (Urenco)

    *No unique technology gaps at this scale. R&D needs for fabrication and licensing of TRISO fuels, nuclear grade graphite and helium containment
  - Liquid metal heatpipe cooled:
    - MegaPower (Los Alamos)
    - eVinci™ (Westinghouse)
    - Oklo Inc.

    *Unique R&D needs not met by other R&D lines.

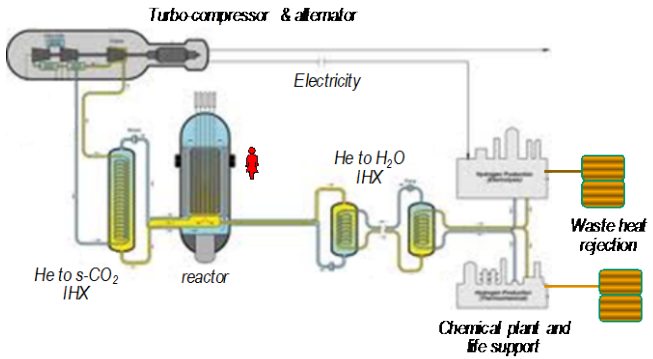
**Key findings:**

- The only micro-reactor types being actively developed by the US-based entities are gas-cooled and heatpipe-cooled concepts.
- A Swedish company is pursuing lead-cooled fast reactor in the power range, but has not shown interest in either licensing or R&D in the U.S.
- Development of high temperature moderator materials could benefit both concept areas.

# Examples of Advanced Micro-Reactor Designs Being Developed for Remote Applications

## Gas cooled

*High pressure, low power density, large thermal inertia*




STARCORE NUCLEAR

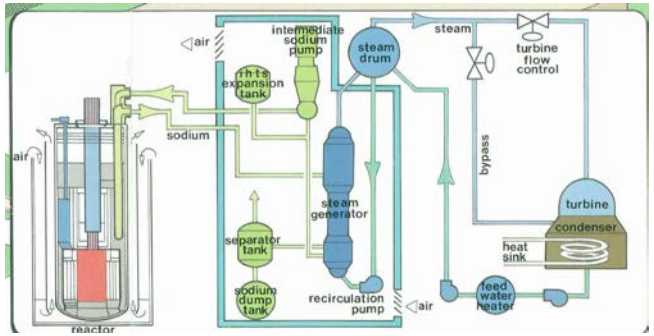
US ULTRA SAFE NUCLEAR

U BATTERY Local Modular Energy

HolosGen™

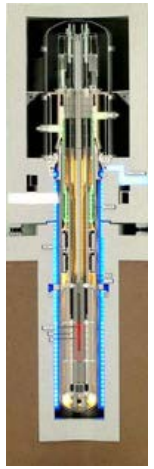
## Liquid metal cooled

*Low pressure, higher power density*



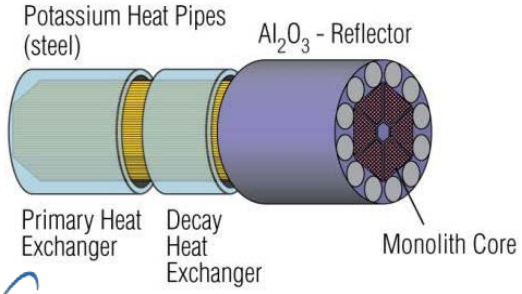

TOSHIBA

4S – Super-Safe, Small and Simple



## Heat pipe cooled

*Low pressure*




Los Alamos NATIONAL LABORATORY EST. 1943

Oklo Inc.

Westinghouse

EVINCI™ Micro Reactor

# FY19 Scope: RC-11

- Applications are sought for technologies that support portable compact reactors that would be used to produce electricity in a microgrid configuration, and/or to use heat directly for other applications.
- The program seeks technologies that advance existing concepts toward market readiness or improve on their economic performance, safety, security, and/or environmental impact.
- Specific areas of interest for special purpose reactors include:
  - Advanced manufacturing to support factory manufacture of reactor and system components
  - Advanced instrumentation and control approaches that support semi-autonomous or autonomous control
  - Novel power conversion systems, static or dynamic, that improve on the current state of the art, as well as the associated heat exchanger designs
- Although proposals are not limited to the example work areas above, applicants should indicate how their proposed work will support current DOE, national laboratory, and/or U.S. nuclear industry deployment and commercialization R&D initiatives.

# Contact Information

- **Federal POC:**
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- **Technical Area Lead (TPOC for CINR call):**
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- **ORNL Lead:**
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# Additional Information: FY18 Activity Areas

- Database Development to Catalogue Previous Research
- Systems Integration Decision Support
  - Definition of use cases and decision framework
  - High fidelity systems analysis
  - Economic and market studies
- Technology Maturation
  - Identified development areas include core structural materials, heat exchangers, power conversion systems, reactor control and shutdown system
  - Materials and manufacturing
  - High temperature moderator materials
- Technology Maturation Roadmap for MW-class Reactors
- Licensing Analysis: Operation and Transport

# Systems Integration Decision Support

- **Use-Cases:**
  - Military bases
  - Remote communities: Community power, district heating, water purification, etc.
  - Remote industrial users: Heat and power to industrial processes

**Steps:**

- Define power requirements, ramp rates, operational constraints for each use case
- Define dependencies:
  - Geographic factors
    - Water/land use requirements
    - Transmission availability
  - Necessary interconnections
    - Core design (including fuel, core block, etc.)
    - Heat exchangers
    - Power conversion system
    - Intermediate loop requirements
    - Energy user

Priority is to identify and examine supporting/interfacing systems that would optimize vSMR deployment

# Systems Integration Decision Support

- Microgrid considerations
  - Size, typical loads
  - Key components
  - Constraints
  - Operational considerations – resilience
  - Economics – Comparative points
- Working with industry leaders for relevant technologies to assess best-fit technologies
- Developing approach to optimize vSMR design for each use-case
- Developing a decision framework to prioritize use cases and associated technologies
- High fidelity analysis to demonstrate load-following, "walk-away" safety, transient analysis (start-up, operational transients, etc.)
- Work associated with heat exchanger interfaces beginning in FY19

# Technology Maturation - General

- Maturation activities maintain a broad scope, encompassing multiple reactor types / vendor concepts
- Previous design analyses identify long-lead items that include:
  - Internal core structures
    - Engineering design, fabrication approaches
    - Instrumentation design and installation
    - High temperature moderator materials (~900-1000°C)
  - Robust and versatile heat exchange system that allows combined heat and power systems
    - HX design, analysis and interface with PCS
  - Reliable reactor power control and shut-off system (semi-autonomous)

# Technology Maturation: Materials and Manufacturing

- **Advanced manufacturing (AM) for structural components**
  - Consider potential novel applications of AM, such as integrated in situ sensors for instrumentation and control
  - Fabricate and test structural components using AM techniques
    - Initial trials expected to include a metal component, such as a prismatic block, and a ceramic component, such as a heat or radiation shield
    - After demonstrating fabrication, work toward making it an NQA-1 certified process
  - Leverage experience and existing infrastructure within the DOE laboratories
- **High temperature moderator materials**
  - Development of high temperature (900-1000 C) hydrides that will allow for a moderated system while maintaining size constraints
  - May support reduced enrichment fuels

# Technology Maturation Roadmap

- This task will ultimately result in a detailed roadmap (~FY19) outlining the approach to elevate the technology readiness level of a MW-class reactor concept and its associated components from conceptual design to initial prototype demonstration
- The initial outline for the roadmap will be developed in FY18, with the full roadmap developed in FY19 after use cases and technology options have been narrowed and knowledge gaps identified

# Sensors, Instrumentation & Controls

- Establish the required I&C set for operation and for regulatory compliance
- Identify existing I&C and sensor technologies that will meet those requirements
- Identify novel I&C and sensors technology that could enable enhanced performance
- Specific FY19 Tasks within SPA program:
  - Instrumentation design, modeling and benchtop experiments
  - Instrumentation design and installation (in coordination with use of advanced manufacturing for structural materials)
  - Reactor control system design (general approach)
- Includes initial thermo-structural performance assessment to support risk-based approach to code case development

# Licensing Analysis

- **Assess licensing paths for NRC, DOE and DOD, including cross-walk between approaches**
- **Engage NRC on licensing strategy for vSMRs**
- **Licensing framework analysis includes:**
  - System integration options
  - Transportation for fueled vSMR
    - Pre-operation
    - Post-operation for redeployment or return to factory
  - Advanced manufacturing, structural materials
  - Autonomous operation