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Department of Defense Microreactors

Setting the Stage

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U.S. DEPARTMENT OF ENERGY BATTELLE

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Why DOD Microreactors

Study	Key Findings
2011. Feasibility of Nuclear Power on US Military Installations. Center for Naval Analysis.	Small modular reactors (SMRs) – commercial status, regulatory challenges, average energy use, cost of energy, and delineation by location
2011. National Defense University. SMRs for Military Installations	Integration of nuclear power plants for improved resilience and reduction of logistics vulnerabilities
2017. DOD Installation Energy Resilience Approaches. Massachusetts Institute of Technology.	Methodology for critical load evaluation, mission requirements, and performance
2018. Roadmap for Deployment of microreactors for DOD domestic installations. Nuclear Energy Institute.	Proposed actions include identifying site requirements, contracting with design agent, fuel quals (and packaging), regulatory engagement, timelines, and schedule accelerators
2020. Alaska Center for Economic Development. Microreactor Use Case Analysis	Feasibility, drivers, and end-use analysis of communities of interest, value proposition, opportunities, and barriers to implementation of nuclear reactors
2021. Global Market Analysis of Microreactors. DOE/INL.	Describes economic and market opportunities for the market potential of microreactors with regulatory considerations
2022. Proposed Decision Framework for DOD Investment in Nuclear Energy Technology (NET). RAND (Haak, K.).	Location-technology pairing; monetary and non-monetary benefits (costs); identification of potential installations for microreactor use
2022. Prospects for Nuclear Microreactors. Nuclear Technology, 209: Sup1	Reviews the existing literature on the technology, potential markets, economic viability, and regulatory and institutional challenges of nuclear microreactors
2023. Pathways to Commercial Liftoff: Advanced Nuclear. DOE.	Identifies and outlines pathways for commercialization, constraints and solutions, and ongoing engagement to drive scaling and implementation of advanced nuclear power
2023. Advanced Nuclear Reactors: Technology Overview and Current Issues. Congressional Research Service.	Summary of advanced reactors and technology descriptions; criteria for evaluations; federal support and funding approaches; licensing frameworks, constraints, and alternatives

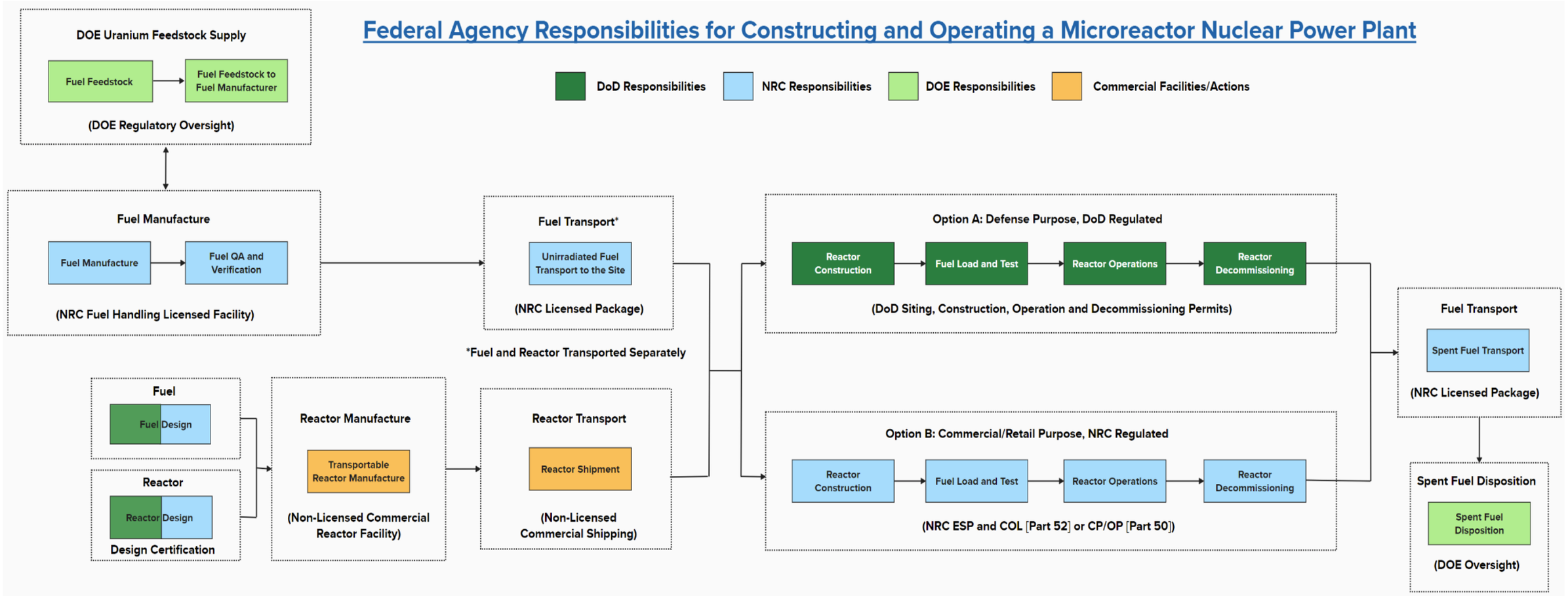
Status of Advanced Micro-Reactor Technologies

Current – Evolving Rapidly

Design	Designer	Power MWe	Primary Coolant	Fuel	Fuel Enrichment	Power conversion	Operation - refueling
eVinci (Heat Pipe)	Westinghouse	0.2 - 5	Liquid Na w/heat pipes	TRISO	5–19.75%	Brayton cycle	>3 years
Aurora (Heat Pipe)	Oklo Inc.	1.5	Liquid Na w/heat pipes	Metallic Uranium–Zirconium	<20%	Brayton cycle	20 years
Hermes	Kairos	30 (thermal)	Flouride salt	TRISO	19.75	Test Rx (NRC Sct 104, Const Permit)	
Holos Mobile Generator	HolosGen	3–100	High Temp Gas	TRISO	8–15%	Direct Brayton cycle + ORC	3–20 years
Xe-Mobile, Xenith (HTGR)	X-energy	2-7	High Temp Gas	TRISO	19.75%	Direct Brayton cycle	>3 years
NuScale (micro-IPWR)	NuScale Power	10–50	Light water	UO_2	<20%	Rankine cycle*	>10 years
MMR (HTGR)	Ultra-Safe Nuclear Corporation	5	High Temp Gas	FCM or TRISO fuel	19.75%	Rankine cycle with molten salt storage	20-year (plant lifetime)
BANR (HTGR)	BWXT	50 (thermal)	High Temp Gas	TRISO (UCO, UNC)	19.75%	Rankine cycle	5 years
Kaleidos	Radiant Nuclear	~5 (thermal)	High Temp Gas	TRISO	19.75%	Brayton cycle	TBD
Pele	BWXT	1-2	High Temp Gas	TRISO (UCO)	19.75%	Brayton cycle	>3 years

DOD Microreactor Regulatory Landscape

NOTIONAL - All of Government Approach



Fuel and Microreactor Lifecycle

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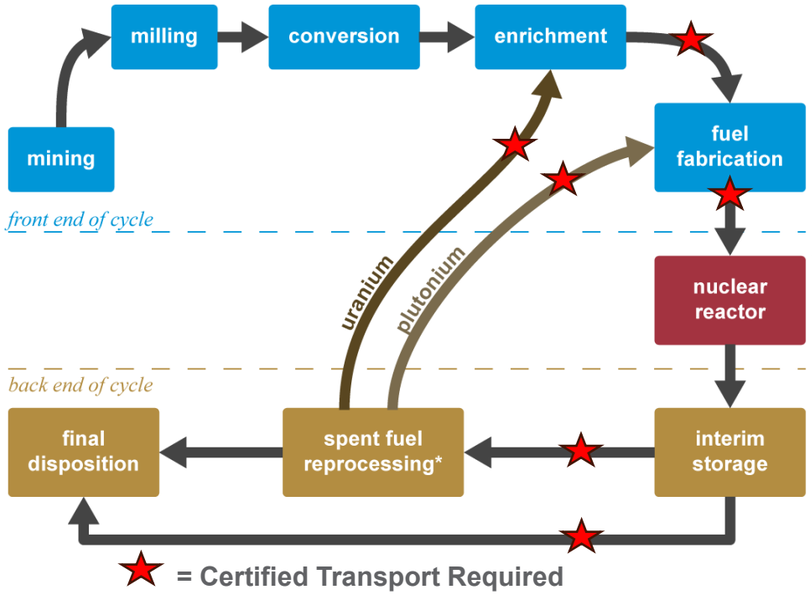
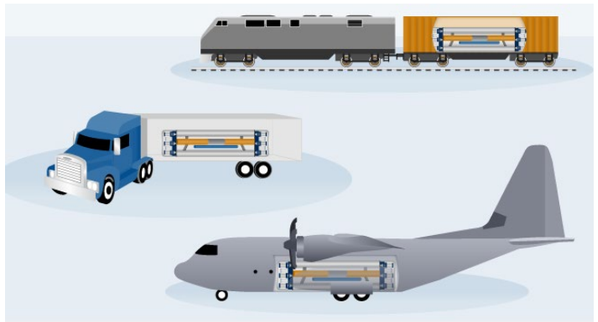
Nuclear fuel cycle

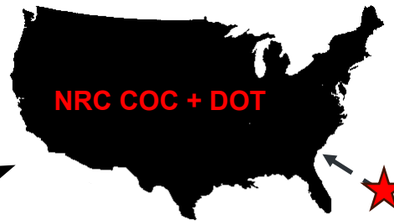


Multi-Mode Transportation



Source: GAO. | GAO-20-380SP

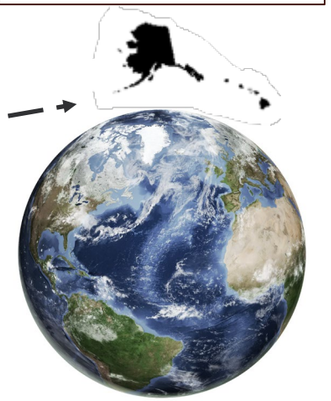
CONUS



Driving Tenets

- Nuclear Regulatory Commission package approval Certificate of Compliance (CoC)
  - IAW 10 CFR 71
- US DOT approval of transport

OCONUS



Driving Tenets

- Coordination with US DOT
- Foreign competent authority approval
  - Commonly referencing an NRC package approval (CoC)
- Compliance with international safety, security, and safeguards regulations (e.g., IAEA SSR-6, etc)
- Possible compliance with other International Maritime Organization items (SOLAS, EMS, MARPOL, IMDG, etc).
- If outside US jurisdiction, compliance with Treaty, Traversing, and Host Nation requirements.

Challenges

- Transporting a factory-fueled reactor must meet Type B (radiological) package requirements:
  - Maintain subcriticality, shielding, containment, and thermal management under ALL possible transport conditions.
- Current regulatory paradigm is structured around thick-walled pressure vessel, not a readily transportable vessel as a fueled reactor.
- DOD could utilize a vehicle such as military exemption/national security but cannot use/tap commercial entities for design/development maturation.

DOD Leadership – Challenges and Opportunities

Development of microreactors will require unique solutions. Examples of DoD areas of potential influence/impact:

Topic	DOD Solution Space (Examples)
Aircraft Impact	Map NUREG 0800 (Sct. 3.5.1.6) to APZ/CZ, control of space, frequency and consequence analysis. Design and fuel specific; use generic quantities for interim evaluation; strive for hazards equivalent (e.g., quantity-distance).
Oversight and Inspection	Regulatory agnostic, new paradigm for design, manufacturing, construction, and operations. Map to procurement/contract authorities, IMC 2515 (Rx Inspection and Oversight Process).
Security	Address requirements and limitations from 10CFR73 to design-basis threat (DBT) at a DOD location or in DOD control (ex. IAW DOD Manual 5200.08).
Emergency Preparedness	Nexus to siting: 10CFR50.47 (EPZs), 10CFR50.2/10CFR100.3 (exclusion area definitions), RG 2.6 (Emergency Planning for Non-Power or Utilization Facilities). Unique to DOD – on post with whom lies the authority to determine all activities including exclusion or removal of personnel and property from the area.
Siting	Nexus to EP: Control and Exclusionary Boundaries; population and proximity related siting requirements ((e.g., on-base DOD, on-base public, unrestricted). Assess against criteria included in NRC SECY-20-0045 (ML19262H055) for population-related siting consideration for Adv Rx.
Transportation	CONUS: transportation safety shall by IAW requirements of 10 CFR 71 (NRC Certificate of Compliance) and US DOT approval of transport. Every movement of nuclear material requires regulatory approval and maintenance of sub-criticality, shielding, containment, and thermal control; movement of a fueled reactor is a new paradigm.
Integrated Operations	Mixed authority's challenge – regulator, operations, dispatch, and control in an integrated DOD Installation environment. Use-cases addressing integrated operations (power, power and steam, manufacturing, privatized utilities, etc) must target reductions in complexity and risk.
OCONUS	Eligibility (or non-eligibility) and compliance with conventions (e.g., IAEA) for nuclear safety, security, safeguards, and liability for treaty, traverse, and host nations depending on licensing pathway, location, transport, and voluntary offer agreement (VOA) interpretation (microreactor(s) for 'defense purpose' or alternative).

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Thank You

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DOD Regulatory Authority

Atomic Energy Act Chapter 9–Military Application of Atomic Energy

Sec. 91. Authority

b. The President from time to time may direct the Commission (1) to deliver such quantities of special nuclear material or atomic weapons to the Department of Defense for such use as he deems necessary in the interest of national defense, or (2) to authorize the Department of Defense to manufacture, produce, or acquire any atomic weapon or utilization facility for military purposes: Provided, however, that such authorization shall not extend to the production of special nuclear material other than that incidental to the operation of such utilization facilities.

Sec. 110. Exclusions

Nothing in this subchapter shall be deemed ~

b. to require a license for the manufacture, production, or acquisition by the Department of Defense of any utilization facility authorized pursuant to section 91, or for the use of such facility by the Department of Defense or a contractor thereof.