DOE/EA-2146

U.S. Department of Energy
Idaho Operations Office

Draft Environmental Assessment for the Microreactor Applications Research, Validation and Evaluation (MARVEL) Project at Idaho National Laboratory

January 2021

Idaho National Laboratory

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Prepared for the
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CONTENTS

FIGURES

TABLES

ACRONYMS

AC	Alternating Current
ALARA	As Low As Reasonably Achievable
APAD	Air Permitting and Applicability Determination
APE	Area of Potential Effect
ATR	Advanced Test Reactor
CD	Control Drum
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CRMP	Cultural Resource Management Plan
dBA	Decibels
DBA	Design Basis Accidents
DC	Direct Current
DID	Defense-in-Depth
DOE	U.S. Department of Energy
DOE-NE	Department of Energy Office of Nuclear Energy
DOT	Department of Transportation
EA	Environmental Assessment
EBR	Experimental Breeder Reactor
ECU	Engine Control Unit
EFF	Experimental Fuels Facility
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESRP	Eastern Snake River Plain
FASB	Fuels and Applied Science Building
GA	General Atomics
HAP	Hazardous Air Pollutant
HEPA	High-Efficiency Particulate Air
HFEF	Hot Fuel Examination Facility at the Fuel Manufacturing Facility
HVAC	Heating, Ventilation, and Air Conditioning
I&C	Instrumentation and Controls
IBC	International Building Code
ICRP	International Commission on Radiological Protection
IDAPA	Idaho Administrative Procedures Act

IHX	Intermediate Heat Exchanger
INL	Idaho National Laboratory
kW	Kilowatt
kWe	Kilowatt Electric
kW_{th}	Kilowatt Thermal
LCF	Latent Cancer Fatality
LLW	Low-level Waste
LMP	Licensing Modernization Project
LOCA	Loss of Cooling Accident
MARVEL	Microreactor Applications Research, Validation and Evaluation Project
MEI	Maximally Exposed Individual
MFC	Materials and Fuels Complex
MLLW	Mixed Low-level Waste
MTHM	Metric Tons of Heavy Metal
MW_e	Megawatt electric
MW_{th}	Megawatt Thermal
NAAQS	National Ambient Air Quality Standards
NaK	Sodium-Potassium Alloy
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NRC	Nuclear Regulatory Commission
NRHP	National Register of Historic Places
OSHA	Occupational Safety and Health Administration
PCS	Primary Coolant System
PM	Particulate Matter
PSD	Prevention of Significant Deterioration
R&D	Research and Development
rem	Roentgen- Equivalent- Man
RCRA	Resource Conservation and Recovery Act
RPS	Reactor Protection System
RSAC	Radiological Safety Analysis Computer
SHPO	State Historic Preservation Office
SNF	Spent Nuclear Fuel

SS	Stainless Steel
SSC	Structures, Systems, and Components
TED	Total Effective Dose
TREAT	Transient Reactor Test Facility
TRIGA	Training, Research, Isotopes, General Atomics
TRU	Transuranic
TSS	Transportation Safeguards System
USC	United States Code
WMP	Waste Management Program
ZPPR	Zero Power Physics Reactor

HELPFUL INFORMATION FOR THE READER

Scientific Notation

Scientific notation expresses numbers that are very small or very large. Negative exponents, such as 1.3×10^{-6}, express very small numbers. To convert the number to decimal notation, move the decimal point to the left by the number of places equal to the exponent, in this case 6. Thus, the number becomes 0.0000013. For large numbers, those with a positive exponent, move the decimal point to the right by the number of places equal to the exponent (e.g., the number 1.3×10^{6} becomes 1,300,000).

Units

The document uses English units with conversion to metric units given below. Occasionally, metric units are used if metric is the common usage (i.e., when discussing waste volumes or when commonly used in formulas or equations).

ft	foot	Gy	Gray
in.	inch	mrem	millirem
km	kilometer	ppm	parts per million
lb	pound	rem	Roentgen-equivalent-man
m	meter	yd	yard
		yr	year

Conversions

English to Metric			Metric to English		
To Convert	Multiply By	To Obtain	To Convert	Multiply By	To Obtain
ft	3.048×10^{-1}	m	m	3.28084	ft
lb	4.536×10^{2}	grams	grams	2.204×10^{-3}	lb
gallons	3.785	liters	liters	2.641×10^{-1}	gallons
mi	1.609334	km	km	6.214×10^{-1}	mi
square mi	2.590	square km	square km	3.861×10^{-1}	square mi
yd	9.144×10^{-1}	m	m	1.093613	yd

Understanding Small and Large Numbers

Number	Power	Name
1,000,000,000,000,000	10^{15}	quadrillion
1,000,000,000,000	10^{12}	trillion
1,000,000,000	10^{9}	billion
1,000,000	10^{6}	million
1,000	10^{3}	thousand
10	10^{1}	ten
0.1	10^{-1}	tenth
0.01	10^{-2}	hundredth
0.001	10^{-3}	thousandth
0.000001	10^{-6}	millionth
0.000000001	10^{-9}	billionth
0.000000000001	10^{-12}	trillionth
0.000000000000001	10^{-15}	quadrillionth

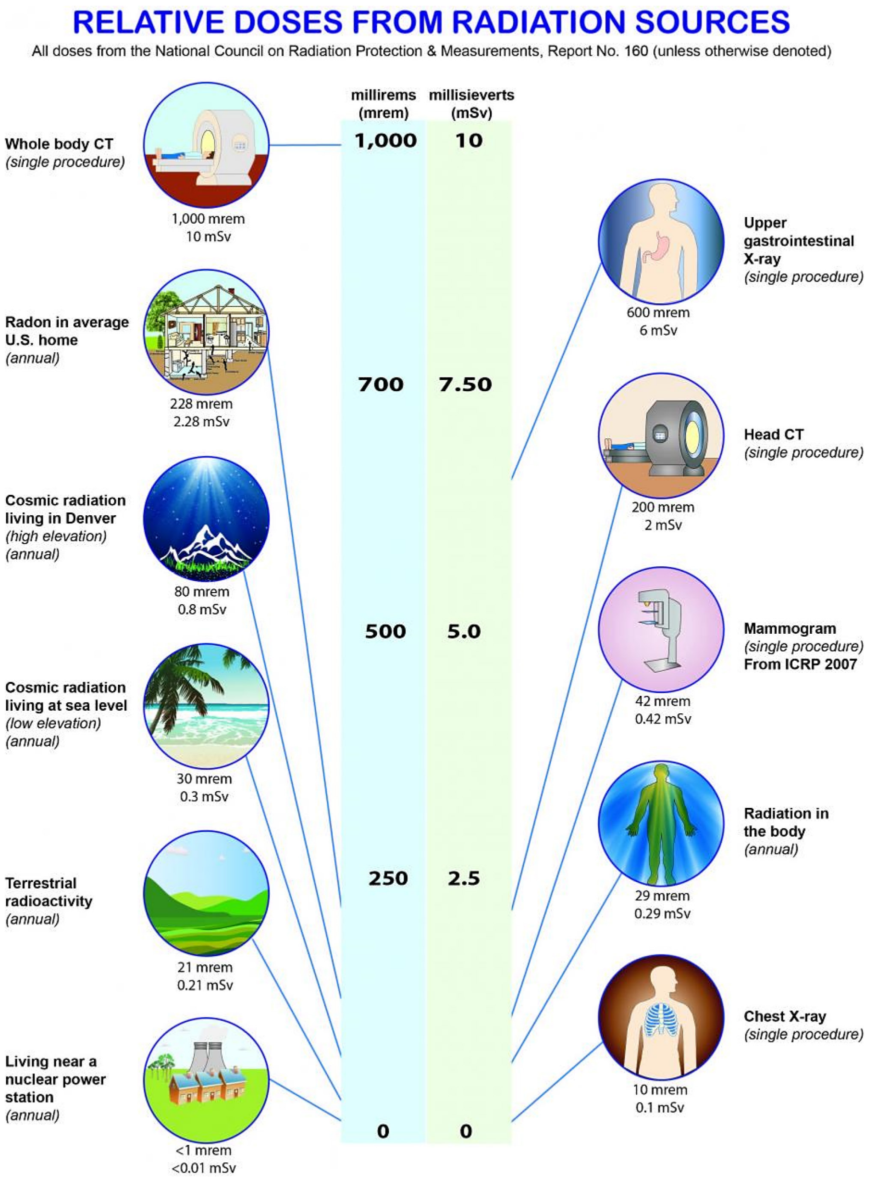
Understanding Dose (Millirem Doses) and Latent Cancer Fatality

Relative Doses[a]

A dose is the amount of radiation energy absorbed by the body. The United States unit of measurement for radiation dose is the Roentgen Equivalent Man (rem) (see Glossary). In the U.S., doses are most commonly reported in millirem (mrem). A millirem is one thousandth of a rem (1000 mrem = 1 rem). The **inset diagram** compares radiation doses from common radiation sources, both natural and man-made. According to the National Council on Radiation Protection and Measurements (NCRP), the average annual radiation dose per person in the U.S. is 620 millirem. Use this information to help understand and compare dose information described in this document.

Latent Cancer Fatality Calculations

The consequence of a dose to an individual is expressed as the probability that the individual would incur fatal cancer from the exposure. Based on a dose-to-risk conversion factor of 0.0006 latent cancer fatality (LCF) per person-rem[b], and assuming the linear no-threshold model, an exposed worker receiving a dose of 1 rem would have an estimated lifetime probability of radiation-induced fatal cancer of 0.0006 or 1 chance in 1,700.[c]



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[a] https://www.epa.gov/radiation/radiation-sources-and-doses

[b] Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE) ISCORS Technical Report No. 1 (DOE, 2003)

[c] The use of this relationship to assess by extrapolation the risk of low and very low doses deserves great caution. Recent radiobiological data undermine the validity of estimations based on LNT in the range of doses lower than a few dozen mSv which leads to the questioning of the hypotheses on which LNT is implicitly based. For the LNT model, there is concern that the summation of trivial exposures may inappropriately attribute LCF to individuals far from the site of the accident. While the possibility of LCF from very low doses cannot be ruled out, it is considered by organizations such as, ICRP, National Council on Radiation Protection and Measurements and the Health Physics Society to be an inappropriate use of these exposures. Assessment of Latent Health Effects Attributable to Ionizing Radiation and Public Communication of Offsite Consequences https://www.nrc.gov/docs/ML1202/ML12024A366.pdf

The Basics of Nuclear Power Reactors

In some elements, the nucleus of an atom can split as a result of absorbing an additional neutron, through a process called nuclear fission. Such elements are called fissile materials. When a nucleus fissions, it causes three important events that result in the release of energy. Specifically, these events are the release of radiation, release of neutrons (usually two or three), and formation of two new nuclei (fission products). Some of the released neutrons collide with other atoms in the fissile materials, causing them to also fission and release more neutrons. Fission also releases a large amount of heat.

Nuclear reactors contain fissile material in the nuclear fuel. A nuclear reactor achieves criticality (and is said to be critical) when each fission event releases a sufficient number of neutrons to sustain a steady-state, ongoing series of reactions. This is called a chain reaction. Generally, the heat produced from fission is removed from the reactor by various methods, sometimes a circulating fluid, and can then be used to produce electricity.

Not every arrangement of fuel can be brought to criticality. A critical concentration of fissile material must be present in order to bring the reactor to a critical state. Otherwise, neutrons can be absorbed by other reactor components, which can inhibit a sustained chain fission reaction. Similarly, even where there is a high-enough concentration of fissile material for criticality, a nuclear reactor must have an appropriate volume and a prescribed geometric form, or interactions between neutrons and fissile material will not be sufficient to sustain a chain reaction. This requirement imposes a limit on the minimum critical volume and critical mass within a reactor.

There are several different types of nuclear reactors, but they have many common characteristics, including a supply of fissionable fuel in the reactor core. Some nuclear reactors also have neutron moderators, which are materials that slow down neutrons to increase their probability of causing fissions or neutron absorbers, which are materials that absorb neutrons and shut down the nuclear reaction and the heat it creates. Reactor control is normally achieved using components made from neutron-absorbing materials such as cadmium, hafnium, or boron. Some nuclear reactor designs also contain a coolant, which absorbs and transports heat from the reactor for electric power production and cools the reactor core to ensure the fuel and core structures maintain their integrity. Finally, a nuclear reactor must have specifically designed shielding around it to absorb and reflect radiation in order to protect plant personnel from exposure.

An “advanced nuclear reactor” is defined in legislation enacted in 2018 as “a nuclear fission reactor with significant improvements over the most recent generation of nuclear fission reactors” or a reactor using nuclear fusion (P.L. 115-248, 2018). Advanced nuclear reactors include light water reactor designs that are far smaller than existing nuclear reactors, and they use different moderators, coolants, and types of fuel. Many of these advanced designs are considered to be small modular reactors, which the Department of Energy (DOE) defines as reactors with electric generating capacity of 300 megawatts and below. Microreactors are small, transportable, and often self-adjusting small modular reactors capable of producing less than 20 megawatts of thermal energy that can be used as heat or to produce electricity. In contrast, existing commercial nuclear reactors generate an average of about 3,000 megawatts of thermal energy.

Many advanced reactor concepts include safety, efficiency, and other improvements over existing commercial reactors. These include gas-cooled reactors, which use graphite as a neutron moderator or have no moderator; liquid metal-cooled reactors, which are cooled by liquid sodium or other metals and have no moderator; molten salt reactors, which use liquid fuel; and fusion reactors, which release energy through the combination of light atomic nuclei rather than fission.

The Department of Energy’s Advanced Reactor Demonstration Program is seeking development and demonstration of additional reactors within this decade.

Glossary

Area of potential effects (APE): The geographic area (or areas) within which a federal undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist.

Cladding: The outer layer of a nuclear fuel rod, which is located between the coolant or test environment and nuclear fuel. Cladding prevents radioactive elements from escaping the fuel into the coolant or test environment and contaminating it.

Clean Air Act: The federal Clean Air Act is the basis for the national air pollution control effort. Basic elements of the act include National Ambient Air Quality Standards for major air pollutants, hazardous air pollutants, state attainment plans, motor vehicle emission standards, stationary source emission standards and permits, acid rain control measures, stratospheric ozone protection, and enforcement provisions.

Cultural resource: A broad term for buildings, structures, sites, districts, or objects of significance in American history, architecture, archaeology, engineering, or culture that are identifiable through field inventory, historical documentation, or oral evidence. Cultural resources may be, but are not necessarily, eligible for nomination to the National Register of Historic Places (NRHP) (see entry for Historic property).

Decay Heat: For the purposes of this document, decay heat is the heat generated by a nuclear reactor following shut down.

Defense-in-Depth: The practice of using physical systems and administrative systems in a structure of mutual reinforcement to avoid exposure of the public, the workforce, and the environment to nuclear radiation and to radioactive materials.

Dose consequences: The dose consequence is the consequence of a person being exposed to ionizing radiation. The increased chance of a person getting a cancer as a result of being exposed to the dose is a risk-based consequence. If the dose is high enough, there is a chance the dose will result in a latent cancer fatality. Collectively, dose, chance of getting a cancer, and risk of a latent cancer fatality occurrence is the dose consequence.

Effective dose (ED): The sum of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health-effects risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue.

The effective dose, or ED, includes the committed ED from internal radionuclides deposition and the doses from penetrating radiation sources external to the body. The ED is expressed in units of rem. The U.S. Environmental Protection Agency (EPA) regulations in 40 Code of Federal Regulations (CFR) Part 61, Subpart H specify that estimates of radiological dose to a member of the public be reported in terms of EDE or total ED equivalent, consistent with an older methodology described in International Commission on Radiological Protection (ICRP) Publication 26 (ICRP 1977) and ICRP Publication 30 (ICRP 1979–1988).

Fuel pin/fuel rod: Individual units of coated or clad nuclear fuel.

Graded approach: A process by which the level of analysis, documentation, and actions necessary to comply with a requirement are commensurate with (1) the relative importance to safety, safeguards, and security; (2) the magnitude of any hazard involved; (3) the lifecycle stage of a facility; (4) the programmatic mission of a facility; (5) the particular characteristics of a facility; and (6) any other relevant factor.

Heat rejection: The unused portion of the thermal energy that must be removed from the system. Waste heat rejection systems include systems and components provided to remove unused or wasted thermal energy from systems (such as the power conversion and residual heat removal system), and channel or direct this energy to the environment.

Historic property: Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the NRHP.

Hot cell: Shielded containment chambers that are used to protect workers from radiation by providing a safe containment area in which workers can control and manipulate the equipment required.

Hot shutdown: Shutdown situation in which a nuclear reactor is maintained at a temperature and pressure at or closely below operating conditions.

Inverter: A power electronic device or circuitry that changes direct current (DC) to alternating current (AC).

Kilowatt-electric (kW_e): One thousand watts of electric capacity. A measurement of electric power output.

Kilowatt-thermal (kW_{th}): A unit of heat-supply capacity used to measure the potential output from a heat source. It represents an instantaneous heat flow and should not be confused with units of produced heat (i.e., KWh (th), or kilowatt-hours-thermal).

Latent cancer fatality (LCF): Based on the *Linear-non-threshold model*, the value reported as an LCF is the risk that a death results from a dose sustained. The Nuclear Regulatory Commission defines LCF as death resulting from cancer that became active after a latent period following exposure to radiation. The Department of Energy defines it as a death from cancer resulting from, and occurring sometime after, exposure to ionizing radiation or other carcinogens.

Linear-non-threshold model: The hypothesized model that assumes that additional cancer risk to persons exposed to ionizing radiation is linear and proportional with respect to the absorbed dose, and becomes zero only at zero dose.

Low-income: The U.S. Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who is in poverty (i.e., classified as "low-income"). If a family's total income is less than the family's threshold, then that family and every individual in it is considered in poverty. The official poverty thresholds do not vary geographically but are updated for inflation using the U.S. Consumer Price Index. The official poverty definition uses monetary income before taxes and does not include capital gains or noncash benefits (such as public housing, Medicaid, and food stamps).

Low Level Waste: Low-level radioactive waste is radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in Section 11e. (2) Of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material.

Minority: Individual(s) who are members of one or more of the following population groups as designated in the U.S. Census Bureau data: Black or African-American, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, Some Other Race, as well as Hispanic or Latino of any race.

Mixed Waste: Waste that contains both source, special nuclear, or byproduct material subject to the Atomic Energy Act of 1954, as amended, and a hazardous component subject to the Resource Conservation and Recovery Act.

National Emissions Standards for Hazardous Air Pollutants: The Clean Air Act requires the EPA to regulate airborne emissions of hazardous air pollutants (including radionuclides) from a specific list of industrial sources called "source categories." Each "source category" that emits radionuclides in significant quantities must meet technology requirements to control them and is required to meet specific regulatory limits.

Neutron: A subatomic particle that has no net electrical charge and mass slightly greater than a proton.

Neutron flux: A measure of the intensity of neutron radiation, determined by the rate of flow of neutrons. The neutron flux value is calculated as the neutron density (n) multiplied by neutron velocity (v), where n is the number of neutrons per cubic centimeter (expressed as neutrons/cm^3) and v is the distance the neutrons travel in 1 second (expressed in centimeters per second, or cm/sec). Neutron flux (nv) is measured in neutrons/cm^2/sec.

Neutron moderator: Neutron moderators are a type of material in a nuclear reactor that work to slow down neutrons to make them more effective in the fission chain reaction.

Neutron reflector: A layer of material immediately surrounding a reactor core that scatters back (or reflects) into the core neutrons that would otherwise escape. The returned neutrons can then cause more fissions and improve the neutron economy of the reactor.

Nuclear fuel: Coated or clad nuclear material designed and fabricated to be used to power nuclear systems.

Person-rem: A person-rem is a collective radiation dose applied to populations or groups of individuals. It is the product of the average dose per person (expressed in rem) times the number of people exposed, or the population affected.

Prevention of significant deterioration: This term applies to new major sources, or major modifications at existing sources, for air pollutants where the area at which the sources are located is in attainment or unclassifiable with the National Ambient Air Quality Standards. If significant impact levels (as defined in the regulation) are exceeded at any public receptor, a detailed air quality impact analysis is required to determine if controls are necessary to maintain air quality.

Radiation shielding: Reduction of radiation by interposing a shield of absorbing material between any radioactive source and a person, work area, or radiation-sensitive device.

Reactivity control: Reactivity control systems are used to control the neutron multiplication under normal, abnormal, and emergency conditions.

Receptors or receptor locations:

> *Member of the public (public receptor location or hypothetical member of the public)*: Location where a member of the public could be when the activity is taking place. "Public receptor locations" correspond to the location of either an actual or hypothetical person. These receptor locations are used because they correspond to those where the highest dose to a member of the public could occur.
>
> *Facility worker*: Person working inside a facility when the activity is taking place. These workers could be protected by technical safety requirements, administrative procedures, and personal protective equipment that would minimize their dose in event of an accident occurring inside a facility. However, doses provided here do not credit these protective measures.
>
> *Collocated worker*: Hypothetical person working outside of the facility where the activity is occurring.
>
> *Crew member*: The driver and passenger of a transportation vehicle.

Reactor core: The central portion of a nuclear reactor, which contains the fuel assemblies, moderator, neutron poisons, control rods, and support structures. The reactor core is where fission takes place.

Reactivity: A term expressing the departure of a reactor system from criticality. A positive reactivity addition indicates a move toward supercriticality (power increase). A negative reactivity addition indicates a move toward subcriticality (power decrease).

Roentgen-equivalent-man (rem): The United States unit of measurement used to express effective dose (ED) (see Glossary). It provides a measure of the biologic effects of ionizing radiation. A millirem (mrem) is one thousandth of a rem (0.001 rem), often used to express dosages commonly encountered from medical imaging (X-rays) or natural background sources.

Spent Nuclear Fuel: Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. Test specimens of fissionable material irradiated for research and development only, and not production of power or plutonium, may be classified as waste, and managed in accordance with the requirements of DOE O 435.1 when it is technically infeasible, cost prohibitive, or would increase worker exposure to separate the remaining test specimens from other contaminated material.

Thermal power: Thermal power describes how fast heat is produced. Generally, thermal power refers to the heat input used to generate electricity.

Total Effective Dose: Sum of the ED (for external exposures) and the committed ED (for internal exposures).

Transient: A change in the reactor coolant system temperature, pressure, or both, attributed to a change in the reactor's power output.

Transuranic Waste: Transuranic waste is radioactive waste containing more than 100 nanocuries (3700 becquerels) of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level radioactive waste; (2) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the 40 CFR Part 191 disposal regulations; or (3) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61.

Draft Environmental Assessment for the Microreactor Applications Research, Validation and Evaluation (MARVEL) Project at Idaho National Laboratory

1. Introduction

1.1 Background

The U.S. Department of Energy (DOE) Microreactor Program supports research and development (R&D) of technologies related to the development, demonstration, and deployment of very small, factory fabricated, transportable reactors to provide power and heat for decentralized generation in civilian, industrial and defense energy sectors. Such applications currently face economic and energy security challenges that can be addressed by this new class of innovative nuclear reactors. Led by Idaho National Laboratory (INL), the program conducts both fundamental and applied R&D to reduce the risks associated with new technology performance, manufacturing readiness, and deployment of microreactors. The program aims to verify that microreactor concepts can be licensed and deployed by commercial entities to meet specific use case requirements.

In addition, the National Reactor Innovation Center (NRIC), also led by INL and established by DOE in August 2019, supports the DOE Microreactor Program and aims to accelerate the demonstration and deployment of advanced nuclear energy. NRIC offers capabilities for building and demonstrating reactor concepts.

Microreactors, often referred to as special-purpose reactors or very small modular reactors, are factory manufacturable, easily transportable, and designed to produce up to 20 megawatts thermal (MWth) energy. This power limit allows microreactors to be classified as Hazard Category 2 per the Code of federal Regulations (CFR) at 10 CFR 830 and DOE-STD-1027 (2019)These reactors are decentralized energy sources that have the ability to provide sustainable and affordable heat and power to remote communities and to industrial users, while having self-contained geometry that requires very low maintenance. Microreactors reactors are inherently safe because they are self-regulating and do not rely on engineered systems to ensure safe shut down and removal of decay heat (Owusu, Holbrook, & Sabharwall, 2018).

1.2 Purpose and Need

The primary mission of the DOE Office of Nuclear Energy (DOE-NE) is to advance nuclear power as a resource capable of meeting the nation’s energy, environmental, and national security needs by resolving technical, cost, safety, security, and proliferation resistance, through research, development, and demonstration. Many microreactor concepts under development in the United States anticipate commercial deployment within the next decade. To advance the deployment of microreactors, DOE needs to resolve technical challenges to improve the economic competitiveness of microreactors, develop experimental infrastructure to enable the testing and demonstration of microreactor technologies, and enable microreactor integration into end-user applications for broad deployment and use.

As the nation's premier nuclear science and technology lab, INL leads DOE-NE efforts for research, development and demonstration projects to help the nation maintain and expand the use of nuclear energy. INL offers a one-of-a-kind research environment with unique capabilities and facilities for advancing nuclear energy. INL has dedicated facilities focused on nuclear R&D, including nuclear fuel fabrication and examination and handling facilities. The DOE-NE Advanced Reactor Development program develops new and advanced reactor designs and technologies to improve nuclear energy competitiveness and support meeting the nation’s energy, environmental, and national security needs.

As part of the Advanced Reactor Development program, INL perform R&D on reactor concepts and technologies that includes modeling and simulation, materials and nuclear fuel development and testing, instrumentation and sensors, and systems testing. Additionally, INL also performs research on integrated energy systems that includes R&D on coupling of nuclear and renewable energy resources to better optimize energy use for the electricity, industrial manufacturing, and transportation sectors.

The purpose of the Microreactor Applications Research Validation and Evaluation (MARVEL) project is to meet the R&D needs of DOE and NRIC by designing and building a nuclear microreactor application test platform at INL that will offer experimental capabilities for performing R&D on various operational features of microreactors and improving integration of microreactors to end-user applications, such as off-grid electricity generation and process heat.

2. Alternatives

In July 2020, the Council on Environmental Quality (CEQ) comprehensively updated its National Environmental Policy Act (NEPA) regulations, which went into effect on September 14, 2020. However, the CEQ clarified that these regulations apply to all NEPA processes begun after the effective date, but gave agencies the discretion to apply them to ongoing NEPA processes (85 Fed. Reg. 137, 2020). This Environmental Assessment (EA) for the MARVEL microreactor was started prior to the effective date of the revised CEQ regulations, and DOE has elected to complete this EA pursuant to the CEQ regulations at 40 CFR 1508.9(b) (1978, as amended 1986 and 2005). The relevant regulations require that an EA include a brief discussion of alternatives to a MARVEL microreactor. The DOE Idaho Operations Office (DOE-ID) considered alternatives for meeting the need to develop and demonstrate a nuclear microreactor application at INL. For the alternatives to be feasible, the microreactor design and development must meet the following criteria:

- Have a small size, low power output, and low decay heat output
- Use well-established, robust fuel, coolant, and structural materials that are stable and compatible
- Have low fuel burnup, small inventory of fuel, and limited available source term
- Have low-decay heat generation, removed by inherent and passive means
- Incorporate high thermal conductivity materials and enhanced convective and radiative heat transfer to reduce temperature hot spots and large thermal mass to give capacity for heat absorption and dissipation
- Use inherent reactivity feedbacks to ensure reactor power is controlled by physics during overpower or over temperature events
- Incorporate multiple passive barriers to inhibit-fission product release
- Use an ambient pressure system to remove sources of pressure and limit driving forces for postulated release
- Supply electricity for end-user applications
- Supply low-grade and high-grade heat for end-user applications
- Use an available facility not requiring substantial modifications and without interfering with other INL R&D efforts.

2.1 Proposed Action - Microreactor Applications Research, Validation and Evaluation (MARVEL) Project

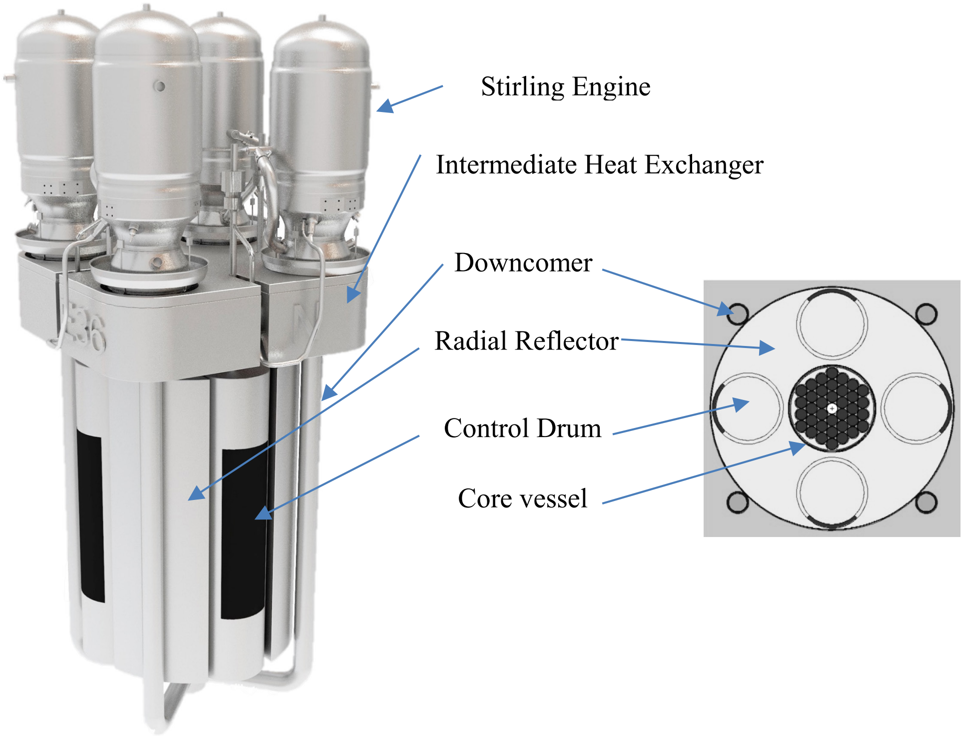
The MARVEL microreactor design is a 100-kilowatt thermal (kW_{th}) and about 20-kW electric (kW_e) microreactor that can be integrated with multiple applications, such as heat and power cogeneration and hydrogen generation, to solve associated R&D challenges. Table 1 summarizes the MARVEL microreactor design parameters discussed in this section. Figure 1 shows a lateral conceptual rendering of the MARVEL microreactor system on the left and cross-sectional rendering of the core on the right.

Table 1. MARVEL microreactor design parameters.

Major Systems	Parameters	Value/Type	Units
Core	Thermal Power	100	kW_{th}
	Core Life	2	years
	Fuel Type	Uranium Zirconium Hydride (UZrH)	
	Fuel Uranium Enrichment	<19.75	%U235
	Maximum Uranium in Core	<30	kg U
	Number of Fuel Pins	36	
	Neutron Moderator	Hydrogen in U-ZrH	
	Peak Cladding Temperature	550	°C
Coolant			
	Heat-Transfer Method	Liquid-Phase Natural Circulation	
	Heat-Transfer Fluid (Sodium-Potassium Eutectic [NaK])	120	kg
Reactivity Controls	Reactivity Control	Vertical Control Drums and Inherent Core Reactivity Feedback	
	Reactivity Control Method 1	Vertical Control Drums	
	Reactivity Control Motor Type	Radiation-resistance, High-temperature Stepper/Servo Motors	
	Bearing Type	Lubricant-free Thrust and Guide Bearings	
	Quantity of Reactivity Method 1	4	
	Reactivity Control Method 2	Inherent Core Reactivity Feedback	
Reflector & Shield	Neutron Reflector Material	Beryllium Oxide, Beryllium Metal	
	Neutron Absorber Material	Boron Carbide (B_4C)	
	Neutron Radiation Shield Material	Boron Carbide (within reactor)	
		Borated Polyethylene (outside the reactor)	
	Gamma Radiation Shield	Stainless Steel (within reactor)	
		Concrete (outside the reactor)	
Power Conversion	Power Conversion Technology	Frictionless, Free-Piston Stirling Engines (PCK80, Qnergy)	
	Power Conversion Efficiency @500° C inlet temperature	20-25	%
	Electrical Power	18-25	kW_e
	Number of Power Generators	4	

Major Systems	Parameters	Value/Type	Units
	Heat Rejection Loop	Water-Propylene Glycol, Closed Loop	
	Ultimate Heat Rejection Medium	Ambient Air	
	Raw Power Output (voltage)	295-365	VDC
	Maximum Power Output per Engine	7.1	kW_e
High Grade Heat Extraction	High Grade Heat Extraction Fluid	Helium or Nitrogen	

Figure 1. MARVEL microreactor pre-conceptual product design.



Hazard evaluations are performed to support each phase of the MARVEL microreactor's design efforts. The hazard evaluation process for the MARVEL microreactor for compliance with the requirements in 10 CFR 830, *Nuclear Safety Management*, follows a process similar to the Licensing Modernization Project (LMP) as outlined in Nuclear Energy Institute (NEI)-18-04, *Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development* (2018). The LMP process is adapted to fit DOE reactor regulatory requirements as applicable and appropriate using a graded approach. This approach provides reasonable assurance of meeting the requirements of 10 CFR 830 (2011)for protection of the public, worker, and environment for the MARVEL microreactor design.

The hazard evaluation of MARVEL microreactor events and associated operations was performed for selection and evaluation of safety classification of structures, systems and components (SSCs), SSC safety functions, and design basis accidents (DBAs) applicable to the MARVEL microreactor design.

With these SSCs in place, the MARVEL microreactor can be built and operated safely in the existing Transient Reactor Test (TREAT) facility. The MARVEL microreactor will not be operated at the same time as the TREAT Reactor is operating. The MARVEL microreactor safety-in-design approach implements a defense-in-depth (DID) strategy by adopting the traditional five layers of DID to the MARVEL microreactor. The DID layers are an integral part of the SSC classification and performance requirement determination.

The MARVEL microreactor is proposed to be located in the TREAT Reactor building in the north high-bay equipment pit. Additional space within the TREAT building may be required for heat rejection and instrumentation and control (I&C) equipment, and other equipment may be located outside the building. As such, the documented safety analysis for the MARVEL Project will be in the form of an addendum to the existing TREAT final safety analysis report.

The following discussion summarizes the MARVEL microreactor design.

Reactor Structure System

The Reactor Structure System is the main structural member of the reactor and primary coolant flow path. It includes a machined billet/forging made from 316 stainless steel (SS) and supports the reactor related components located on the reactor, contains primary coolant, and prevents the core from being uncovered during a postulated loss of coolant accident (LOCA). It also supports the reactor vessel and primary coolant piping.

The MARVEL microreactor core barrel, or reactor vessel, is made from a 10-in. 316 SS, schedule 80 pipe. The lower section supports the reactor core fuel assembly, while the upper section supports the cover gas, drain and fill connections, and a safety valve. The upper and lower sections of the reactor core barrel are attached to the top and bottom of the primary support structure, which supports outer permanent reflectors and control drums (CDs) and transfers reactor loads to the pit floor via the secondary containment structure.

The secondary support structure supports the Stirling engines and high-grade heat exchangers and transfers its loads to the pit floor via the secondary containment structure. It also has attachments for instrument and power cable routing.

The primary output structure attaches to the reactor secondary support structure. It can also support a high-grade heat exchange unit, which is interchangeable with the Stirling engines. This unit may be exchanged as necessary to satisfy changing needs of the MARVEL microreactor. A new primary output structure may be designed and interchanged to reside on the secondary support structure.

Secondary Containment Structure

The secondary containment structure, or guard vessel, is a sealed container that secures the reactor onto the pit floor and prevents the core from being uncovered during a postulated LOCA by preventing coolant leakage from the reactor system. If primary coolant leaks into the secondary containment, the fluid level in the secondary containment will rise as liquid level in the primary system falls, until both systems equilibrate. The reactor core and the primary coolant piping reside inside the secondary containment.

The Secondary Containment Structure is the support structure for the reactor and associated primary and secondary components. It supports the reactor system loads, including seismic loads. Radiation shielding fills the interspace voids. The containment has connections for purge gas and a safety valve and attachments for instrument cable routing for reactor instrumentation, including neutron detectors.

Core System

The primary function of the reactor core system is to supply a continuous, stable, and sustainable fission heat source (~100 kW_{th} maximum power level) for the duration of the operation of the system, (i.e., four years). The MARVEL microreactor core is designed to operate continuously for two years, but the microreactor will not operate continuously. Instead, the MARVEL microreactor will be turned on and off numerous times during its lifetime to support research needs. Operations are discussed later in this document. The core contains 36-fuel elements (also referred to herein as fuel pins) arranged in three hexagonal rings around a central hollow channel (Figures 2 and 3) that is available for sensors and detectors.

The side reflector is a stack of beryllium oxide that moderates and reflects neutrons back into the active core. The beryllium oxide side reflector also houses the four rotating CDs

There are also six in-core inserts that displace and re-direct primary coolant away from the core periphery and through the 36-element array to enhance cooling and natural circulation. These inserts are fabricated out of beryllium metal. The core barrel acts as both the up-flow coolant boundary and the inner wall support for the beryllium side reflector annulus.

Figure 2. Cross section of the MARVEL microreactor 36-fuel element reactor core.

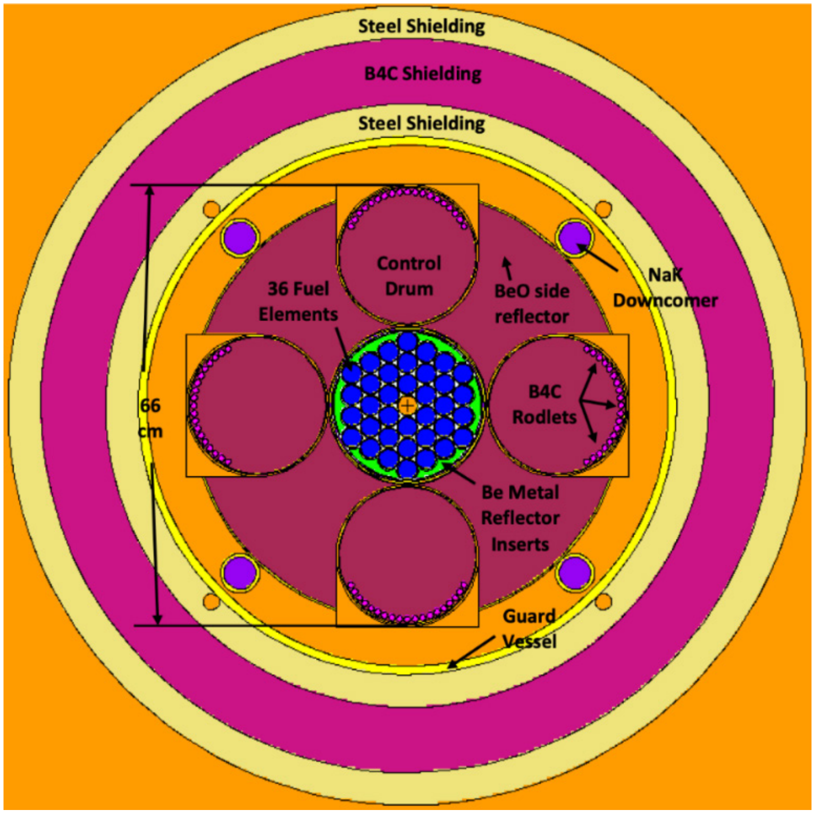
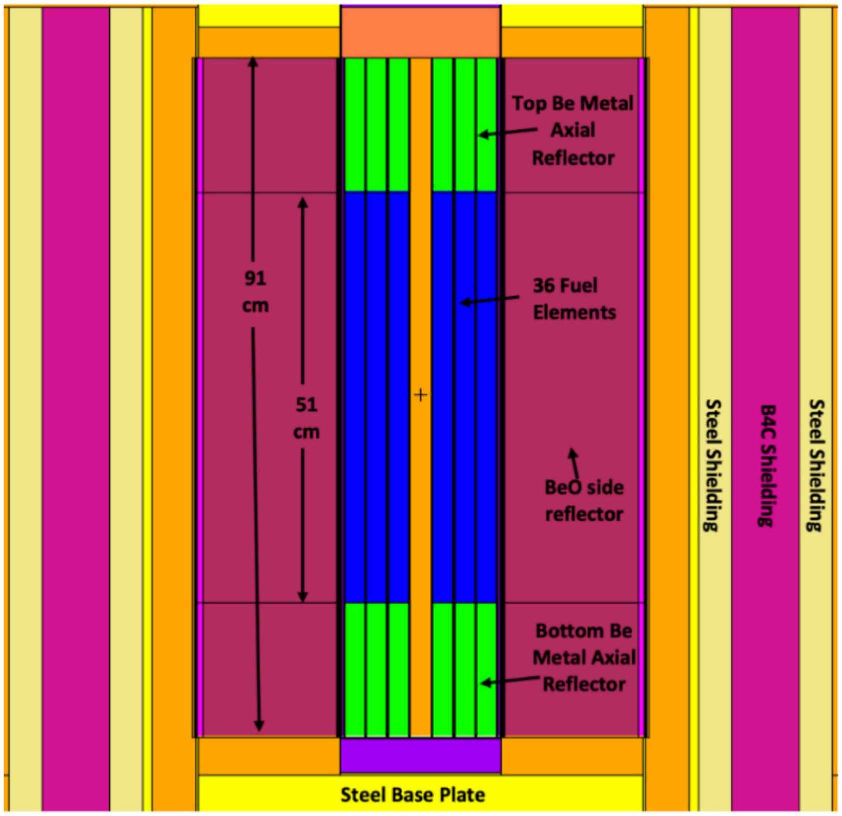


Figure 3. Axial view of the 36-fuel element reactor core system.



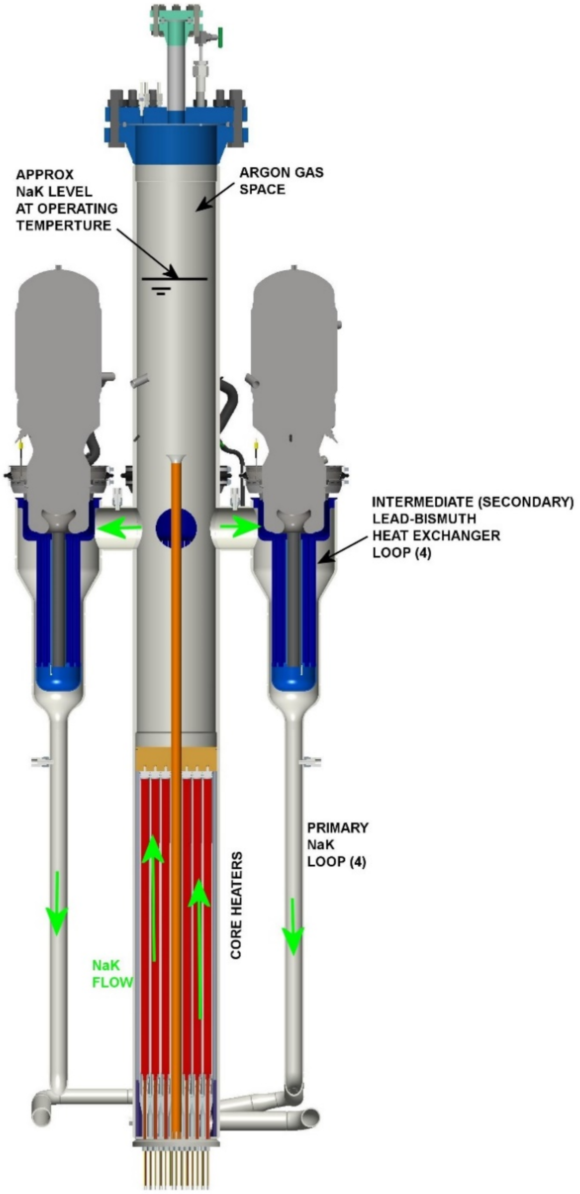
Reactor Coolant System

The primary coolant system (PCS) is a four-loop hydraulic circuit assembled to transport nuclear fission heat from the nuclear fuel to the Intermediate Heat Exchanger (IHX) using natural circulation of the primary coolant. The PCS also transfers decay heat to the ultimate heat sink. The following subsystems comprise the PCS: lower plenum, reactor core, reactor vessel, riser, upper head, IHX region, downcomers, the primary coolant, and the inert cover gas. The PCS limits radiation effects and integrates instrumentation for relaying system information to the I&C system. Figure 4 is a preliminary and conceptual rendering that depicts the PCS and IHX components.

The lower plenum is a welded shell located below the bottom of the reactor core and consists of the downcomer, pipes nozzles, and outer thermal insulation. The lower plenum is designed to collect flow from the four downcomer pipes and mix and homogenize the primary coolant before it enters the core.

The primary coolant boundary for the MARVEL microreactor design consists of the reactor vessel, downcomer piping, cover gas line piping, and the reactor vessel head. These SSCs ensure that primary coolant, which may contain any leaked fission or activation products remain within the vessel and oxygen remains outside.

Figure 4. Design of the Primary Coolant System and IHX.



About 120 kg sodium potassium eutectic (NaK), a liquid metal at room temperature, serves as the primary coolant (Baily, 2020). The NaK coolant acts as a radionuclide barrier by retaining fission products by plate-out, chemical solubility, or adsorption mechanisms. Fission heat is generated in the core and removed by natural circulation of NaK. NaK flows upward through the core, rises above the top of the active core, flows through the upper grid plate and radiation shielding to the four Stirling engine heat exchangers.

The Stirling engine heat exchangers connect to the reactor vessel and interface with the NaK coolant via the IHX. The criteria for the IHX coolant are (1) fluid has to be liquid at operating temperature (2) fluid has to be unreactive with air and water at elevated temperature, and (3) the fluid must be able to retain its thermal conductivity properties in radiation environment without significant degradation, and (4) melting point of the coolant should be less than 300 degrees Celsius to avoid manual engine stall, which can simplify controls of these engines. Therefore, lead-bismuth is selected as the coolant choice for the IHX. The IHX contains about 280 kg of lead-bismuth eutectic in total. The cumulative activation of lead bismuth (relative to pure lead) has been evaluated in the *MARVEL Initial Shielding and Dose Calculations* (Trellue, Vedant, Rao, Lange, & Sterbenz, 2021). An argon gas blanket may be maintained on the IHX to reduce formation of lead and bismuth oxide over time during prolonged exposure to ambient air. The lead-bismuth can be allowed to freeze and thaw between operating cycles, without much stressed to the structural components of the IHX and the Stirling tubes. For faster restarts, immersion electrical heater may be utilized to maintain lead in molten states during hot standby.

The Stirling engines are interchangeable with the high grade heat exchangers. These heat exchangers will also be immersive heat exchangers into the lead-bismuth pool of the IHX, designed solely to extract high temperature heat from the primary coolant for process heating applications. Hence between experiments, either Stirling engines or high grade heat exchangers are placed in the four IHXs, while the lead-bismuth is molten.

The Stirling engine coils or high-grade heat exchanger, depending on configuration, extract heat from the primary coolant and reduces the NaK temperature. The cooled, denser NaK then flows outward to the periphery of the reactor, downward through four downcomer pipes located outside the beryllium oxide side reflector and through in the lower plenum. The NaK then rises back up through the active core under natural circulation forces driven by the heated section of the active core (51-cm active fuel height).

The riser is a welded shell connected to the top part of the vessel. It homogenizes the NaK exiting the core and supplies the fluid a hot column for establishing natural circulation flow. The top of the riser is connected to the bottom of the upper head.

The upper head allows thermal expansion for the primary coolant, contains the PCS inert atmosphere, and is the path for moving the NaK flow from the riser to the IHX region. The upper head is made of 316-SS machined billet. The machined billet furnishes four horizontal flow paths (one for each loop) for the NaK flow. A welded shell, connected to the top of the billet, provides an expansion volume for the NaK during thermal transients and contains the argon gas for the inert atmosphere and enough NaK to maintain the fluid level above the top of the billet in case of a postulated LOCA. A flange is installed on the top head that allows opening the PCS, and a relief valve is located on the flange.

The four IHX regions are welded to the billet of the upper head subsystem and to the four downcomers. The IHX region is a 316 SS cylindrical shell and a 316 SS reducer welded together. The reducer homogenizes and drives the NaK flow from the IHX bottom head to the inlet of the downcomers. The four downcomers are welded to the IHX region and to the lower plenum subsystems. They drive the NaK flow downward, and serve as the cold legs of the PCS to enable natural circulation. The downcomer subsystem is made of 316 SS pipe and thermal insulation.

Bended sections in the downcomers reduce thermal stresses on the vessel and are rounded to minimize pressure drops. In the last part of the downcomers, a dedicated restricted section allows for installing electromagnetic flow meters (one per loop) to relay information regarding flow rate.

The head space in the reactor above the NaK level contains high purity argon gas (about 50 liters in volume). To accommodate thermal expansion and contraction of the NaK without creating excessive pressures in the primary system, a head tank connects to the reactor vessel gas space. The tank is sized to maintain an acceptable pressure in the vessel throughout the full temperature range. The primary vessel cover gas space, head tank, and piping will be sealed and monitored to identify leaks. The inert gas is supplied from one or more standard high purity Argon gas cylinders through pipes and a regulator. Supply pressure will be less than 15 psig.

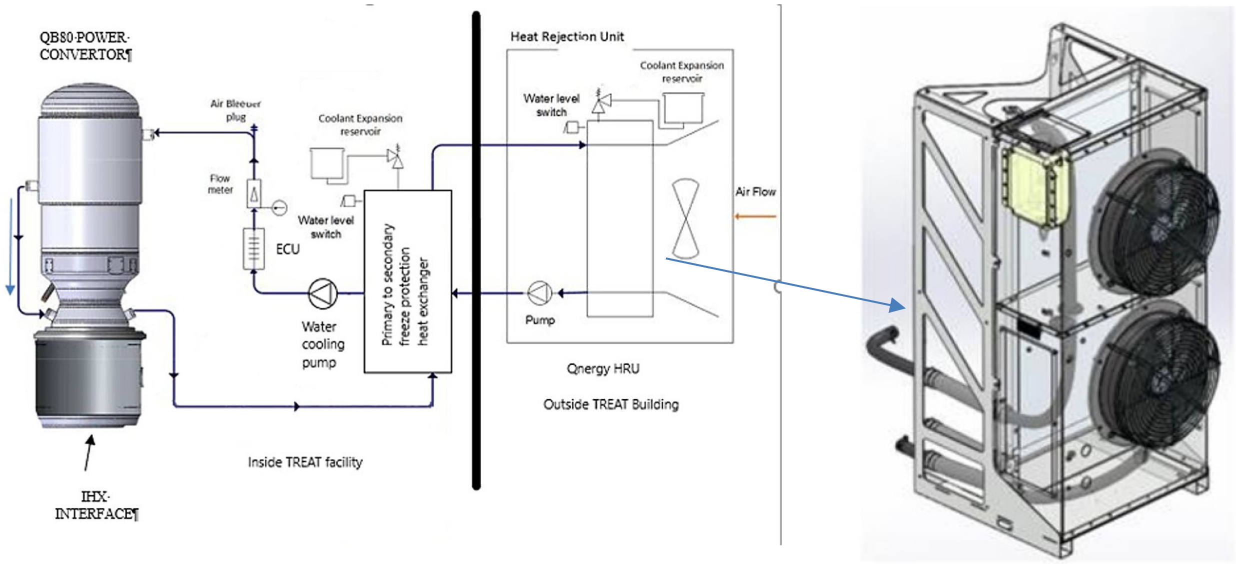
Other means of enhancing primary flow may be implemented if needed. This includes an optional gas injection system. This is accomplished by circulating cover gas into the primary coolant near the core outlet using a small gas compressor. The bubbles reduce the local coolant density above the core. The bubbles rise and collect in the cover gas. This gives the downcomer fluid a relatively higher density difference, thus increasing flow rate of the natural circulation. The Gas Injection System will only be implemented if the reactor needs a higher flow rate during development tests.

During startup and restarts, there are no planned maintenance expected on the reactor and power conversion system. The lead-bismuth may utilize external heating to maintain liquid phase for ease of switching Stirling engines and high-grade heat exchangers during initial startup and restarts. Due to the short core life, changing filter elements and installing a purification loop and aerosol filtration and removal system for the argon cover gas system of the primary coolant are not required.

Power Conversion and Heat Rejection System

The power conversion and heat rejection system removes and extracts high-temperature process heat from the IHX, converts that heat into power, and delivers useful electricity to user loads. Alternately, some or all the high-grade heat may be extracted and delivered to a thermal storage medium for integration with heat applications. Figure 5 gives an overview of the power conversion and heat rejection system.

Figure 5. Power conversion and heat rejection equipment.



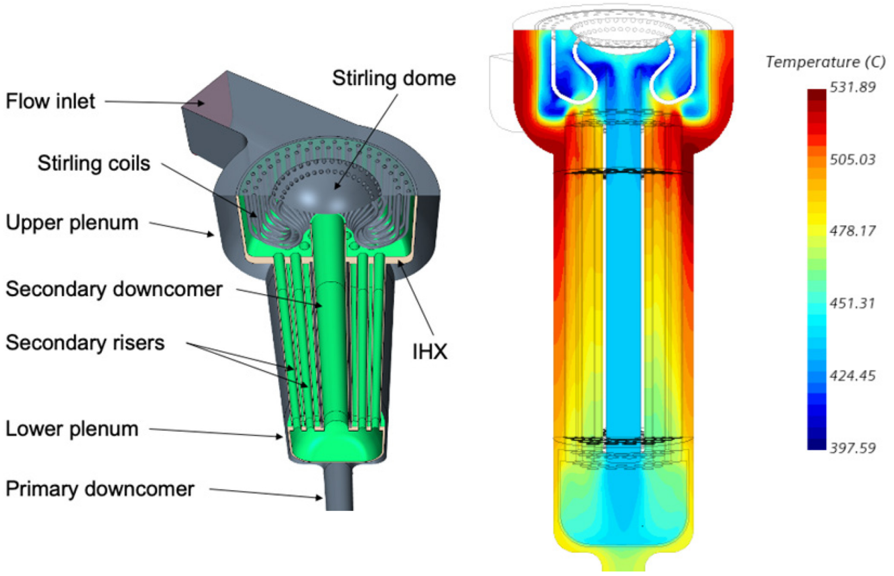
The power conversion and heat rejection system uses Stirling power conversion equipment and associated controls or a high-grade heat exchanger depending on the configuration, to absorb heat from the reactor and cooling loops. The power convertor absorbs heat from the reactor and uses it to produce electrical energy. The four Stirling engines have custom engine control units (ECU). The piston-free Stirling engines can generate about five kilowatts of power with a 500°C heat source in their hot end heat exchanger. However, net power production starts at about 250°C with a wide range of thermal input, up to a maximum of 7.1 kW per engine. The hot heat exchanger system of the Stirling engine or the high-grade heat exchanger absorbs heat from the reactor and converts it to mechanical motion. Linear alternators convert this mechanical motion to electrical energy and supply direct current (DC) voltage. The system sends the DC voltage to a bus or to an inverter system that converts it to alternating current (AC).

The ECU starts the Stirling engine and receives DC voltage output from the linear alternator. The ECU also monitors system components such as coolant flow, coolant inlet and outlet temperature, and idle mode electrical power dissipation (no electrical load). It also has a shutdown trigger to turn off input heat.

The Stirling engines are closed systems containing helium (110 g per engine) as the power generation coolant. The helium has a maximum allowable working pressure of 73 bar (1060 psig). Heat from the helium gas during the Stirling engine cycle is removed through an external water and propylene glycol, closed loop cooling system. Figure 6 shows the conceptual IHX that connects the Stirling engines to the reactor and the primary coolant.

The low-grade heat rejection system delivers waste heat to the ultimate ambient heat sink (air) through the heat rejection unit located outside the TREAT Reactor building. The low-grade heat rejection system includes a set of pumps and radiators that can be reconfigured for optimized performance.

Figure 6. Section schematic of Stirling engine heat exchangers and intermediate lead-bismuth loop.



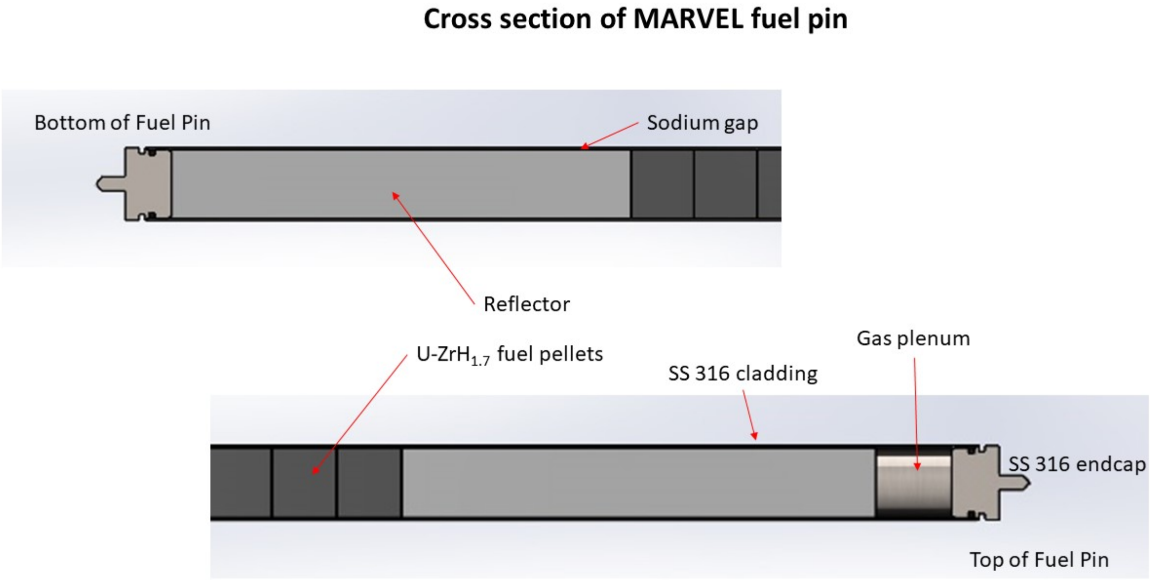
Fuel System

The fuel system generates heat through fission reactions and transfers it into the primary coolant via the cladding. The fuel system is designed to contain the fuel and fission products. The MARVEL microreactor fuel is based on a well-known Training, Research, Isotopes, General Atomics (TRIGA) fuel material and utilizes sodium bonding between the fuel and cladding to gives sufficient margin to failure to assure the fuel performs safely over the life of the MARVEL microreactor. The fuel cladding functions as the primary fission product boundary.

The MARVEL microreactor requires INL to assemble and weld a maximum of 70 fuel pins, 22-34 of which will be used to verify the quality assurance of the fabrication process. The remaining 36 fuel pins will fuel the MARVEL microreactor. The program proposes to store assembled fuel pins at the Materials and Fuels Complex (MFC) ZPRR facility until transfer to TREAT for core loading. Transporting the fuel pins to TREAT occurs on roads with access controlled by INL security using an approved transport vehicle. Prior to core loading, the fuel will be temporarily stored in the high bay of the TREAT Reactor building.

The MARVEL microreactor fuel is a uranium zirconium hydride (U-ZrHx) containing 30-40wt% uranium that is enriched with 19.75% U235. The MARVEL microreactor fuel material is U-ZrH$_{1.7}$ sodium bonded to type 316 SS cladding. The fuel system consists of cladding, endcaps, fuel pins, neutron reflectors, and gap conductance fluid (sodium) as shown in Figure 7. The entire fuel system is composed of 36 fuel pins, or about 150 kg of fuel, which includes about 50 kg of fuel required for the 22-34 fuel pins that are for quality assurance of the fabrication process. Therefore, less than 100 kg of fuel will be involved in the fission process. Each pin measures about 38-in. (96.5-cm) long. The cylindrical U-ZrH fuel pellets are stacked vertically, cladded in SS, and sodium-bonded to improve fuel pin heat transfer characteristics. Within each fuel pin clad, a top and bottom beryllium oxide (BeO$_2$) reflector is located above and below the fuel pellet stack, and a fission gas plenum is located above the top beryllium oxide reflector.

Figure 7. Fuel pin assembly.



Each fuel pellet measures about 1.17 in. (29.72 mm) in diameter by about 1.1 in. long (27.97 mm). Each fuel pin contains 18 fuel pellets. Each fuel pin contains two neutron reflectors made from beryllium oxide; one above the fuel stack and one below the fuel stack and enough sodium, when liquid, to cover the lower reflector, the fuel stack, and one-half to three-fourths the length of the top reflector. Each pin also contains a plenum space to accumulate any released fission gases and gaseous hydrogen.

The cladding and endcaps of the fuel pins are made of 316/316 SS (or Incoloy 800). The 316/316 SS cladding has an interior diameter measuring about 1.25 in. (31.8 mm) and a wall thickness of 0.035 in. (0.89 mm). It is possible to use Incoloy 800 cladding. Incoloy 800 is a high temperature alloy with a higher nickel content than SS 316 and has better high temperature mechanical properties. Overall, the neutronic effect of moving from 316 SS to Incoloy 800 with no other design changes is a reduction in reactivity. This reactivity loss can be compensated for with other design choices. For example, reducing fuel rod cladding thickness has a large neutronic effect that could improve the reactivity of the core to offset reactivity losses (Parry, Lange, Parisi, Wagner, & Arafat, 2020). Regardless of cladding material, the cladding will be manufactured to a consensus standard and will have margin to failure during MARVEL microreactor operation for both off normal and anticipated events.

Two options are available for obtaining MARVEL microreactor fuel: INL production or supply from TRIGA International. TRIGA International, a General Atomics (GA) and Compagnie pour l'Etude et la Realisation de Combustibles Atomiques joint venture, have re-established the TRIGA fuel manufacturing capability in France that was previously performed by GA in San Diego, California. In both procurement scenarios (i.e., INL and TRIGA International) the fuel will fall within the range of U235 enrichment and uranium loading covered by NUREG-1282 (NRC, 1987).

Fuel fabrication at INL is the preferred path for obtaining the MARVEL microreactor fuel and uses traditional powder metallurgy processes and laboratory equipment already in use at INL at MFC in the Experimental Fuels Facility (EFF) using the tri-arc melter and the High-Density Fuels argon glovebox. Fuel pin welding and assembly takes place in an inert glovebox in EFF. The ZrH_2 will be procured from commercial vendor.

The proposed fuel fabrication method involves mixing about 30-40 wt% U, either in the form of U powder or UH_3 powder, with 60-70 wt% ZrH_2 powder, which is pressed into compacts and densified in a partial pressure of hydrogen to form $ZrH_{1.7-1.9}$ (Weeks & Goeddel, 1960). Depleted uranium and highly enriched uranium feedstock are used to achieve the required pellet enrichment of 19.75% U-235. These feedstock materials will be sourced from INL uranium feedstock stores and analyzed for purity prior to use. Surface oxidation is removed via established acid cleaning techniques in EFF.

If INL cannot manufacture the fuel, TRIGA International would manufacture fuel for the MARVEL microreactor and ship the fuel to INL. The unassembled fuel parts would then be assembled at INL in the Fuels and Applied Science Building (FASB), stored in ZPPR, and transported to TREAT for storage prior to core loading, as described above. TRIGA International would ship a maximum of five fuel pins per cask in about six shipments directly from France to INL using a TN-BGC shipping cask. The Nuclear Regulatory Commission (NRC) evaluated the impacts on human health and the environment of shipping radioactive materials, including imports, in NUREG-0170 (1977).

Reactivity Control Systems

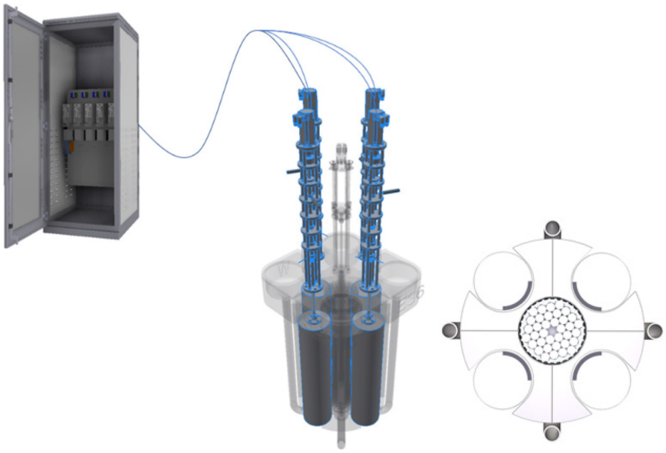
The reactivity control system includes the four MARVEL microreactor CD systems and supporting electrical components (see Figure 8) that controls criticality and can shut-down the MARVEL microreactor. Criticality occurs when the nuclear fuel sustains a fission chain reaction and each fission releases a sufficient number of neutrons to sustain an ongoing series of nuclear reactions. Neutron absorbing materials disrupt the fission chain reaction by absorbing neutrons to prevent them from causing further fissions. By controlling the number of neutrons available to induce fission, the power of the reactor can be moderated.

The supporting electrical components are installed on the CDs or housed in an adjacent control cabinet. The control cabinet houses the instrumentation necessary to drive the CDs and process data from the system. Electrical cables routed between the CDs and the control cabinet send motor driving signals and other information to and from the system instrumentation.

The CD cylinders are made from beryllium oxide and are ~7.2 in. (18.4 cm) in diameter and ~36 in. (91) cm long. Each drum is supported by 0.75 inch (1.9 cm) diameter rod through the center, and each drum has a neutron absorbing plate made of boron carbide that is ~0.4 in. (1 cm) thick. A non-structural, sheet metal cylindrical wrap may be used to house all the BeO plates. The drums weigh ~110 lbs (50 kg).

Rotation of the CDs controls the number of neutrons available in the core to induce fission, which influences target output electrical power. The rotation of the CDs' neutron absorbing material relative to the core is used to achieve and control criticality or shutdown the reactor and maintain it in a subcritical state. A single CD can shut-down the 36-element core during reactor operations. The CD system has drum forcing components (e.g., motor, spring, and damper) that rotate the CDs, and these components are configured and sized to accommodate operational (a motor rotates the drum) and accident modes (a spring drives the CD system when a safety trip is triggered).

Figure 8. Reactivity control system (showing two of the four CD drive systems).



For the MARVEL microreactor, criticality is achieved when the CD neutron absorbing materials are rotated away from the core. When the CD system positions the neutron absorbing materials directly toward the core, the core is subcritical, or shutdown. As the CDs rotate the poison away from the core, there is a point where initial criticality is achieved. Rotating the CDs beyond the initial criticality position controls the number of neutrons available for sustaining the fission chain reaction in the core and the rate at which fissions occur, thus controlling reactor performance. Instrumentation relays information regarding the position and rotation of the CDs.

The CDs can be controlled manually and automatically using system instrumentation. If a safety related circumstance occurs (e.g., loss of power, seismic event, over temperature, etc.), the Reactivity Control System rotates the CDs past their initial criticality position to shut-down the reactor automatically. The manual rotation mode requires direct activation of the motion control system using manual interfaces linked to the motor driver. The automated mode uses computer activation triggered by information received from system instrumentation (e.g., computer logic executes withdrawal when a reactor parameter measurement sensor achieves a target). These remotely controlled reactor activation modes allow personnel to be remote from the reactor hazards during reactor startup and operation.

Radiation Shielding System

The radiation shielding system absorbs and reflects radiation to protect the facility and reactor materials and components and protect people and the environment during normal operations and accident conditions. Shielding requirements and dose calculations are described in *MARVEL Initial Shielding and Dose Calculations* (Trellue, Vedant, Rao, Lange, & Sterbenz, 2021). Additional shielding may be required pursuant to additional analysis.

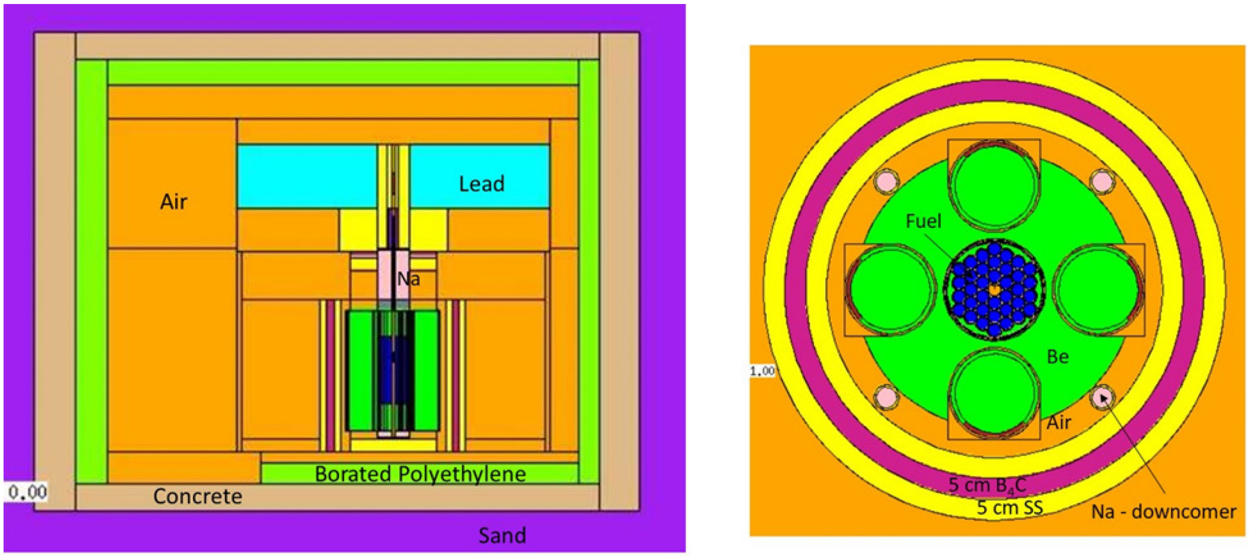
The reactor itself will be located in a concrete pit within the TREAT Reactor building at INL that gives a means of isolating the reactor within the TREAT Reactor building. Dimensions of the pit are in Table 2 below.

Figure 9 shows shielding locations and materials. Within the reactor, a large square SS plate above the core serves as the main gamma shielding to protect the Stirling engines or high-grade heat exchanger and other components above the core. This plate is about 30 in. (76 cm) thick and includes an about 4 in. (10 cm) thick section of boron carbide neutron shielding. The core and reflector regions are surrounded by SS and boron carbide cylindrical sections to provide gamma and neutron shielding within the reactor assembly. External to the reactor, 6 in. (15 cm) of borated polyethylene sheets line the concrete pit (sides, top, and bottom below the reactor).

Table 2. Dimensions of TREAT Pit.

Item	Dimension
Pit Floor Thickness	1 ft - 2 in. (35.56 cm)
Pit Wall Thickness	1 ft - 0 in. (30.48 cm)
Depth below cover blocks	10 ft – 0 in. (304.8 cm)
Pit Length	12 ft (365.76 cm)
Pit Width	9 ft (274.32 cm)
Cover thickness	8 in. (20.32 cm)

Figure 9. Cross section view of MARVEL microreactor with shielding



Instrumentation & Control System

The I&C system is responsible to acquire data on key parameters of the systems via the instrumentation and sensors and provide the means to control the MARVEL system. The I&C system has the following main functions: reactor control instrumentation, plant protection, interlocks, drum control, post-accident monitoring, electrical distribution, low-grade heat removal, the control system, and human-machine interface.

The reactor core instrumentation measures the rate of neutron generation (neutron flux), temperature, flow, NaK level and senses for leaks. This system uses neutron sensors (source range and steady state), thermocouples within the primary and secondary loops, flow meters on the primary loop, NaK level probes and leak detection probes to send the operator key information regarding the state of the reactor core. If a NaK leak is detected by the sensors, the sensors send a scram response to the Reactor Protection System (RPS), which shuts the reactor down. The I&C system also monitors other measured parameters and provides for automatic shutdown signals to the Reactor Protection Systems. The reactor power can be calculated from the neutron sensors and from the temperature and flow measurements.

The RPS includes components that shutdown the reactor or shutdown the power conversion system. This system has two safety significant purposes. The first is a manual scram button, and the second is the seismic sensors. Relays supply power to an electromagnetic clutch, which, if de-energized, allows a spring to move the drums to the shutdown position (i.e., scram). The relays are configured so that a power loss causes a scram. The relays are actuated by a manual scram button, accelerometers for detecting seismic events, computer trips, local manual scram and reset buttons. There are two relays that are actuated for each scram type for defense in depth purposes.

Table 3 lists these other components of the system.

Table 3. Non-safety related I&C components

Non-Safety Related I&C Components	
Component	Function
Interlocks	Limit the excess reactivity insertion and prevent improper event sequencing. Mechanical relays limit the drum rotation to one drum at a time to prevent improper sequencing.
Drum Control	Sends commands to the motor controller and receiving position indicator. Displays CD position.
Post-Accident Monitoring System	Gives information after an accident or unexpected event. Continuously measures dose levels with radiation monitors, detects NaK leaks, indicates reactor shutdown, and stores plant data for analysis
Electrical Production	Communicates with the ECU controller to start and stop power generation, setup electrical parameters, and monitor status and other electrical distribution items from the generators.
Low-Grade Heat Rejection System	Measure flow and temperature, move secondary coolant, and turn fans on and off.
Control System	Performs the logic for control and data conditioning to create indicators for the operator.
Human Machine Interface	Platform where the operator controls plant functions and receives information about the plant conditions. Computer receiving and displaying information via monitors. Interfaces with the control system through a local area network connection.

Siting and Operations

DOE proposes to install the MARVEL microreactor in a concrete storage pit in the north high bay of the TREAT Reactor building near MFC at the INL Site. TREAT provides the MARVEL microreactor with an existing operating Category B reactor facility (pending DOE approval of the TREAT safety basis with the addition of the MARVEL microreactor), operating crews, and recent restart experience. Modifications to the TREAT Reactor building to accommodate the MARVEL microreactor are anticipated to take 5 to 7 months. Constructing, assembling, and performing preoperational testing is expected to last another 2 to 3 months prior to fuel loading.

The preferred location for the I&C system hardware is near the pit inside the TREAT Reactor building. Other options include using a portable shipping container, which will be located outside the TREAT Reactor building. Fluid piping for a closed heat rejection unit connects the power conversion of the reactor to the heat rejection units. Other ancillary equipment may be located outside the building. Figure 10 shows a conceptual layout of equipment. The location of equipment outside of the reactor pit and outside of the TREAT Reactor building could change, but this configuration is limited to the high bay area and the area within the fenced TREAT Facility perimeter.

Modifications of the TREAT Reactor building are necessary to support the MARVEL microreactor. These modifications include installing shield blocks and a Heating, Ventilation, and Air Conditioning (HVAC) system in the north storage pit, installing industry standard I&C components, electrical power and electronic racks, reactor and control room infrastructure, fire suppression system, and heat rejection and electric load dissipation equipment north of the TREAT Reactor building. The proposed modifications to the TREAT Reactor building include the following activities:

- Make penetrations in the fuel storage pit cover(s) for heat rejection fluid loop (i.e., the water-propylene glycol, closed loop)
- Install shielding in the reactor pit
- Route heat rejection ducting from the pit to a condenser unit outside the TREAT Reactor building
- Install a temporary NaK filling station
- Route gas lines and portable gas cylinders to the NaK fill station
- Route conduit and wiring to the condenser unit and the fuel storage pit (power and signal)
- Install fire suppression using an argon gas supply for passivation.

The preparation to bring a new reactor online requires a formal plan to assemble and load the reactor and bring the reactor critical. After achieving criticality, some amount of testing is required to validate the assumptions in the safety basis and demonstrate compliance to the technical specifications for operating the reactor. This process for the MARVEL microreactor is detailed in the *MARVEL Startup Roadmap: Assembly, Fuel Loading, and Initial Startup of MARVEL* (Parry, Chase, & Biggs, 2020) and summarized below:

Reactor assembly involves assembly of the reactor vessel, nuclear instrumentation and chassis, reactivity control systems, primary plant instruments, reactor trip systems (i.e., safety systems, seismic scram system), manual shutdown system, heat rejection system, and shielding. Following assembly, operability testing is performed on these systems. During this time, the system is also used for operator training and procedure testing.

After operability testing, reactor loading begins. The reactor fuel will be loaded manually using methods standard in the nuclear industry. Only one fuel pin will be handled at a time under strict criticality controls to prevent inadvertent criticality. After fuel loading, the top grid plate will be installed; the reactor vessel head will be installed; and the vessel will be filled with NaK and sealed. At this point the final connections to the Stirling engines or high-grade heat exchanger, load banks, and heat exchangers will be made. Once the final connections are complete and have been tested, the reactor trip systems will be re-tested, which is the final check before the initial approach to critical.

The reactor core starts-up from a cold (room temperature) zero-power condition prior to coming up in power. The four CDs are then rotated in small increments to bring the core to a critical state. The regulating CD puts the core on a slow power period and ramps-up in power in a controlled manner. Relays ensure one CD is rotated at a time to avoid any transient overpower conditions during startup.

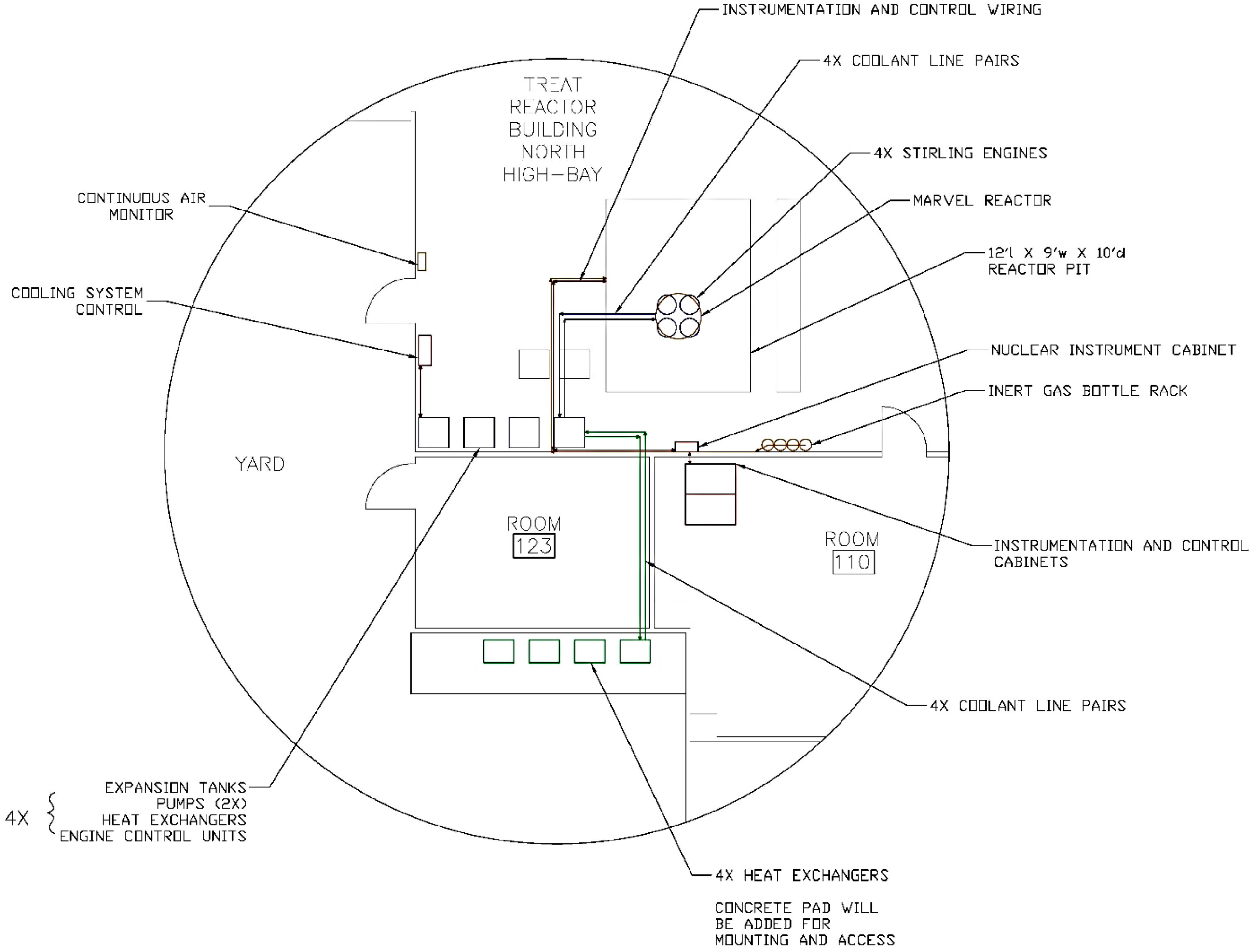
Similar to commercial reactors, during the initial approach to criticality, the reactor operating parameters will be monitored at predefined hold points to verify the process is proceeding safely and as anticipated. If the reactor operating conditions are not performing as expected, operations will be halted to determine the cause of abnormalities and resumed only when safe operating conditions are again established.

After criticality is achieved, the reactor will be shut down and the process will be repeated to confirm consistency. After initial criticality, reactor physics parameters will be measured to calculate the shutdown margin and excess reactivity for comparison to technical specifications. The reactor will then be increased in power to raise temperature enough to complete a heat balance calibration of the nuclear instruments to determine losses and to test the decay heat removal system.

The final stages of startup include testing the power production of the microreactor. The reactor will be raised to a high enough temperature to start the Stirling engines or high-grade heat exchanger, and the power production will be measured at this level. The power will be increased incrementally to test the range of power production up to 100% reactor power. To improve startup efficiency and remove the complications of the secondary lead heat exchanger solidifying, a hot shutdown mode may be defined and employed for the MARVEL microreactor. Hot shutdown indicates that CDs are rotated in fully in and de-latched to prevent inadvertent criticality.

During normal operations, the reactor core is stepped-up in power before reaching a desired maximum power level. At each power step, predetermined hold points are evaluated to confirm engine efficiency and proper reactor system performance. Operation at maximum power (100 kW) is referred to as the normal hot operation condition. The MARVEL microreactor will normally operate in an automatic control mode including shutdown function involving the CDs. However, the reactor operator can manually control the reactor, in which case the operator has the option to switch from automatic control to manual control. The operator can then manually rotate the control drums to shut the reactor down.

Figure 10. Layout of MARVEL microreactor in the TREAT Reactor building.



The MARVEL microreactor will not operate on days the TREAT reactor is operating. The MARVEL microreactor requires about 10 additional employees (eight employees for construction and two for operations). During normal operation, onsite staff evacuate the TREAT Reactor building and control the MARVEL microreactor from building MFC-724. The control room is located more than half of a mile away and houses the TREAT operator station.

Deactivation and Decommissioning

Deactivation & Decommissioning (D&D) of the MARVEL microreactor is anticipated to occur in phases that vary in length and scope. Because the TREAT Reactor building must be evacuated when the TREAT reactor is operating, D&D activities cannot take place when the TREAT Reactor is operating.

The first phase begins upon final shutdown of the reactor after completion of critical project operations. This phase includes monitoring the reactor and other equipment as systems cool down and radiation levels decay. Systems or components not exposed to a high-radiation field will be disconnected and stored for re-use on other projects or dispositioned. This includes draining, breaking down, and storing equipment from the heat reject system located outside of the reactor pit.

When radiation levels are low enough for safe pit access, the Stirling engines, high-grade heat exchanger used in some operating configurations, pit HVAC, and IHX will be decommissioned, the bulk of the NaK primary coolant (most of the 61 gallons or 120 kg) will be drained from the system, and residual NaK remaining on pipes, vessels, and other components in the reactor vessel systems will be neutralized. Initially, a small amount of moisture is introduced in an inert gas purge to remove the remaining NaK. A water wash is then used to react any lingering coolant. The reaction wash will generate an alkali solution of potassium and sodium hydroxide. The concentration and contact rate is low enough that no detectable reaction with the stainless steel fuel cladding will be observed. This initial phase of the MARVEL microreactor D&D is dependent on the power history and decay times of the radioactive isotopes from the core and activated equipment, which could be from months to years after shutdown.

In order to drain and remove the NaK coolant from the reactor vessel, the argon cover gas will be evacuated and replaced due to potential contamination. The cover gas will be extracted by a simple gas transfer line into a gas storage container, which will be disposed of as discussed in Section 3.7.

NaK removal involves installing a pump or using a vacuum to evacuate the NaK. Vacuum evacuation is preferred. The NaK requires neutralization treatment to convert it to a nonhazardous form for disposal, which could be completed at MFC or through an offsite Treatment Storage Disposal (TSD) facility. After treatment, NaK can be filtered to remove the radioactive components. An alternative approach involves solidification after treatment. During removal of the NaK, argon gas will be added to the vessel to maintain a cover gas on NaK residuals.

Once the bulk of the NaK has been drained, the residual NaK will need to be removed from the pipes, vessels, and other components. Neutralizing and removing the residual NaK is required prior to defueling the reactor to avoid defueling the reactor with NaK contaminated fuel rods. Neutralizing residual NaK generally involves converting the sodium and potassium to their respective hydroxide forms using a chemical reaction with high temperature steam and an appropriate cover gas, typically nitrogen, followed by conversion to their respective carbonate forms via chemical reaction with carbon dioxide. The resultant aqueous carbonate solution is then solidified for disposal (Herrmann, Buzzell, & Holzemer, 1998). Following neutralization, the system will be rinsed to remove the constituents formed during neutralization.

The next step removes the IHX. The IHX contains lead-bismuth in a solid form. Separating the IHX from the reactor vessel allows it to be stored for decay or shipped to a treatment facility. Maintaining the IHX intact requires removing the Stirling engines and separating them from the reactor without breaking the IHX boundaries. Removing the IHX intact is necessary to eliminate releasing Polonium-210, which is produced in the IHX from activation of bismuth in the lead-bismuth eutectic coolant.

After neutralizing residual NaK in the core, defueling begins with evacuating the argon cover gas and removing the vessel head to access the fuel. Fuel pins will be removed one at a time, and each will be wiped down to verify it is dry and clean. Radiation and contamination surveys will be performed as each assembly is removed. After inspection the assemblies will be placed in designated shipping or storage containers following criticality control protocols. Containers can be dry stored at TREAT or shipped to MFC for storage or reprocessing. Section 3.8 discusses spent fuel in more detail.

After the core is de-fueled, the nuclear instruments will be disconnected and disposed of or stored for re-use. Power to in-pit systems will be disconnected, and reactivity control systems will be removed and disposed of separate from the reactor vessel. The activated beryllium can also be removed from the motor systems and managed as discussed in Section 3.7.

After removing instrumentation, the reactor vessel can be size reduced for packaging and disposal. This can take place in the pit or the vessel can be removed from the pit to the high bay floor. Size reduction requires using contamination controls such as tents and active ventilation. Alternatively, a special waste container could be fabricated, and the entire vessel could be disposed of intact. The reactor pit shielding can be removed for storage if needed, but it is assumed it will remain in place.

2.1.1 Alternative 2 – No Action

The "No Action" alternative establishes a baseline against which this EA compares the MARVEL microreactor. No action does not necessarily mean doing nothing, but involves maintaining or continuing the existing status or condition. In this document, no action means not manufacturing and operating the MARVEL microreactor concept. INL would continue to pursue other aspects of microreactor R&D such as developing non-nuclear thermal testing of microreactor heat removal systems, evaluating new fuels, materials, instrumentation, and sensors for microreactor designs and investigating power conversion systems.

Not demonstrating the MARVEL microreactor concept would limit DOE's ability to obtain critical information regarding the reliability, efficiency, and safety of microreactors and their integration with end-user applications. This would negatively impact the development and improvement of advanced microreactors.

2.1.2 Alternatives Considered and Eliminated from Analysis

Table 4 gives a brief description of alternatives to the MARVEL microreactor that were considered for the MARVEL microreactor and the reasons they were eliminated from further evaluation.

Table 4. Alternatives considered for the MARVEL microreactor and criteria for elimination from further analysis.

Alternative	**Alternatives and Criteria for Elimination from Further Analysis** Criteria
INL Facilities other than the TREAT Reactor Building	The MARVEL microreactor project evaluated other INL facilities, including the Experimental Breeder Reactor (EBR)-II containment dome and the Zero Power Physics Reactor (ZPPR). Other facilities evaluated required substantial modifications to support the MARVEL microreactor and/or have ongoing R&D programs with which the MARVEL microreactor would interfere. Therefore, only the TREAT Reactor building was carried forward for additional analysis.
Primary Reactor Coolant	Sodium was evaluated as a candidate for the primary reactor coolant as detailed in Baily (Baily, 2020). Due to the anticipated duty cycle of the reactor and potential safety implications of freezing sodium due to failure of electrical heating systems, sodium was eliminated from consideration.

Alternative	**Alternatives and Criteria for Elimination from Further Analysis** Criteria
Pumped Primary Coolant	Different primary and secondary flow configurations including natural circulation, pump, and gas bubble assisted natural circulation for primary and secondary loops were evaluated in *MARVEL Coolant Options* (Baily, 2020). It was determined that the challenges and unknown risks of a pumped configuration outweigh the advantages. Specifically: Natural circulation has the fewest components and least amount of piping and piping connections of the evaluated alternatives. Other designs involve incorporating coolant pumps, using double walled piping for an external secondary loop, and developing a heat exchanger. The natural circulation design can be modified to give access to high grade heat through one or more of the Stirling engine connection locations or high-grade heat exchanger that may be used in some operating configurations. This meets the requirement to supply high-grade heat for end-user applications.

3. Affected Environment and Environmental Impacts

This section provides a brief background description of only those environmental aspects affected by the MARVEL microreactor project.

Under the No Action alternative (Alternative 2), activities at the INL Site would continue under present day operations, and the MARVEL microreactor project would not be implemented. The No Action alternative would not result in impacts to resources at the INL Site beyond those captured in the discussion of the affected environment. The environmental impacts of future activities at the INL Site would be evaluated in project or program specific analyses in compliance with NEPA. Therefore, impacts from the No Action alternative are not discussed further in this EA.

This EA describes the resources that may be affected by the MARVEL microreactor. Discussion of the present day setting in this document is limited to environmental information that relates to the scope of the MARVEL microreactor. The level of detail varies depending on the potential for impacts for each resource area. This section summarizes several site-specific and recent project-specific documents that describe the affected environment and incorporates these documents by reference.

Decisions will be made during ongoing design phases of the MARVEL microreactor that could affect the eventual final design and construction. Application of the safety-in-design principles identified in DOE-STD-1189-2016 (2016), and the evaluations to ensure adequate protection of facility and collocated workers in the safety basis, provide assurance that the design is capable of meeting the requirements outlined in DOE O 420.1C (2019) and 10 CFR 830 (2011) for the TREAT Reactor building location.

The early stages of design development are guided by deterministic decisions that outline the desired safety characteristics for a given design. The safety goals in nuclear facility design and operation are to ensure adequate protection of the public, workers, and environment. This will be achieved for the MARVEL microreactor by proper selection of fuel, cladding, coolant, and structural materials that are stable and compatible, and by following high quality practices in construction and operation. The MARVEL microreactor design will consider the proposed operational ranges for systems and components and ensure that material selection provides for reliable operations during normal operations.

Since the design thermal power of the reactor is not expected to change, the use of an early model for preliminary source term calculations is used for this EA. Any changes in the reactor design will not significantly alter the source term or invalidate the source term’s use in the preliminary dose and hazard evaluations (Parry J. , 2020). Therefore, the impacts evaluated in this EA are considered bounding.

An important component in analyzing impacts is identifying or defining the geographic area in which impacts to resources are anticipated to occur. The area of impact is specific to the type of effect evaluated.

The area potentially affected was determined by the scope of the MARVEL microreactor, including all potential direct and indirect impacts associated with project. The geographic boundaries for analyses of cumulative impacts in this EA vary for different resources and environmental media. Table 5 briefly describes the areas of impact for each resource area evaluated in this EA.

Table 5. Geographic area in which impacts from the MARVEL microreactor are anticipated to occur.

Resource Area	Region of Influence
Geology and Soils	The area surrounding TREAT and MFC.
Air Quality	INL and nearby offsite areas that could be affected by air quality impacts from the MARVEL microreactor.
Ecological Resources	INL and adjacent offsite areas where ecological communities exist, including non-sensitive and sensitive habitats and species that could be directly or indirectly affected by the MARVEL microreactor.
Cultural and Historical Resources	The TREAT Reactor building.
Infrastructure	INL utilities including power supply, water, and sewer
Waste Management	INL waste treatment, storage, and disposal facilities.
Human Health – Normal Operations	INL onsite project workers and the offsite public within 50 miles of the project location.
Human Health – Facility Accidents	INL noninvolved workers and the offsite public within 50 miles of the project location.

In addition, cumulative impacts can result from individually minor, but collectively significant, onsite or offsite actions occurring over time (40 CFR 1508.7). Those actions within the spatial and temporal boundaries (i.e., project impact zone) of the MARVEL microreactor are considered in this EA. There are several proposed projects at the INL Site that DOE considers reasonably foreseeable that could contribute to cumulative impacts. Those that DOE reviewed include the following:

- Remote-Handled Low Level Waste (LLW) Disposal Facility
- Plutonium-238 Production for Radioisotope Power Systems
- Recapitalization of Infrastructure Supporting Naval Spent Nuclear Fuel Handling
- Expanding Capabilities at the Power Grid Test Bed
- Versatile Test Reactor
- Construction and Demonstration of a Prototype Advanced Mobile Nuclear Microreactor
- Utah Associated Municipal Power Systems Carbon Free Power Project
- Oklo, Inc. microreactor.

DOE reviewed the resources at risk; geographic boundaries; past, present, and reasonably foreseeable future actions; and baseline information in determining the significance of cumulative impacts. Actions that have no impact do not result in cumulative impacts. Conclusions regarding cumulative impacts are included in the following sections.

To guide the assessment of environmental impacts, this EA uses three levels of impact—SMALL, MODERATE, or LARGE—which are defined as follows:

SMALL – Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

MODERATE – Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE – Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

Scoping and preliminary analyses indicate the MARVEL microreactor would not impact the following elements; therefore, this EA does not analyze these elements further for the reasons described:

- Environmental Justice – Analysis identified no adverse human health or environmental effects for the MARVEL microreactor at the INL Site or in surrounding areas. Therefore, the MARVEL microreactor would not affect minority or low-income populations.
- Ground and Surface Water – There are no perennial or permanent surface water bodies near MFC. All facilities within the MFC fenced area are in a single local topographically closed watershed. The MFC watershed contains natural drainage channels, which can concentrate overland flow during periods of high precipitation or heavy spring runoff. TREAT is located in an adjacent local topographically closed watershed, which also contains no identifiable perennial, natural surface water features. The elevation of TREAT is 5,122 ft above sea level and more than 7 ft above the water level predicted to occur under the probable maximum flood event corresponding to repeated rainfall events over frozen ground; therefore, TREAT is not subject to flooding. The MARVEL microreactor does not include activities that physically or chemically alter surface water resources. The MARVEL microreactor system is a closed system and does not have any liquid or gaseous discharges into the environment during normal operation. Therefore, the MARVEL microreactor does not affect ground or surface water resources.
- Land Use – The facility modifications, construction, and operations proposed as part of the MARVEL microreactor would occur in existing facilities. The MARVEL microreactor does not require construction of new facilities or additional land use or ground disturbance. The MARVEL microreactor would have no impacts on land use or aesthetics.
- Noise – The TREAT Facility is about 3.5 miles from the INL Site boundary. The closest noise-sensitive receptor is an agricultural homestead that is about 5.0 miles from MFC and about 1.9 miles from U.S. Highway 20, which is expected to be the primary noise at this location. Discernable noise from the MARVEL microreactor is generated from the heat rejection units located outside the TREAT Reactor building. Based on manufacturer data, this equipment produces sound in the range of about 65 to 66 decibels (dBA). To give context, a whisper registers about 30 dBA, normal conversation about 50 to 60 dBA, a ringing phone 80 dBA, and a power mower 90 dBA (OSHA, 2011). The MARVEL microreactor will be located at the TREAT Reactor building, which includes a number of noise-generating sources typical of industrial activities such as industrial HVAC equipment, blowers, moving equipment, and vehicles. The noise generated from the MARVEL microreactor and associated facility modifications and other activities would be consistent with other existing industrial equipment at the TREAT Facility and the potential concurrent noise would be similar to existing levels. As a result, the MARVEL microreactor would not cause a change in the noise environment at the INL Site.
- Socioeconomics – Implementing the MARVEL microreactor would result in hiring up to 10 employees at the INL Site. In 2018 the total population of Bannock, Bingham, Bonneville, Butte, Clark, Jefferson, and Madison counties was 322,434. The impacts to population, housing, employment, income, community services, public transportation, and public finance from an additional 10 employees would be negligible. The impacts to socioeconomic factors from the MARVEL microreactor would not likely be distinguishable from current INL Site operations, and the anticipated change would not noticeably alter socioeconomic conditions in the seven county region around the INL Site.

3.1 Idaho National Laboratory Site

The INL Site is an 890-square-mile DOE facility located on the Eastern Snake River Plain. It is primarily located within Butte County, but portions of the INL Site are also in Bingham, Jefferson, Bonneville, and Clark Counties. All land within the INL Site is controlled by DOE, and public access is restricted to highways, DOE-sponsored tours, special-use permits, and the Experimental Breeder Reactor-I National Historic Landmark. The INL Site location and boundary is shown in Figure 11.

Public highways U.S. 20 and 26 and Idaho 22, 28, and 33 pass through the INL Site, but off-highway travel within the INL Site and access to INL Site facilities are controlled. Currently, INL employs about 5,200 people. No permanent residents reside on the INL Site. Population centers in the region include large cities (more than 10,000 residents), such as Idaho Falls, Pocatello, and Blackfoot, located to the east and south, and several smaller cities (less than 10,000), such as Arco, Fort Hall, Howe, and Atomic City, located around the INL Site.

Vegetation is dominated by low shrubs, such as sagebrush and rabbitbrush, a wide variety of grasses, and some juniper trees. The area is populated with animals that inhabit sagebrush grasslands. Animals include pronghorn, deer, elk, coyotes, badgers, rabbits and many birds including raptors, game birds, and waterfowl, a variety of small rodents, and several small reptiles. Many of the plants and animals that live within the boundaries of INL are culturally significant to the Shoshone-Bannock Tribes.

Cultural resources are numerous on the INL Site (DOE-ID, 2016). Resources that have been identified include:

- Pre-contact archaeological sites representing Aboriginal hunter-gatherer use over a span of approximately 12,000 years
- Historic archaeological sites representing settlement and agricultural development during the period from 1805 and the late 1920s
- Historic architectural properties associated with World War II and with the development of nuclear science and technology
- Areas of cultural importance to the Shoshone-Bannock Tribes.

Many of these resources are eligible for nomination to the National Register of Historic Places (NRHP). Archaeological sites and Native American resources are generally located in undeveloped areas, while historic architectural properties are found within facility perimeters at the INL Site. A tailored approach to management of these resources and compliance with relevant federal and state law is included in DOE-ID's INL Cultural Resource Management Plan (DOE-ID, 2016), which is based on a Programmatic Agreement among DOE-ID, the Idaho State Historic Preservation Office (SHPO) and the Advisory Council on Historic Preservation as well as an Agreement in Principle between DOE-ID and the Shoshone-Bannock Tribes.

The area surrounding the INL Site is classified as a Prevention of Significant Deterioration Class II area, designated in United States Code (USC) under the Clean Air Act (42 USC 7401 et seq) as an area with reasonable or moderately good air quality while still allowing moderate industrial growth. Craters of the Moon Wilderness Area, which is about 30 miles from the TREAT Facility, is classified as a Prevention of Significant Deterioration Class I area, and is the nearest area to the INL Site where additional degradation of local air quality is severely restricted. The INL routinely monitors air quality using a network of air monitors. The monitors collect samples to measure particulate matter (PM), radioactivity, and other air pollutants.

Releases of radionuclides to the environment from current INL operations can expose individuals near the INL Site to radiation. Types and quantities of radionuclides released from INL operations are listed in the National Emission Standards for Hazardous Air Pollutants (NESHAP) annual reports (DOE-ID, 2020), along with estimated doses caused by these releases. Historically, the dose to the maximally exposed individual (MEI) has been in the range of hundredths of an mrem/yr, and therefore less than 1% of the 10-mrem/yr federal standard.

INL Site workers receive the same dose as the general public from background radiation, but they also receive an additional dose from working in facilities with nuclear materials. The average dose to the individual worker (involved worker) and the cumulative dose to all INL Site workers (total workers) fall within the radiological regulatory limits of 10 CFR 835 (2011). According to the accepted risk estimator of 6.0×10^{-4} latent cancer fatality (LCF) per person-rem among workers, 0.05 LCF is projected for INL Site workers from normal operations in 2018 (DOE, 2020).

MFC is the most eastern INL facility complex. It is located about 38 miles west of Idaho Falls in Bingham County in the southeastern corner of INL. MFC is about 100 acres (inside the MFC fence) and about 2.7 miles from the southern INL Site boundary. MFC includes a wide variety of facilities and capabilities that support INL's nuclear research missions. Activities performed at MFC include R&D for new reactor fuels and related materials and demonstration of various nuclear energy technologies. In addition, MFC supports DOE programs for space and defense radioisotope power systems.

The TREAT Facility is located about 0.8 miles northwest of MFC. It is considered to be a part of MFC but is not located within the MFC fenced area. The TREAT Reactor building includes the TREAT Reactor, high bays, pre and post-irradiation test equipment, and fuel storage. The TREAT Reactor is an air-cooled reactor capable of pulsed transients up to 20 GW of power that is designed to perform transient testing of nuclear fuels and materials to support advances in nuclear energy. A paved access road to TREAT leads from MFC past the TREAT Reactor Control Building to the TREAT Reactor Building. The TREAT Reactor Control Building is about 0.45 miles from TREAT. A fence surrounds the perimeter of TREAT and encloses about 3.5 acres. The environmental impacts of TREAT operations were evaluated in the *Final Environmental Assessment for the Resumption of Transient Testing of Nuclear Fuels and Materials and Finding of No Significant Impact* (U.S. Department of Energy, 2014). Figure 12 shows the location of MFC and TREAT in relation to other INL Site facilities.

Figure 11. Location of the INL Site.

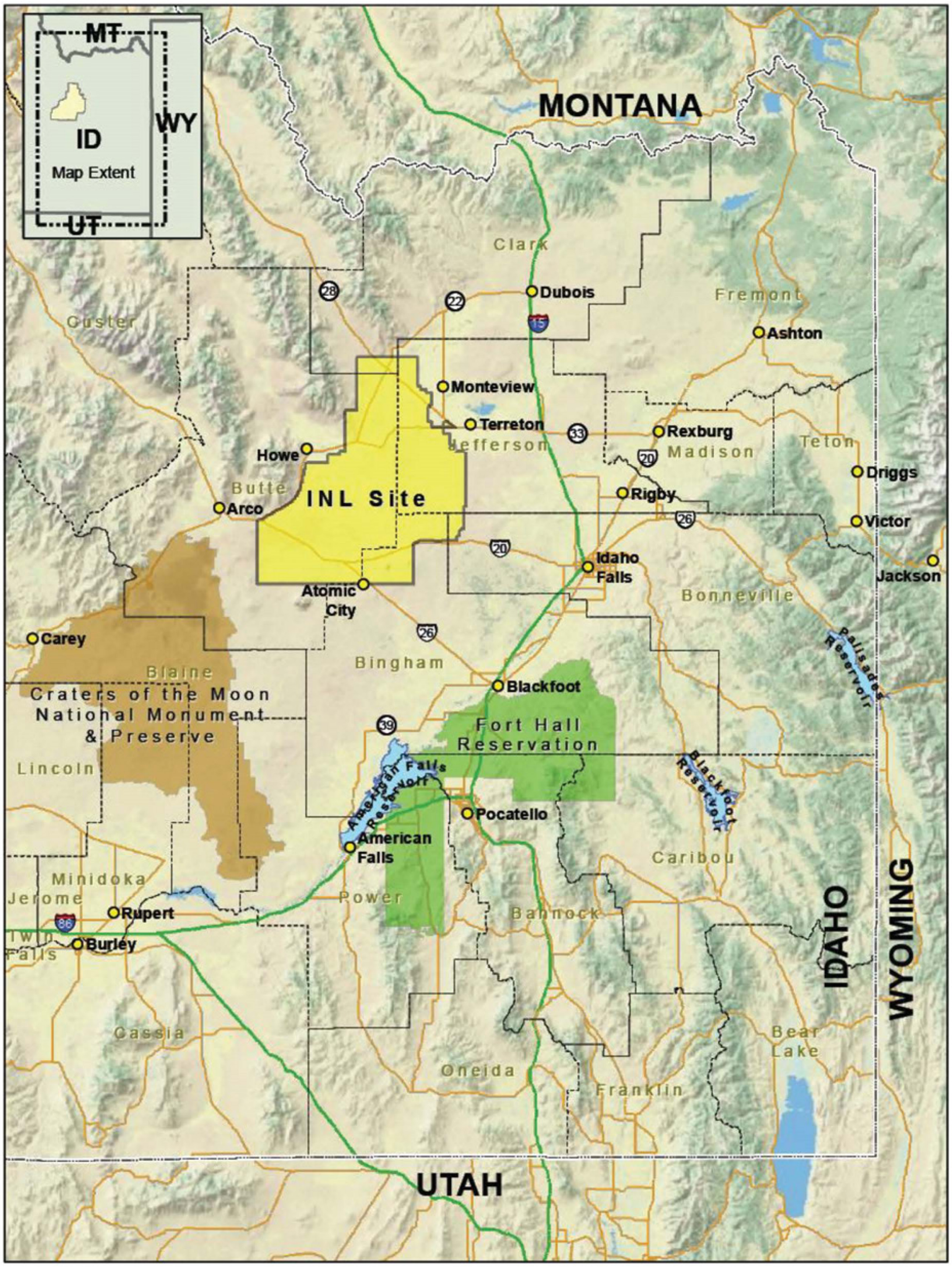
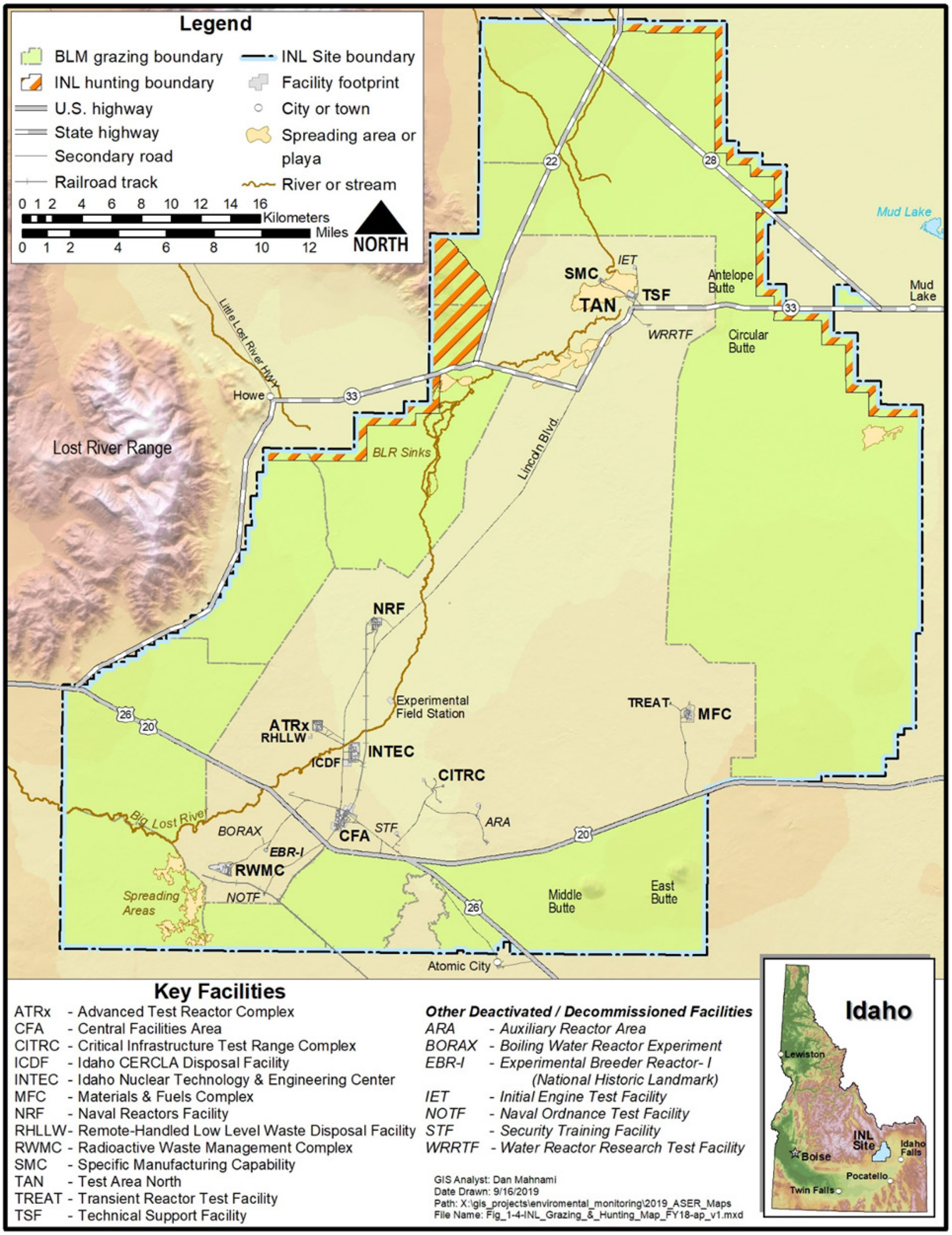


Figure 12. INL Site and facilities



3.2 Air Quality

Sources of nonradiological air emissions at the INL Site include oil-fired boilers, diesel engines, emergency diesel generators, small gasoline, diesel, and propane combustion sources, and from using chemicals and solvents. Boilers generate steam for heating facilities and are the main source of nonradiological air emissions at the INL Site. Diesel engines are mainly used to generate electricity for facility operations. Miscellaneous non-vehicle sources include small portable generators, air compressors, and welders.

Radionuclide emissions at INL occur from (1) point sources, such as process stacks and vents; and (2) fugitive sources, such as waste ponds, buried waste, contaminated soil areas, and decontamination and decommissioning (D&D) operations. Airborne releases of radionuclides from INL Site operations are reported each calendar year with the calendar year 2019 report released in June 2020 (DOE-ID, 2020). For calendar year 2019 the effective dose equivalent to the MEI member of the public was 5.59E-02 millirem (mrem) per year, which is 0.56 percent of the 10 mrem per year standard for the INL Site.

Radiological air emissions from MFC occur from spent fuel treatment at the Fuel Conditioning Facility, waste characterization, and fuel R&D at the Hot Fuel Examination Facility (HFEF), fuel R&D at the Fuel Manufacturing Facility, and post-irradiation examination at the Irradiated Materials Characterization Laboratory. These facilities are equipped with continuous emission monitoring systems and radionuclide sources are controlled with high-efficiency particulate air (HEPA) filters. The effective dose equivalent to the MEI member of the public from MFC operations in 2019 was about 5.37E-02 millirem (mrem) per year, which is about 96% of the effective dose equivalent to the MEI member of the public for the INL Site (DOE-ID, 2020).

3.2.1 Impacts to Air Quality

The MARVEL microreactor has the potential to generate minor amounts of toxic air pollutants and to generate radionuclide air emissions.

Modifications to the TREAT Reactor building would have no radiological impact on the general public. Required facility modifications are minimal and are typical activities currently performed at INL. Construction activities that occur in nonradiological areas and facility modifications within radiological areas would not generate radiological air emission.

Combustion equipment such as generators, portable heaters, ventilation equipment, and heavy equipment fueled with diesel may be used during project activities. In general, emissions during construction are exempt from Prevention of Significant Deterioration (PSD) review because the PSD requirements are primarily for major stationary sources and specifically exempt temporary increases in these emissions. Emissions from mobile generators are exempt from regulation since the generators will be in place less than 1 year.

In addition, trucks transporting the fuel pins from the fuel fabrication location at MFC to the TREAT Facility produce exhaust emissions. This analysis assumes transportation of fuel pins from MFC to TREAT requires at least 10 batches of shipments between the two facilities. Combustion of fossil fuels in construction equipment, trucks, and worker commuter vehicles would emit nonradiological hazardous air pollutants (HAPs). Temporary emissions include reactive organic gases, nitrogen oxides, and respirable PM with an aerodynamic diameter of 10 micrometers or less (referred to as PM_{10}). PM_{10} consists of PM emitted directly into the air (e.g., fugitive dust, soot, and smoke) from mobile and stationary sources and construction operations.

The mobile and intermittent operation of construction emission sources combined with most construction and facility modifications occurring indoors would result in dispersed concentrations of these HAPs adjacent to construction activities. The substantial transport distance of construction emissions from MFC to the nearest locations of the INL Site boundary (about 3 miles) would produce further dispersion and negligible concentrations of HAPs beyond the INL Site boundary. The intermittent operation of construction and trucks transporting MARVEL microreactor fuel from MFC to the TREAT Reactor building and worker commuter vehicles on public roads would result in low concentrations of HAPs. HAPs concentrations generated by facility modifications and fuel and worker transportation activities would not result in adverse air quality impacts.

Fuel fabrication activities at EFF and FASB, for MARVEL and ongoing activities, have the potential to generate minor amounts of toxic air pollutants and radiological emissions. Fuel fabrication for the MARVEL microreactor at INL uses traditional powder metallurgy processes and bench-scale laboratory equipment already in use at these facilities.

Emissions associated with activities occurring within EFF, including MARVEL and ongoing activities, include small amounts of uranium fumes and particulates and associated chemicals used during the fuel fabrication processes. EFF includes a dual stage bank of HEPA filters and a stack (MFC-794-001). Use of depleted uranium in EFF is limited to 1,000 kg/yr. Use of 5% enriched uranium is limited to 20 kg/yr, and use of 93% enriched uranium is limited to 12 kg/yr. Use of low enriched uranium is limited to 100 kg/yr for the EFF Atomizer (INL, 2019a).

FASB houses a vault, small hot cells, gloveboxes, hoods, and other equipment (sample preparation equipment, multiple microscopes, and other analytical equipment). Research-scale experimental fuel is produced by cleaning, alloying, forming, encapsulation, melting and casting, metal forming and cutting, reactions, welding, and powder processing. Multiple furnaces are used at FASB with a maximum operating temperature of 2200ºC. The FASB west room contains the pyrochemistry glovebox, which is an inert atmosphere glovebox used for developing low-enrichment fuels, treating waste from glovebox operations, working with corrosive materials, and testing equipment used in other facilities.

Emissions associated with activities occurring within FASB include radionuclides and very small amounts of chemicals. The effective dose equivalent (EDE) from FASB operations was calculated using the release factors based on the Environmental Protection Agency (EPA) approved methodology and is less than 0.1 mrem/year. FASB operations do not discharge air pollutants in quantities equal to or exceeding 100 tons per year, nor any pollutants equal to or exceeding the significant emission rates. Evaluations document that each toxic air pollutant emitted is less than all applicable acceptable ambient concentrations and all applicable acceptable ambient carcinogenic concentrations (INL, 2018).

As noted, similar fuel manufacturing activities currently occur in EFF and FASB. Fuel fabrication activities for the MARVEL microreactor uses existing processes in these existing facilities in accordance with the limitations set for in Air Permitting and Applicability Determinations (APAD) for these facilities (INL, 2018) (INL, 2019a). The dose from these facilities is tracked based on inventory on a quarterly basis. Emissions from fuel fabrication for the MARVEL microreactor at EFF, FASB and other facilities at MFC would be consistent with current emissions and operations. The MARVEL fuel fabrication in these INL facilities is not considered a modification in accordance with Idaho Administrative Procedures Act (IDAPA 58.01.01, 2000) and 40 CFR 61 Subpart H (Verdoorn, 2018). As a result, fuel fabrication at INL for the MARVEL microreactor is not anticipated to cause a change in air emissions from these facilities and would not result in adverse air quality impacts. The impacts from fabricating the MARVEL microreactor fuel at INL would be small.

The safety goal of MARVEL microreactor is to control the release of radionuclides to minimize the risk to the public, workers, and environment. This goal is achieved by maintaining fuel integrity, which is the primary contributor to radionuclide release. Fuel integrity is maintained by ensuring the fuel stays below the temperature at which fuel and clad damage occurs. The available data suggest that if fuel temperatures are kept below ~650°C during operation, fission-gas release from fuel into the plenum is negligible. The low fuel centerline temperature reduces fission-product release to negligible amounts and decreases stored energy in the fuel (Olander et. al. 2007). The peak cladding temperature during normal MARVEL microreactor operations is 550°C.

In addition, several barriers inhibit the release to the environment of radioactivity from fission products generated in the MARVEL microreactor. The first barrier is the fuel itself. Many of the fission products will remain trapped in the fuel matrix, though some may diffuse out of the fuel and into the sodium bond liquid or the gas plenum where the fuel cladding, the second barrier, retains the fission products. The third fission-product barrier is the NaK coolant system and the sealed coolant system piping and core barrel. The fourth barrier is the TREAT reactor building with confinement properties that include the building walls, floor, and ceiling. Negative air pressure combined with HEPA filtrations further filters building exhaust air.

The NaK coolant acts as a radionuclide barrier by retaining fission products by plate-out, chemical solubility, or adsorption mechanisms. The radionuclides that are not retained are activation products of potassium, mainly Ar-39 and Ar-41, and will accumulate in the cover gas space. Because the system is sealed, accumulation of Ar-39 can also increase the pressure of the system. It is estimated that about 25 ml of Ar-39 (1.5 curies) and 2.55×10^{-5} ml of Ar-41 (1.96 curies) would be produced over the life of the reactor.

During reactor operation, discharges of liquid or gas from the primary system is not anticipated. The gas volume is sealed, and the total cover gas volume is large enough to accommodate thermal expansion and contraction of the NaK. Discharging NaK or cover gas from the reactor will not be required until decommissioning. At the end of life, prior to coolant draining, the cover gas will be extracted by a simple gas transfer line into a gas storage container, which will be disposed of as LLW as discussed in Section 393.7.

An argon gas blanket may be maintained on the lead-bismuth eutectic heat exchangers to reduce formation of lead and bismuth oxide, and the process of maintaining this blanket would involve venting small volumes of argon gas (about one cubic foot per day or less). This gas will not contain radionuclides, and the gas temperature will be low enough that there should only be trace amounts of lead fumes. Formation of oxide may require periodic oxide removal and replenishment of the heat exchangers.

Because the MARVEL microreactor is a closed-loop system, there are no direct emissions from the fission process during normal operations. However, neutron activation of the air in the pit (region between the microreactor and the shielding) could conceivably generate minor quantities of particulate and gaseous radionuclides that could be exhausted from the TREAT reactor building stack when the ventilation system is activated. The impact of these potential unabated radioactive air emissions on a collocated worker and offsite member of the public were assessed by Sondrup (2021) and determined to be extremely low compared to regulatory limits. Doses were calculated with CAP88-PC, a set of computer programs, databases, and associated utility programs for estimation of dose and risk from radionuclide emissions to the air. CAP88-PC is both a mature and the EPA-recommended model for demonstration of compliance with the applicable performance objective (40 CFR 61, Subpart H).

During decommissioning, hazardous and radioactive materials will be removed to ensure protection of workers, public health and safety, and the environment. Activities associated with D&D of the MARVEL microreactor will be performed in existing INL facilities. The actual emissions would be determined when more definite operational conditions have been defined. D&D operations will comply with all regulatory requirements of the Clean Air Act, and, therefore, are bounded by the regulatory limits. INL will develop an APAD for each applicable source of radiological air emissions associated with the MARVEL microreactor to ensure compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP), Subpart H, including the regulatory limit that facilities must not exceed those amounts that would cause a member of the public to receive an effective dose equivalent (EDE) of 10 mrem/year. The APADs will also demonstrate compliance with the facility emissions cap site wide permit. In the event a Permit to Construct is required, an application for the Permit to Construct will be submitted to Idaho Department of Environmental Quality, pursuant to IDAPA 58.01.01, "Rules for the

Control of Air Pollution in Idaho" and an Approval to Construct application will be submitted to EPA, pursuant to 40 CFR 61.96."

As described above, the MARVEL microreactor (including facility modifications, fuel production, operation, D&D, and waste management) would generate emissions. Review of the impacts shows that the combined activities would produce minor amounts of air emissions. Transport of these emissions to the INL Site boundary would produce negligible ambient air pollutant concentrations at offsite locations. Therefore, the minor increase in offsite air pollutant concentrations produced from the MARVEL microreactor, in combination with emissions from other past, present, and reasonably foreseeable future actions, would result in air pollutant concentrations that would not exceed the state and National Ambient Air Quality Standards and would not substantially contribute to cumulative air quality impacts. Similarly, any radioactive air emissions would result in negligible dose impacts to collocated workers and offsite members of the public. The impacts from the MARVEL microreactor, including cumulative impacts, would be small.

3.3 Ecological Resources

Ecological resources include the plant and animal species, habitats, and ecological relationships of the land and water areas within the area of impact, which is the area directly or indirectly affected by the MARVEL microreactor. Particular consideration is given to sensitive species, which are those species protected under federal or state law, including threatened and endangered species, migratory birds, and bald and golden eagles. For the purposes of this EA, sensitive and protected ecological resources include plant and animal species that are federally (United States Fish and Wildlife Service) or state- (Idaho Department of Fish and Game) listed for protection. Historical reports and further information on ecological resources on the INL Site are available on the DOE-ID Environmental Surveillance, Education, and Research contractor's website (INL 2019b).

3.3.1 Impacts to Ecological Resources

Impacts to ecological resources are considered significant if they result in a loss of protected or sensitive species or loss of local populations from direct mortality or diminished survivorship.

The facility modifications and operations proposed as part of the MARVEL microreactor would occur in existing facilities. The MARVEL microreactor does not require construction of new facilities or additional land use or ground disturbance. The MARVEL microreactor would have no impacts on ecological resources from these proposed activities.

Trucks transporting fuel pins from the fuel fabrication location at MFC to the TREAT Reactor Facility and worker commuter vehicles have the potential to impact wildlife from inadvertent vehicle strikes. Vehicle noise also disturbs wildlife, causing populations to relocate. While elk and deer adapt to busy highways, roads with continuous, slow-moving traffic cause displacement and changes in range use. Roads displace larger animals, but smaller animals suffer different effects. Because smaller animals are less noticeable and slower-moving, direct kills from motorized vehicles are common.

This analysis assumes transportation of fuel pins from MFC to TREAT requires at least 10 batches of shipments between the two facilities. Increased motor vehicle activity from transportation events between TREAT and MFC would not result in major disruptions to wildlife or increases in wildlife mortality, because the MARVEL microreactor is located where vehicle use regularly occurs. The intermittent operation of trucks transporting MARVEL microreactor fuel from MFC to the TREAT and the low transport speed between facilities further reduce the likelihood of vehicle and wildlife collisions. The loss of protected or sensitive species or loss of local populations from direct mortality or diminished survivorship is not anticipated.

The MARVEL microreactor is anticipated to require an additional 10 employees at the INL Site. The addition of 10 additional worker commuter vehicles on public roads would not be discernible from current INL operations. Therefore, impacts to wildlife would be negligible.

Radiological activities that cause direct radiation of the environment, or that discharge or otherwise release radioactive material into the environment must comply with DOE-STD-1153-2019, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE, 2019b) to show that dose rates to representative biota populations do not exceed the dose rate criteria in DOE Order 458.1. The impact of potential radioactive air emissions on terrestrial biota were assessed using RESRAD-BIOTA and a Level 1 screening analysis are documented in *The Analysis of Radiological Impacts to Terrestrial Biota in Support of the Environmental Assessment for the Microreactor Applications Research, Validation, and Evaluation (MARVEL) Microreactor at Idaho National Laboratory* (Claver & Case, 2020). Radionuclide soil concentrations around the TREAT reactor facility from potential air emissions were conservatively estimated and compared to Biota Concentration Guides (BCGs). Terrestrial BCGs are limiting concentrations of radionuclides in soil that would not cause dose rate criteria for protection of populations of terrestrial biota to be exceeded. The analysis shows that the limits established for protection of terrestrial biota would not be exceeded.

From a cumulative impact perspective, the incremental impacts of the MARVEL Project when added to past, present, and reasonably foreseeable actions at the INL Site are small.

3.4 Cultural and Historic Resources

The MARVEL microreactor was reviewed under section 106 of the National Historic Preservation Act (NHPA) per 36 CFR 800 (2000) through processes identified in the INL Cultural Resource Management Plan (CRMP) (DOE-ID, 2016) and supporting documents by INL Cultural Resource Management Office personnel meeting the appropriate Secretary of the Interior's Professional Qualifications Standards for cultural resource management under 36 CFR 61 (1999). The Cultural Resource Review is documented in BEA-20-H116 (Scales-English, 2020) and is summarized below:

The direct and indirect Area of Potential Effect (APE) includes the following architectural properties: TREAT Reactor building (MFC-720), TREAT Reactor (MFC-726), TREAT Control Room Building (MFC-724), FASB (MFC-787), and EFF (MFC-794). Of these properties, two were previously evaluated as potentially eligible for listing to the NRHP, one is newly recommended eligible, and two are determined not eligible (MFC-721 and MFC-794). The three historic properties evaluated for potential effects include the following: the TREAT Reactor building (MFC-720) (Category 1), TREAT Reactor (MFC-726) (newly evaluated), and FASB (MFC-787) (Category 3) (DOE-ID, 2016).

The proposed fuel production aspects of the MARVEL microreactor project includes the use of FASB and EFF. FASB is recommended eligible for listing to the NRHP and is considered a historic property per the INL CRMP (DOE-ID, 2016). EFF is recommended not eligible (DOE-ID, 2016). As described, no modifications to the facilities are required, but some internal reconfiguration of bench-scale equipment may occur. Internal reconfigurations of active laboratories are an exempt activity and do not have the potential to affect the historic character of architectural properties.

The TREAT Reactor building and TREAT Reactor are potentially eligible under Criteria A and C for contributions to Science and Engineering dating from 1942 to 1970. FASB is potentially eligible for its contributions to Science and Engineering during the same time period as the TREAT Reactor building (MFC-720) and TREAT Reactor (MFC-726). Within the APE, there are no archaeological resources present, as confirmed by 2013 surveys conducted by Pace and Williams (Pace & Williams, 2013).

Construction of the TREAT Reactor building (MFC-720) began in February 1958 on the high-bay containment building that would house the TREAT Reactor (MFC-726). The TREAT Reactor building was first modified and expanded in 1960. Subsequent modifications and expansions of the building occurred in 1972 and around 1980. It is likely these modifications were made to accommodate expansion in mission and facility needs as the nuclear science and engineering program across the INL Site was in full swing. The reactor was shut down in 1994 and placed in stand-by mode while the building was closed, cool and dim.

Construction began on The TREAT Reactor in February 1958 on the subsurface aspects of the reactor structure and was complete by November in the same year. With the completion of the MFC-720 in 1958, the above-ground components of the reactor were installed and operational by 1959. Criticality occurred on February 23, 1959 (Boland, Geier, MacFarlane, Elias, & Fruend, 1960). Over the years, some modifications have been made to the research equipment used during operation, such as the addition of a hodoscope, but the original structural integrity of the reactor remains intact. During standby from 1994 to 2017, reactor modifications were not made, but components were prepped in a manner which allowed for successful operation after decades of inactivity.

In 2014, actions were initiated to restart the reactor (MFC-726) and upgrade components of the containment building (MFC-720) to meet new needs in research and mission for DOE (DOE-ID, 2014). Restart and use of the facility began in 2017.

Of the three historic properties present within the APE, modifications to meet the needs of the MARVEL microreactor will occur only within the TREAT Reactor building (MFC-720). Due to the operation of MARVEL microreactor inside the MFC-720 and in proximity to the TREAT Reactor (MFC-726), consideration of potential effects to the TREAT Reactor have been evaluated. Modifications to the TREAT Reactor (MFC-726), FASB (MFC-787), or EFF (MFC-794) are not anticipated for the MARVEL microreactor. If reconfiguration of active laboratory spaces are to occur within EFF and FASB, they are considered to be an exempt activity (Internal Reconfiguration of Active Laboratories), as per the INL CRMP (DOE-ID, 2016). MFC-726 will not be impacted in any way throughout the implementation and operation of the MARVEL microreactor project.

The MARVEL microreactor will be placed in a storage pit located in the northern bay of MFC-720. Venting components from the enclosed space during operations require penetrations to accommodate heat and emergency piping and equipment located on the exterior aspect of the building.

As described, the MARVEL microreactor will have no adverse effects to historic properties. The proposed use of the storage pit and indicated modifications to MFC-720 and MFC-721 are consistent with the ongoing R&D activities associated with science and engineering at INL. Furthermore, placing and operating the MARVEL microreactor in proximity to the TREAT Reactor will not affect the historic property. Use of EFF and FASB for fuel production is consistent with science and engineering research activities and does not pose a threat to the historic integrity of FASB.

The MARVEL microreactor would have no adverse effects to eligible or potentially eligible NRHP sites. Therefore, the MARVEL microreactor does not contribute to cumulative impacts to eligible cultural and historical resources.

The proposed use of FASB for fuel fabrication is not anticipated to alter the historic character. Furthermore, internal bench-level reconfigurations of these facilities fall within the definition of an exempt activity (Internal Reconfiguration of Active Laboratories). As such, the proposed use of FASB is determined to have no effect on the historic property.

Per the requirements identified in the INL CRMP (DOE-ID, 2016), the SHPO will not be consulted prior to issuance of the EA for public comment given the undertaking is anticipated to have No Adverse Effects to TREAT building (MFC-720) and TREAT reactor (MFC-726), and No Effects to FASB (MFC-787).

3.5 Geology

The TREAT Facility at INL is located on the Eastern Snake River Plain (ESRP), part of the Snake River Plain, a large physiographic region (~90 km [56 mi] wide and 560 km [348 mi] long) with low-relief and covered by basaltic lava flows and sediments. The Snake River Plain extends in a broad arc across southern Idaho from the Yellowstone Plateau, Wyoming on the east and into eastern Oregon on the west (Figure 13). Surface elevations on the Snake River Plain decrease continually and gradually from approximately 2,000 m (6,562 ft) near Yellowstone, to approximately 650 m (2,132 ft) near the Idaho-Oregon border.

The ESRP represents the track of buried and extinct volcanic centers associated with passage of the North American plate over the relatively stationary "Yellowstone hotspot" (Pierce & Morgan, The Track of the Yellowstone Hot Spot: Volcanism, Faulting, and Uplift, 1992) (Pierce & Morgan, 2009) (Smith, et al., 2009). From about 6.3 to 8.4 million years ago, the crust beneath the ESRP at and near INL's location was impacted by volcanism associated with the Yellowstone hotspot (McCurry, et al., 2016) (Anders, et al., 2014) (Schusler, Pearson, McCurry, Bartholomay, & Anders, 2020). Volcanism within the last 2.1-million years associated with the Yellowstone hotspot is now beneath the Yellowstone Plateau (Christiansen, et al., 2007), 160 to 230 km (99 to 143 mi) northeast of the INL Site. Since about 4 million to 2,100 years ago in the ESRP at and around INL, basaltic magma has continued to periodically erupt producing volcanic vents and lava flows (Kunz, et al., 1994) (Kunz, Anderson, Champion, Lanphere, & Grunwald, 2002) (Kuntz, Skipp, Champion, Gans, & Van Sistine, 2007). Surface basalt flows at the INL Site range in age from 13,000 years old to 1.2 million years old (Kunz, et al., 1994). During intervening eruptive periods, sediments have been deposited by wind and surface water. Along the southern INL Site border, basaltic magma stagnated in the crust and eventually evolved in composition to erupt from 300,000 years to 1.4 million years ago as rhyolitic domes which formed five buttes with heights between 120 and 750 m (394 to 2,460 ft) (McCurry, Hayden, Morse, & Mertzman, 2008).

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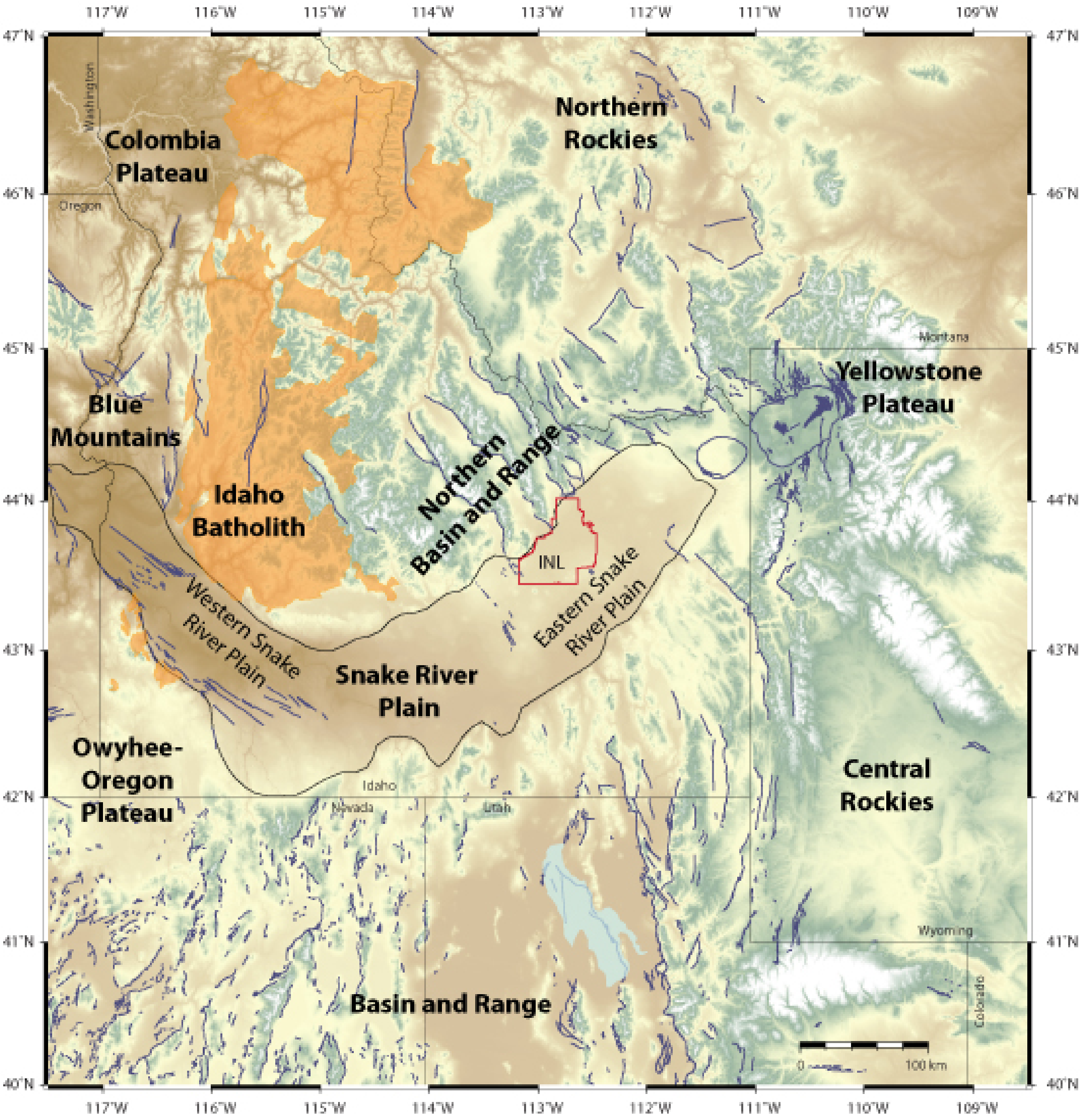
Figure 13. Location of the Snake River Plain and the INL Site.



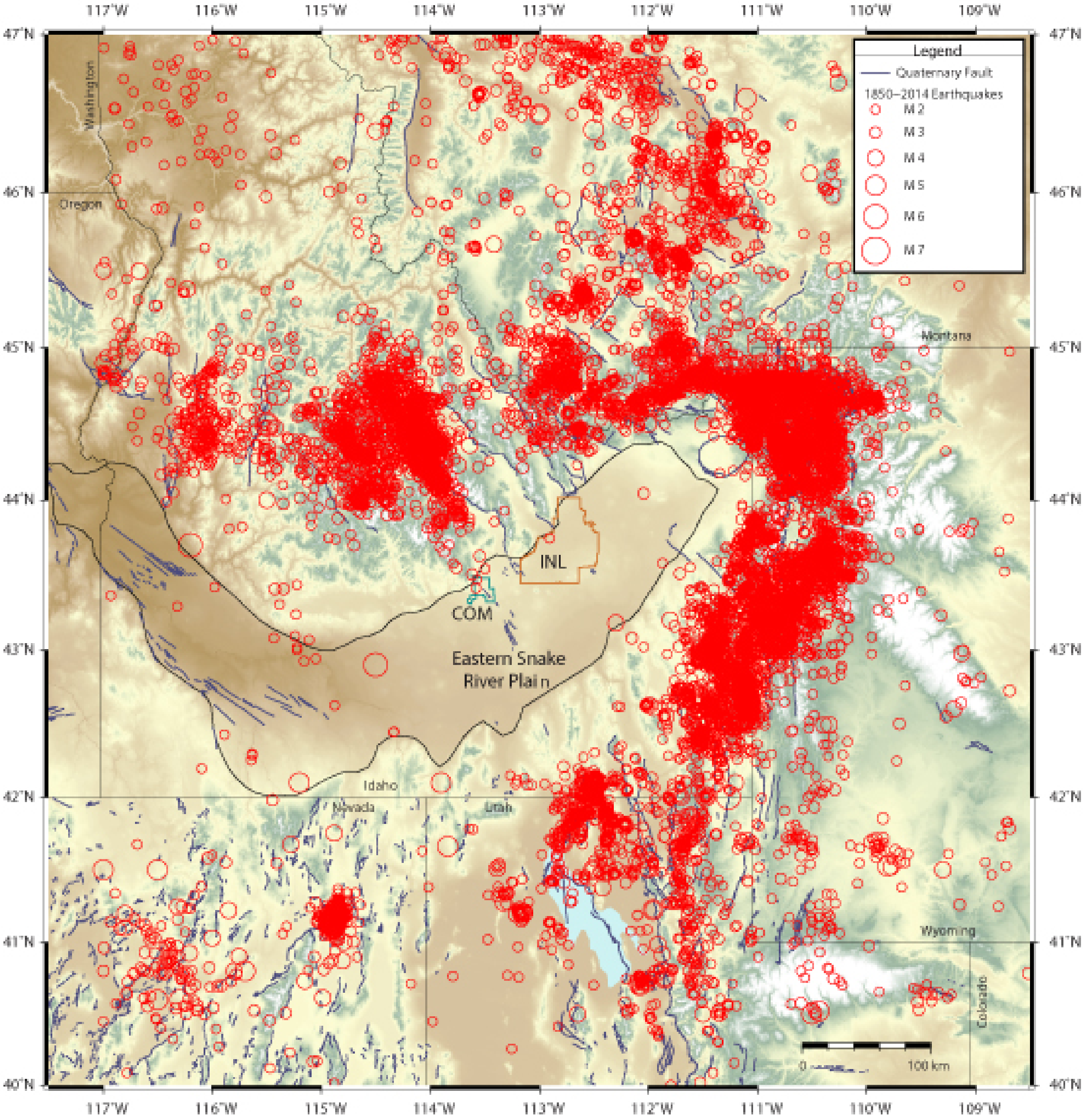
The Snake River Plain transects and sharply contrasts with the surrounding mountainous country of the Northern Basin and Range Province. Summits of mountains surrounding the Snake River Plain rise to an elevation of 3,660 m (12,000 ft), producing a maximum elevation contrast of about 2,150 m (7,050 ft). North and northwest trending mountain ranges, up to 200 km (124 mi) long and 30 km (19 mi) wide, are separated by intervening basins filled with terrestrial sediments and volcanic rocks. Quaternary (<2.6 million year old) normal faults typically bound the basins along one side adjacent to range fronts.

Earthquakes occurring from 1850 to 2014 with magnitudes >2.0 compiled from INL's and other nearby seismic networks show a parabolic distribution of epicenters in the mountainous region outside of the ESRP (Figure 14). The two largest earthquakes, 1959 moment magnitude (M) 7.3 Hebgen Lake, Montana and 1983 M 6.9 Borah Peak, Idaho, produced surface ruptures along 30 to 36 km long normal faults (Doser, 1985) (Crone, et al., 1987). The 1983 earthquake caused ground shaking but no damage at INL since its epicenter was 80 to 115 km (50 to 70 mi) northwest of the INL Site (Figure 14) (Richins, et al., 1987). Infrequent small magnitude earthquakes occur within the ESRP. From 1972 to 2018, INL's seismic network has located 111 microearthquakes with magnitudes <2.4 in the ESRP (Bockholt, Payne, Graw, & Sandru, 2020). Of these, 18 occurred within INL boundaries and none were located near the TREAT Facility.

The TREAT Facility at MFC is located on the eastern part of the INL Site and on thin surficial sediments of primarily eolian origin overlying basaltic lava flows. Surface sediment thicknesses range from ~0.3 m (1 ft) to 3 m (10 ft) and are composed primarily of sandy silt and clayey silt containing basalt rock fragments at some locations. Basaltic lava flows at MFC erupted as Pahoehoe flow types and generally have rubbly zones from the top of the flow to more massive interiors at the center (Northern Testing Laboratories, 1978). MFC is underlain by basalt lava flows that erupted from nearby vents from ~350,000 years ago to over 1.4 million years. The closest basaltic vents are >7 km (4.3 mi) east and south of TREAT. There are no mapped faults at or near TREAT nor volcanically induced features such as ground cracks or fractures (Northern Testing Laboratories, 1978) (Kunz, et al., 1994).

No environmental impacts are assessed from the MARVEL microreactor in TREAT as a result of potential future earthquakes. The TREAT Reactor building is classified as a seismic design category (SDC), SDC-2. Per DOE Order 420.1C, *Facility Safety* (2019), implemented through DOE Standard, DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria* (2016), seismic design criteria for TREAT are obtained from the International Building Code (IBC). The MARVEL microreactor and its installation in TREAT will be designed to withstand vibratory ground motions (or ground shaking) as specified by IBC. Ground shaking levels are obtained from the U.S. National Seismic Hazard maps available online from the U.S. Geological Survey (https://www.sciencebase.gov/catalog/item/5d5597d0e4b01d82ce8e3ff1) for the specific rock conditions and geographical location of TREAT. Because no impacts from the MARVEL microreactor would occur as a result of earthquakes, cumulative impacts are not expected.

Figure 14. Earthquakes occurring from 1850 to 2014 with magnitudes >2.0 in areas surrounding the INL Site.



3.6 Infrastructure

Site infrastructure includes basic resources and services required to support planned construction and operation activities and the continued operations of existing facilities. For the purposes of this EA, infrastructure is defined as electricity, fuel, water, and sewage.

The facility modifications, construction, operations, and D&D proposed as part of the MARVEL microreactor would occur in existing facilities. The MARVEL microreactor does not require construction of new facilities or additional land use or ground disturbance. In addition, current electrical energy consumption at INL is 156,639 MW-hours annually. The MARVEL microreactor would use about 10 kW-hours of electricity supplied by the INL Site power infrastructure over the life of the project, so the increase in use is anticipated to be less than 0.3%. Impacts to electrical energy consumption at MFC and the INL Site would be small and nearly indiscernible from current consumption rates.

The MARVEL microreactor water loop heat exchanger uses about 116 gallons of water and adding 10 new employees under the MARVEL microreactor would result in a small increase in water consumption. The small increase in water consumption would not affect the ability of the system to provide an adequate supply to meet the requirements for personnel, process, and fire protection purposes.

MFC has a sanitary sewer system to collect and treat domestic wastewater from the facilities. The MFC wastewater lagoons were designed for flows of about 14,950 gallons per day. Adding 10 new employees under the MARVEL microreactor would not result in discernable impacts to the system.

INL employs about 5,200 employees (Jankowski, 2020). During a typical workweek, the majority of employees take buses to various work areas at the INL Site, covering about 70 bus routes. About 1,200 private vehicles also travel to and from the INL Site daily. Adding 10 new commuter trips per day under the MARVEL microreactor would not result in discernable impacts traffic at the INL Site or on public roads.

The MARVEL microreactor would have small impacts on INL Site infrastructure. These small impacts would be nearly indiscernible from current operations when combined with past, present, and reasonably foreseeable future actions. Cumulative impacts would be small.

3.7 Waste Management

The INL Waste Management Program (WMP) provides the processes and procedures for compliant management of radioactive waste, hazardous waste, mixed waste, universal waste, and hazardous recyclables at INL. The INL WMP facilitates management of containerized radioactive waste, hazardous waste, mixed waste, universal waste, and hazardous recyclables from characterization through disposal so that long-term waste storage prior to disposition is minimized and exposures are below allowable levels and as low as reasonably achievable (ALARA) in compliance with DOE Order 435.1 (2007).

All radioactive waste is managed according to subject to DOE O 435.1, *Radioactive Waste Management* (see glossary for definitions of waste types).

The construction and mobilization phase of the MARVEL microreactor would generate non-radioactive electronic waste, scrap metal, and other construction-related debris. Construction debris, electronic waste, and scrap metal could be recycled or disposed of at onsite facilities or sent offsite, but would be recycled to the extent possible, regardless of facility. The various non-radioactive total waste volumes generated as part of the MARVEL microreactor construction and mobilization are expected to be less than 3 m^3 (90 ft^3), some of which can be recycled. To put this volume in perspective, the INL industrial waste landfill accepts and buries about 23,000 m^3 (about 812,000 ft^3) of waste and trash each year. The impact from constructing and mobilizing the MARVEL microreactor on industrial waste generation at the INL Site would be small.

LLW may be generated during construction and would include contaminated used personal protective equipment, wipes and rags, and tools. Solid LLW would be sent to an offsite disposal facility permitted and licensed to accept LLW. It is expected that the contamination levels on the LLW from construction would be very small as a result of the handling of MARVEL microreactor components containing reactor fuel and working in established Radiological Buffer Areas in the TREAT Reactor Facility. The volumes of these various LLWs generated during this phase are expected to be less than 5 m^3 (180 ft^3). The INL WMP has an established source term for contamination and LLW originating in the TREAT Reactor Facility. At the time of disposition, Waste Management personnel will evaluate the source term contribution from the MARVEL microreactor fuel depending on activities that generated the waste, but it is expected that the TREAT source term will be bounding for all LLW.

No mixed low-level waste (MLLW) (waste which is both radioactive and hazardous) is anticipated to be generated during the construction and mobilization phase. However, if MLLW were to be generated, the volumes would likely be minimal and would be accumulated and stored in accordance with federal and state regulations and disposed of at an offsite permitted and licensed facility following existing processes.

Construction and mobilization phase waste will use established INL WMP waste disposition outlets. The expected volumes of all types of construction and mobilization phase waste will not impact existing WMP resources and schedules. This phase may generate up to eight cubic meters (about 280 ft^3) of all waste types. MFC waste management personnel typically handle an average of 680 m^3 (24,000 ft^3) per year.

Waste generate from fuel fabrication in EFF and FASB will generate small amounts of industrial waste, LLW, and MLLW.

It is expected that the waste generated during the microreactor operations phase will be limited to LLW associated with the day-to-day operations and maintenance of the MARVEL microreactor. For comparison purposes, the TREAT and total MFC LLW waste generation for FY2020 was used to evaluate the MARVEL microreactor generation rate, as shown in Table 6.

Table 6. Annual LLW Generations rates for MFC, TREAT and the MARVEL microreactor.

Reactor or Complex	Annual LLW Generation Rate
TREAT	2.72 m^3 (96 ft$^{3)}$
MARVEL	2.72 m^3 (96ft^3) (assumed the same as TREAT)
MFC	FY2020- 832.45 m^3 (29394 ft^3)

The LLW generated from MARVEL operations would be included in the TREAT facilities' total but was set equivalent for this estimate. This volume expected from MARVEL operations would contribute about 3.3% of the MFC LLW volume. The TREAT facility has a routine LLW collection program and the small contribution from the MARVEL microreactor operation and maintenance would be easily accommodated into standard radioactive waste management programs. The LLW generation at this rate would use existing established INL Waste Management Program waste disposition outlets and would have a negligible impact on Waste Management resources and schedules.

No MLLW is anticipated to be generated during the reactor operations phase. However, if MLLW were to be generated, the volumes would likely be minimal and would be accumulated and stored in accordance with federal and state regulations and disposed of at an offsite permitted and licensed facility following existing processes. The most likely source of MLLW would be sampling and analysis waste, which would be neutralized during the analysis and disposed of as laboratory waste. If the samples are not completely used, the resulting waste will meet requirements for onsite permitted storage, which currently has disposition paths open for treatment and disposal.

For D&D of the MARVEL microreactor, an activation analysis and modeling of the MARVEL microreactor beryllium oxide side reflectors reveals that these components will be DOE LLW or NRC Class A LLW and can be dispositioned through existing disposition paths, either DOE or commercial sites (Black & Grant, 2021) (Trellue, Vedant, Rao, Lange, & Sterbenz, 2021). It is assumed that this analysis would be bounding for other components and wastes that may be generated. Given this, it is concluded that all radioactive waste, other than the reactor fuel, generated in this phase will be NRC Class A LLW or MLLW and has current disposition paths in DOE or commercial facilities.

The disposition of the primary coolant, NaK, will be one of the major waste generating operations. NaK used as the primary coolant can become activated in a neutron flux with predominate activation products being the short-lived, (Trellue, Vedant, Rao, Lange, & Sterbenz, 2021). A minor amount of coolant activation products will be present due to activation of impurities in the coolant. The approximate 61 gallons of NaK primary coolant can be packaged in a manner that can be treated and dispositioned by existing disposition vendors. It may be necessary to package the NaK in small containers to meet Department of Transportation (DOT) and vendor waste acceptance requirements. The treatment methods may include GeoMelt or water/steam deactivation. NaK has been safely managed at MFC facilities through experience with the Experimental Breeder Reactor (EBR)-II sodium systems and the EBR-I NaK systems. The primary coolant treatment from both reactors was conducted at MFC.

Primary system piping and components will need to be drained and free from NaK to be dispositioned as LLW. This LLW debris can be dispositioned using existing disposition paths. These components will also be packaged and treated using an appropriate treatment technology (GeoMelt or water/steam deactivation). Both methods have been successfully demonstrated and completed at MFC and Perma-Fix in Richland, Washington. The proposed technologies to remove and treat the NaK are available and have been conducted in the past.

Propylene glycol can be dispositioned using existing disposition paths. In the event that the ethylene glycol becomes contaminated or potentially contaminated there are disposition paths for radioactive fluids of this type. This waste can be dispositioned in either a liquid or a solid form.

Stirling engine heat exchangers will likely contain hazardous constituents (electronics, heavy metals, etc.) which will require them to be dispositioned as MLLW. Additionally, the portions of the engines that are in the PCS must be demonstrated to be free of unreacted sodium or NaK and reactivity via water submersion with no hydrogen generated. The NaK contaminated Stirling engines will be treated using GeoMelt or water/steam deactivation as discussed above. As noted, both methods have been successfully demonstrated and completed at MFC and Perma-Fix. The metal hazardous constituents can be treated at the same vendor as the NaK. The engines will be disposition as MLLW using existing disposition paths.

Removing the IHX intact is necessary to eliminate releasing Polonium-210, which is produced in the IHX from activation of bismuth in the lead-bismuth eutectic coolant. The IHX containing lead-bismuth eutectic will be removed intact and discarded intact. The IHX would be managed as MLLW due to the lead-bismuth alloy. Disposal facilities are readily available.

Miscellaneous electronics and components may contain hazardous constituents. Due to the existing radiological conditions in the areas surrounding the reactor and radiological conditions that will be created as part of the D&D process, it will likely not be economical to radiologically free release items. Given this, most items that contain hazardous constituents will be classified as MLLW. Disposition of this waste stream will be through existing vendors and disposition paths.

Reactor fuel, reactor vessel and associated activated metal components will be disassembled and analyzed using existing MFC facilities and processes. The resulting waste from this analysis will be dispositioned using existing waste disposition paths (i.e., transuranic (TRU), remote-handled LLW level waste, contact-handled LLW, and MLLW).

Given the small size of the reactor and associated components and systems, the waste volumes generated in this phase will have a small impact on the WMP and disposition vendors. Cumulative radiological and waste generating impacts would be minimal. Radiological releases during normal waste management operations would not result in adverse health impacts. Additional waste volumes would be small compared to current waste volumes at INL. These small volumes would be nearly indiscernible from current operations when combined with past, present, and reasonably foreseeable future actions. Cumulative impacts from waste generation, management, and disposal would be small.

3.8 Spent Nuclear Fuel

Management of spent nuclear fuel (SNF) includes the processes necessary to support the safe and secure storage of the SNF in a configuration that is ready for shipping to an Independent Spent Fuel Storage Installation or permanent repository. This includes: (1) the interim storage for the dissipation of heat and reduction of radiation dose immediately after discharge, (2) treatment of reactive materials and damaged fuel, (3) potential recovery of TRU material (if desirable or as a result of treatment processes), (4) packaging for extended dry storage or transport to a repository, (5) extended dry storage while awaiting packaging or transport to a repository, and (6) transport to a repository. Disposition refers to the permanent disposal of the SNF.

The MARVEL microreactor core will be disassembled and analyzed using existing MFC facilities and processes. Fuel pins are removed from the reactor and surveyed for radiation and contamination. After inspection the assemblies will be placed in designated shipping or storage containers following criticality control protocols. Containers can be dry stored at TREAT or shipped to MFC for storage or reprocessing in accordance with legal, regulatory, operations and scheduling requirements for the transfer and storage of these fuels.

For onsite transport at INL, DOE Order 460.1D (2016) allows for the preparation of a Transportation Safety Document to demonstrate equivalent safety for deviations from hazardous materials transportation requirements. The *INL Transportation Safety Document* (INL, 2017) describes the INL packaging and transportation program and explains the methodology for complying with the rules, laws, and regulations governing onsite and offsite transportation functions at the INL Site.

Non-routine shipments are shipments that do not fully comply with DOT hazardous material regulations and require the preparation of a Transport Plan. Cases that require the preparation of Transport Plans include variations to packaging requirements (such as the use of a packaging not authorized by DOT for shipping the material), packaging limits (such as radiation or contamination limits), and any other DOT requirements that cannot be met. The *INL Transportation Safety Document* (INL, 2017) requires that Transport Plans identify, as applicable, the specific DOT requirement(s) not met, hazard category, safety analysis, technical safety requirements, administrative controls, hazard controls, engineered barriers, and site-mitigating conditions that ensure a level of safety equivalent to that afforded by DOT requirements for routine shipments.

INL allows an alternative to preparing Transport Plans for non-routine shipments. This alternative involves preparing a Documented Safety Analysis that includes transportation activities at nonreactor nuclear facilities. If the Documented Safety Analysis addresses all transportation hazards and controls necessary to provide safety equivalent to DOT regulations, then the requirements of DOE Order 460.1D (DOE O 460.1D, 2016) are met and a Transport Plan is not required for the transportation of the material covered by the Documented Safety Analysis. The INL report *Safety Analysis Report for Intra-INL and MFC Inter-Facility Transfers* (INL, 2019b) is an example of a Documented Safety Analysis prepared in lieu of a Transport Plan. The technical safety requirements derived from INL (INL, 2019b) are contained in the INL report (INL, 2019d).

Preliminary criticality and radiation shielding evaluations for various transfer and storage configurations of the 36 MARVEL microreactor fuel elements were performed (Kitcher, 2020).

Configurations include various transfer casks for transferring SNF and irradiated experiments between INL facilities and a SNF storage canister currently in use at INL. The ATR transfer cask, HFEF-5 transfer cask, and the High Load Charger are used for the transfer of irradiated fuel between INL facilities, and these casks could potentially be used for transferring irradiated MARVEL microreactor fuel between INL facilities.

The analysis in Kitcher (2020) also suggests that all three transfer casks give sufficient radiation shielding to workers during transfer of the MARVEL microreactor fuel and storage. These calculations support the planning and strategy for the MARVEL microreactor and demonstrate the technical viability of the different configurations discussed and help identify where engineering and administrative controls may be necessary. A complete criticality safety analysis and radiation shielding analysis, including validation and contingency and accident analysis must be completed by licensed and authorized personnel before any transfer or storage of irradiated MARVEL microreactor fuel.

The MARVEL fuel will be U $ZrH_{1.7}$ sodium bonded to type 316 SS or Incoloy 810 cladding. Sodium-bonded SNF requires special consideration and treatment due to the potential for chemical reaction between elemental sodium and air and water. Thus, the sodium bearing SNF from the MARVEL microreactor requires deactivation or removal of the sodium before disposal. The MARVEL microreactor fuel will be similar to sodium bonded fuel currently managed by DOE at INL. The Fermi-1 and EBR-II SNF serve as examples of uranium metal sodium-bonded fuel. Current technologies can be applied to provide safe and secure management of the MARVEL microreactor SNF. INL currently treats sodium-bonded EBR-II assemblies at MFC using processes evaluated in the *Final Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (Sodium-Bonded Fuel Environmental Impact Statement [EIS]) (DOE, 2000). Treatment processes may produce various waste streams that must be dispositioned. Waste forms and disposition are discussed in Section 3.7.

The principal function of treating and conditioning the MARVEL microreactor SNF is to remove sodium from SNF containing sodium metal to make it acceptable at a repository. Once the sodium has been separated from the SNF, the material is sorted as a non-sodium-contaminated waste. To treat the elemental sodium extracted by the process, it is anticipated that existing MFC facilities would be used. The analysis in the *Final Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (DOE, 2000) showed that there would be no significant impacts on air quality, water resources, socioeconomics, public and occupational health and safety, environmental justice, and transportation from the various treatment options for sodium-bonded SNF. It further showed that the radiological and nonradiological gas and liquid releases, as well as the associated exposures to workers and the public, would be well below regulatory standards and guidelines and no mitigation measures would be warranted.

While the MARVEL microreactor fuel is not specifically addressed in the *Final Environmental Impact Statement for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel*, the 150 kg of MARVEL microreactor fuel represent a minute fraction of the 60 metric tons of heavy metal (MTHM) of sodium-bonded SNF analyzed in the Sodium Bonded Fuel EIS. Activities supporting the treatment and management of the MARVEL microreactor sodium-bonded SNF and other planned INL activities would not generate larger volumes of radioactive, hazardous, or solid waste beyond the current and projected capacities of INL waste storage or management facilities as evaluated in the Sodium-Bonded Fuel EIS.

The current SNF inventory at INL includes over 250 different types of SNF (Hill & Fillmore, 2005). The INL SNF inventory totals about 315 MTHM (INL, 2019c) stored in both wet and dry storage facilities at the INL site. Disposal options for many of these fuels were identified as part of the Yucca Mountain Repository project, including all necessary treatment packaging and transportation requirements for final disposition. Additional information on these fuel groups may be found in the *Yucca Mountain Repository License Application Safety Analysis Report* (DOE, 2009).

Packaging of SNF serves three necessary purposes: (1) preparation of SNF for extended dry storage, (2) preparation of SNF for transport, and (3) preparation of SNF for eventual disposal in a permanent repository. The DOE Standard Canister provides a high-integrity leak-tight barrier that satisfies the necessary safety functions and facilitates storage, transport, and disposal operations. Per the current DOE SNF disposition strategy, MARVEL microreactor SNF is expected to be disposed of using the DOE Standard Canister once the appropriate evaluation and analyses are performed. INL has several facilities with fuel handling and packaging capabilities, though additional modifications for packaging into DOE Standard Canisters may be required. For the MARVEL microreactor fuel concept, existing INL facilities at MFC currently have the capability to handle similar fuels in the INL SNF inventory. Therefore, it is likely that the MARVEL microreactor SNF can be handled using these facilities.

The SNF is required to be stored using a design that (1) assures sub criticality, (2) maintains the fuel as integral units that can be individually handled for repackaging, (3) provides structure that is able to confine the radioactive material to prevent a release to the environment in operational and accident conditions, 4) provides thermal control to dissipate heat that could adversely affect the system's containment function, and 5) provides radiation shielding to minimize personnel dose to levels acceptable in storage and transportation (10 CFR 830, 2011).

The regulations relevant to the storage of SNF are recorded as schedules in the Code of Federal Regulations (CFR). The key schedules dealing with the storage of SNF is 10 CFR 72 which deals with packaging and storing SNF. In addition, INL manages SNF in accordance with the numerous DOE Records of Decision (RODs) and EISs on SNF management, including the *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Program* (DOE, 1995). This ROD records a department-wide decision for DOE-owned SNF management and contains decisions dealing with site-wide environmental restoration and waste management programs at the INL Site (DOE, 1995).

MARVEL microreactor SNF may be managed in existing INL facilities so far as the legal, regulatory, operational, and scheduling requirements for the transfer and storage of these fuels in existing facilities are met. Transfer to existing facilities will be predicated on the appropriate analyses and procedures. Existing INL facilities are available to provide extended dry storage for the MARVEL microreactor SNF, including the Radioactive Scrap and Waste Facility, until final disposition is available.

SNF debris would be securely stored with DOE's spent fuel and spent fuel debris inventory awaiting a future disposal facility. The environmental impacts associated with management of spent nuclear fuel debris are addressed in the *Programmatic Spent Nuclear Fuel (SNF) and Idaho National Engineering Laboratory (INEL) Environmental restoration and Waste Management Environmental Impact Statement* (DOE, 1995).

The regulations relevant to the final disposition of SNF are contained in 40 CFR 197 and 10 CFR 63 for the disposal of SNF at the Yucca Mountain site and 40 CFR 191 and 10 CFR 60 for disposal at sites other than Yucca Mountain.

To protect workers from impacts from radiological exposure, 10 CFR Part 835 imposes an individual dose limit of 5,000 millirem in a year. In addition, worker doses are monitored and controlled below the regulatory limit to ensure that individual doses are less than an INL administrative limit of 700 millirem per year, and maintained at ALARA levels (DOE-STD-1098-2017, 2017). INL would monitor worker doses and take appropriate action to limit individual worker doses below this administrative level. The dose received by workers would be monitored and limited for the MARVEL microreactor SNF management operations at any existing facility.

Individual worker doses from transportation would also be limited to meet DOE administrative worker dose limits. During transfer and storage, the spent fuel would be contained in transportation or storage casks, limiting exposure to workers. DOE limits the dose resulting from the handling of these casks to 10 millirem per hour at a distance of 2 meters from the cask. Spent fuel handling would not impact the total worker exposure.

As with all SNF at present, the question of permanent disposition of SNF is directly dependent on the identification and licensing of a permanent repository for SNF in the United States. However, given the diversity of existing SNF that must be prepared and packaged for direct disposal, it is not anticipated that MARVEL microreactor fuel will pose any new challenges. The cumulative impacts from managing the MARVEL microreactor SNF would be small.

3.9 Radiation Exposure and Risk

DOE monitors radiation in the environment and exposure of workers and calculates the radiation doses of members of the offsite general public and onsite workers from operation of the INL Site. Historically, the dose to the MEI has been in the range of hundredths of an mrem/yr and less than 1% of the 10-mrem/yr federal standard (40 CFR 61 Subpart H). For calendar year 2019 the EDE to the MEI member of the public from INL Site operations was 5.59E-02 mrem per year, which is 0.56 percent of the 10 mrem per year standard, for the INL Site (DOE-ID, 2020). The risk of developing a Latent Cancer Fatality (LCF) from this dose is small, much less than 1 in a million. In addition, the annual dose to an individual from INL Site operations is several orders of magnitude less than the average dose of 383 mrem per year from exposure to natural background radiation (e.g., cosmic gamma, internal, and terrestrial radiation) for someone living on the Snake River Plain (VNS Federal Services, 2019). The impacts from radiological air emissions are discussed in Section 3.2.1.

To protect workers from impacts from radiological exposure, 10 CFR Part 835 imposes an individual dose limit of 5,000 mrem (5 rem) per year. In addition, worker doses must be monitored and controlled below the regulatory limit to ensure that individual doses are less than an administrative limit of 2,000 mrem (2 rem) per year DOE-STD-1098-2017, *Radiological Control* (DOE-STD-1098-2017, 2017), and maintained ALARA.

3.9.1 Impacts from Radiation Exposure and Risk

Because the MARVEL microreactor is a closed-loop system, there are no direct emissions from the fission process during normal operations. However, neutron activation of the air in the pit (region between the microreactor and the shielding) could conceivably generate minor quantities of particulate and gaseous radionuclides that could be exhausted from the TREAT reactor building stack when the ventilation system is activated. The potential dose to an offsite member of the public from these unabated emissions was estimated by Sondrup (2021) and found to be extremely low (3.9E-08 mrem/yr). This is 0.00007% of the 2019 dose to the MEI member of the public for all INL Site operations. Thus, cumulative impacts to the public would be minimal. The dose from MARVEL air emissions to a collocated worker at the TREAT reactor control building (nearest location) was also estimated by Sondrup (2021) and determined to be 5.7E-08 mrem/yr. This is also extremely low and minimal compared to the already low exposures estimated for INL workers (see discussion below). Thus there is effectively no increase in cumulative impacts to the public or collocated workers from radioactive air emissions during normal operations, as discussed in Section 3.2.1.

Fuel fabrication activities for the MARVEL microreactor uses existing processes in these existing facilities in accordance with the limitations set for in 10 CFR Part 835 DOE-STD-1098-2017 (2017), and maintained ALARA. The gloveboxes to be used during fuel fabrication use shielding and radiological designs adequate to limit operator radiological exposure.

INL Site workers receive the same dose as the general public from background radiation, but they also receive an additional dose from working in facilities with nuclear materials. Potential committed doses to workers, the public, and the environment, would be assessed in full compliance with DOE Order 458.1, *Radiation Protection of the Public and the Environment* (2020), and 10 CFR Part 835, *Occupational Radiation Protection*. Dose based consequences of the MARVEL microreactor, as detailed in this EA, are derived from the Annals of the International Commission on Radiological Protection (ICRP) Publication 103, *The 2007 Recommendations of the International Commission on Radiological Protection* (ICRP, 2007), and in consideration of the latest available scientific information of the biology and physics of radiation exposure.

The MARVEL microreactor would require about 10 workers involved in radiological operations that could receive measurable doses. Based on exposure data for 2019 the average dose to a TREAT worker that receives a dose is about 17 mrem per year, which equates to 0.085 mrem per day (assuming 200 days of work per year). MARVEL microreactor operations would potentially add 2 mrem/yr to an estimated 25 TREAT workers for an additional 50 person-mrem. Consequently, the average MARVEL microreactor worker would be expected to receive a dose of approximately 19 mrem and the total MARVEL microreactor worker dose would be approximately 190 person-mrem. Tables 7 and 8 present the doses and the LCF risks associated with these worker doses. All doses are well within the administrative control level for INL workers (700 mrem per year). During all operations, DOE would implement measures to minimize worker exposures and maintain doses ALARA, including the use of shielding, personal protective equipment, and training mock-ups to improve the efficiency of operations and reduce exposure times (Clark & Christiansen, 2020).

Table 7. MARVEL microreactor personnel anticipated annual worker dose and LCF.

Worker Radiological Risk Normal Operations	Dose for Project	Radiological Risk (LCF)
Average worker	19 mrem	0 (0.00001)
Total workers	190 person-mrem	0 (0.0001)

Table 8. TREAT personnel microreactor anticipated increase in annual worker dose and LCF.

Worker Radiological Risk Normal Operations	Dose for Project	Radiological Risk (LCF)
Average worker	2 mrem	0 (0.000001)
Total workers	50 person-mrem	0 (0.00003)

For comparison, the average total effective dose (TED) for INL employees from 2014 to 2018 was 70.4 mrem as shown in Table 9. Operating the MARVEL microreactor would have a small impact on worker occupational exposure to radiation.

Table 9. Annual radiation doses to INL workers during operations from 2014 to 2018.

Year	Collective TED (person-rem)	Number with Measurable Dose	Avg. Meas. TED (rem)	Radiological Risk (LCF)*
2014	61.292	1257	0.073	0 (0.04)
2015	71.814	1437	0.05	0 (0.04)
2016	92.67	1273	0.073	0 (0.06)
2017	123.232	1331	0.093	0 (0.07)
2018	82.66	1368	0.063	0 (0.05)
AVERAGE	86.3336	1333.2	0.0704	0 (0.05)
*Calculated using a dose conversion factor of 6×10^{-4} LCF per rem (6 x 10-7 LCF per mrem). Values in parentheses are calculated values. A value of less than 0.5 is considered to result in no LCFs.				

Activities associated with D&D of the MARVEL microreactor will be performed in existing INL facilities. The activation of reactor components has been evaluated in the *MARVEL Initial Shielding and*

Dose Calculations (Trellue, Vedant, Rao, Lange, & Sterbenz, 2021). INL would monitor worker doses and take appropriate action to limit individual worker doses below this administrative level. DOE-STD-1098-2017 (2017) identifies an effective ALARA process as including implementation of both engineered and administrative controls to control worker dose. All equipment and operations would be designed and implemented following this principle. Therefore, needed worker protection would be incorporated into the final D&D process potentially reducing worker doses. The dose received by workers would be monitored and limited for the MARVEL microreactor D&D operations at any existing facility in accordance with regulatory limits.

The impacts from radiation exposure from the management of SNF are discussed in Section 3.8.

The average dose to the individual worker (involved worker) and the cumulative dose to all INL Site workers (total workers) fall within the radiological regulatory limits of 10 CFR 835 (2011). Existing low population exposures of humans to radiation from the MARVEL microreactor would remain low because the level of effluent releases and regulatory requirements are not anticipated to change.

3.9.2 Accident Analysis

The hazard evaluation of MARVEL microreactor events and associated operations was performed for selection and evaluation of safety classification of structures, systems and components (SSCs), SSC safety functions, and DBAs applicable to the MARVEL microreactor design. With these SSCs in place, the MARVEL microreactor can be built and operated safely in the existing Transient Reactor Test (TREAT) facility. The MARVEL microreactor will not be operated at the same time as the TREAT Reactor is operating and would not result in an accident event involving the TREAT Reactor.

The MARVEL microreactor will be located in the TREAT Reactor building in the north high-bay equipment pit. As such, the documented safety analysis (DSA) for the MARVEL Project is in the form of an addendum to the existing TREAT final safety analysis.

The MARVEL microreactor is designed to survive a wide variety of off normal, upset or accident conditions. A thorough evaluation of potential accident conditions is ongoing, including an assessment of DBAs for which the reactor is designed and demonstrated to successfully handle with minimal to no release. These events include reactivity insertion events leading to a transient overpower, cooling issues related to loss of flow, and loss of heat sink scenarios. In these DBAs, the MARVEL microreactor is designed to successfully withstand the accident conditions without intervention of active safety systems, instead relying on the passive safety of the design to prevent the release of fission products to the environment.

In all DBA scenarios, the plant control and trip system is designed to activate, and at least 3 of the 4 CDs passively rotate inward to shut down the reactor. In the event that the control and trip system fails, the inherent reactivity feedback mechanisms incorporated into the design provide for the reactor power to be suppressed to a low power stable state without failure of the fuel and fission product boundaries. The passive heat removal system ensures that the reactor heat is rejected without the need for forced flow and external power. Although temperatures in the core may elevate, the passive heat removal design ensures that fuel, clad, and primary coolant boundary temperatures remain within their design performance limits. The fuel, clad, and primary coolant boundary will not be damaged, and all confinement barriers would remain intact. Therefore, there are no radiological releases or radiological consequences postulated in these scenarios.

While the MARVEL microreactor design incorporates significant safety benefits based on passive safety systems, it is plausible that a severe accident could occur that would be beyond the plant design basis. Thus, a maximum reasonably foreseeable accident involving a natural phenomena hazard event, with the energy to structurally impact the core and overwhelm the design of the passive safety features of the reactor is evaluated in ECAR-5363, *MARVEL Environmental Assessment Inhalation Dose Consequence Calculations* (Reiss, 2021). Of the potential events considered, a structural damage event leading to failure of the CDs to insert and rearrangement of the core leading to a significant reactivity insertion (i.e., power increase) is identified. It is postulated that in the limiting event sequences, the resulting step insertion of reactivity could lead to core damage.

The model and calculations for the reactor accident are documented in ECAR-5363, *MARVEL Environmental Assessment Inhalation Dose Consequence Calculations* (Reiss, 2021). The accident analysis was conducted using Radiological Safety Analysis Computer (RSAC) Program 7.2 to model accident conditions. RSAC 7.2 is a radiological safety analysis tool developed and used extensively at INL for calculating the inhalation dose to collocated workers and offsite public due to accidental radiological releases. It has been independently verified and validated for these types of calculations.

The RSAC 7.2 program used in the analysis allows the user to specify meteorological conditions at the time of the release and calculate diffusion, dispersion, and depletion factors. Other parameters used for inhalation dose consequence evaluation include source term, plume dispersion, receptor breathing rate, ICRP dose conversion factor for each receptor, and deposition factors where appropriate in determining an estimated total effective dose (TED) at each receptor location.

The methodology for dose estimates is further detailed in (Reiss, 2021). The results from the RSAC accident consequence calculations are shown in Table 10.

Table 10. Summary of dose impacts for the highest postulated accident consequences for the MARVEL microreactor.

Receptor	Dose (TED), rem	LCF*
TREAT Control Room at 770 m	2.71E+00	0 (2.0E-03)
Nearest Site Boundary, 6,000 m	1.31E-01	0 (8.0E-05)
Nearest Low Population Zone, 32,000 m	2.28E-02	0 (1.4E-05)
Idaho Falls, 48,000 m	1.66E-02	0 (1.0E-05)

*Calculated using a dose conversion factor of 6 × 10^{-4} LCF per rem. Values in parentheses are calculated values. A value of less than 0.5 is considered to result in no LCFs.

Significant adverse consequences from significant releases of radioactive or hazardous materials are limited by the MARVEL core size and fission product inventory. However, DOE requirements for emergency planning in DOE O 151.1D, *Comprehensive Emergency Management System* (DOE, 2019a), the large distances to site boundaries on DOE facilities, and additional safety management programs, mitigate the consequences from these extremely low probability events. In all cases, the release of the fission products is well within guidelines for public exposure. Existing low population exposures of humans to radiation from postulated accidental events associated with the MARVEL microreactor would remain small.

Onsite shipments containing radiological materials undergo an extensive safety analysis and review process to ensure proper safety plans are developed and implemented. Accidents, including minor accidents, are not likely to occur more than once in every 100,000 miles on public roadways (NRC, 2012). Minor accidents are even less likely to occur on INL because of the low transport speeds and because access along the INL transportation route will be restricted. The total number of miles traveled on the INL Site per year is expected to be less than 1,000. Based on mileage alone, there is very little chance that even a minor accident would occur in any year.

The level of radioactive material releases from effluent releases associated with the bounding accident scenario, when combined with past, present, and reasonably foreseeable actions at INL, are small.

Therefore, cumulative effects from the MARVEL microreactor would also be small. Therefore, cumulative impacts from accidental releases would be small.

3.10 Nonradiological Health and Safety

Nonradiological exposures at the INL Site are controlled through programs intended to protect workers from normal industrial hazards. These programs are controlled by the safety and health regulations for DOE contractor workers governed by 10 CFR 851 (2012), which establishes requirements for worker safety and health programs to ensure that DOE contractor workers have a safe work environment. Provisions are included to protect against occupational injuries and illnesses, accidents, and hazardous chemicals.

Potential impacts from noise, exposure to chemicals, and occupational injuries are and would continue to be regulated to be protective of human health. Per 10 CFR 851 (2012), employee exposures to hazardous agents are maintained below the American Conference of Governmental Industrial Hygienists threshold limit values, the Occupational Safety and Health Administration (OSHA) permissible exposure limits, and other applicable standards as defined by DOE. When exposure limits defined by the various agencies conflict, INL policy is to comply with the more stringent limit.

Hazardous materials (radiological and chemical) at the INL Site are minimized to those necessary to accomplish the mission. The MARVEL microreactor will follow site-wide procedures for handling and storing hazardous materials.

Standard Industrial Hazards are hazards that are routinely encountered in general industry and construction; for these hazards, national consensus codes and standards, such as OSHA standards and DOE-prescribed occupational safety and health standards, guide safe design and operation of the MARVEL microreactor. In accordance with the guidelines in DOE-STD-1027-2018, *Hazard Categorization of DOE Nuclear Facilities* (2019), and DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis* (DOE-STD-3009-2014, 2014), no special analysis is required for these occupational hazards unless they are possible initiators for an uncontrolled release of radioactive or hazardous material.

The level of exposure nonradiological hazards, the regulatory requirements for managing those hazards, and existing exposures are not anticipated to change. Therefore, the direct, indirect, and cumulative impacts from exposure to normal industrial hazards at INL would be small.

3.11 Emergency Preparedness

DOE Order 151.1D, *Comprehensive Emergency Management System,* (DOE, 2019a) describes detailed requirements for emergency management that DOE must implement. Each DOE site, facility, and activity, including the INL Site, establishes and maintains a documented emergency management program that implements the requirements of applicable federal, state, and local laws, regulations, and ordinances for fundamental worker safety programs (e.g., fire, safety, and security). In addition, each DOE site, facility, and activity containing hazardous materials, such as radioactive materials or certain chemicals that do not fall under the purview of fundamental worker safety programs, establishes and maintains an Emergency Management Hazardous Materials Program. Finally, each site that receives or initiates shipments managed by the Office of Secure Transportation must be prepared to manage an emergency involving such a shipment, should that emergency occur on site.

The emergency management system at INL includes emergency response facilities and equipment, trained staff, and effective interface and integration with offsite emergency response authorities and organizations. INL maintains the necessary apparatus, equipment, and a state-of-the-art Emergency Operations Center in Idaho Falls to respond to emergencies, not only at INL, but throughout the local communities.

A readiness assessment will be completed prior to constructing and operating the MARVEL microreactor in the TREAT Reactor building to demonstrate that there is a reasonable assurance that operations are performed safely and provide adequate protection of workers, the public, and the environment. This assessment includes, but is not limited to, an evaluation of safety management programs; operational interfaces, selection, training, and qualification of operations and support personnel; implementation of facility safety documentation; programs to confirm and periodically reconfirm the condition and operability of all safety and support systems; procedures; emergency management; and conduct of operations processes.

3.12 Intentional Destructive Acts

DOE considered Impacts of intentional acts of destruction occurring at an INL facility or during transport between facilities. INL's protective force mitigates the potential for an act of sabotage occurring on site. INL routinely uses a variety of measures to mitigate the likelihood and consequences of intentional destructive acts. The DOE maintains a highly trained and equipped protective force intended to prevent attacks against and entry into the facilities.

The protective force monitors and patrols site perimeters to prevent unauthorized entry. Access to INL roads would be restricted during transport of radioactive materials. Security measures would be in place to mitigate the likelihood and consequences of sabotage. Transportation crewmembers would be screened for behavioral and substance abuse issues and would receive safety and security training. Crewmembers would conduct a thorough inspection of vehicles and loads before transport. During transport, crewmembers have a means of communication and immediately report suspicious activity encountered while in route.

The potential for and consequences of intentional destructive acts against the TREAT Reactor were based on conservative assumptions and evaluated in the *Final Environmental Assessment for the Resumption of Transient Testing of Nuclear Fuels and Materials* (DOE-ID, 2014), which states that an act of sabotage at the TREAT Reactor building would result in dose consequences similar to the highest consequence event scenarios evaluated for the TREAT Reactor. The EA for the Resumption of Transient Testing (DOE-ID, 2014) further found that (1) doses and LCFs for members of the public were negligible for all scenarios at the TREAT Reactor building, (2) that administrative controls and protective actions and equipment would be used to mitigate worker doses, and (3) the accident consequences for workers are also considered to be negligible.

Accident analyses for the MARVEL microreactor were also evaluated based on conservative assumptions using parameters resulting in the highest postulated dose to workers and public receptors as described in Section 3.9.2, and any acts of sabotage, should they occur, would be expected to result in consequences that would be bounded by the results of accident scenarios detailed in Section 3.9.2. Significant adverse consequences from significant releases of radioactive or hazardous materials are limited by the MARVEL core size and fission product inventory.

Table 11 shows the dose to workers at the TREAT Control Building and the public at the nearest INL Site boundary from the bounding accident analysis for the TREAT Reactor and MARVEL microreactor. Assuming an act of sabotage resulting from the bounding releases from both reactors, the release of fission products would remain small and within guidelines for public exposure. Resultant health impacts to members of the public would be small. Resultant health impacts to workers would be mitigated by normal response actions and would also be small.

Table 11. Summary of dose impacts for the highest postulated accident consequences for the TREAT Reactor and MARVEL microreactor at the TREAT Control Building and nearest INL Site Boundary

Source	Dose (TED), rem	LCF
TREAT Control Building 770 m		
TREAT Reactor	6.5	0 (0.015)
MARVEL Microreactor	27.5	0 (0.02)
Public Exclusion Boundary 6,000 m		
TREAT Reactor	0.24	0 (1.4E-04)
MARVEL	2.65	0 (2.0E-3)

3.13 Conclusion

Table 12 lists a summary of the anticipated environmental impacts from the MARVEL microreactor as described in this EA. Implementing the MARVEL microreactor would result in small adverse impacts to the environment. However, these impacts, in conjunction with other past, present, and reasonably foreseeable future actions, would not result in discernible cumulative impacts.

Table 12. Summary of environmental impacts under the MARVEL microreactor.

Resource	MARVEL microreactor
Air	The MARVEL microreactor would produce minor amounts of pollutants and radioactive air emissions. The small increase in offsite air pollutant concentrations produced from the MARVEL microreactor, in combination with emissions from other past, present, and reasonably foreseeable future actions, would not result in air pollutant concentrations that would exceed the state and National Ambient Air Quality Standards and would not substantially contribute to cumulative air quality impacts. Doses to members of the public from radioactive air emissions are insignificant relative to regulatory limits.
Ecological	The facility modifications and operations proposed as part of the MARVEL microreactor would occur in existing facilities. The MARVEL microreactor does not require construction of new facilities or additional land use or ground disturbance. Impacts from radioactive air emissions would be much less than limits established for protection of terrestrial biota. From a cumulative impact perspective, the incremental impacts of the MARVEL microreactor when added to past, present, and reasonably foreseeable actions at the INL Site are small.
Historical and Cultural	There would be no adverse effects to eligible or potentially eligible NRHP sites.
Geology	No environmental impacts would occur from MARVEL in TREAT as a result of potential future earthquakes.
Infrastructure	The MARVEL microreactor would have small impacts on INL Site infrastructure. These small impacts would be nearly indiscernible from current operations when combined with past, present, and reasonably foreseeable future actions.
Waste Management	Additional waste volumes from the MARVEL microreactor would be small compared to current disposal volumes at INL. These small volumes would be nearly indiscernible from current operations when combined with past, present, and reasonably foreseeable future actions.
Spent Nuclear Fuel	Activities supporting the treatment and management of the MARVEL microreactor sodium-bonded SNF and other planned INL activities would not generate volumes of

Resource	MARVEL microreactor
	radioactive, hazardous, or solid waste beyond the current and projected capacities of INL waste storage or management facilities.
Radiation Exposure and Risk	The level of effluent releases, regulatory requirements (including those for occupational doses), and existing low exposures are not anticipated to change. The level of the expected normal radioactive gaseous effluent releases would remain the same. Normal radioactive liquid effluent releases would remain unchanged. Therefore, cumulative impacts from radiation exposure are not anticipated.
Health and Safety	Potential impacts from noise, exposure to chemicals, and occupational injuries are and would continue to be regulated to be protective of human health. No adverse impacts to human health and safety are anticipated from the MARVEL microreactor. Nonradiological emissions would be minimal.
Emergency Preparedness	INL maintains the necessary apparatus, equipment, and a state of the art Emergency Operations Center in Idaho Falls to respond to emergencies, not only at from the MARVEL microreactor and other INL Site operations, but also throughout local communities.
Intentional Destructive Acts	Acts of sabotage are unlikely, but should they occur, resultant health impacts to members of the public would be small. Resultant health impacts to workers would be mitigated by normal response actions and would also be small.

4. Permits and Regulatory Requirements

The MARVEL microreactor would be regulated by numerous federal and state legal requirements addressing environmental compliance. For some activities, DOE has sole authority to take action, such as under the Atomic Energy Act of 1954. The MARVEL microreactor would be authorized by DOE, just like previous test reactors (e.g., ATR and TREAT). The MARVEL microreactor will not be licensed by the NRC.

The U.S. Department of Transportation regulates commercial transportation of hazardous and radioactive materials. The U.S. Environmental Protection Agency (EPA) would regulate many aspects of the proposed activities. In many cases, EPA has delegated all or part of its environmental protection authorities to the States but retains oversight authority. In this delegated role, the Idaho Department of Environmental Quality regulates most air emissions; discharges to surface water and groundwater; drinking water quality; and hazardous and nonhazardous waste treatment, storage, and disposal. Under DOE Order 436.1, *Departmental Sustainability* (2011), it is DOE’s policy to carry out its mission in a sustainable manner by maximizing energy and water efficiency; minimizing chemical toxicity and harmful environmental releases; promoting renewable and other clean energy development; and conserving natural resources while sustaining assigned mission activities.

The major federal laws, regulations, Executive Orders (Presidential directives that apply only to federal agencies), and DOE Orders; state laws and regulations; and other requirements that could apply to the MARVEL microreactor analyzed in this EA are identified in Table 13.

Table 13. Applicable laws, regulations, orders, and other requirements.

Law, Regulation, Order, or Other Requirement	Description
General Environmental	
NEPA of 1969, as amended, 42 U.S. Code (USC) § 4321 et seq.	Establishes a national policy for environmental protection and directs all federal agencies to use a systematic, interdisciplinary approach to incorporating environmental values into decision- making.
Council on Environmental Quality, Regulations for Implementing NEPA, 40 CFR Parts 1500–1508	Defines actions that federal agencies must take to comply with NEPA.
DOE National Environmental Policy Act Implementing Procedures, 10 CFR Part 1021	Establishes DOE's program implementing the procedural provisions of NEPA.
Executive Order 11514, *Protection and Enhancement of Environmental Quality*, as amended by Executive Order 11991	Requires Federal agencies to direct their policies, plans, and programs so as to meet national environmental goals established by NEPA.
Executive Order 12088, Federal Compliance with Pollution Control Standards	Directs federal agencies to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the Clean Air Act (CAA), Noise Control Act, Clean Water Act (CWA), Safe Drinking Water Act, Toxic Substances Control Act, and Resource Conservation and Recovery Act (RCRA).
Executive Order 13834, *Efficient Federal Operations*	Focuses on meeting statutory requirements to improve efficiency, optimize performance, eliminate unnecessary use of resources, and protect the environment.
DOE Order 231.1B, *Environment, Safety, and Health Reporting*	Ensures timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues as required by law or regulations or as needed by DOE.
DOE Order 436.1, *Departmental Sustainability*	Defines requirements and responsibilities for managing sustainability within DOE.
DOE Policy 450.4A, *Integrated Safety Management Policy*	Sets forth the framework for identifying, implementing, and complying with environmental safety and health requirements so that work is performed in the DOE complex in a manner that ensures adequate protection of workers, the public, and the environment.
DOE Policy 451.1, *National Environmental Policy Act Compliance Program*	Establishes DOE's expectations for implementing NEPA; the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500-1508); and the DOE NEPA Implementing Procedures (10 CFR Part 1021).
Water Resources	

Law, Regulation, Order, or Other Requirement	Description
Federal Water Pollution Control Act (Clean Water Act [CWA]), 33 USC 1251 et seq.	Establishes a national program to restore and maintain the chemical, physical, and biological integrity of navigable waters by prohibiting the discharge of toxic pollutants in significant amounts without a permit; requires federal agencies to comply with federal, state, and local water quality requirements; Section 404 of the CWA regulates development activities in jurisdictional surface waters and wetlands, and delegates EPA and the U.S. Army Corps of Engineers (USACE) to share Section 404 enforcement authority regarding the discharge of dredged or fill material into waters of the United States; allows EPA to delegate primary enforcement authority for National Pollutant Discharge Elimination System (NPDES) permits (Section 402) to Idaho. As of 2016, Idaho DEQ received permitting authority to address water pollution by regulating point sources that discharge pollutants to Idaho's surface water.
Safe Drinking Water Act of 1974, as amended, 42 USC 300f et seq.	Establishes a national program to ensure the quality of drinking water in public water systems; allows EPA to delegate primary enforcement authority to Idaho.
National Primary Drinking Water Regulations, 40 CFR Part 141	Creates standards for maximum contaminant levels for pollutants in drinking water; used as groundwater protection standards.

Law, Regulation, Order, or Other Requirement	**Description**
Procedures for Decision-making (Permitting), 40 CFR Part 124	Contains EPA procedures for issuing, modifying, revoking and reissuing, or terminating all RCRA, PSD, and NPDES permits.
Rules Regulating the Idaho Pollutant Discharge Elimination System Program, IDAPA 58.01.25	EPA authorized permitting authority to the Idaho Pollutant Discharge Elimination System (IPDES) Program, like NPDES, to address water pollution by regulating point sources that discharge pollutants to waters of the United States.
Idaho Ground Water Protection Act of 1989 Idaho Wastewater Rules, IDAPA, 58.01.16 Idaho Recycled Water Rules, IDAPA 58.01.17	Establishes the Idaho Groundwater Quality Plan and declares the policy to provide for the protection of the state's ground water for beneficial uses as a public resource. Establishes Creates procedures and requirements for the planning, design, and operation of wastewater facilities and the discharge of wastewaters and human activities which may adversely affect public health and water quality in the waters of the state. Establishes procedures and requirements for the issuance and maintenance of pollution source permits for reuse facilities, also referred to as "reuse permits."
Idaho Groundwater Quality Rules, IDAPA 58.01.11	Establishes minimum requirements for protection of groundwater quality through standards and an aquifer categorization process; serves as basis for administration of programs which address groundwater quality but do not in and of themselves create a permit program.

Law, Regulation, Order, or Other Requirement	Description
Individual/Subsurface Sewage Disposal Rules and Rules for Cleaning of Septic Tanks, IDAPA 58.01.03	Establishes limitations on the construction and use of individual and subsurface sewage disposal systems and establishes the requirements for obtaining an installation permit and an installer's registration permit.
Idaho Rules for Public Drinking Water Systems, IDAPA 58.01.08	Controls and regulates the design, construction, operation, maintenance, and quality control of public drinking water systems to provide a degree of assurance that such systems are protected from contamination and maintained free from contaminants that may injure the health of the consumer.
Air Quality	
Clean Air Act of 1970, as amended, 42 USC 7401 et seq.	Requires federal agencies to comply with air quality regulations; includes four major programs: 1) the National Ambient Air Quality Standards (NAAQS); state implementation plans; new source performance standards; and NESHAP; allows EPA to delegate authority for most CAA provisions to Idaho, who would issue or modify permits, as needed, for stationary sources associated with the proposed activities.
Ambient Air Quality Standards/State Implementation Plans, 40 CFR Parts 51 and 58	Establishes the NAAQS, which are divided into primary and secondary categories for carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide, and PM.
Prevention of Significant Deterioration, 40 CFR 51.166	Establishes processes for maintaining air quality in areas already in compliance with the NAAQS (attainment areas); requires comprehensive preconstruction review and the application of best-available control technology for major stationary sources.
New Source Performance Standards, 40 CFR Part 60	Creates industry- and process-specific standards that apply to any new, modified, or reconstructed sources of air pollution.
National Emission Standards for Hazardous Air Pollutants and for Source Categories, 40 CFR Parts 61 and 63	Defines HAPs (such as radionuclides, mercury, and asbestos) and maximum achievable control technologies by industry or process. (Proposed activities would add to site HAPs emissions, whose combined ambient concentrations are then compared to the standards).

Law, Regulation, Order, or Other Requirement	Description
National Emission Standards for Emissions of Radionuclides other than Radon from DOE Facilities, 40 CFR Part 61, Subpart H	Establishes requirements for monitoring radionuclide emissions from facility operations and analyzing and reporting radionuclide doses; limits, in Subpart H, the radionuclide dose to a member of the public to 10 mrem per year.
State Operating Permit Programs, 40 CFR Part 70	Defines minimum permit requirements, including air pollution control, reporting, monitoring, and compliance certification requirements; includes permitting program known as Title V for major sources of air pollution.
Idaho Environmental Protection and Health Act, IC, Title 39, Health and Safety, Chapter 1, Department of Health and Welfare, Sections 39-105 Rules for the Control of Air Pollution in Idaho, IDAPA 58.01.01	Provides for development of regulations for the control and permitting of air emission sources. Provides rules and permitting programs to control air pollutant emissions in Idaho.
Ecological Resources	
Migratory Bird Treaty Act of 1918, 16 USC 703 et seq. Migratory Bird Permits, 50 CFR Part 21	Implements several international treaties related to the protection of migratory birds and makes it illegal to take, capture, or kill any migratory bird, or to take any part, nest, or egg of any such birds; applies to purposeful actions, not to incidental take.
Endangered Species Act of 1973, 16 USC 1531 et seq. Interagency Cooperation – Endangered Species Act of 1973, as amended, 50 CFR Part 402	Requires federal agencies to assess whether actions could adversely affect threatened or endangered species or their habitat.
Cultural and Historic Resources	
American Antiquities Act of 1906, 16 USC 431 et seq. Preservation of American Antiquities, 43 CFR Part 3	Protects prehistoric American Indian ruins and artifacts on federal lands; authorizes the President to designate historic areas as national monuments.
Historic Sites Act of 1935, 16 USC 461 National Historic Landmarks Program, 36 CFR Part 65	Provides for the preservation of historic American sites, buildings, objects, and antiquities of national significance, and serves other purposes.

Law, Regulation, Order, or Other Requirement	**Description**
National Historic Preservation Act of 1966, 16 USC 470 et seq. National Register of Historic Places, 36 CFR Part 60 et seq. Curation of Federally Owned and Administered Archaeological Collections, 36 CFR Part 79 Protection of Historic Properties, 36 CFR Part 800	Sets forth the procedural requirements for listing properties on the National Register of Historic Places; identifies the process for evaluating the eligibility of properties for inclusion in the National Register of Historic Places: requires consultation with the State Historic Preservation Officer and Native American tribes prior to any action that could affect historic resources (this consultation will be accomplished for the proposed activities, as needed).
Archaeological and Historic Preservation Act of 1974, as amended, 16 USC 469 et seq.	Requires the preservation of historical and archaeological data (including relics and specimens) that might otherwise be irreparably lost or destroyed as the result of federal construction projects.
American Indian Religious Freedom Act of 1978, 42 USC 1996	Protects and preserves, for American Indians, their inherent right of freedom to believe, express, and exercise their traditional religions, including access to sites.
Archaeological Resources Protection Act of 1979, 16 USC 470aa-mm Protection of Archaeological Resources, 43 CFR Part 7	Protects archaeological resources and sites on federal and American Indian lands and establishes the uniform definitions, standards, and procedures to be followed by all federal land managers in providing protection for archaeological resources located on public lands and American Indian lands of the United States, including collections of prehistoric and historic material remains, and associated records, recovered under the authority of the American Antiquities Act (16 USC 431-433), the Reservoir Salvage Act (16 USC 469–469c), Section 110 of the National Historic Preservation Act (16 USC 470h-2), or the Archaeological Resources Protection Act (16 USC 470aa-mm).
Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments*	Requires consultation and coordination with American Indian Tribes prior to taking actions that affect federally recognized tribal governments.
Executive Order 13287, *Preserve America*	Promotes the protection of federal historic properties and cooperation among governmental and private entities in preserving cultural heritage.
DOE Order 144.1, *Department of Energy American Indian Tribal Government Interactions and Policy*	Establishes a policy committing DOE to consultation with American Indian tribal governments to solicit input on DOE issues.
DOE Policy 141.1, *Department of Energy Management of Cultural Resources*	Ensures that DOE programs and field elements integrate cultural resources management into their mission and activities.

Law, Regulation, Order, or Other Requirement	Description
Idaho Historic Preservation Act, IC, Title 67, Chapter 46, Preservation of Historic Sites	Requires consultation with responsible local governing body for historic preservation.
Infrastructure	
Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, Chapter 103, Subchapter 1, Hazardous Substances Releases, Liability, Compensation	Regulates construction of hazardous waste storage, including for radioactive materials.
Waste Management	
Low-Level Radioactive Waste Policy Act of 1980, 42 USC 2021 et seq. Criteria and Procedures for Emergency Access to Non-Federal and Regional Low-Level Waste Disposal Facilities, 10 CFR Part 62	Specifies that the federal government is responsible for the disposal of certain LLW, including LLW owned or generated by the DOE; and specifies States are responsible for the disposal of commercially generated LLW; pertains to waste that could be generated by the proposed activities.
Nuclear Waste Policy Act of 1982, 42 USC 10101 et seq. Disposal of High-Level Radioactive Wastes in Geologic Repositories, 10 CFR Part 60 Licensing Requirements for the Independent Storage of SNF and High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste, 10 CFR Part 72	Establishes national program for the disposal of high-level radioactive waste and used nuclear fuel.
Byproduct Material, 10 CFR Part 962	Defines byproduct material as identified in the Atomic Energy Act, and clarifies that the hazardous portion of mixed radioactive waste is subject to RCRA
DOE National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Public Law 96-164, 93 Stat. 1259	Includes information related to the authorization basis of the Waste Isolation Pilot Plant for the disposal of contact-handled and remote-handled transuranic waste.
Solid Waste Disposal Act of 1965 as amended by RCRA of 1976 and the Hazardous and Solid Waste Amendments of 1984, 42 USC 6901 et seq. RCRA Regulations for Non-hazardous Waste, 40 CFR Parts 239-259 RCRA Regulations for Hazardous Waste, 40 CFR Parts 260-273	Establishes comprehensive management system for hazardous wastes, addressing generation, transportation, storage, treatment, and disposal; allows, per Section 3006 of RCRA (42 USC 6926), States to establish and administer permit programs with EPA approval; allows EPA to delegate primary enforcement authority to Idaho.

Law, Regulation, Order, or Other Requirement	Description
Federal Facility Compliance Act of 1992, 42 USC 6961 et seq.	Waives sovereign immunity for federal facilities under RCRA; requires DOE to conduct an inventory and develop a treatment plan for mixed wastes.
Toxic Substances Control Act of 1976, 15 USC 2601 et seq. Toxic Substances Control Act, 40 CFR Parts 700-799	Gives EPA the authority to screen and regulate new and existing chemicals to protect the public from the risks of exposure to chemicals; establishes specific provisions to address polychlorinated biphenyls, asbestos, radon, and lead-based paint.
Pollution Prevention Act of 1990, 42 USC 13101 et seq. Comprehensive Procurement Guidelines for Products Containing Recovered Materials, 40 CFR Part 247	Establishes requirement to prevent pollution by emphasizing source reduction and recycling. EPA is charged with developing measures for source reduction and evaluating regulations to promote source reduction.
DOE Order 435.1, *Radioactive Waste Management*	Ensures that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety and the environment.
Idaho Hazardous Waste Management Act, IC Title 39, Chapter 44 Idaho Rules and Standards for Hazardous Waste, IDAPA 58.01.05	Requires proper controls for the management of solid and hazardous waste. Establishes requirements applicable to all hazardous waste management facilities in Idaho.
Idaho Solid Waste Facilities Act, IC Title 39, Chapter 74 Idaho Solid Waste Management Rules, IDAPA 58.01.06	Establishes requirements applicable to all solid waste and solid waste management facilities in Idaho.
Nuclear Materials Management	
Atomic Energy Act of 1954, as amended, 42 USC 2011 et seq.	Provides fundamental jurisdictional authority to DOE and NRC over governmental and commercial use, respectively, of nuclear materials; authorizes DOE to establish standards to protect health or minimize dangers to life or property for activities under DOE jurisdiction; allows DOE to issue a series of orders to establish a system of standards and requirements that ensure safe operation of DOE facilities.
Procedural Rules for DOE Nuclear Facilities, 10 CFR Part 820	Governs the conduct of persons involved in DOE nuclear activities and, in particular, to achieve compliance with DOE nuclear safety requirements.
Nuclear Safety Management, 10 CFR Part 830	Governs the conduct of DOE contractors, DOE personnel, and other persons conducting activities (including providing items and services) that affect, or may affect, the safety of DOE nuclear facilities.
DOE Order 410.2, *Management of Nuclear Materials*	Establishes requirements and procedures for the lifecycle management of nuclear materials within DOE.

Law, Regulation, Order, or Other Requirement	Description
DOE Order 425.1D, *Verification of Readiness to Start Up or Restart Nuclear Facilities*	Establishes requirements for DOE for verifying readiness for startup of new nuclear facilities and for the restart of existing nuclear facilities that have been shut down.
DOE Order 426.2, *Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities*	Establishes selection, qualification, and training requirements for management and operating contractor personnel involved in the operation, maintenance, and technical support of DOE reactors and nonreactor nuclear facilities.
DOE Order 433.1B, *Maintenance Management Program for DOE Nuclear Facilities*	Establishes a safety management program required by 10 CFR Part 830 for maintenance and the reliable performance of structures, systems, and components that are part of the safety basis at Hazard Category 1, 2, and 3 DOE nuclear facilities.
DOE Policy 470.1B, *Safeguards and Security Program*	Ensures that DOE efficiently and effectively meets all its obligations to protect special nuclear material, other nuclear materials, classified matter, sensitive information, government property, and the safety and security of employees, contractors, and the general public.
DOE Order 470.4B, *Safeguards and Security Program*	Identifies roles and responsibilities for the DOE Safeguards and Security Program.
Human Health	
Occupational Safety and Health Act of 1970, 29 USC 651 et seq. Occupational Safety and Health Standards, 29 CFR Part 1910, 29 CFR Part 1926	Ensures worker and workplace safety, including a workplace free from recognized hazards, such as exposure to toxic chemicals, excessive noise levels, and mechanical dangers. Establishes standards to protect workers from hazards encountered in the workplace (Part 1910) and construction site (Part 1926).
Worker Safety and Health Program, 10 CFR Part 851	Creates DOE's health and safety program to control and monitor hazardous materials to ensure that workers are not being exposed to health hazards, such as toxic chemicals, excessive noise, and ergonomic stressors.
Occupational Radiation Protection, 10 CFR Part 835	Establishes radiation protection standards, limits, and program requirements for protecting workers from ionizing radiation resulting from DOE activities.
Chemical Accident Prevention Provisions, 40 CFR Part 68	Provides the list of regulated substances and thresholds, and the requirements for owners or operators of stationary sources concerning the prevention of accidental releases, and the state accidental release prevention programs approved under CAA Section 112(r).
Environmental Radiation Protection Standards for Management and Disposal of SNF, High-Level, and Transuranic Radioactive Wastes, 40 CFR Part 191	Applies to radiation doses received by members of the public as a result of the management (except for transportation) and storage of SNF, transuranic, or high-level radioactive wastes.
DOE Order 420.1C, *Facility Safety*	Establishes facility and programmatic safety requirements for DOE facilities, including nuclear and explosives safety design criteria, fire protection, criticality safety, natural phenomena hazards mitigation, and the System Engineer Program.
DOE Policy 420.1, *Department of Energy Nuclear Safety Policy*	Documents DOE's nuclear safety policy.

Law, Regulation, Order, or Other Requirement	Description
DOE Order 430.1C, *Real Property Asset Management*	Establishes a corporate, holistic, and performance-based approach to real property lifecycle asset management that links real property asset planning, programming, budgeting, and evaluation to program mission projections and performance outcomes. To accomplish the objective, this Order identifies requirements and establishes reporting mechanisms and responsibilities for real property asset management.
DOE Order 440.1B, *Worker Protection Program for DOE (including the National Nuclear Security Administration) Federal Employees*	Describes the DOE program to protect workers and reduce accidents and losses; adopts occupational safety and health standards.
DOE Order 458.1, *Radiation Protection of the Public and the Environment*	Establishes requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of DOE, pursuant to the Atomic Energy Act of 1954, as amended.
Transportation	
Hazardous Materials Transportation Act of 1975, 49 USC 5101 et seq. Transportation, Subchapter C, Hazardous Materials Regulations, 49 CFR Parts 171–180	Provides the U.S. DOT with authority to protect against the risks associated with transportation of hazardous materials, including radioactive materials, in commerce. Establishes DOT requirements for classification, packaging, hazard communication, incident reporting, handling, and transportation of hazardous materials.
DOE Order 460.1D, *Hazardous Materials Packaging and Transportation Safety*	Describes DOE safety requirements for the proper packaging and transportation of offsite shipments and onsite transfers of radioactive and other hazardous materials.
DOE Order 460.2A, *Departmental Materials Transportation and Packaging Management*	Describes DOE requirements and responsibilities for materials transportation and packaging management to ensure the safe, secure, and efficient packaging and transportation of materials, both hazardous and nonhazardous.
DOE Order 461.1C, *Packaging and Transportation for Offsite Shipment of Materials of National Security Interest*	Affirms that the packaging and transportation of all offsite shipments of materials of national security interest for DOE must be conducted in accordance with DOT and NRC regulations that would be applicable to comparable commercial shipments, except where an alternative course of action is identified in the Order.
DOE Order 461.2, *Onsite Packaging and Transfer of Materials of National Security Interest*	Establishes safety requirements and responsibilities for onsite packaging and transfers of materials of national security interest to ensure safe use of Transportation Safeguards System (TSS), non-TSS Government- and contractor-owned and/or leased resources.
Idaho Transportation of Hazardous Waste, IC Title 18, Chapter 39 Hazardous Materials/Hazardous Waste Transportation Enforcement, IC Title 49, Chapter 22	Regulates transportation of hazardous materials/hazardous waste on Idaho highways.
Environmental Justice	

Law, Regulation, Order, or Other Requirement	**Description**
Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, as amended by Executive Order 12948	Requires each federal agency to identify and address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations.
Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks*, as amended by Executive Order 13296	Requires each federal agency to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children and to ensure that its policies, programs, activities, and standards address disproportionate environmental health or safety risks to children.
Emergency Management	
Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601 et seq.	Provides broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.
Emergency Planning and Community Right-to-Know Act of 1986, 42 USC 11001 et seq.	Requires that Federal, State, and local emergency planning authorities be provided information regarding the presence and storage of hazardous substances and their planned and unplanned environmental releases, including provisions and plans for responding to emergency situations involving hazardous materials.
Price-Anderson Act and Amendments, 42 USC 2210 Financial Protection Requirements and Indemnity Agreements, 10 CFR Part 140	Establishes a system of financial protection for persons who may be liable for and persons who may be injured by a nuclear incident.
Oil Pollution Prevention, 40 CFR Part 112	Outlines the requirements for both the prevention of and the response to oil spills; includes requirements for Spill Prevention, Control, and Countermeasure Plans, and for Facility Response Plans.
Designation, Reportable Quantities, and Notification, 40 CFR 302	Requires facilities to notify federal authorities of spills or releases of certain hazardous substances designated under the Comprehensive Environmental Response, Compensation, and Liability Act and Clean Water Act; specifies the quantities of hazardous substance spills/releases that must be reported to authorities and delineate the notification procedures for a release that equals or exceeds the reportable quantities.
Emergency Planning and Notification, 40 CFR Part 355	Describes emergency planning provisions for facilities in possession of an extremely hazardous substance in a quantity exceeding a specified threshold quantity; could apply to substances to be used in the proposed facilities.
Hazardous Chemical Reporting: Community Right-To- Know, 40 CFR Part 370	Establishes reporting requirements for providing the public with important information on the hazardous chemical inventories in their communities.
Toxic Chemical Release Reporting: Community Right- To-Know, 40 CFR Part 372	Establishes reporting requirements for providing the public with important information on the release of toxic chemicals in their communities.
Radiological Emergency Planning and Preparedness, 44 CFR Part 351	Requires emergency plans for DOE nuclear facilities; defines additional DOE responsibilities for assisting the Federal Emergency Management Agency.

Law, Regulation, Order, or Other Requirement	Description
Executive Order 12580, *Superfund Implementation*	This EO gives responsibility to a federal agency for hazardous substance response activities when the release is from, or the sole source of the release is located in, any facility or vessel under the control of that agency.
Executive Order 12656, *Assignment of Emergency Preparedness Responsibilities*	Ensures that DOE has sufficient capabilities to meet defense and civilian needs during national emergency; establishes DOE as the lead agency responsible for energy-related emergency preparedness and for assuring the security of DOE nuclear materials and facilities.
Executive Order 12856, *Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements*	Requires all federal facilities to comply with the provisions of the Emergency Planning and Community Right-to-Know Act (EPCRA); requires reports to be submitted pursuant to EPCRA, Sections 302–303 (Planning Notification), 304 (Extremely Hazardous Substances Release Notification), 311–312 (Material Safety Data Sheet/Chemical Inventory), and 313 (Toxic Chemical Release Inventory Reporting).
DOE Order 151.1D, *Comprehensive Emergency Management System*	Establishes policy; assigns roles and responsibilities; provides the framework for developing, coordinating, controlling, and directing DOE's emergency management system (i.e., emergency planning, preparedness, response, recovery, and readiness assurance).
DOE Order 153.1, *Departmental Radiological Emergency Response Assets*	Establishes requirements and responsibilities for the DOE national radiological emergency response assets and capabilities and Nuclear Emergency Support Team assets.
Standards and Procedures for Application of Risk-Based Corrective Action at Petroleum Release Sites, IDAPA 58.01.24	Establishes standards and procedures to determine whether and what risk-based corrective action measures should be applied to petroleum release sites.

5. Coordination and Consultation

5.1 Shoshone-Bannock Tribes

DOE briefed the Shoshone-Bannock Tribes Tribal staff on September 9, 2020 and the Fort Hall Business Council on September 30, 2020 on the MARVEL microreactor EA and project.

5.2 State of Idaho

DOE briefed the Idaho Governor's Office on the MARVEL EA and project on September 14, 2020.

5.3 Congressional

DOE briefed staff members of Sen Risch, Sen Crapo, and Congressman Simpson on September 15, 2020.

5.4 Idaho Department of Environmental Quality

DOE briefed staff from the Idaho Department of Environmental Quality on the MARVEL microreactor and EA on September 14, 2020.

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