INL/RPT-23-70707

# Materials and Fuels Complex FY-23 – FY-27 Five-Year Investment Strategy

January 2023

Idaho National Laboratory

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# Materials and Fuels Complex
# FY-23 – FY-27
# Five-Year Investment Strategy

January 2023

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Idaho Falls, Idaho 83415

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Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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# ACRONYMS

| | |
|---|---|
| AFF | Advanced Fuel Facility |
| AL | Analytical Laboratory |
| AMWTP | Advanced Mixed Waste Treatment Project |
| ANL | Argonne National Laboratory |
| ATF | Accident Tolerant Fuel |
| ATR | Advanced Test Reactor |
| BCS | Building Control System |
| BOP | balance of plant |
| CAMS | Continuous Air Monitoring System |
| CAS | Criticality Alarm System |
| CH | contact-handled |
| CHC | Complex Health Committee |
| CLG | Casting Laboratory Glovebox |
| D&D | decontamination and decommissioning |
| DEQ | (Idaho) Department of Environmental Quality |
| DDC | Direct Digital Controls |
| DM | Deferred Maintenance |
| DOE | Department of Energy |
| DOE-NE | Department of Energy Office of Nuclear Energy |
| DOME | Demonstration of Operational Microreactor Experiments |
| DU | depleted uranium |
| EBR-II | Experimental Breeder Reactor-II |
| ECP/EBL | Element Contact Profilometer/Element Bow & Length Machine |
| EDGB | East Development Glovebox |
| EELS | Electron Energy Loss Spectrometer |
| EM | DOE Office of Environmental Management |
| EML | Electron Microscopy Laboratory |
| EMM | Electro-mechanical manipulators |
| EMT | electrometallurgical treatment |
| EOL | end-of-life |
| EPMA | Electron Probe Micro-Analysis |
| FASB | Fuels and Applied Science Building |
| FCF | Fuel Conditioning Facility |

| | |
|---|---|
| FIB | Focused Ion Beam |
| FMF | Fuel Manufacturing Facility |
| GAIN | Gateway for Accelerated Innovation in Nuclear |
| GASR | Gas Assay Sample and Recharge |
| GPP | General Purpose Project |
| HALEU | high assay low enriched uranium |
| HC | Hazard Category |
| HEU | high enriched uranium |
| HFEF | Hot Fuel Examination Facility |
| HLW | high level waste |
| HVAC | heating, ventilating, and air conditioning |
| IA | Instrument Air |
| IAEA | International Atomic Energy Agency |
| IASCC | irradiation assisted stress corrosion cracking |
| ICERR | International Centre based on Research Reactor |
| ICP | Inductively Coupled Plasma |
| ICP-MS | Inductively Coupled Plasma Mass Spectrometer |
| IFM | Idaho Facilities Management |
| INL | Idaho National Laboratory |
| IRA | Inflation Reduction Act of 2022 |
| ISA | Idaho Settlement Agreement |
| LA | laser ablation |
| LEU | low-enriched uranium |
| LFTD | laser-flash thermal-diffusivity |
| LLW | low-level waste |
| LOTUS | Laboratory for Operation and Testing in the United States |
| LWR | light water reactor |
| MC-ICP-MS | Multi-Collector Inductively Coupled Plasma Mass Spectrometer |
| MEITNER | Modular Examination Instrument for Transportable Nuclear Energy Research |
| MFC | Materials and Fuels Complex |
| MLLW | mixed low-level waste |
| MTRU | Mixed Transuranic |
| NE | Office of Nuclear Energy |
| NHS | National Homeland Security |
| NR | Naval Reactors |

| | |
|---|---|
| NRAD | Neutron Radiography Reactor |
| NRIC | National Reactor Innovation Center |
| NS&T | Nuclear Science and Technology |
| NSUF | Nuclear Science Users Facilities |
| NTP | Nuclear Thermal Propulsion |
| NU | natural uranium |
| ORNL | Oak Ridge National Laboratory |
| PFCN | Private Facility Control Network |
| PIE | post-irradiation examination |
| RAMS | Radiation Area Monitoring System |
| RCRA | Resource Conservation and Recovery Act |
| RD&D | research, development, and demonstration |
| RDD&D | research development, demonstration, and deployment |
| RH | remote-handled |
| RHLLW | Remote Handled Low Level Waste |
| RLWTF | Radioactive Liquid Waste Treatment Facility |
| RN | Repair Needs |
| ROM | rough-order of-magnitude–Generally engineering judgement estimates for conceptual purposes with a range of -50%/+100%. Used as a placeholder prior to initiating detailed planning activities. |
| RWDP | Remote Waste Disposition Project |
| SC-ICP-MS | Single Collector Inductively Coupled Plasma Mass Spectrometer |
| SCMS | Sodium Components Maintenance Shop |
| SEM | Scanning Electron Microscopy |
| SNF | Spent Nuclear Fuel |
| SNFWG | Spent Nuclear Fuel Working Group |
| SPG | Special Project Glovebox |
| SSC | structure, system, and component |
| SSPSF | Space and Security Power Systems Facility |
| STP | Site Treatment Plan |
| TCM | Thermal Conductivity Microscope |
| TEM | Transmission Electron Microscopy |
| TESB | TREAT Experiment Support Building |
| TIMS | thermal ionization mass spectroscopy |
| TREAT | Transient Reactor Test Facility |

| | |
|---|---|
| T-REXC | TREAT Micro-Reactor Experiment Cell |
| TRIGA | Training, Research, Isotope, and General Atomics |
| TSDF | Treatment, Storage, and Disposal Facility |
| U&IS | Utilities and Infrastructure Support |
| VFD | variable frequency drive |
| VTR | Versatile Test Reactor |
| WIPP | Waste Isolation Pilot Plant |
| WMP | Waste Management Program |
| ZPPR | Zero Power Physics Reactor |

# 1. INTRODUCTION

The Department of Energy Office of Nuclear Energy (DOE-NE) vision is to "Advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs." The Materials and Fuels Complex (MFC) serves as the foundation of a nuclear RD&D enabling test bed at Idaho National Laboratory (INL) and is an integral part of a National Reactor Innovation Center (NRIC) strategy. MFC facilities focus on developing and maintaining RD&D capabilities that can increase research throughput, reduce barriers to deployment, and facilitate commercialization of new ideas and technologies for clean and secure sources of energy.

The MFC Five-Year Investment Strategy plan is complementary to the MFC Five-Year Mission Strategy and MFC Operations Management Improvement (OMI) Strategy. The relationships between these documents can be summarized as follows:

- The MFC Five-Year Investment Strategy defines infrastructure needs, cost, and timeline necessary to meet the MFC mission strategy.
- The MFC Five-Year Mission Strategy defines the MFC outcomes and strategies required to meet DOE and INL Laboratory objectives identified in the INL Laboratory Plan and DOE-NE programs.
- The OMI Strategy identifies barriers to MFC success in terms of people, processes, and additional equipment needs not identified in the investment strategy. The OMI Strategy defines actions and timelines to remove those barriers.

Last, annual budget development is done through the Integrated Resource Planning Tool which identifies and allocates resources and funding required to meet mission objectives.

## 1.1 An Investment Strategy for the Materials and Fuels Complex

MFC supports current RD&D missions while enabling new projects and missions working with DOE-NE sponsors, other federal agencies, private industry, and academia. The investment strategy described in this document guides the efforts to build, expand, and sustain DOE-NE research capabilities at MFC, increase access to MFC capabilities by industry and the nuclear RD&D community, and revitalize existing MFC nuclear infrastructure. The strategy also anticipates and guides the preparations necessary for demonstration of advanced nuclear energy technologies in support of NRIC, the DOE Gateway for Accelerated Innovation in Nuclear (GAIN) initiative, and nuclear energy and other related critical outcomes identified in the INL Laboratory Plan.

MFC's core research and/or production competencies exist in the following areas:

- Nuclear fuels fabrication
- Fuel characterization
- Materials characterization: Radiation damage in cladding and reactor components
- Fuel recycling and nuclear material management
- Transient irradiation testing
- Radioanalytical chemistry
- Space nuclear power
- Focused basic research
- Isotope production
- Nuclear nonproliferation and nuclear forensics.

The investment strategy for MFC entails building and improving on these core competencies, introducing new and revitalized RD&D capabilities, and maturing the NRIC test bed. MFC is also implementing new business and operations models to help transform MFC into a complex that supports an advanced nuclear technology development test bed. The strategy for MFC is presented in several parts, each focusing on an element needed for success.

Key areas of emphasis for this strategy include the following:

- Facility Infrastructure and Operations – This emphasizes executing efficient base operations as a core foundation of RD&D execution excellence. Investments in plant health beyond basic preventative and corrective maintenance addresses revitalization and refurbishment activities focused on improving facility reliability and accelerating research throughput. This supports DOE-NE programmatic objectives by maintaining and improving existing test bed infrastructure and constructing new support infrastructure, as needed, to ensure the safe, more efficient operations of MFC.
- Mission Operations and Maintenance – This critical part of the MFC-wide operations model transitions MFC towards a user facility concept by providing predictable and reliable base funding to support a core team of expert RD&D support staff and critical RD&D test bed systems and infrastructure. The term "user facility" denotes a step change transition from providing only stable reliable single source funding for compliance-level base operations and maintenance; it also includes funding to maintain RD&D support staff and critical research infrastructure to ensure available staff and systems are ready to support important research missions. This is distinct from base operations which focuses on systems and infrastructure associated with building operations (heating, ventilating, and air conditioning [HVAC], electrical, safety systems, building roofs and shells, etc.) and maintains facility safety bases and compliance requirements. Mission operations and maintenance ensures reliable state-of-the-art research capabilities are available to effectively operate and maintain a test bed capability as envisioned by GAIN and serves as a foundation of the NRIC. Full cost recovery from research programs for costs related to executing mission related RD&D support activities is still part of the financial model.
- Instrument Science – This area emphasizes RD&D development where MFC has a core strength. This includes collaborating with the Nuclear Scientific Users Facility, INL Nuclear Science and Technology (NS&T) programs, National Homeland Security (NHS) programs, NRIC, and others to prioritize and pursue funding for construction or enhancement of future or current capabilities where national gaps exist. This can also include indirect laboratory investment in scientific capabilities. It recognizes leveraging the key partnerships with other DOE national laboratories such as Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), and others as well as enhancing relationships and furthering partnerships with DOE-NE's extended research network to fill capability gaps that will not be added to MFC. This area seeks to improve or establish relationships with U.S. universities to further extend the nuclear research network, provide a pipeline for recruiting future staff, and positively influence educational programs. This also provides additional collaboration pathways with the international community through INL's designation as an International Centre based on Research Reactor (ICERR) by the International Atomic Energy Agency (IAEA).

This investment strategy positions INL and its sponsor, DOE-NE, to deliver an effective nuclear RD&D capability supporting current programs and continue to build an accessible, comprehensive, reliable, and cost-effective nuclear demonstration capability that supports deployment of nuclear technology. This capability will play a key role in developing advanced nuclear technology concepts that can positively impact the ability of U.S. nuclear energy technology to keep pace with a changing world energy market.

This document includes:

- A description of MFC facility infrastructure support needs in Section 2
- A description of MFC scientific infrastructure support needs in Section 3
- A forward-looking vision for development of the MFC campus in Section 4
- Details of specific plant health and RD&D capability target areas in Appendixes A and C
- Descriptions of general infrastructure needs in Appendix B
- Detailed descriptions of Transient Reactor Test Facility (TREAT) instrument capability activities in Appendix D.

**NOTE:** *The cost estimates listed in this document in the tables in Sections 2 and 3 are based upon best engineering judgement at the time the scope was identified by the Mission Directors. In every case the cost estimates will change as work proceeds through planning, design, and execution. The intent of these tables is to provide a strategic context on what areas within MFC facility and scientific infrastructure have been identified as important to address facility reliability, RD&D capability sustainment, and capability growth to support the test bed and NRIC concept.*

## 1.2 Anticipated Investment Strategy Outcomes

MFC recognizes that implementing this strategy requires significant investment. This commitment is not taken lightly. As with any investment, a return on that investment is expected. Implementing this strategy results in the following outcomes:

- Increased facility and equipment reliability and availability, reducing the experiment lifecycle of RD&D critical to DOE-NE and other missions
- More efficient operations, increasing the amount of critical knowledge gained per dollar spent on research
- A wider range of RD&D capabilities that support a range of objectives from scientific discovery and model validation to demonstration and licensing
- Increased capability to broaden technology readiness level coverage and support the Nuclear Energy R&D Test Bed concept in a reliable manner.

MFC performance metrics focus on factors important to enabling and monitoring MFC's nuclear energy RD&D mission. Metrics target the following areas:

- Reduction of deferred maintenance and repair needs – Documented levels of deferred maintenance in the Facility Information Management System will be reduced
- Increased facility availability – The percentage of time major facilities are available to support RD&D will increase with increased reliability of key operational systems in the R&D facilities
- Increased instrument and equipment use – Use of key RD&D instruments will be tracked to provide data for identifying instrument reliability, performance, and resource issues and to help with future planning for instruments and personnel resources
- Increased ability to meet key RD&D's operational and strategic milestones and objectives – MFC maintains a comprehensive list of RD&D program, key operational, and strategic milestones and objectives and tracks performance to these commitments
- Quality, relevance, and impact of research output – Metrics used to demonstrate an increase in the contribution MFC is making to nuclear energy knowledge includes the following:
  - Number and quality of peer-reviewed publications and reports
  - Number of external users relying on MFC RD&D capabilities

- Stakeholder Feedback through entities such as the INL Materials and Fuels Complex Strategic Advisory Committee or others (e.g., NS&T, NHS, external industry, small business, and university users)
- Compliance with regulatory requirements, ensuring commitments are understood and met.

## 1.3 Funding Model

MFC is the hub of the DOE-NE test bed and NRIC. The funding strategy below aligns MFC with the overall DOE-NE objective of developing a nuclear energy test bed that can enable innovative nuclear energy technology to pass swiftly through the technology readiness levels. This positions new technology for deployment into the commercial sector as a safe cost-competitive carbon-free energy source.

Figure 1 provides a diagram of the main funding areas addressed in this investment strategy. Elements shaded blue are proposed to be funded by the Idaho Facilities Management (IFM) program and the green shaded element should be supported by multiple funding sources including NE RD&D programs and laboratory indirect investments. Key here is stable, predictable funding to cover the base operations, maintenance and plant health and mission operations and maintenance areas described in Section 1.1. Overall funding levels to build an effective test bed and to reestablish DOE-NE as the world leader in innovative nuclear energy technology are identified in Table 1. New construction associated with developing the NRIC/GAIN test bed and demonstration platform described in Section 4 is separate funding from test bed infrastructure operations included here.

***INL's ability to perform world class research, development, and demonstration depends on maintaining nuclear RD&D facilities, scientific instruments, necessary scientists and staff to support greater science throughput and shorten the experiment lifecycle***

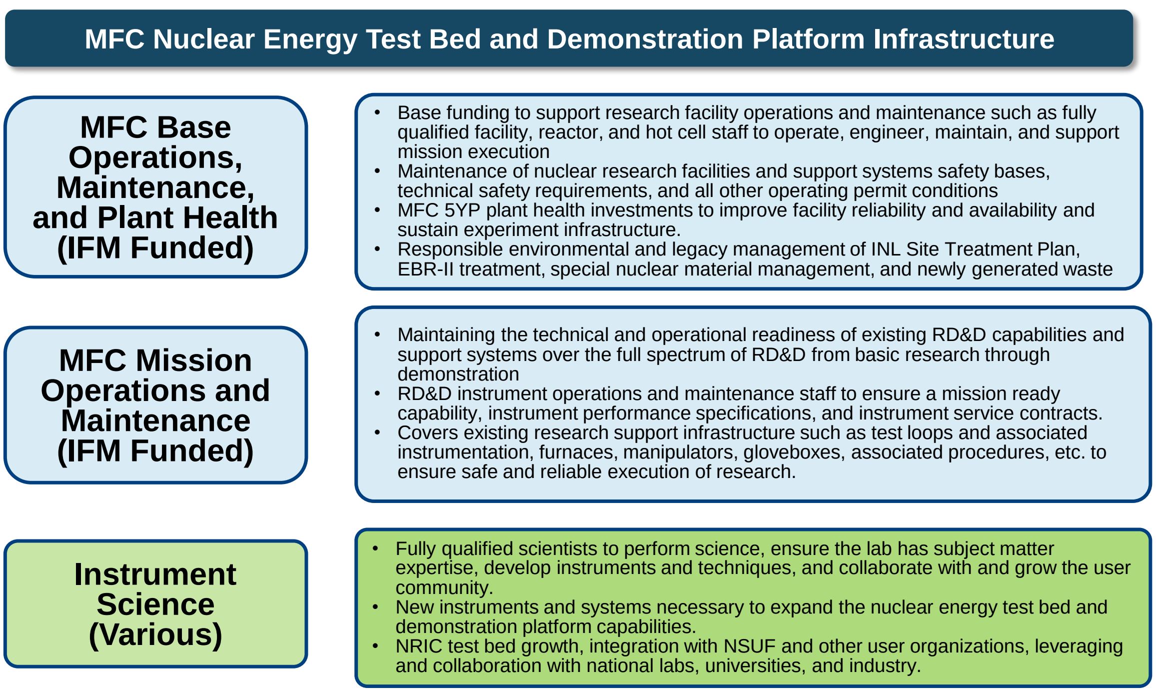



Figure 1. DOE-NE Test Bed and Demonstration Platform Funding Strategy.

# 2. MFC FACILITY OPERATIONS AND INFRASTRUCTURE

Facility Infrastructure has been divided into four areas:

1. MFC Base Operations and Maintenance – This area provides compliance-level support to operate and maintain MFC nuclear and radiological facilities in a safe, stable, and compliant state of readiness to accept work. This includes TREAT base operations listed separately in the table below. (Subsection 2.1)
2. MFC Mission Operations and Maintenance – This area provides funding above compliance level that provides the technical staff and material necessary to operate, maintain, and sustain current RD&D capabilities and associated support systems at a mission readiness level to be ready to support RD&D mission execution. (Subsection 2.2)
3. MFC Plant Health Strategic Investments – These are investments in plant systems and infrastructure above historical levels of corrective and preventative maintenance. These investments are focused on refurbishment and replacement of aging plant systems and instruments that can impact facility reliability and availability and negatively affect mission execution and RD&D outcomes. The selection of plant health activities has been formalized into a prioritization process involving input by facility-specific technical personnel with an MFC-wide evaluation and prioritization by the MFC Complex Health Committee made up of the mission directors and chaired by the MFC Associate Laboratory Director. (Subsection 2.3)
4. Waste and Materials Management – These activities support meeting regulatory agreements between DOE and government entities such as the Idaho Settlement Agreement (ISA) and Site Treatment Plan. This also includes activities executed to reduce the legacy liability of INL. (Subsection 2.4)

A funding profile is shown in Table 1. These funding levels support the reliable infrastructure necessary to provide a mature test bed and demonstration capability.

Table 1. MFC proposed funding levels.

| MFC Area | FY-22 Omnibus Level | FY-23 Omnibus Level | FY24 Proposed Level | FY25 Proposed Level | FY26 Proposed Level | FY27 Proposed Level |
|---|---|---|---|---|---|---|
| ***MFC Reactor Operations*** | | | | | | |
| NRAD Operations and Maintenance | 2,334 | 3,177 | 4,504 | 5,184 | 6,392 | 6,647 |
| TREAT O&M | 25,886 | 26,921 | 27,998 | 29,118 | 30,283 | 31,494 |
| **MFC Reactor Operations Total** | **28,220** | **30,098** | **32,502** | **34,302** | **36,674** | **38,141** |
| ***MFC Infrastructure and Operations*** | | | | | | |
| MFC Base Operations & Maintenance | 92,000 | 105,430 | 109,647 | 114,033 | 118,594 | 123,338 |
| MFC 5 Year Plant Health Investments | 17,687 | 15,663 | 30,000 | 30,000 | 30,000 | 30,000 |
| MFC Mission Operations and Maintenance | 42,754 | 48,280 | 50,211 | 52,220 | 54,308 | 56,481 |
| SNM Program/Processing | 4,502 | 4,682 | 4,869 | 5,064 | 5,266 | 5,477 |
| SPL OPC's | 3,450 | 5,950 | 6,000 | 850 | | |
| **Total MFC Infrastructure and Operations** | **160,393** | **180,005** | **200,727** | **202,166** | **208,169** | **215,296** |
| ***MFC Regulatory Support*** | | | | | | |
| INL Regulatory Compliance | 1,490 | 5,000 | 5,200 | 5,408 | 5,624 | 5,849 |
| EBR II | 8,475 | 8,814 | 10,300 | 10,600 | 10,900 | 11,200 |
| **MFC Regulatory Support Total** | **9,965** | **13,814** | **15,500** | **16,008** | **16,524** | **17,049** |
| **Total MFC Operations** | **198,578** | **223,918** | **248,729** | **252,477** | **261,368** | **270,486** |
| ***Line Item Construction*** | | | | | | |
| Sample Preparation Laboratory | 41,850 | 7,300 | | | | |
| Reactor Fuels Research Capability | | | 5,000 | 35,000 | 30,000 | 30,000 |
| **Construction Total** | **41,850** | **7,300** | **5,000** | **35,000** | **30,000** | **30,000** |
| **GRAND TOTAL** | **240,428** | **231,218** | **253,729** | **287,477** | **291,368** | **300,486** |

## 2.1 MFC Base Operations and Maintenance

Base operations funding provides the resources needed to maintain nuclear and radiological facilities in a compliant state of readiness to accept work. This base work scope is not considered discretionary. This state of readiness has historically been defined as maintaining the facilities in a safe, compliant, and stable configuration within the established safety bases and regulatory framework to be available to support RD&D programs (Compliance Level).

Execution within the base operations framework includes managing the operations, maintenance, and support of nuclear facilities and resources to be ready to enable the conduct of advanced nuclear energy research at MFC.

Specific tasks include:

- Performing surveillance, maintenance, and operation activities required to control existing material and waste, and to maintain facilities in a safe and stable condition
- Ensuring regulatory requirements are met that relate to health and safety, fire protection, nuclear safety (facility authorization basis), criticality safety, and safeguards and security
- Ensuring compliance with state and federal environmental and operating permit requirements
- Performing the engineering for structure, system, and component (SSC) modifications necessary to ensure safety and functionality
- Enabling specific activities such as an equipment reliability program, systems engineering, improving configuration management, and plant health monitoring that efficiently ensures reliability of SSCs and the efficiency and safety in which maintenance and engineering is executed
- Ensuring enabling infrastructure such as fuel handling capabilities, a full suite of waste disposition pathways, and integrated cask management is available to support the mission
- Additional engineering and other technical support resources needed to address the technical issues associated with operating multiple shifts in aging facilities to meet mission demands.

## 2.2 MFC Mission Operations and Maintenance

Implementing a sustainable and reliable nuclear RD&D capability requires a funding model that supports effective and efficient management of research instruments and research facilities critical to execution of the current DOE-NE research portfolio and in support of an expanded mission anticipated through the GAIN initiative. RD&D Mission Operations and Maintenance provides the foundation for a comprehensive, reliable, and sustained research capability and a stable environment for recruiting, retaining, training, and improving the expertise of the scientific and support work force.

The proposed RD&D Mission Operations and Maintenance activities support technical and operational readiness of RD&D capabilities (instruments) and the associated support systems including:

- Operation of instruments to develop new methods and techniques while not performing direct program work
- Maintenance of instruments including instrument service contracts (vendor maintenance agreements) to ensure performance specifications are maintained
- Upgrade and develop unique instrument applications to ensure world-class instrument and process performance
- Feasibility and safety evaluations for the use of various fuels and materials configurations
- Preparation of regulatory documentation to support RD&D needs

- Support for general user program relative to experiment setup and data analysis
- Training of staff and users in the operation or maintenance of instruments
- Maintenance, operation, and engineering of support systems such as inert gas, manipulators, experiment loops gloveboxes and furnaces to ensure safe and reliable performance
- Performance testing of integrated instrument systems
- Coordination and logistical support for instrument usage, maintenance, and testing
- Commodity usage such as gas and chemicals that support instrument usage
- Maintenance on in-cell/glovebox utilities and equipment that support instrument and RD&D capabilities such as feedthroughs and process instrumentation
- Maintaining inter-facility transport capabilities
- Operating and maintaining data and control networks.

Establishing a robust, direct-funded mission operations and maintenance platform is a key element in transition to a user facility model that has been successfully deployed in many government-sponsored research facilities and is critical to improve research throughput and efficiency. Steady and reliable mission operations and maintenance funding ensures that RD&D capabilities including instruments and scientific and technical resources are available to support DOE-NE mission execution. This eliminates the uncertainty associated with variable programmatic fund sources and ensures that facilities and instruments are maintained as world-class and mission-ready with the necessary technical expertise to enable mission success. This approach will dramatically increase throughput and reduce the experiment life-cycle time. Additionally, the U.S. ability to lead collaborative efforts is instrumental in reestablishing U.S. leadership in advanced nuclear energy technologies and research techniques.

## 2.3 MFC 5-Year Plant Health Strategic Investments

MFC plant health investments are a key aspect of a healthy and efficient NE RD&D test bed model required to support NRIC. This requires dedicated and sustained funding to address MFC's plant health needs. Targeted major maintenance and repair addresses system and equipment degradation increasing facility availability and throughput. Targeted major maintenance and repair efforts (described in Section 3) include hot cell window replacements, next-generation manipulators, and Analytical Laboratory (AL) HVAC upgrades. These upgrades will result in a reduction in MFC deferred maintenance (DM) and key repair needs (RN). This funding enables facilities to sustain multiple shifts and to handle the increased maintenance burden as they operate at increased capacity. The MFC investment strategy identifies the highest priority risks to facility reliability and RD&D experiment throughput and proposes a multi-year strategy to address these risks. The strategy also addresses DM across all MFC nuclear and radiological facilities. Priorities are established by analysis of overall risk to facility availability and system reliability. The total integrated plant health and RD&D capability and sustainment requests are detailed in Table 2 and Table 11.

Funding available to support plant health investments has been significantly less than the $30M annual levels requested in the investment strategy. These reduced levels require a focus on areas where the leadership team has determined provide the highest return in terms of facility reliability and research throughput. MFC has implemented a disciplined process to identify and assign a relative priority to plant health issues using an MFC Complex Health Committee (CHC) prioritization process. This process is captured in MFC-ADM-0006, "Materials and Fuels Complex (MFC), Facilities and Complex Health Reporting Process." This procedure describes the integrated and coordinated complex wide reliability and health issue management process that the Materials and Fuels Complex (MFC) uses to identify, evaluate, monitor, maintain, repair, and upgrade site Structures, Systems, and Components (SSCs) important to safe and reliable facilities operation and to meeting the mission goals of MFC. This process utilizes the

Long Term Asset Management (LTAM) component of the ER Suite software. It addresses key aspects necessary for the CHC to prioritize MFC plant health needs with available funding. This process is designed to identify and prioritize risks to facility reliability and RD&D mission execution with a goal of ensuring facility reliability risks are identified and addressed before impacts to facility availability or RD&D capability occur. Steady and reliable funding to support a sustained plant health campaign is a critical aspect of the new test bed model and is essential to enable increased RD&D throughput and mission execution success.

The Hot Fuel Examination Facility (HFEF) is DOE-NE's core post-irradiation examination (PIE) facility originally commissioned in 1974. Nearly all irradiated samples are processed through HFEF before being sent out to other facilities. This 5YS addresses deficiencies in HFEF systems that currently limit research throughput and ensures that MFC's support for DOE's mission is not negatively impacted. Critical HFEF systems and research equipment are being refurbished and replaced to increase facility reliability, and experiment throughput. MFC is focusing in in-cell handling equipment such as manipulator and cranes as well as refurbishing hot cell windows,

The HFEF main cell pressure/temperature, purification, and compressed argon systems use obsolete technology. The argon compressors have been replaced by a new tank system. Key components of the temperature and pressure system are exhibiting increasing failure rates and many times spares are not available or require a vendor to custom fabricate special-order spares on a limited basis. This approach to patching the system is expensive, time consuming, and does not fundamentally resolve the reliability issues. Current efforts to update these systems will minimize future programmatic impacts due to system reliability.

HFEF electrical systems have, for the most part, remained unchanged and have only had minor modifications performed since HFEF was constructed in the 1970s. System failures are increasing and spare parts and vendor support is rapidly disappearing; there are no spares available for the breaker panels and motor control centers.

HFEF recently replaced aging back-up power generators relocated adjacent to HFEF from the HFEF basement. This frees up footprint for HFEF to expand test bed capabilities related to the neutron beam lines associated with NRAD while minimizing facility downtime associated with transition to the new generators.

The Analytical Laboratory (AL) is MFC's principal facility for conducting analytical chemistry and experimental data analysis on nuclear fuels and materials. AL received its first hot fuel sample from the Experimental Breeder Reactor-II in 1964 and has been in continuous operation since. AL is a Hazard Category (HC)-3 Nuclear Facility with approximately 10,000 $ft^2$ of laboratory space. The AL HVAC system was no longer capable of supporting additional research or analytical capability. The HVAC system is being refurbished and upgraded to support growth in RD&D capabilities and increase facility reliability. AL is also executing lab renovations and fume hood replacements throughout the facility to modernize the labs and increase operating efficiency

The HFEF, FCF, and AL master/slave manipulators and electro-mechanical manipulators (EMM) are key systems that move equipment and material and execute RD&D within the MFC hot cells. These are aging and replacement components are difficult or impossible to acquire. Each set of manipulators services a unique capability(s) within the facility hot cells; manipulator failures remove that particular capability from service and impact mission execution. To address a large portion of this issue, MFC has partnered with a vendor to design and fabricate the next generation of manipulators that are currently in production. Addressing the manipulators is phased over several years and will eventually result in replacement of all manipulators with reliable next-generation and more ergonomic equivalents. New models of manipulators from another vendor have been installed in the AL hotcells. These are significant improvements to the older models and support more efficient sample analysis. Ongoing evaluation of these alternatives to the current suite of manipulators will continue.

The hot cell windows at HFEF and FCF were fabricated over 50 years ago. These windows are four feet thick and comprise tank units filled with alternating layers of glass and mineral oil. Several of the units are leaking mineral oil, which requires resources to manage and mitigate the impacts, increasing cost and decreasing operations efficiency. An ongoing window replacement campaign staged over several years targets HFEF, FCF, and AL hot cell windows. AL is also investigating the use of oil free hot cell windows to reduce maintenance associated with leaking windows.

FCF priorities include addressing the facility control system for hot cell operations and for in-cell process equipment. The first phase, funded in FY-19, replaced the small logic controllers for the system. These were producing spurious failure notifications decreasing facility reliability and requiring significant time and effort to troubleshoot and address. Follow on phases will include facility programmable logic controllers and other process control systems. The reliability of the high bay crane will be addressed in the future.

Several facility reliability issues at FCF are now being addressed with additional funding received as part of the 2022 Inflation Reduction Act (IRA). This funding is associated with IRA funding earmarked to address NE infrastructure. This includes the process control systems discussed above. Other material handling capabilities such as the Suited Entry Repair Area (SERA) crane are also being refurbished. Additional funds may be provided to address scope associated with HALEU production.

FMF and ZPPR facilities replaced the current criticality alarm systems (CAS). These were funded in FY-19 and scheduled for completion in FY-20. The FMF HVAC system also needs refurbishment. FMF and ZPPR roofs are aging and are being replaced (FMF) and repaired (ZPPR) to address infiltration of precipitation.

After 4 years of resumed operation of the TREAT reactor, following over 23 years of non-operational standby, the TREAT team is learning more about maintenance needs for the facility and reactor equipment. Plant Health priorities for TREAT reflect emerging reliability issues with older equipment, such as 1980s-era control chassis or the Digital Microprocessor tester, discoveries of latent conditions with uncertain effects, such as unusual welds on control rod segments, and challenges obtaining obsolete parts.

Ongoing investment in data communications infrastructure (wired and wireless) is necessary to improve overall effectiveness and efficiency at MFC. Cyber security considerations must also be assessed and managed to support secure execution of the RD&D mission. Continued update and refurbishment of communications and cyber infrastructure enable safety, security, and mission effectiveness and becomes more urgent as technology advances and communication, cyber security, and data management needs increase.

A sustained plant health campaign at proposed funding ensures aging infrastructure at MFC remains reliable and available to support DOE-NE mission execution and can support the additional RD&D capacity and capabilities anticipated as the test bed grows and expands across more technology readiness levels.

Table 2. Prioritized MFC Plant Health Investment. Cost in thousands ($K).

| MFC Overall Priority | Asset Name | Name | Prior Years | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | ROM Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AL | Replace or Upgrade the AL HVAC System | $11,297 | $5,316 | $ 697 | | | | | | $17,310 |
| 2 | HFEF/FCF/ AL | Manipulator Refurbishment and Replacement Campaign in HFEF, FCF, and AL | $5,383 | $ 577 | $2,000 | $3,000 | $3,000 | $3,000 | $3,000 | | $19,960 |
| 3 | HFEF/FCF/ AL | Window Replacement Campaign in HFEF, FCF, and AL | $1,844 | $ 130 | $2,000 | $2,000 | $2,000 | $2,000 | $2,000 | TBD | $11,974 |
| 4 | FCF | Multi-Function Furnace #1 | $6,017 | $2,021 | $1,616 | | | | | | $9,654 |
| 5 | HFEF/FCF/ AL | Radioactive Liquid Waste Treatment Facility Process/Storage Tanks Replacement | $2,095 | $ 749 | $ 724 | | | | | | $3,568 |
| 6 | HFEF | Small and Large Transfer Lock Doors and Drive Control System Upgrade | $ 992 | $ 236 | $ 445 | | | | | | $1,673 |
| 7 | HFEF/FCF | Electro-mechanical Manipulator, Cranes, Hoists and Other In-Cell Handling Equipment Refurbishment and Replacement | $3,713 | $1,410 | $4,900 | $4,000 | $4,000 | $1,212 | | | $19,235 |
| 8 | FCF | Replace FCF SERA/DSC Crane and Control Equipment | | | $ 500 | $3,500 | $4,000 | | | | $8,000 |
| 9 | FCF | New SCRAPE Cathode Module for FCF Electrorefiner | $1,677 | $ 102 | $ 871 | | | | | | $2,650 |
| 10 | FCF | Replace FCF Facility Control System | $2,500 | | $1,800 | $4,800 | $4,800 | $ 600 | | | $14,500 |
| 11 | AL | AL Lab Space Renovations | $2,354 | | $1,700 | $2,000 | $2,000 | | | | $8,054 |
| 12 | HFEF | Argon regeneration valves | $ 44 | $ 500 | | | | | | | $ 544 |
| 13 | FCF | Design, fab, and install feedthrough in FCF to support $CO_2$ cold jet decon system | $ 473 | $ 85 | $ 122 | | | | | | $ 680 |
| 14 | HFEF | MET Box refurb - purification system replacement | $ 688 | $ 63 | $ 232 | | | | | | $ 983 |
| 15 | HFEF | Containment Box lid seal & hoist | $ 505 | $ 412 | $ 108 | | | | | | $1,025 |
| 16 | HFEF | Fabricate Replacement Parts for HFEF Transfer Lock Ram | $- | $2,000 | | | | | | | $2,000 |
| 17 | FCF | FCF In-Cell Lighting Upgrade | $ 300 | $2,000 | $ 700 | | | | | | $3,000 |
| 18 | TREAT | Replace TREAT Loop Handling Cask Winch System | $- | | $ 100 | | | | | | $ 100 |
| 19 | TREAT | TREAT Dedicated Microprocessor Tester Installation | $- | | | $ 150 | | | | | $ 150 |

| MFC Overall Priority | Asset Name | Name | Prior Years | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | ROM Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | TREAT | TREAT Radio Signal Booster | $ 100 | | $ 100 | | | | | | $ 200 |
| 21 | TREAT | Experiment Data Acquisition System (EDACS) Installation/Upgrade | | $ 40 | $ 440 | | | | | | $ 480 |
| 22 | TREAT | Replace TREAT Control Rod Segments | | | | $ 250 | $ 500 | $ 500 | | | $1,250 |
| 23 | MFC | Fire barrier refurbishment for MFC Nuke and Rad Facilities | | | $1,000 | | | | | | $1,000 |
| 24 | HFEF | Refurbish Precision Gamma Scanner | | | $1,500 | $1,500 | | | | | |
| 25 | MFC | Replace MFC fire protection and potable water system | | | $2,250 | $4,500 | $4,500 | $3,750 | | | $15,000 |
| 26 | MFC | Replace MFC industrial waste water system | | | $1,500 | $3,500 | $3,500 | $1,500 | | | $10,000 |
| 27 | AL | Emergency Shower/Eyewash Compliance Updates | | | $ 750 | | | | | | $ 750 |
| 28 | Nuke/Rad Facilities | Roof Repairs for Nuke/Rad Facilities | | | $6,000 | $7,000 | $7,000 | | | | $20,000 |
| 29 | AL | Ultra Pure Water Stations | | | $ 300 | | | | | | $ 300 |
| 30 | HFEF | HFEF decon cell fire suppression system | | | $ 750 | $2,500 | $1,250 | | | | $4,500 |
| 31 | FCF, FASB | Install Facility Specific Plant Cooling Water Systems | | | | $1,000 | $1,000 | $1,000 | $1,000 | $6,000 | $10,000 |
| 32 | HFEF | HFEF Hot Cell Chiller Replacement | | | | $ 500 | $1,500 | | | | $2,000 |
| 33 | IMCL | IMCL Laboratory House Chiller System | | | | $ 500 | $1,000 | | | | $1,500 |
| 34 | TREAT | Transient Rod Drive Controller Replacement | | | | 30 | | | | | $ 30 |
| 35 | NRAD | NRAD Fuel Procurement | | | | $1,300 | $1,400 | $1,300 | | $3,000 | $7,000 |
| 36 | MFC | MFC Glovebox Oxygen Monitors | | | | $ 900 | | | | | |
| 37 | RSWF /RHLLW | Procure Transfer Container for Large Liners at RSWF | | | | $5,000 | | | | | $5,000 |
| 38 | RHLLW | RHLLW Maintenance Bldg Overhead Door Replacement | | | | $ 500 | | | | | $ 500 |
| 39 | FCF | Refurbish FCF Air Cell Transfer Hatch Ram | | | | | $ 300 | $ 300 | $ 700 | | $1,300 |
| 40 | TREAT | MFC-720 Replace Roll-up Doors | | | | $ 450 | | | | | $ 450 |
| 41 | FCF | Replace FCF Decon Spray Chamber Chiller Unit | | | | | $ 500 | $1,500 | | | |
| 42 | HFEF | HFEF Intrafacility Pneumatic Sample Transfer Systems Overhaul | | | | | | $ 850 | | $1,500 | $2,350 |

| MFC Overall Priority | Asset Name | Name | Prior Years | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | ROM Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43 | MFC | Compressed Air Supply System for Research Facilities | | | | | | $4,000 | | $8,000 | $12,000 |
| 44 | HFEF | HFEF Hot Cell HEPA Replacement | | | | $1,000 | $3,500 | $ 500 | | | $5,000 |
| 45 | IMCL | New Instrument Room and Mezzanine in IMCL | | | | | $2,000 | | | | $2,000 |
| 46 | FCF | Replace McQuay Air Conditioner at FCF | | | | | $1,500 | | | | $1,500 |
| 47 | FCF | FCF High Bay Crane Refurbishment/upgrade | | | | | $2,500 | $2,500 | | | $5,000 |
| 48 | IMCL | Hoar Frost Buildup on HVAC Intake Filters | | | | | $ 350 | | | | $ 350 |
| 49 | AL/RCL | RCL Backup Power | | | | | | $1,750 | | | $1,750 |
| 50 | AL | Abandoned lines and equipment (can be incrementally funded) | | | | | | | | $10,000 | $10,000 |
| 51 | MFC | Cask Integration, Management, and Capability Sustainment | | | | $1,000 | $1,000 | $ 400 | $ 600 | | $3,000 |
| 52 | MFC | Interfacility pneumatic shuttle transfer system refurbishment | | | | | $ 650 | $7,150 | $2,200 | | $10,000 |
| 53 | AL | Analytical Lab Process Management System Upgrade | | | | | $ 250 | $1,000 | | | $1,250 |
| 54 | TREAT | TREAT Critical Spares for ARCS, DIS, and RTS | | | | $ 400 | | | | | $ 400 |
| 55 | TREAT | TREAT Flex Test 40 Controllers | | | | $ 400 | | | | | $ 400 |
| 56 | FMF | FMF HVAC/Suspect Exhaust System | | | | | | | | $2,500 | $2,500 |
| 57 | FCF | FCF HRA reactivation | | | | | | $ 500 | $3,500 | $3,000 | $7,000 |
| 58 | TREAT | TREAT Diesel Generator Replacement | | | | | | | | $ 250 | $ 250 |
| 59 | TREAT | TREAT Filtration Cooling System VFD Motor Replacement | | | | | $ 40 | | | | $ 40 |
| 60 | TREAT | He-3 Injection System Final Design and Hardware Procurement | | | $ 200 | $1,000 | | | | | $1,200 |
| 61 | NRAD | NRS Elevator and Cask Interface Upgrade | | | | | | $ 250 | $1,100 | $2,750 | $4,100 |
| 62 | FCF | FCF Material Tracking System and Support Infrastructure Replacement | | | | | | | $1,500 | $4,000 | $5,500 |
| 63 | HFEF | Decontamination Spray System | | | | | | | $1,200 | | $1,200 |

| MFC Overall Priority | Asset Name | Name | Prior Years | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | ROM Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | FCF | Replace FCF Argon Cell North and South Recirc Blower and Install Purification Instrument | | | | | | $ 300 | $1,200 | | $1,500 |
| 65 | HFEF | In-Cell Compressed Argon Manifold Supply and Associated Controls | | | | | | | $ 500 | | $ 500 |
| 66 | HFEF | Building Lab Exhaust Fan Replacement | | | | | | | $1,150 | $ 850 | $2,000 |
| 67 | HFEF | Replace HFEF Freight Elevator | | | | | | | $ 300 | $1,700 | $2,000 |
| 68 | FASB | Upgrade FASB Ventilation System | | | | | | | $ 500 | $1,500 | $2,000 |
| 69 | AL | AL Hot Cell 5 and 6 Reconfiguration | | | | | | | $1,200 | $4,200 | $5,400 |
| 70 | AL | Waste Volume Reduction Capability (A28) | | | | | | | $ 400 | $4,600 | $5,000 |
| 71 | AL | Replace AL Backup Diesel Generator | | | | | | | $2,500 | | $2,500 |
| 72 | AL | Instrument UPS Installation | | | | | | | $1,000 | | $1,000 |
| 73 | AL | AL Multi-Zone System Overhaul | | | | | | | $2,500 | $2,000 | $4,500 |
| 74 | FMF/ZPPR | Implement uniform SNM containers and design verification | | | | | | | | $3,500 | $3,500 |
| 75 | FCF | In-cell Periscope and Camera System Replacement | | | | | | | | $2,500 | $2,500 |
| 76 | FMF | New Decon Fume Hood for Container Examination | | | | | | | | $ 750 | $ 750 |
| 77 | FASB | Remove RERTR Glovebox | | | | | | | | $1,000 | $1,000 |
| 78 | MFC | Install Perma-Con containment to replace aging waste management tent workrooms | | | | | | | | $3,000 | $3,000 |
| 79 | AL | Addition of Pneumatic Transfer Line from AL Hot Cells | | | | | | | | $3,500 | $3,500 |
| 80 | IMCL | Contamination Control Updates | | | | | | | | $1,500 | $1,500 |
| 81 | Nuke/Rad Facilities | MFC Private Facility Control Network (PFCN) Critical Infrastructure, Industrial Controls Servers, and Data Repository Storage Facility | | | | | | | | $10,000 | $10,000 |
| 82 | AL | AL Acid Scrubber Replacement | | | | | | | | $3,000 | $3,000 |
| | FCF | Integrate Bottle Inspection w/Wire Removal Process Improvement - Complete | $1,918 | $ 189 | $ 13 | | | | | | $2,120 |

| MFC Overall Priority | Asset Name | Name | Prior Years | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | ROM Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | HFEF | Argon Cell Temperature and Pressure Controls - Complete | $2,186 | | | | | | | | $2,186 |
| | FMF | Replace the Criticality Alarm System (CAS) in FMF - Complete | $1,325 | | | | | | | | $1,325 |
| | ZPPR | Replace the Criticality Alarm System (CAS) in ZPPR - Complete | $1,259 | | | | | | | | $1,259 |
| | HFEF | Facility Out-of-Cell 40-TonHigh Bay Crane - Complete | $3,217 | | | | | | | | $3,217 |
| | HFEF/ IMCL | Compressed Argon Supply System - Complete | $1,087 | | | | | | | | $1,087 |
| | MFC | Legacy Materials Disposition - Complete | $3,764 | | | | | | | | $3,764 |
| | RCL | Convert heating from steam to electric - Complete | $ 647 | | | | | | | | $ 647 |
| | FMF/ZP PR | FMF Roof Replacement/ ZPPR Roof Repair - Complete | $5,400 | $2,700 | | | | | | | $8,100 |
| | IMCL | Noise Reduction Modifications - Complete | $ 148 | | | | | | | | $ 148 |
| | IMCL | Fixed Air Sampling System - Complete | $ 575 | | | | | | | | $ 575 |
| | IMCL | IMCL facility ventilation system optimization - Complete | $ 86 | | | | | | | | $ 86 |
| | IMCL | IMCL facility manipulator repair capability - Complete | $1,058 | $ 142 | | | | | | | $1,200 |
| | IMCL | IMCL Communications Infrastructure - Complete | $ 278 | | | | | | | | $ 278 |
| | IMCL | IMCL Material Transfer Optimization - Complete | $ 16 | | | | | | | | $ 16 |
| | Sitewide | Radiation Monitoring Updates - Complete | $1,500 | | | | | | | | $1,500 |
| | AL | ENU Replacement - Complete | $1,603 | | | | | | | | $1,603 |
| | HFEF | Exterior roof/stack access stairs - Complete | $ 250 | | | | | | | | $ 250 |
| | HFEF | Argon compressor removal - Complete | $ 581 | | | | | | | | $ 581 |
| | HFEF | HFEF Truck Lock Floor Repair - Complete | $- | $ 250 | | | | | | | $ 250 |
| | EBR-II | Continued EBR-II Dome test bed platform refurbishment (carryover) - Complete | $2,853 | | | | | | | | $2,853 |
| | HFEF | HFEF Standby Diesel Generator Removal & Replacement - Complete | $4,240 | $1,431 | | | | | | | $5,671 |

| MFC Overall Priority | Asset Name | Name | Prior Years | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | ROM Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | FASB | Install Equipment Enclosure and North Side Upgrades - Complete | $ 500 | | | | | | | | $ 500 |
| | ZPPR | ZPPR Vault Cooling System Upgrade - Complete | $ 390 | | | | | | | | $ 390 |
| | ZPPR | ZPPR Vault Cooling System Upgrade - Complete | $- | $ 400 | | | | | | | $ 400 |
| | AL | AL EIFS Installation - Complete | $1,104 | | | | | | | | $1,104 |
| | AL | Lab B-103 Refurbishment - Complete | $1,315 | | | | | | | | $1,315 |
| | AFF | AFF Modifications (HVAC) - Complete | $2,860 | | | | | | | | $2,860 |
| | | **TOTALS** | **$80,142** | **$20,353** | **$21,268** | **$29,380** | **$30,240** | **$30,012** | **$28,050** | **$84,600** | **$316,045** |
| | | **Total IFM 5YS Funding Authorized** | **$89,006** | **$17,564** | **$12,000** | | | | | | **$118,570** |
| | | **IRA Funding** | | | **$12,050** | **$23,300** | **$23,800** | **$5,850** | **$-** | **$-** | **$65,000** |

Note: Costs/Funding levels reflect actual costs through FY 22 plus estimates at completion for activities still in progress. Remaining funding levels are rough order of magnitude estimates based upon current scope understanding and will be refined as detailed execution planning is completed.

Green shaded represent scope authorized to proceed

Authorized to proceed. Funded by the Inflation Reduction Act of 2022

The ranking priority of scope in the "Outyear" column is subjective and will certainly change as emergent scope is identified and priorities evolve

## 2.4 MFC General Infrastructure

The MFC Utilities and Infrastructure Systems (U&IS) support department is developing a comprehensive approach to address overall health of our mission supporting infrastructure. This scope is reflected as part of Table 3. This scope reflects the significant growth in personnel supporting the research mission at MFC and new facilities and research capabilities such as micro-reactor demonstrations. The approach will position MFC to optimally support a diverse research mission for decades to come and includes consideration for Net Zero efforts, climate change vulnerabilities, and resiliency planning.

MFC supporting infrastructure systems were installed throughout the 1960's with few exceptions. Age related failures are beginning to impact mission accomplishment on a more regular basis due to component and piping failures. In the last two fiscal years MFC experienced three piping failures in the fire main system and two in the plant cooling water system all of which impacted mission execution. MFC is currently dealing with a failing 13.8K-480v transformer that optimally would be replaced by sectionalizer technology to forgo taking down multiple mission facilities to perform predictive, preventative, or corrective maintenance. This is sustainable in the short term but neglects a strategic approach which would ensure reliable mission supporting infrastructure for decades.

Infrastructure examples are included in Table 3 below, and detailed descriptions are provided in Appendix B. This includes maintenance campaigns on general support infrastructure systems such as electrical distribution, water distribution, drainage, and roads. This also addresses energy efficiency needs through roof/window/building skins replacement across the campus, additional office space for TREAT and micro reactor teams and refurbishment of the TREAT office building. Most of this scope is proposed to be addressed through incremental strategic laboratory investments. Some specific systems examples also include:

- Technical obsolescence of electrical distribution system substation breakers, age of transformers, and overall cable condition
- Age and failure rates of fire main, plant cooling water, potable water – valves, piping, pumps
- Lack of capacity of the TREAT office building septic system which was designed for approximately 20 personnel and is now supporting 60 plus
- The lack of capacity for instruments and facility systems data transmission and storage
- Age and obsolescence, as well as emissions impact, of the standby diesel generator fleet
- Age and failure rates of general office building HVAC systems, and
- The need for a holistic approach to MFC roads and grounds stormwater runoff control.

IRA funding discussed in Section 2.3 has been appropriated to address NE infrastructure. A portion of this funding will address fire protection/potable water systems, industrial wastewater, and nuclear research facility roofs. Detailed planning has commenced on these areas with the majority of the work anticipated to be executed FY-24 – FY-27. This work will be carefully integrated with mission execution to minimize impacts on mission operations.

Table 3. Primary areas for general infrastructure investment.

| General Infrastructure Area | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears |
|---|---|---|---|---|---|---|---|
| MFC-773 Substation Maintenance | $500 | $1,500 | | | | | |
| Building HVAC Maintenance | $1,000 | $1,000 | $1,000 | $500 | $500 | $500 | $4,500 |
| Asphalt Replacement and Roadway Maintenance | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 | $15,000 |
| MFC Communications Network Infrastructure Maintenance | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 | $19,000 |
| MFC Warehouse Loading Dock Reconfiguration | $500 | $1,500 | | | | | |
| Office/Space Maintenance | $500 | $1,500 | $1,000 | $1,000 | $500 | $500 | $4,500 |
| Cathodic Protection Maintenance | $500 | $1,000 | $1,000 | | | | |
| MFC Fire Protection and Potable Water System Maintenance | | $1,000 | $1,000 | $1,000 | $1,000 | | $16,000 |
| MFC-786 Substation Maintenance | | | | | | | $25,000 |
| Re-establish Western Loop of MFC Main Road | | $1,000 | $1,000 | $1,000 | $1,000 | | |
| MFC Storm Drain System Maintenance | | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 | $11,000 |
| MFC Sanitary Sewer System Maintenance | | $1,000 | $1,000 | $1,000 | $1,000 | $1,000 | $4,000 |
| MFC Industrial Wastewater System Maintenance | | | $500 | $2,000 | $1,500 | | |
| Roofs - non-nuke/rad | | | $500 | $1,000 | $1,000 | | |
| **Totals** | **$5,000** | **$12,500** | **$10,000** | **$10,500** | **$9,500** | | **$99,000** |

## 2.5 Waste and Materials Management

### 2.5.1 Newly Generated Waste Management

MFC manages various newly generated and legacy research-related materials and wastes as part of the environmental stewardship responsibility and compliance with DOE O 435.1 requirements. Detailed treatment and disposition paths have been established and alternative disposition paths are being evaluated. The approach to disposition of newly generated waste is leveraging actions taken to address legacy liabilities. The strategy is to identify off-site treatment as the preferred approach considering several factors, including how quickly the respective inventories could be dispositioned, realizing efficiencies by focusing on more than one off-site treatment provider, total lifecycle cost savings, and INL capabilities associated with disposition that should be retained, expanded, or retired with respect to the enduring mission of INL

All newly generated waste is managed under an INL service center full cost-recovery program that ensures waste costs are paid for by the generating programs or facilities and funding is available in the future for disposition of all waste types. The INL Waste Management Program (WMP) administers nine site-wide service centers. The INL Waste Generator Services service center collects revenue and pays disposition costs for waste with a readily available disposition path and supports establishing disposition paths for new waste streams prior to generation. The INL RH Waste Service Center collects revenue for newly generated RH waste that are dispositioned at the INL RHLLW Disposal Facility or for TRU that will be dispositioned to Waste Isolation Pilot Plant (WIPP). MFC is working with the research community to ensure full cost recovery for material storage and ultimate disposition is incorporated into every experiment baseline. Material disposition planning and budgeting by research organizations will be required prior to initiating research at MFC. This will be standardized and implemented as part of any new experiment planning and for any research currently being worked with NS&T.

BEA is using the EM ID Idaho Cleanup Contract contractor capabilities and WIPP certified transuranic (TRU) program certification for disposition of contact-handled (CH) and RH-TRU. The current version of the 5-year plan assumes this pathway exists under the new ICP contract. DOE EM decided to close the Advanced Mixed Waste Treatment Project (AMWTP) at the end of 2019. BEA is developing establishing a TRU certification program to support ongoing newly generated TRU waste. Multi-year Laboratory investments have been made to initiate TRU program development. This plan will address increased waste generation from new and emerging programs such as the NRIC microreactors and high assay low enriched uranium (HALEU) programs, assess what is needed to support waste certification and characterization, and investigate siting options for this capability. Development of a BEA High Level Program (HLW)is underway to address future HLW generation. AMWTP provided critical characterization, certification, and transportation support for BEA-generated CH-TRU waste. A major capability of AMWTP facilities was waste conditioning and waste repackaging. This capability will not be needed for BEA-generated CH-TRU waste. BEA’s TRU program planning will assess the capabilities of the AMWTP facilities and make recommendations regarding retention of characterization and certification equipment and siting of this capability for future program support. For example, co-locating this CH-TRU capability with RH-TRU capability at INTEC may have significant benefit. In addition to this TRU program planning activity, BEA is also taking leadership in the formulation of a Battelle community of practice specifically addressing TRU waste disposition as analogous situations exists at other Battelle-managed national laboratories.

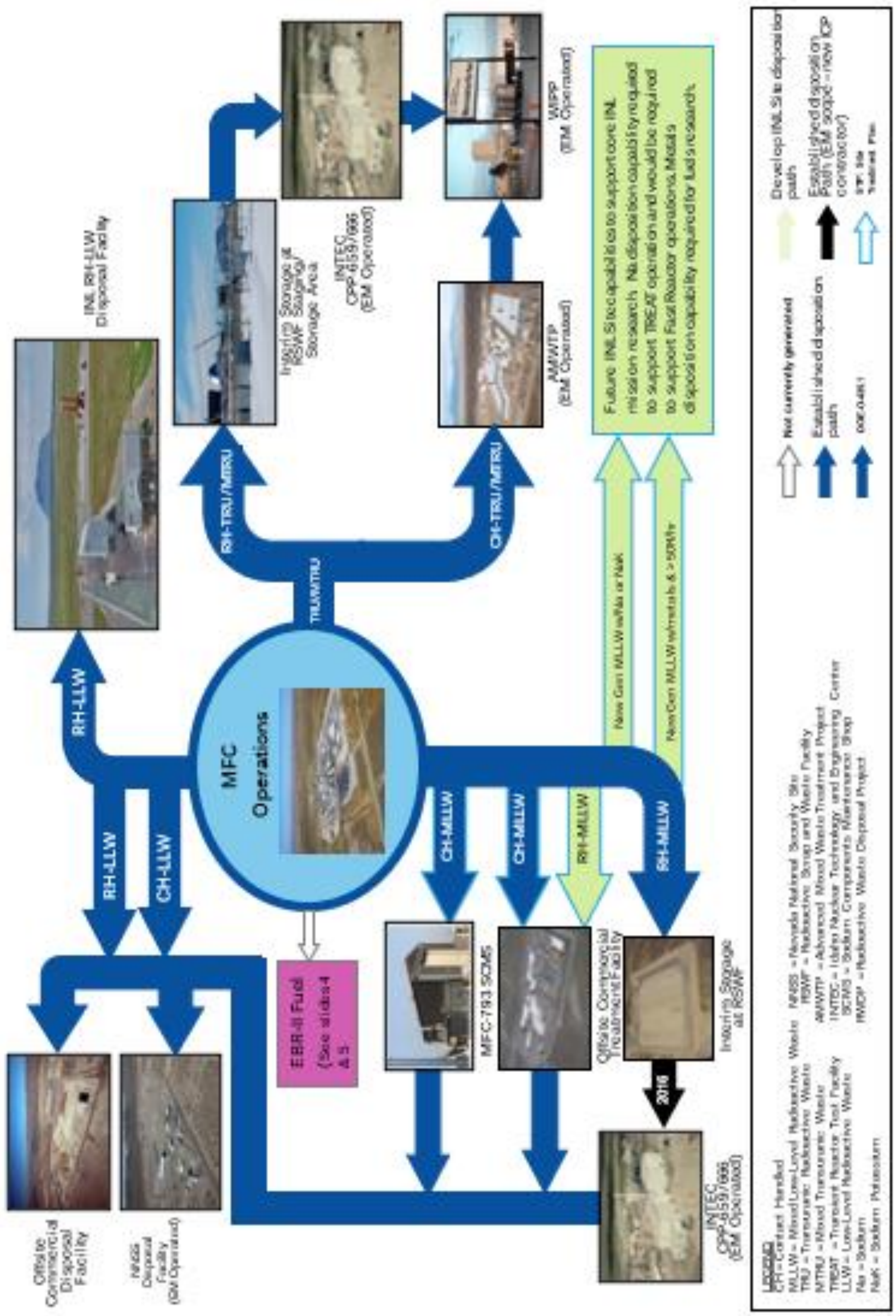



Figure 2. MFC Radioactive Waste Disposition Path Flowsheet.

### 2.5.2 Legacy Materials Management

DOE-NE is responsible for the storage, management, and disposition of a number of legacy waste and spent nuclear fuel (SNF) inventories including irradiated sodium-bonded uranium-based material from the EBR-II reactor, sodium-contaminated CH and RH mixed transuranic waste (MTRU), RH mixed low-level waste (MLLW), CH-MLLW, EBR-II driver and blanket SNF and material, contact-handled excess nuclear material, and ATR SNF. The majority of these items, with the exception of the contact-handled excess nuclear material, are managed under the INL Site Treatment Plan (STP) as directed by the consent order between DOE and the Idaho Department of Environmental Quality (DEQ) or under the 1995 Idaho Settlement Agreement and subsequent associated agreements. All of these legacy liabilities and associated disposition costs are detailed in the INL Other Legacy Environmental Liabilities Register, INL LST-1149, Rev 7, October 10, 2022. See Table 4 for a summary. These liabilities are currently being addressed with several different funding sources as discussed below.

Table 4. INL Other Legacy Environmental Liabilities, LST-1149 Summarized.

| Other Legacy Environmental Liability Title (LST-1149) | FY-22 Estimated Cost to Address ($M) | Current Status |
|---|---|---|
| EBR-II Spent Fuel and Related Materials | $874 | EBR-II Na bonded driver fuel SNF (525M) is being treated with incremental annual operations funding.<br>Additional R&D for blanket fuel required to address other materials. |
| Excess Plutonium | $1,045 | Contact handled SNM being addressed with incremental annual operations funding |
| Remote Handled Low Level Waste Stored at MFC | $109 | This involves a current total of 301 273 waste cans/liners containing legacy RH LLW that are currently stored in RSWF at MFC. The waste consists primarily of irradiated metals. Current planning and incremental annual operations funding covers disposition of RH-LLW at the RH-LLW Disposal Facility |
| Remote Handled Transuranic Waste | $13 | Post-irradiation examination and lab related misc. waste streams (irradiated experimental component debris, HEPA filters, PPE, sample waste, etc.) generated by HFEF and FCF. Waste containers are currently in storage at RSWF and RSWF Staging/Storage Area. |
| Site Treatment Plan Consent Order CH MLLW/RHLLW | $1,062 | CH MLLW – This inventory (SCMS Backlog) consists of primarily sodium and sodium-potassium alloy contaminated irradiated material that must be treated prior to disposition. The current disposition is being addressed with regulatory compliance incremental annual funding.<br>RHMLLW – The waste consists primarily of sodium contaminated irradiated metals and research material that must be treated prior to disposition (RWDP Backlog). The conditional transfer of this liability from NE to EM is documented in the memorandum from Ines Triay, EM-1, to Shane Johnson, NE-1, dated May 4, 2009. EM will accept responsibility for this liability as EM receives baseline funding needed to perform the work and disposition the waste. EM typically provides funding each year to disposition a fixed number of the original 168 waste containers and items identified during the liability transfer negotiations. Additional information regarding the NE to EM liability transfer can be found in the memorandum from Shane Johnson to Ines Triay dated February 20, 2009. |
| **Total Estimated Costs ($M)** | **$3,090** | |

#### *2.5.2.1 NE Funded Other Legacy Environmental Liabilities*

MFC manages a substantial inventory of excess contact-handled special nuclear material (SNM). The major quantities of excess contact-handled SNM are associated with ZPPR fuel, unirradiated fast reactor fuel and associated fabrication scrap, and feedstock materials. The overarching nuclear material management goal is to maintain and enhance the capability to efficiently support excess material disposition and programmatic missions while minimizing the number of facilities and locations that are required to manage significant quantities of special nuclear material. MFC supports programmatic planning efforts to ensure nuclear material is available to meet anticipated needs while minimizing the inventory of excess SNM stored at MFC. Prior efforts have resulted in tons of excess SNM and approximately 170 MT of excess source nuclear material being removed from MFC. Current efforts focus on monitored safe storage of the existing material inventory, along with continued processing and shipment of legacy highly enriched uranium (HEU) scrap materials. These efforts facilitate transition of the HEU to beneficial reuse where practical, produce a more stable and better characterized material form, free up vault storage space to support new RD&D missions, and demonstrate continued progress towards responsible removal of excess nuclear material from the state of Idaho. Future efforts will focus on developing new equipment capabilities needed to process and disposition the legacy plutonium-bearing scrap materials.

Currently BEA is using the EM ID Idaho Cleanup Contract contractor capabilities and Waste Isolation Pilot Plant (WIPP) certified Transuranic (TRU) program certification for disposition of TRU waste; this pathway is assumed to exist under new ICP contract. MFC is currently packaging legacy RH-TRU/MTRU waste located in the HFEF and FCF Hot Cells, Analytical Laboratory in a manner compatible with characterization capabilities located at INTEC (e.g., externally clean 55-gallon drums) and shipping these to INTEC for eventual final disposition. There are also nine containers at RSWF that can be retrieved, as is, and transported to INTEC when schedules allow and funding is available.

A strategy, consisting of several tactical actions, to address disposition of legacy environmental liabilities for reactives (typically sodium or sodium-potassium alloy contaminated items) has been developed and implemented. This strategy, documented in PLN-4588, Disposition Plan for Current and Future Reactives and Other Environmental Liabilities, is designed to ensure compliance with the INL STP and 1995 ISA while minimizing DOE-NE budget requirements needed to maintain progress towards compliance agreements. This plan establishes a path for off-site treatment capabilities for the CH-MLLW, and portions of the RH-MLLW, in part, under the Remote Waste Disposition Project (RWDP) backlog, with the potential for application of the treatment capability against future reactive waste or materials on a case-by-case basis. The strategy also includes leveraging industry technology advances, engagement with complex wide activities through active participation with Energy Facilities Contractors (EFCOG) Waste Management Group, DOE National TRU Program Users Group , Spent Nuclear Fuel Working Group (SNFWG) as well as engagement with international consortia and the International Atomic Energy Agency. Off-site treatment capabilities established after years of collaborating with technology and service providers has resulted in significant legacy liability disposition cost reduction. Disposition paths for remaining legacy inventory and potential newly generated waste streams have been established.

Identifying off-site treatment as the preferred approach considering several factors, including how quickly the respective inventories could be dispositioned, realizing efficiencies by focusing on more than one off-site treatment provider, total lifecycle cost savings, and INL capabilities associated with disposition that should be retained, expanded, or retired with respect to the enduring mission of INL. PLN-4588 also provides the key activities, preliminary cost estimates, and high-level schedules that are required to implement the preferred approach. MFC has taken action to integrate with the VTR and other advanced reactor programs to ensure that off-site and on-site capabilities exist to manage potential waste and SNF generated, in compliance with INL regulatory drivers.

Table 5. NE Funded Environmental Liabilities and Proposed Funding to Address Them.

| Activity | Description | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Total ($K) |
|---|---|---|---|---|---|---|---|---|
| EBR-II Sodium Bonded SNF Treatment (NE-3) | EBR-II driver fuel and EBR-II blanket elements in storage at MFC pending treatment prior to disposal at a geologic repository | 8,475 | 8,814 | $10,300 | $10,600 | $10,900 | $11,200 | **$60,289** |
| Site Treatment Plan/Consent Order CH MLLW SCMS Backlog (NE-3) | Identified in the INL Site Treatment Plan as legacy contact-handled mixed low-level waste that contains sodium (Na), sodium potassium alloy (NaK), or a combination of both. | $1,490 | $5,000 | $5,200 | $5,408 | $5,624 | $5,793 | **$28,515** |
| RH TRU/MTRU Repack (NE-3) | Remote-Handled Transuranic Post-irradiation examination and lab related misc. waste streams (irradiated experimental component debris, HEPA filters, PPE, sample waste, etc.). | | | $2,000 | $3,000 | $4,000 | $4,000 | **$13,000** |
| Contact Handled SNM Management and Disposition (NE-3) | Disposition efforts associated with equipment development, processing, repackaging, consolidation, and shipment of excess plutonium-bearing contact-handled material (dominated by ZPPR clad fuel) from MFC. | $4,329 | $4,682 | $4,869 | $5,015 | $5,166 | $5,320 | **$29,381** |
| **Total Proposed NE-3 Funding** | | **$14,294** | **$18,496** | **$22,369** | **$24,023** | **$25,690** | **$26,313** | **$131,185** |

#### 2.5.2.2 Laboratory Funded Legacy Material Disposition

INL has provided laboratory funding for disposition of excess materials not covered under the ISA or STP and which are located at various locations across MFC. These materials range from excess ZPPR reactive materials to miscellaneous equipment and material utilized by past programs and projects no longer active and no longer needed. The funding profile is identified below in Table 6.

Table 6. Laboratory Funded Excess Material Disposition.

| Activity | Description | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Total ($K) |
|---|---|---|---|---|---|---|---|---|
| Excess legacy material and equipment | Excess legacy material and equipment which were used in programs, projects or facilities that are no longer in operation and no longer needed. This does not include excess material or equipment generated by existing programs. | $500 | $500 | $500 | $500 | $500 | $500 | $3,000 |
| **Total Proposed Laboratory Funding** | | **$500** | **$500** | **$500** | **$500** | **$500** | **$500** | **$3,000** |

#### 2.5.2.3 EM Funded Other Legacy Environmental Liabilities

As management and disposition of the INL Other Legacy Environmental Liabilities is shared with and dependent upon DOE EM, it is critical to maintain a strong relationship with DOE EM. BEA, working with NE ID has developed a strong relationship with EM ID and EM HQs that has resulted in partnering in development of technology solutions and knowledge enabling more effective and efficient management of legacy liabilities described in LST-1149. An example of this is BEA, using EM funding, executing a proof-of-concept demonstration with the objective of developing and demonstrating a prototype system to improve the RWDP liner retrieval process identified in Table 7. This prototype system has been designed to provide a size-reduced liner thereby improving the efficiency of down-stream waste handling and providing for alternative processing/disposition. The first proof-of-concept demonstration completed in FY-21 and included a coupled demonstration of the advanced liner retrieval system and new off-site treatment options. Additional retrievals with coupled offsite treatment are planned for FY-22. It is anticipated that this alternative RWDP liner disposition approach will significantly reduce cost and schedule associated with the liability captured in the INL STP.

The conditional transfer of this liability from NE to EM is documented in the memorandum from Ines Triay, EM-1, to Shane Johnson, NE-1, dated May 4, 2009. EM will accept responsibility for this liability as EM receives baseline funding needed to perform the work and disposition the waste. EM typically provides funding each year to disposition a fixed number of the original 168 waste containers and items identified during the liability transfer negotiations. Additional information regarding the NE to EM liability transfer can be found in the memorandum from Shane Johnson to Ines Triay dated February 20, 2009. This waste stream consists of primarily sodium contaminated irradiated metals and research material that must be treated prior to disposal.

**UPDATE:** *A new Memorandum of Agreement (MOA) between DOE-EM and DOE-NE has recently been issued. Implementation and changes to this plan as a result of this MOA are still being worked. Once the implementation details have been finalized, this section will be revised to reflect this strategy in the next annual revision.*

Table 7. EM Funded Other Legacy Environmental Liabilities Dependent Upon Future Funding.

| Activity | Description | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Total ($K) |
|---|---|---|---|---|---|---|---|---|---|
| RWDP Backlog - RH MLLW retrievals (currently DOE-EM funded) | RH MLLW stored at MFC is included in the backlog associated with the Remote Waste Disposition Project. | $250 | $1,000 | TBD | TBD | TBD | TBD | TBD | $1,250 |
| RWDP Backlog – Proof of Concept Demonstration for RH MLLW Advanced Retrievals (DOE-EM funded) | DOE EM Technology Development One-Time Proof-of-Concept Funding | $1,200 | $3,900 | TBD | TBD | TBD | TBD | TBD | $5,100 |
| **Total DOE-EM Funding to Date** | | **$1,450** | **$4,900** | | | | | | **$6,350** |

### 2.5.3 Strategy to Accelerate Production of High Assay Low-Enriched Uranium Material

The irradiated sodium-bonded uranium-based material from the EBR-II reactor includes ~25 metric tons of heavy metal. Due to the reactive nature of the sodium component of this material, it is not a candidate for direct geologic disposal under current DOE policy, unless the reactive hazard is mitigated. Consequently, the material has been consolidated and placed into interim storage at INL site for evaluation and processing to address the reactive hazard.

The current processing method is the electrometallurgical treatment (EMT) process for treatment of both the highly enriched uranium driver fuel and depleted uranium-based blanket elements irradiated in EBR-II. The technology has been demonstrated to be effective at simultaneously separating the components of the used fuel and neutralizing the bonded sodium. As part of the EMT process, the metallic uranium used in the original construction of the element is separated from the fission products and transuranic elements produced during irradiation. The highly enriched uranium separated and recovered during the treatment of the driver fuel elements has been identified as a source of HALEU and industry interest in this material as a potential source of feedstock to support new fuels in advanced reactor concepts has had a significant impact on the strategy for treatment of the irradiated EBR-II elements.

FCF was previously operated 4 days/week, 10 hours/day in accordance with baseline funding of approximately $8M which supported 25 FTEs and a production rate of 6 batches of driver fuel processed annually. However, due to industry interest in the HALEU product, FCF added personnel and transitioned to a 7d/12h work schedule in FY-19 to support production of a HALEU product that is capable of being used as a fuel feedstock and handled in gloveboxes based on conceptual fuel fabrication scenarios. This expanded work schedule is supported by additional annual funding, provided by DOE’s office of Nuclear Fuel Cycle and Supply Chain (NE-4) (see Table 5).

In November 2019, a Supplemental Agreement to the 1995 Idaho Settlement Agreement was established between the State of Idaho and the Department of Energy which provided conditions to support re-commencing research on commercial used fuel at INL. As part of the framework of this Supplemental Agreement, DOE agreed to several terms and conditions related to the treatment of the irradiated EBR-II driver fuel pins into product material for HALEU production, with the most relevant as follows:

- DOE shall treat at least 165 pounds heavy metal of sodium-bonded EBR-II driver fuel pins per year on a three-year rolling-average basis
- DOE shall complete treatment of all sodium-bonded EBR-II driver fuel pins by December 31, 2028
- Except for high-level waste (HLW), DOE shall dispose of any waste materials, including but not limited to fuel-pin cladding material generated during treatment outside of the State of Idaho by no later than January 1, 2035
- Any HLW generated during treatment shall be treated so as to put it into a form suitable for transport to a permanent repository or interim storage facility outside the State of Idaho by a target date of December 31, 2035
- If DOE has not put all the treated product material to beneficial use, DOE will remove all treated product material from the State of Idaho by January 1, 2035.

In order to comply with the conditions agreed to by DOE, INL will need to accelerate treatment of the EBR-II Driver Fuel beginning in FY-24 beyond current 7d/12h work schedule and will hire and train additional personnel beginning in FY-22. Improvements for efficiency and/or alternative processing technologies had previously been identified as necessary to successfully meet the original 2035 deadline agreed to in the ISA. Accordingly, INL has initiated investigations aimed at identifying potential management alternatives, as well as possible process enhancements to the current system. The goal of the investigation is to identify new technologies and methods for efficiency improvements and cost reductions in order to successfully achieve the conditions established in the 2019 Supplemental Agreement, as well as those previously developed to comply with the 2035 ISA deadline.

The age of FCF and processing equipment, coupled with the harsh operating environment and unique material handling needs associated with the existing batch process, introduces risks to sustained high throughput operations. To mitigate these risks, the plant health process described within this plan includes refurbishment and replacement of the through-wall tele-manipulators and overhead electro-mechanical manipulators (see Table 2, items 4 and 14). Additional plant health investments are funding process improvements including installation of a new, redundant cathode processor (multi-function furnace), a new remotely operated workstation to consolidate bottle inspection and wire removal, and a new scraped cathode module for use in the electrorefiners. These investments will help to eliminate existing single-point failures and increase operating efficiencies for the existing processing equipment.

#### 2.5.3.1 Funding and Schedule Estimate to Achieve Desired Production Rate

The incremental acceleration and utilization of legacy inventory including treatment in the Mk-IV electrorefiner along with 20 ingots recast in HFEF metal waste furnace from the legacy-recovered uranium inventory resultant from past EBR-II driver fuel treatment.

The strategy is summarized as follows:

- Continue processing EBR-II SNF at the current rate, complete processing improvements, including introduction of improved product form (~3kg ingots) and adding a new processing furnace to supplement the current cathode processor (~Fall of 2021).
- Integrate recasting or isotopic cleanup of legacy product inventory using process enhancements to produce a smaller, lower-dose product.
- Increased FCF's working schedule to 7 days/week, 12 hours/day in 2019, and further increase to 7 days/week, 24 hours/day by FY-24, with preparations beginning in FY-22.
- Escalate required funds at 3%/yr 2019–2023, funding requirements will increase in 2024 for additional cost of retrieving EBR-II driver fuel from RSWF. Further cost increases will be observed in FY-22 to support acquisition and training of additional personnel associated with 24 hour/day operations.
- Recast all legacy inventory by 2024. All driver fuel treatment complete by December 2028.
- Have 5MT of HALEU feedstock available by December 2024.

Table 8. Funding for EBR-II Processing ISA 2035 Baseline Case.

| Activity | Description | FY-20 | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | FY-28 | Total ($K) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EBR-II Sodium Bonded SNF Treatment (NE-3) per PLN-6098 | EBR-II driver fuel and EBR-II blanket elements in storage at MFC pending treatment prior to disposal at a geologic repository | $8,228 | $8,228 | $8,475 | $8,814 | $10,300 | $10,600 | $10,900 | $11,200 | $11,500 | **$88,245** |

Table 9. Accelerated HALEU Production Funding Profile required to support ISA supplemental agreement.

| Activity | Description | FY-20 | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | FY-28 | Total ($K) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Proposed Accelerated HALEU Production Funding Level (NE-4) per PLN-6098 | Accelerating EBR-II treatment recasting EBR-II spent fuel treatment product to support HALEU feedstock development for advanced reactor fuel. Funded by the NE Materials Recovery and Waste Form Development program (NE-4) | $8,000 | $8,250 | $17,500 | $25,750 | $26,600 | $27,400 | $28,250 | $29,100 | $29,975 | **$200,825** |
| Actual Funding Received to Accelerate HALEU | This row identifies actual levels of funding received from NE-4 | $8,000 | $10,000 | $15,000 | $27,000 | TBD | TBD | TBD | TBD | TBD | **$60,000** |

| Activity | Description | FY-20 | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | FY-28 |
|---|---|---|---|---|---|---|---|---|---|---|
| EBR-II HALEU Cumulative Production | Total cumulative estimated HALEU production from both operations | 715 kg | 1,015 kg | 1,615 kg | 2,615 kg | 4,245 kg | 6,005 kg | 7,805 kg | 8,845 kg | 9,754 kg |

## 2.6 Integrating Reactor Demonstration into Base Operations

### 2.6.1 Reactor Demonstration Funding Model

The funding model related to reactor demonstration follows the overall funding strategy summarized in Figure 1. These capabilities must be carefully integrated into the NE test bed to ensure continuity of operations. Funding impacts to base operations and infrastructure must be well understood and accepted by INL and its NE sponsors prior to developing these new capabilities.

Specific activities are discussed below:

- Establishment of new reactor demonstration capabilities – This area can be funded by numerous funding sources. Any benefitting program can establish new research capabilities within the NE test bed. This includes both program and laboratory investments. Typically, this includes facility modification costs, experiment installation, physics testing, costs associated with program specific preparations to execute research (DSA modifications, procedures, training, etc.). Material disposition and research program close-out costs are also the responsibility of the benefitting program.
- Base operations associated with reactor demonstration – Base operations and maintenance supporting new permanent capability increases to the test bed such as LOTUS, DOME, and Beartooth require budgetary increases to the IFM budget as well as Safeguards and Security budgets. NFMs, operators, system engineers, nuclear safety engineering, radcon, security, and maintenance will require more FTEs to adequately support new base growth of research operations. Base O&M operations must be managed by a single stable funds stream, IFM, to enable continuity across all aspects of the NE test bed. This will include bridge time funding to maintain research operations expertise. Test bed support will include additional reactor development personnel added to base who are essential to experimental support for mission execution. Trained and qualified nuclear research support staff require a significant investment to be available to support the research mission. As personnel transition from current experiments to support future experiments, funding needs to be available to bridge the "valleys" as experiments close out and new experiments are readied for operation.

### 2.6.2 New Reactor Demonstration Infrastructure

New research infrastructure is being developed to expand the NE test bed and NRIC capabilities. Current new infrastructure is described below.

#### *2.6.2.1 Demonstration of Operational Microreactor Experiments (DOME)*

DOME will be capable of hosting operational modular/mobile nuclear reactor concepts that produce less than 10MW thermal power. Modular/mobile reactors demonstrated in the DOME will be larger than the LOTUS machines, but still small enough to fit in a standard cargo shipping container. This is being executed as a line item construction project and is pending line item appropriation before moving into capital execution. Recent accomplishments include:

- Completed the conceptual and preliminary designs.
- Completed the final design necessary for the developing a construction requisition.
- Completed the Safety Design Strategy for DOE approval.
- Revised the environmental compliance permit including verification of an approved cultural resource review.
- Developed the Preliminary Documented Safety Analysis for DOE approval.
- Developed the preliminary project execution plan.
- Initiated the post final design cost estimate and project baseline.
- Developed the construction project expression of interest.

#### *2.6.2.2 Laboratory for Operation and Testing in the United States (LOTUS)*

LOTUS will provide the physical infrastructure to support demonstration of experimental reactor concepts at the smallest scale practical. This test bed site will be capable of hosting operational nuclear reactor concepts that produce less than 500kW thermal power and that require additional safeguards and security controls. This is being executed as a capital asset GPP. Recent accomplishments include:

- Completed the conceptual design report.
- Received an approved Mission Needs Statement and approved CD-0 from DOE.
- Received a request for proposal for developing the preliminary and final designs. Contract award is projected for FY-23.
- Completed the pre-CD-1 cost estimate.
- Developed the preliminary project execution plan.
- Developed the project Acquisition Strategy and Construction Product Data Sheet and submitted to DOE.
- Developed the draft Analysis of Alternatives and Conceptual Design Safety Report for DOE approval.
- Worked extensively with DOE to define the project execution strategy.

#### *2.6.2.3 TREAT Micro-Reactor Experiment Cell (T-REXC)*

T-REXC is an INL capability needed to demonstrate small reactors and relevant technologies. Establishing T-REXC is a response to the increasing need for advanced reactors in the private sector as well as other DOE programs. INL’s unique infrastructure can facilitate this capability as it currently has an operating Category B facility (TREAT). MARVEL will be the first user with other potential users including the General Atomics company, MCRE and Project Pele having expressed interest based on their strategic visions. Modifications made to support this project include installing shield blocks for the north storage pit, industry standard instrument and controls infrastructure, electrical power infrastructure, control room infrastructure, T-REXC HVAC system, fire suppression system, and a reject heat and load bank system. Recent accomplishments include:

- Conceptual design is complete on pit lid, shielding, and load plate and preliminary design activities are underway
- Electrical power upgrades are underway
- Instrumentation and control infrastructure upgrades are underway
- Contracting for T-REXC component fabrication is in process.

### 2.6.3 Planned Reactor Demonstration Experiments

There are several new reactor demonstration initiatives currently in development. These constitute the first wave of reactor demonstrations utilizing the NE test bed/NRIC infrastructure and are described below. Figure 3 below provides a notional timeline for these initiatives.

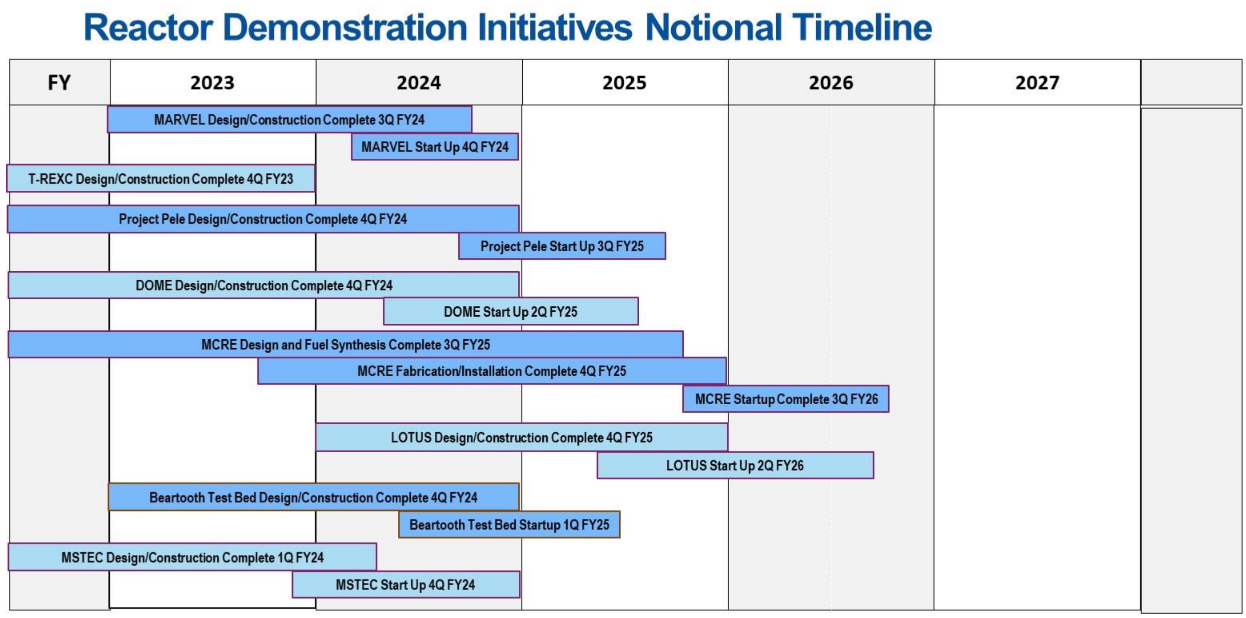



Figure 3. Reactor Demonstration Initiatives Notional Timeline

#### *2.6.3.1 The Microreactor Applications Research, Validation and Evaluation (MARVEL)*

MARVEL will provide an opportunity to establish and exercise key capabilities to support future microreactor demonstrations through development of a small-scale reactor for R&D purposes for the first time in nearly 50 years. MARVEL is a platform to test unique operational aspects and applications of microreactors. Envisioned end-users are those with applications of interest to connect to a reactor for testing and ultimate deployment. MARVEL will be the first project to utilize the TREAT Reactor Experiment Cell.

#### *2.6.3.2 Portable Energy for Lasting Effect (Project Pele)*

DOE provided BWXT with $85 million to develop its design for a transportable, TRISO-fueled reactor. In June, the Department of Defense awarded BWXT about $300 million to deliver a prototype transportable reactor to Idaho National Lab in 2024, where it will be tested for up to three years. Operating at between one and five megawatts, that reactor would be the first operating advanced microreactor in the U.S. This effort will be the first user of the DOME test bed.

#### *2.6.3.3 The Molten Chloride Reactor Experiment (MCRE) Advanced Reactor Demonstration project*

Selected for funding under the U.S. Department of Energy's (DOE) Advanced Reactor Demonstration Program (ARDP), the MCRE project will advance TerraPower's Molten Chloride Fast Reactor (MCFR) — a technology that could provide low-cost, clean energy for a sustainable future. This project designs and installs the MCRE reactor, a 500-kilowatt reactor that TerraPower and Southern Company will build at DOE's Idaho National Lab to test technologies required for Natrium. MCRE will demonstrate a fuel salt synthesis process using existing DOE fuel and support the MCRE Advanced Reactor Demonstration. The demonstration will be in the NRIC LOTUS test bed.

#### 2.6.3.4 The Special Nuclear Material test bed capability (Beartooth)

Beartooth is a R&D test bed that will contain the necessary unit operations for the dissolution, separation, and conversion of special nuclear materials (SNM) such as plutonium (Pu), enriched uranium (EU), thorium (Th) in support of fuel cycle R&D. This is a nuclear glovebox system to be installed at FCF and capable of processing and/or purifying enriched uranium, thorium, plutonium and other special nuclear material (SNM). The test bed will consist of glovebox lines containing the necessary unit operations and associated equipment required to process SNM including dissolution, separations, down-blending, conversion, off-gas treatment, and waste management. Beartooth is capable of processing various SNM feedstocks, including trace minor actinides and fission products.

#### 2.6.3.5 The Molten Salt Thermophysical Examination Capability (MSTEC)

MSTEC is a new shielded cell to be installed in FCF. MSTEC is a shielded modular hotcell with an inert argon atmosphere, housing characterization equipment for determining thermophysical and thermochemical properties of high temperature liquids not limited to but focusing on highly irradiated fuel salts. MSTEC will produce critical data needed to design, demonstrate, license, and operate a Molten Salt Reactor.

## 2.7 Inflation Reduction Act of 2022

Section 50172 of the Inflation Reduction Act of 2022 provided $150 million dollars to address infrastructure owned by DOE-NE. A significant portion of this is supporting upgrades to MFC infrastructure. Table 10 below describes the areas where this funding will be applied. This funding was made available at the beginning of FY-23. It is to remain available until the end of FY-27. Detailed planning is underway in all these areas with execution of work planned to take place through FY-27. This scope will be integrated with base operations and mission execution to minimize disruption to execution of the research mission. Some of this work addresses facility reliability such as the FCF crane while a significant portion addresses other aging infrastructure such as facility roofs and water delivery/management systems that are beyond service life.

Table 10. Inflation Reduction Act of 2023 NE Infrastructure Investments.

| Facility | Scope Description | ROM Cost Estimate ($K) | Need/Benefit |
|---|---|---|---|
| MFC FCF | Fuel Conditioning Facility (FCF) facility & process control systems replacement | $12,000 | These components were last replaced in the 1990s and are past obsolescence. The old components operate under the Windows XP platform that is no longer supported or maintained by Microsoft. This enables more reliable HALEU production and compliance with Idaho Settlement Agreement commitments. |
| MFC | MFC research facility roof replacements | $20,000 | Multiple roofs on research facilities are degraded and need to be replaced. Maintenance repairs are quickly becoming less than effective at maintaining roof integrity and need replacement. Cool roofs are the preferred alternative to support energy conservation and better atmospheric control in the nuclear and radiological research facilities. |
| MFC | Replace MFC industrial waste water system | $10,000 | Ensures protection of the aquifer. Current system was installed in the 1970s with approximately 1,500 ft of asbestos cement underground piping and about the same linear footage of open ditches. |

| Facility | Scope Description | ROM Cost Estimate ($K) | Need/Benefit |
|---|---|---|---|
| MFC | Replace MFC fire protection and potable water system | $15,000 | Water conservation and energy efficiency. Approximately 1.2 miles of underground piping and two deep well pumps that were installed as part of the original EBR-II infrastructure in the 1960s. This piping is cast iron and has surpassed service life. Recent piping failures (4) in the past 15 months that have cost over $2.5 million to replace. |
| MFC | Replace FCF SERA/DSC Crane and Control Equipment | $8,000 | Decontamination Spray Chamber (DSC) and Suited Entry Repair Area (SERA) support maintenance of large items that require hands-on servicing. The DSC has a 5-ton-capacity overhead bridge crane which connects with the crane bridge above the DSC; transfer loads between the SERA and the DSC. The crane is essential to move in-cell equipment such as process equipment and manipulators to and from the repair enclosure. This is critical to performing EBR-II fuel processing and HALEU production mission commitments. The crane has experienced control system failures at an increased frequency and problems with crane bridge latching at the interface of the SERA and DSC. This is a single-point-failure risk. |
| | MFC Subtotal | $65,000 | |

# 3. MFC MISSION OPERATIONS AND MAINTENANCE

Mission Operations and Maintenance includes the scientific infrastructure (instruments and support systems), dedicated instrument science teams, and new instrumentation that, when coupled with base operations and maintenance, maintain and expand the test bed and push the boundaries of nuclear energy research. Dedicated predictable funding is required to ensure this capability is available to achieve INL and MFC mission outcomes and provide the ability to fully support the growing research community and industry RD&D needs.

## 3.1 Scientific Infrastructure

MFC RD&D capability sustainment investments are focused on instrument replacement, refurbishment, and enhancement as analytical capability within the industry matures and develops. This area recognizes INL commitment to sustaining world-class nuclear RD&D capabilities across MFC's current areas of expertise. This includes investment in research and development of prototype analytical and PIE systems that will be referred to in this strategy as RD&D capability development. These areas are anticipated to be funded primarily by DOE-NE research programs investment or through strategic laboratory investment. IFM committed to lead support of NE test bed expansion that included completion of the Irradiated Materials Characterization Laboratory (IMCL) thermal properties cell and installing the first suite of instrumentation and establishing the first suite of advanced fuel fabrication capabilities. This established essential new RD&D test bed capabilities that no single research program was willing to fund. IFM appropriations levels have dropped recently and funding above user facility operations levels is focusing on improved facility reliability and strategic plant health investments. This necessitates more laboratory and program investment into scientific infrastructure test bed growth and the NRIC mission.

AL scientific infrastructure currently includes replacement and addition of mass spectrometry capabilities. This strategy includes replacement of an aging, single-point-failure risk ICP-MS that is considered a work-horse instrument that is currently being installed in AL. Another AL emphasis is providing more robust and efficient analytical support to RD&D programs with laser ablation-laser induced breakdown spectroscopy and time-of-flight mass spectrometry now operational. Additional needs include critical fission gas analysis capability to support advanced nuclear fuel development, advanced automated sample preparation with robotics, critical updates as current capabilities age out.

Advanced manufacturing for extreme environments is identified as a major science and technology initiative for INL. Significant investment in FY-18 and FY-19 added new advanced manufacturing capabilities for nuclear fuel fabrication. This included zone refining, melt pool crystal grower, dry bag isostatic press, casting furnace, laser welder, and 3D printing capabilities. Many of these are first-of-a-kind capabilities for nuclear fuels and reactor materials development. HVAC modifications in the Advanced Fuels Facility (AFF) have also completed and support capability growth in this important test bed arena. Additional needs include furnaces to support sintering and post-processing of advanced nuclear materials and components.

HFEF RD&D sustainment activities includes refurbishing the NRAD (Neutron Radiography Reactor) East Radiography Station elevator which was still original equipment installed in 1980 and has no commercially available spares. Several functions have failed, and an upgraded elevator and control system has been installed to provide more efficient and reliable support for this non-destructive PIE capability. Another area is restoring and upgrading the north beam line in NRAD. The North Radiography Station is also 1980 original equipment with several out-of-service functions. This effort included removal of old, out-of-service HFEF equipment which increased the available footprint to support expansion of a beam line RD&D. Other areas of emphasis are important updates to aging instruments including the precision gamma scanner, visual examination machine, and element contact profilometer.

Replacing the SEM at FASB ensures this critical capability, currently 100% fully utilized at MFC, is available to support increasing RD&D work requests. This also provides a redundant capability increasing experiment throughput and reliability.

FCF remains focused on supporting the DOE's commitments documented in the 1995 Settlement Agreement and the 2019 Supplemental Agreement and evolving those capabilities to support the processing of EBR-II spent fuel and development of HALEU fuel feedstock in support of new nuclear reactor concepts. New nuclear reactors may use fuels that incorporate other fissionable materials (e.g., plutonium) and that drive the need for a reactor fuels research capability that has the proper security and radionuclide inventory limits of a HC-2 nuclear facility. The Fuel Cycle R&D workscope at INL is also expanding. Larger gloveboxes, designed specifically for a mission of developing exploratory fuel compositions, forms, and shapes are needed. Use of HALEU feedstock produced from legacy EBR-II. used fuel may require further fission product purification to support newly proposed reactor concepts. INL has been developing head-end cleaning processes that can be directly deployed in FCF. Additionally, defense customers are needing hot cell and laboratory space for their secure missions. FCF intends to fulfill some of those missions maximizing nuclear research facility capacity and capabilities

## 3.2 Scientific Instrument Development Strategy

Many advanced nuclear technologies require new materials and fuels. Efficient development of materials and fuels is enhanced by understanding, starting at the atomic scale, the scale at which radiation damage occurs. Understanding at this scale, reduces the number of trial-and-error experiment cycles required for development. The spectacular scientific and engineering achievements of the last century have followed the same method of transition from basic research to applied science and then to engineering applications, heavily reliant on understanding through instrumentation and testing at each stage of research and development.

Cutting-edge instruments make the production of knowledge more efficient; they enable us to understand physical phenomena with more precision and speed. The development and application of new instruments enables research and development teams to ask and answer increasingly complex questions.

Instrumentation specific to nuclear fuels and materials science is not widely available. Of the hundreds of scanning electron microscopes in the United States, a relative few are available for use on radiological materials. Those instruments that are available for use on radiological materials are almost universally limited to materials with low activity. These materials have cooled for long periods, have not been exposed to high neutron fluence, or have not been irradiated in a prototypic neutron environment, and are often of limited relevance. Rapid, routine, and efficient analysis of high dose-rate fuels and materials using state-of-the-art instrumentation is required if nuclear technology is to advance at a rate similar to other energy technology sectors.

Instruments that enable rapid, routine, and efficient analysis shorten that nuclear development cycle, increase the chance for breakthroughs, and lower the cost of development. Because development of advanced nuclear fuels and materials cannot occur without the capability to fabricate nuclear samples, fabrication capability is included in the MFC instrumentation strategy.

Planned investment in instrumentation at MFC will focus on making nuclear-capable instruments widely available to the research community. The strategy presented here is based on current known program needs and current instrument capabilities and will evolve with increasing engagement of industry and academia. Continuous improvement in instrumentation and data analysis methods, driven by user needs, is a key component of this strategy.

### 3.2.1 MFC RD&D Capability Sustainment

Use of instruments at MFC is rapidly trending upward as new capabilities are installed and new characterization techniques are assimilated by the user community. Current operating FIB, SEM, and EPMA instruments now have a backlog of 3-9 months. The availability of high-resolution TEM and shielded FIB, SEM, and EPMA capability has resulted in a further increase in use.

Replacement or upgrade of instrumentation on a regular basis is required. Major improvements in instrumentation occur approximately on a 3-5 year cycle. Most instrumentation becomes technologically obsolete after 8-10 years. After 10-15 years of service, replacement parts become difficult to find, and vendors may stop supporting service contracts. Replacement of instruments on an 8-10 year cycle ensures that a subset of instruments provide state-of-the-art capabilities to the nuclear research community at all times.

Examples of instrument science needs for 2023 – 2027 include:

- Neutron diffraction that provides information critical to understanding the internal crystallographic structure of fuels and materials.
- Advanced manufacturing fuel fabrication capability that enables fuel RD&D programs that are critical to the development of many advanced reactor concepts. (Several new capabilities are productions ready with others ordered.)
- An advanced non-destructive post-irradiation examination system that greatly reduces the time required for a complete examination while providing higher quality data than current methods.
- Digital neutron tomography in development that will allow routine three-dimensional imaging of fuels and materials.
- Small cask systems that allow efficient transfer of high activity material specimens on-site, nationally, and internationally.
- Gloveboxes that provide material handling, fabrication, and preparation capability.

Funding for instrumentation is proposed at levels of approximately $10-12M annually over the next five years. This is a combination of direct program investments and lab investments. At the end of FY-22, MFC will be equipped with a solid base of research instrumentation readily available to the broad nuclear energy research community. The primary focus of IFM funding has shifted to plant health and facility reliability with diminished funding levels for implementing the 5-Year Investment Strategy. A continued steady-state funding level of $10-$15M per year will expand the DOE-NE NRIC test bed capability and ensure that the suite of instruments remains current, reliable, and upgraded to meet user needs.

Table 11 provides a list of the instrumentation needs. This list will be reviewed annually and may be updated based on the needs of DOE-NE-funded programs, external users, updated NSUF gap analysis, instrument use, and development of new instrument technology.

The descriptions of each instrument or support system are provided in Appendix C.

### 3.2.2 MFC RD&D Capability Replacement Planning

Over the last 5 years, significant efforts have dramatically expanded the NE test bed nuclear research capabilities available to execute the NE mission. Many of these revolve around advanced characterization of nuclear material and advanced fabrication technologies. Many of these high precision instruments are not designed specifically for operation in high radiation environments or designed specifically to work on high radiation samples. Instrument lifecycles in non-high radiation environments are typically 5-7 years. Operating in high radiation environments or on high radiation material can accelerate instrument degradation. Many of these instruments have service contracts that support preventative and corrective maintenance which can slow degradation but not prevent it.

The INL is working with research programs leadership and federal program sponsors to develop an integrated research capability replacement strategy to address replacement of instruments before catastrophic failure occurs impacting the research mission. MFC senior leadership is engaging with research programs and developing a 5-year strategy to replace the current suite of research capabilities. No final funding determination has been made yet and all areas will be evaluated.

The initial compliment of advanced characterization replacement instruments is listed at the bottom of Table 11. This does not imply that these are of less priority than other capabilities listed above them. This is a placeholder list until a formal strategy is issued.

Table 11. Summary of instrument development strategy and ROM cost estimates ($K).

| No. | Facility Name | Capability | Direct/ Indirect Funding | Prior Years | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | TREAT | Re-establish TREAT Na Loop Capability | Direct | $11,381 | $1,654 | | | | | | $13,035 |
| 2 | AL | Fission Gas Mass Spectrometry | Indirect | $1,200 | $1,500 | | | | | | $2,700 |
| 3 | FMF | Multi-program U/Pu Synthesis Glovebox | Indirect | $4,700 | $1,650 | | | | | | $6,350 |
| 4 | IMCL | In-situ testing stage for Titan and Talos transmission electron microscopes | Indirect | $1,100 | | | | | | | $1,100 |
| 5 | AFF | AFF High Temperature Furnace | Indirect | | $800 | $700 | | | | | $1,500 |
| 6 | FASB | FASB Equipment Replacement (Red Devil Furnace) | Indirect | $600 | $395 | | | | | | $995 |
| 7 | TREAT | Multi-program Experiment Assembly Equipment for TREAT Experiment Support Building (TESB) | Indirect | $800 | $150 | | | | | | $950 |
| 8 | NRAD | NRAD Imaging System Upgrades | Indirect | $700 | $545 | | | | | | $1,245 |
| 9 | HFEF | HFEF 2and Manipulator Repair Glovebox | Indirect | $1,200 | $1,210 | | | | | | $2,410 |
| 10 | NRAD | Upgrade NRADS North Beam Shutter to Include Aperture and Filter Drum | Indirect | $700 | $800 | | | | | | $1,500 |
| 11 | HFEF | Sample Preparation Equipment for IMCL | Indirect | $435 | $135 | | | | | | $570 |
| 12 | EFF | EFF X-Ray Diffractometer | Indirect | | $200 | | | | | | $200 |
| 13 | HFEF | Replace EML SEM (Electron Microscopy Laboratory, Scanning Electron Microscope) | Indirect | | $1,000 | | | | | | $1,000 |
| 14 | AFF | Oxy-Gon Hot Press Furnace | Indirect | | $235 | | | | | | $235 |
| 15 | EFF | EFF Radiological EDM Capability Upgrade | Indirect | | $500 | $200 | | | | | $700 |
| 16 | EFF | Laser Powder Diffractometer | Indirect | | $150 | | | | | | $150 |
| 17 | IMCL | ZEISS X-ray Source Upgrade | Indirect | | $750 | | | | | | $750 |
| 18 | HFEF | CNC for experiment disassembly and sample preparation throughput increase at 3M | Indirect | | $1,000 | | | | | | $1,000 |
| 19 | AL | B-wing ICP-OES (non-rad) | TBD | $ — | | $300 | | | | | $300 |
| 20 | HFEF | Improved Electronic Interface for Hot Cell Scales and Balances | TBD | $ — | $200 | $200 | | | | | $400 |
| 21 | HFEF | Visual Mount Inspection System in the HFEF Containment Box | TBD | $ — | $500 | $1,000 | | | | | $1,500 |
| 22 | AL | Automated Sample Prep/Dissolutions | TBD | $ — | $750 | | | | | | $750 |
| 23 | FCF | Multi-Function Furnace #2 | | $ — | $1,000 | $2,500 | | | | | $3,500 |
| 24 | NRAD | Develop Neutron Diffraction Capability in HFEF (NRS) | TBD | $ — | $1,000 | $1,000 | $500 | | | | $2,500 |
| 25 | AL | AL HR ICP-MS | TBD | $ — | | | | | | $1,500 | $1,500 |
| 26 | IMCL | IMCL High Throughput Sample Preparation Capability for Nuclear Fuel (Laser Ablation) | TBD | | | $1,100 | | | | | $1,100 |
| 27 | TREAT | Shielded Experiment Preparation and Inspection Cell (EPIC) - Procurement and installation into TESB | TBD | | | $2,300 | $4,000 | $1,500 | | | $7,800 |
| 28 | NRAD | Design & Install a Rotation Stage in the ERS Elevator to Enable Neutron Tomography of Fuels | TBD | | | | $750 | | | | $750 |
| 29 | AFF | AFF multi-purpose Uranium powder glove box chain | TBD | | | $1,000 | $3,000 | | | | $4,000 |

| No. | Facility Name | Capability | Direct/ Indirect Funding | Prior Years | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | HFEF | ECP/EBLM Refurbishment | TBD | | | | $1,000 | $1,000 | | | $2,000 |
| 31 | AFF | Powder Bed Additive Manufacturing | TBD | | | | $1,000 | | | $1,000 | $2,000 |
| 32 | HFEF | Digital Imaging Studio | TBD | | | | $500 | | | | $500 |
| 33 | NRAD | NRS Elevator Replacement | TBD | | | | | $2,000 | | | $2,000 |
| 34 | NRAD | NRS Sample Preparation Glovebox | TBD | | | | | $500 | | $2,500 | $3,000 |
| 35 | IMCL | Argon Atmosphere in Shielded Sample Preparation Area (SSPA) | TBD | | | | | $1,500 | | | $1,500 |
| 36 | NRAD | NRS Control Console Replacement | TBD | | | | | | | $1,000 | $1,000 |
| 37 | NRAD | NRAD Automated Computed Tomography System | TBD | | | | | $2,400 | | | $2,400 |
| 38 | AL | Robotics Design and Install | TBD | | | | | $500 | | $4,500 | $5,000 |
| 39 | AL | AL Liquid Scintillation Capability | TBD | | | | | $600 | | | $600 |
| 40 | HFEF | Integrated Gas Supply, Collection, and Distribution System in HFEF for Mechanistic Source Term and Component pressure testing at HFEF | TBD | | | | | $250 | | $5,750 | $6,000 |
| 41 | ZPPR | ZPPR multi-purpose uranium processing and synthesis glove box chain | TBD | | | | | | $6,000 | | $6,000 |
| 42 | FMF | FMF multi-purpose glovebox and fume hood combination | TBD | | | | | | $5,000 | | $5,000 |
| 43 | FASB | FASB multi-purpose uranium glove box chain | TBD | | | | | | | $4,000 | $4,000 |
| 44 | NRAD | NRAD Fuel for 1 MW Upgrade | TBD | | | | | | | $5,100 | $5,100 |
| 45 | AL | Replace CNOH Glovebox and Instrumentation | TBD | | | | | | | $5,500 | $5,500 |
| 46 | AL | Inert GB installation in AL Lab B-147 | TBD | | | | | | | $4,000 | $4,000 |
| 47 | AL | Inert GB installation in AL Lab A-102 | TBD | $ — | | | | | | $4,500 | $4,500 |
| 48 | AL | Replace AL Thermal Ionization Mass Spectrometer (TIMS) | TBD | | | | | | | $3,000 | $3,000 |
| 49 | HFEF | Upgrade the Visual Examination Machine (VEM) Camera Controls | TBD | $ — | | | | | | $250 | $250 |
| 50 | AFF | High Capacity, High Temperature Furnace | TBD | | | | | | | $3,000 | $3,000 |
| 51 | EFF | EFF Radiological Machining Capability Enhancement | TBD | | | | | | | $5,500 | $5,500 |
| 52 | FASB | Weld Characterization Suite | TBD | | | | | | | $300 | $300 |
| 53 | AFF | FASB Arc Melter Replacement | TBD | | | | | | | $80 | $80 |
| 54 | AFF | Cold Hearth Furnace | TBD | | | | | | | $1,000 | $1,000 |
| 55 | AFF | Envelope Pycnometer | TBD | | | | | | | $75 | $75 |
| 56 | AFF | Muffle Furnace | TBD | | | | | | | $300 | $300 |
| 57 | EFF | High Capacity Press | TBD | | | | | | | $1,500 | $1,500 |
| 58 | FASB | SEM Light Element Analysis Capability | TBD | | | | | | | $150 | $150 |
| 59 | FASB | Optical Microscope Replacement | TBD | | | | | | | $150 | $150 |
| 60 | FASB | HIP Upgrade | TBD | | | | | | | $700 | $700 |
| 61 | IMCL | Replace IMCL SEM 7600 | TBD | | | | | | | $2,500 | $2,500 |
| 62 | IMCL | Replace IMCL Shielded Ga FIB | TBD | | | | | | | $2,500 | $2,500 |

| No. | Facility Name | Capability | Direct/ Indirect Funding | Prior Years | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | IMCL | IMCL Simultaneous Thermal Analyzer (STA) Mass Spectrometer (MS) Replacement | TBD | | | | | | | $300 | $300 |
| 64 | IMCL | IMCL Thermal Conductivity (and Diffusivity) Microscope (TCM) Upgrade | TBD | | | | | | | $350 | $350 |
| 65 | IMCL | IMCL Laser Flash Analyzer (LFA) Laser and Power System Replacement | TBD | | | | | | | $250 | $250 |
| 66 | IMCL | Analytical Lab Laser Flash Analyzer (LFA) Laser and Power System Replacement | TBD | | | | | | | $250 | $250 |
| 67 | IMCL | IMCL TPC shielding for reducing exposure to personnel | TBD | | | | | | | $100 | $100 |
| 68 | IMCL | User-facility Data Analyses Station for FIBs, SEM, TEM, XRD, PGS, Thermocalc, and Aviso license | TBD | | | | | | | $1,000 | $1,000 |
| 69 | IMCL | Remote Control and Advanced Data Analytics for PIE and Advanced Characterization | TBD | | | | | | | $5,000 | $5,000 |
| 70 | IMCL | Replace IMCL Shielded Electron Probe Microanalyzer (EPMA) | TBD | | | | | | | $6,000 | $6,000 |
| 71 | IMCL | IMCL LEAP5000 APT Major Components Replacement | TBD | | | | | | | $500 | $500 |
| 72 | IMCL | Replace IMCL Shielded G3 PFIB | TBD | | | | | | | $2,500 | $2,500 |
| 73 | IMCL | IMCL ZEISS X-ray Microscope X-ray Source Replacement | TBD | | | | | | | $500 | $500 |
| 74 | IMCL | PI-98 Nanoindenter Upgrade for Micro-mechanical Testing for IMCL | TBD | | | | | | | $70 | $70 |
| 75 | IMCL | IMCL TITAN TEM 4D STEM Detector Upgrade | TBD | | | | | | | $500 | $500 |
| 76 | IMCL | High Temperature Laser Flash Apparatus | TBD | | | | | | | $600 | $600 |
| 77 | IMCL | Micro-XRD Analyses Upgrade | TBD | | | | | | | $100 | $100 |
| 78 | IMCL | Atomic Force Microscope | TBD | | | | | | | $1,000 | $1,000 |
| 79 | AL | ICP-AES (A-wing) | TBD | | | | | | | $1,000 | $1,000 |
| 80 | AL | ICP-ToF-MS | TBD | | | | | | | $1,500 | $1,500 |
| 81 | AL | ICP-MS (B154/B159) | TBD | | | | | | | $1,000 | $1,000 |
| 82 | AL | LA-LIBS | TBD | | | | | | | $1,500 | $1,500 |
| 83 | AL | MC-ICP-MS | TBD | | | | | | | $2,000 | $2,000 |
| 84 | AL | Gas Chromatograph | TBD | | | | | | | $400 | $400 |
| 85 | AL | Gas Mass Spectrometer | TBD | | | | | | | $100 | $100 |
| | HFEF | Eddy Current Head for Oxide Determination in HFEF - Complete | Indirect | $235 | | | | | | | $235 |
| | IMCL | Install Thermal Properties Cell and Glovebox (laser flash, DSC, thermogravimetric, and dilatometry) - Complete | Direct | $3,400 | | | | | | | $3,400 |
| | AFF | Expanded Fuel Fabrication Capability - Complete | Direct | $4,014 | | | | | | | $4,014 |
| | AL | Mass Spectrometers for AL (Quad/ToF-MS/LA-LIBS/Counting Room) - Complete | Direct | $4,515 | | | | | | | $4,515 |
| | HFEF | Complete GASR and Polisher/Grinder Refurbishment - Complete | Direct | $4,600 | | | | | | | $4,600 |
| | HFEF | TREAT Experiment Handling Support at HFEF - Complete | Direct | $1,153 | | | | | | | $1,153 |

| No. | Facility Name | Capability | Direct/ Indirect Funding | Prior Years | FY-23 | FY-24 | FY-25 | FY-26 | FY-27 | Outyears | Point Estimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | HFEF | HFEF East Radiography Station Elevator Repair - Complete | Direct | $902 | | | | | | | $902 |
| | HFEF | North Radiography Station Footprint Repurpose - Complete | Direct | $1,203 | | | | | | | $1,203 |
| | AL | Multi-Collector ICP-MS - Complete | Direct | $2,400 | | | | | | | $2,400 |
| | FCF | Establish NDA capabilities in FCF -Complete | Direct | $625 | | | | | | | $625 |
| | AL | B-116 Gas chromatograph - Complete | Direct | $289 | | | | | | | $289 |
| | IMCL | Secondary Ion Mass Spectrometry (Lab Investment) - Complete | Indirect | $600 | | | | | | | $600 |
| | IMCL | Atom probe tomography instrument (Lab Investment) - Complete | Indirect | $3,759 | | | | | | | $3,759 |
| | HFEF | Replace LEICA metallograph - Complete | Direct | $300 | | | | | | | $300 |
| | IMCL | In-situ mechanical testing for Titan TEM - Complete | Indirect | $842 | | | | | | | $842 |
| | IMCL | Second Plasma FIB in IMCL - Complete | Indirect | $3,070 | | | | | | | $3,070 |
| | EML | Replace Quanta Focused Ion Beam - Complete | Indirect | $1,225 | | | | | | | $1,225 |
| | AL | Expanded CNO capability - Complete | Indirect | $930 | | | | | | | $930 |
| | FASB/HFEF | Digital Image Correlation for Mechanical Testing - Complete | Indirect | $170 | | | | | | | $170 |
| | HFEF | Replace Leitz Metallograph in MetBox with SEM - Complete | Direct | $1,500 | | | | | | | $1,500 |
| | AL | Triple Quadrupole ICP-MS - Complete | Indirect | $750 | | | | | | | $750 |
| | IMCL | Comprehensive Mechanical Testing Capabilities for Light Water Reactor Fuel - Complete | Indirect | $935 | | | | | | | $935 |
| | IMCL | Plasma cleaner for IMCL - Complete | Indirect | $375 | | | | | | | $375 |
| | IMCL | Benchtop optical microscope for IMCL - Complete | Indirect | $240 | | | | | | | $240 |
| | FASB | Replace dilatometer in FASB - Complete | Indirect | $155 | | | | | | | $155 |
| | | **Annual Totals** | | **$61,003** | **$16,124** | **$10,300** | **$10,750** | **$10,250** | | **$86,875** | **$206302** |
| | | **Total FY IFM Funding Authorized** | | **$33,600** | **$1,654** | | | | | | **$38,054** |
| | | **Proposed Laboratory Investment or Program Funding** | | **$7,125** | **$14,470** | **$10,300** | **$10,750** | **$10,250** | **$11,000** | **$11,000** | **$78,495** |

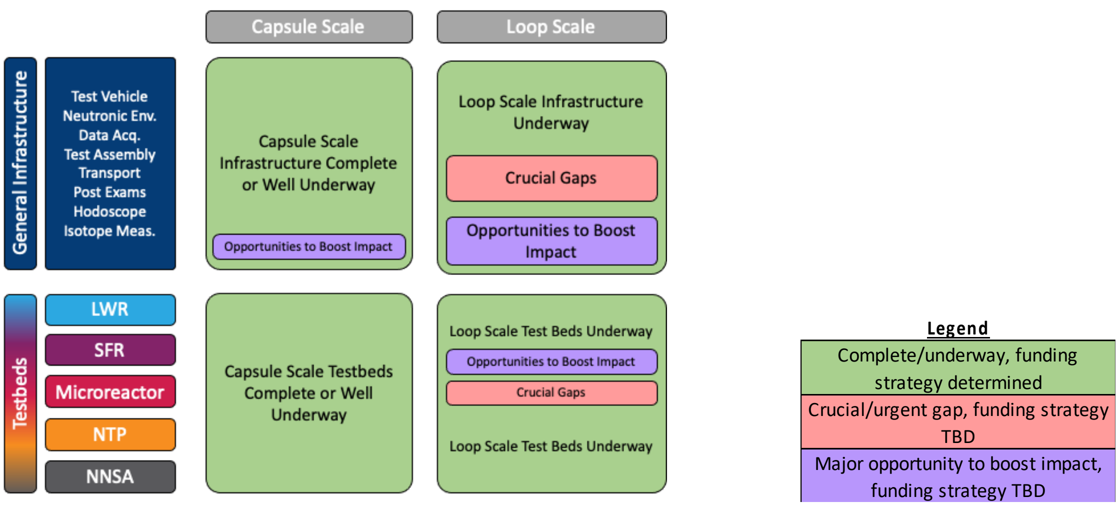
| | |
|---|---|
| Indirect funded lab investments, prior year carryover, **or other non-IFM program funding support many of these investments. Extremely dependent upon IFM appropriation levels.** | Green shaded represent scope authorized to proceed |
| **NOTE:** Costs reflect estimates at completion for activities commenced in FY-22. Remaining costs are rough order of magnitude based upon current scope understanding and will be refined as detailed execution planning is completed. | The ranking priority of scope in the “Outyear” column is subjective and will certainly change as emergent scope is identified and priorities evolve |

### 3.2.3 TREAT Experiment Infrastructure Strategy

The Resumption of Transient Testing Program (RTTP, or colloquially the TREAT restart project) was remarkably successful in achieving restart ahead of schedule and under budget. But, purposely, it did little to establish experiment infrastructure. Since TREAT restart, program funding and expressed interest has aligned with 5 "product lines" for the Transient Testing Program:

- Light Water Reactor fuel safety
- Sodium Fast Reactor fuel safety
- Nuclear Thermal Propulsion fuel testing
- Microreactor testing and support
- National security testing.

In general, the types of tests and experiments needed to support these product lines include 1) capsule-scale tests using relatively affordable static-environment experiment vehicles and 2) loop-scale tests in experiment vehicles using active thermal-hydraulic manipulation. (Some tests, such as those in consideration for national security applications, will use neither of these approaches or specialized applications of static capsules.) The original intention was for the DOE Advanced Fuels Campaign (AFC) to fund and establish experiment infrastructure as a matter of course for its own R&D needs, with the understanding that subsequent programs and users would benefit from that established infrastructure. Year-by-year evolution of annual appropriations increasingly decreased AFC funding and constrained funds available for TREAT experiment infrastructure by earmarking funds for industry developing accident tolerant fuels. As a result, TREAT experiment infrastructure projects are now underfunded or unfunded.




Despite funding constraints, a great amount of the infrastructure is in hand, or nearly so. Roughly $57M out of $87M of estimated experiment infrastructure cost has been funded thus far, establishing a nearly complete capsule-scale testing capability. But most of the experiment vehicles and associated infrastructure (such as equipment and fixtures needed to handle, load, and unload fueled tests in HFEF) remain unfunded or partially completed, with the notable exception of the sodium test loop itself, which is funded and within 2 years of completion. Even with completion of the test loop, testing using the loop will not be possible without additional investments in experiment infrastructure. For TREAT to have the impact envisioned, these remaining capabilities and experiment infrastructure must be completed.

Additional capabilities, such as advanced fuel motion monitoring (an advanced neutron hodoscope) and an experiment fission product release monitoring system have been identified as opportunities to further increase TREAT program impact.

INL-LTD-15-33324 provides an overview of the capabilities required for conducting experiments in TREAT, with recent updates and clarifications provided in SOW-18688, "HFEF Infrastructure to Support the TREAT Sodium Loop Cartridge (NLC)," and TEV-4357, "TREAT Infrastructure to Support the Mk-IIIR Sodium Loop Cartridge (NLC)." These capabilities are to be incorporated sequentially as the complexity of transient testing increases and as scope of test programs increases from light water reactor (LWR) fuels to also include advanced fuels. Simpler, capsule testing capabilities were established coincident (roughly) with resumption of TREAT reactor operations. The capsule testing capabilities are providing the initial transient testing services required for near-term program needs (e.g., the Accident Tolerant Fuels [ATF] Program). Such capability includes equipment, facilities, and expertise to perform basic transient tests using static capsules. However, the complexity of needed testing is increasing significantly to include prototypic environments (pressure, temperature, and recirculating coolant) and state-of-the-art in-pile instrumentation. For that reason, additional investment over the 5-year period from FY-21 to FY-25 is needed to continue to meet nuclear fuel technology development objectives.

The TREAT Experiment Infrastructure Strategy as described in this document focuses on the following capabilities because they currently present the biggest challenges:

- TREAT Multiprogram Experiment Support Infrastructure
- LWR/ATF Fuel Testing
- Fast Reactor Fuel Testing
- Other Test Program investments.

TREAT experiment infrastructure funding needs and proposed funding sources are provided in Table 12. The descriptions of each instrument or support system are provided in Appendix D.

Table 12. Summary of TREAT and Transient experiment infrastructure strategy and ROM cost estimates ($K).

| | Transient Testing Experiment Scientific and Enabling Infrastructure | Proposed Funding Source | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | Totals | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| TREAT Multi-mission Experiment Support Infrastructure | **TREAT Experiment Support Building (TESB)** | | | | | | | | | |
| | TESB: Building Modifications for Habitability | NE-3 (IFM) | | | $1,200 | | | | $1,200 | Building HVAC, life safety systems & rad monitoring, door sealing |
| | TESB: Building Modifications for HC-3 experiment prep. | NE-3 (IFM) | | | | $2,500 | | | $2,500 | Reinforce concrete floor; modular containment with localized HVAC; HC-3 authorization |
| | **TREAT Multi-mission Experiment Support Equipment** | | | | | | | | | |
| | Multi-mission Experiment Assembly/Disassembly Equipment & Glovebox | INL Indirect | $600 | $200 | $750 | $1,750 | | | $3,300 | Generic Experiment Assembly/Disassembly Equipment (similar to TTAF at ATR). Laser welding inert atmosphere enclosure, fume hoods, radiography equipment, machining tools |
| | Multi-mission experiment – closure seals of capsule experiments | INL Indirect | | | | | | | $0 | |
| | Westinghouse Large Experiment Containment Design | Westinghouse FOA | $1,500 | | | | | | $1,500 | Large outer container to support larger experiment vehicles. FY-21 includes design. Devices purchased by many individual programs. |
| | Large Experiment Capability TREAT Modifications | NE-3 (IFM) | | $300 | | | | | $300 | Prepare TREAT for Big-BUSTER containers (fixtures and storage locations) |
| | **Transport and Storage Casks** | | | | | | | | | |
| | HFEF-15 Transfer Cask Return to Use | NE-3 (IFM) | $750 | | | | | | $750 | Complete |
| | HFEF-15 Transfer Cask Modification for Large Experiments | NE-3 (IFM) | | $350 | $1,050 | | | | $1,400 | TREAT large diameter experiment outer container that will accommodate large-dia. experiments for multi-missions. Includes HFEF modifications to support upgraded cask. |
| | **Provide instrumentation to monitor core and fuel behavior during transients** | | | | | | | | | |
| | **Fuel Motion Monitoring** | | | | | | | | | |
| | Hodoscope Operations and Maintenance | NE-42 (AFC) | | $500 | $500 | $500 | $500 | $500 | $2,500 | |
| | Full View Hodoscope (Refurbish all 360 channel system) | NE-42 (AFC) | | | $600 | | | | $600 | |
| | Develop Next-Generation Fuel Motion Monitoring System | NE-42 (AFC) | | | | $1,000 | $1,000 | $1,000 | $3,000 | Project funded for FY-19 through FY-21 by NE-42 (AFC); unclear going forward |
| | **TREAT in-pile instrumentation** | | | | | | | | | |
| | Advanced Transient Instrumentation Development | NE-42 (AFC) & NE-5 (ASI) | $1,500 | $1,500 | $2,000 | $2,000 | $2,000 | | $9,000 | |

| | Transient Testing Experiment Scientific and Enabling Infrastructure | Proposed Funding Source | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | Totals | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| LWR/ATF Fuel Testing | **Experiment Vehicles** | | | | | | | | | |
| | **Capsule Devices** | | | | | | | | | |
| | TWIST experiment vehicle (LOCA testing in capsules) | NE-42 (AFC) | $1,500 | $2,000 | | | | | $3,500 | For time-at-temperature LOCA testing in water. Will replace SERTTA as RIA test vehicle for irradiated fuel. |
| | TWIST vehicle enhancements (pumped, steam, etc.) | NE-42 (AFC) | | $500 | $2,000 | $1,000 | | | $3,500 | Includes contribution from NNSA Nonproliferation |
| | **Flowing Loops** | | | | | | | | | |
| | TWERL: TREAT Water Environment Recirculating Loop | NE-42 (AFC) | | | $500 | $1,000 | $2,000 | $3,000 | $6,500 | For prototypic temperature and coolant conditions for RIA and LOCA testing |
| | **Experiment Support Systems and Equipment** | | | | | | | | | |
| | He-3 injection system final design and hardware procurement | NE-3 (IFM) | | | $1,200 | | | | $1,200 | He-3 injection system necessary to narrow transient pulses to LWR RIA conditions (~40 msec FWHM) |
| | Capsule handling system in HFEF (TWIST) | NE-42 (AFC) | $750 | $500 | $750 | | | | $2,000 | HFEF fixtures & tooling design, assembly, and installation to support TWIST experiment vehicles |
| | Loop handling system in HFEF (TWERL) | NE-42 (AFC) | | | | $750 | $1,000 | $750 | $2,500 | HFEF fixtures & tooling design, assembly, and installation to support TWERL experiment vehicles |
| | Shielded Experiment Preparation and Inspection Cell (EPIC) - Conceptual Design | NE-42 (AFC) | $250 | $250 | | | | | $500 | Design based on copy of the IMCL TPC. May require slightly thicker shielding. |
| | Shielded Experiment Preparation and Inspection Cell (EPIC) - Procurement and installation into TESB | NE-42 (AFC) | | | $2,300 | $4,000 | $1,500 | | $7,800 | For installing instrumentation on previously irradiated fuel rods for testing in ATR and TREAT |
| | Remanufacturing Bench for Irradiated Fuel Rods | | | | | | | | | |
| | Re-Fabrication Bench for Irradiated Fuel Rods at HFEF | NE-42 (AFC) | $1,400 | | | | | | $1,400 | Welding, pressurization, and seal welding setup in Decon Cell in HFEF. Does not include instrumentation bench (next line) |
| | Advanced Fuel Rod Instrumentation Bench at TESB | NE-42 (AFC) & NE-5 (ASI) | $1,000 | $250 | $1,500 | $1,500 | | | $4,250 | Contract with Halden to implement and commission system in TESB shielded cell (ASI supporting out-of-pile testbed facility) |
| Fast Reactor Fuel Testing | **Experiment Vehicles** | | | | | | | | | |
| | **Static Capsule Devices** | | | | | | | | | |
| | THOR development and commissioning | NE-42 (AFC) | $1,000 | $1,000 | | | | | $2,000 | For JAEA and DOE (AFC) joint test program and for other FR-type fuel testing |
| | **Flowing Loops** | | | | | | | | | |
| | Recirculating sodium loop system | NE-3 (IFM) | $2,200 | $2,300 | $1,300 | | | | $5,800 | $8.5M spent in FY-19 through FY-21. Executed in collaboration with TerraPower. TP ADRP is first. |

| | Transient Testing Experiment Scientific and Enabling Infrastructure | Proposed Funding Source | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | Totals | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sodium loop commissioning test | NE-42 (AFC) | | | $2,500 | $1,000 | | | $3,500 | Preparation for first test using sodium loop to shake out all loop handling and operations through test lifecycle |
| | **Experiment Support Systems and Equipment** | | | | | | | | | |
| | Capsule handling system in HFEF (THOR) | NE-42 (AFC) | $250 | $1,250 | | | | | $1,500 | HFEF fixtures & tooling design, assembly, and installation to support THOR experiment vehicles |
| | Sodium loop support infrastructure | | | | | | | | | |
| | HFEF sodium loop equipment and preparation | NE-42 (AFC) | | | $3,500 | $3,200 | | | $6,700 | HFEF fixtures & tooling design, assembly, and installation; SAR revision; procedure dev & mock-up (SOW-18688) |
| | Sodium loop out-of-pile prototype installation | NE-42 (AFC) | | | $1,900 | | | | $1,900 | See TEV-4357 |
| | Sodium loop sodium loading equipment | NE-42 (AFC) | | | $1,000 | | | | $1,000 | See TEV-4357 |
| Other Program Investments | **Flowing Hydrogen Test Loop** | | | | | | | | | |
| | TREAT facility modifications for microreactor demonstrations (T-REXC) | INL Indirect | | $1,315 | $2,407 | | | | $3,722 | To equip the TREAT Reactor Experiment Cell (T-REXC) for microreactor testing and demonstrations |
| | Cross-cutting Reactor System, Structures and Components to Support INL Micro-Reactor Demonstrations in T-REXC | INL Indirect | | $2,261 | $329 | | | | $2,590 | Structures and components to support T-REXC |
| | Hydrogen Flowing Loop System | NASA | $4,000 | $4,000 | $4,000 | | | | $12,000 | For NASA NTP fuel testing. Subsequent application of design and ancillary hardware to other users. |
| | | | | | | | | | | |
| | **Total Scientific Infrastructure ($K)** | | **$16,700** | **$18,476** | **$31,286** | **$20,200** | **$8,000** | **$5,250** | **$99,912** | |

| Funding source | FY-21 | FY-22 | FY-23 | FY-24 | FY-25 | FY-26 | Totals |
|---|---|---|---|---|---|---|---|
| NE-3 (IFM) | $2,950 | $2,950 | $4,750 | $2,500 | $0 | $0 | **$13,150** |
| NE-42 (AFC) | $5,150 | $6,000 | $15,550 | $12,450 | $6,000 | $5,250 | **$50,400** |
| NE-42 (AFC) & NE-5 (ASI) | $2,500 | $1,750 | $3,500 | $3,500 | $2,000 | $0 | **$13,250** |
| Westinghouse FOA | $1,500 | $0 | $0 | $0 | $0 | $0 | **$1,500** |
| INL Indirect | $600 | $3,776 | $3,486 | $1,750 | $0 | $0 | **$9,612** |
| NASA | $4,000 | $4,000 | $4,000 | $0 | $0 | $0 | **$12,000** |
| | | | | | | | **$99,912** |

# 4. MFC CAMPUS VISION

MFC is a central part of the NE test bed and NRIC mission, and the future growth associated with these. To support advanced nuclear technology development, nuclear energy technology RD&D must broaden the technology readiness level scale towards the demonstration and deployment phases. The MFC campus vision comprises a refurbishment and replacement campaign within the facilities that enables new capabilities along with a strategy to expand, replace, and relocate capabilities to support growing test bed needs. These new facilities are described below and range in maturity from capital and line-item construction to conceptual planning beyond the current five-year window. These encompass the need for expanded research and infrastructure capabilities anticipated to support growth related to maturing NRIC test bed capabilities.

The campus vision includes a revised overall layout of MFC, locating research facilities and support facilities into separate geographic areas of the campus to increase efficiency of the flow of research execution and decrease congestion and logistical conflicts. PIE RD&D facilities HFEF, IMCL, and SPL co-located in in the northwest quadrant of the MFC site. Current and future fuel fabrication RD&D facilities are primarily located in the southeast quadrant near FMF. Current and potential future analytical laboratory research and support capabilities will remain in the central or southwest portions of the campus to support all research areas. Industrial support services will move to the northeast quadrant. Traffic will be rerouted around the perimeter of MFC to reduce industrial vehicle and equipment interaction with research and support staff and provide more direct access to industrial portions of MFC.

Additional elements that complement the proposed new facilities will also be addressed as part of the campus vision. Footprint reduction will be leveraged to provide additional expansion space within the fence and reduce resources required to manage and maintain aging infrastructure beyond intended service life. Facility support infrastructure such as electrical and transportation infrastructure, utility loops, and general facility systems refurbishment and replacement are being addressed as funding allows. Deferred maintenance backlog and repair needs are targeted as appropriate. Transportation flow, site drainage, parking, and general roads and grounds are reviewed with respect to the future campus design. Sustainability activities such as xeriscaping and LED light replacement is implemented as funding allows.

There are three primary areas for campus development at MFC:

1. Direct DOE-NE funding for capital asset projects that can include General Purpose Project (GPP) construction and line-item construction projects of new facilities or refurbishment of existing nuclear and radiological facility systems.
2. Direct operating funded plant health related efforts such as updating or refurbishing existing nuclear and radiological facilities and their associated structures and systems (e.g., structural, electrical, or HVAC-related activities), and efforts such as sustainability, legacy material disposition, and footprint reduction.
3. Laboratory-funded investments including general-use buildings, structures, and support infrastructure. Examples include building roofs and skins, utilities and HVAC, lighting replacement, sidewalks and pavement, and other sustainability efforts.

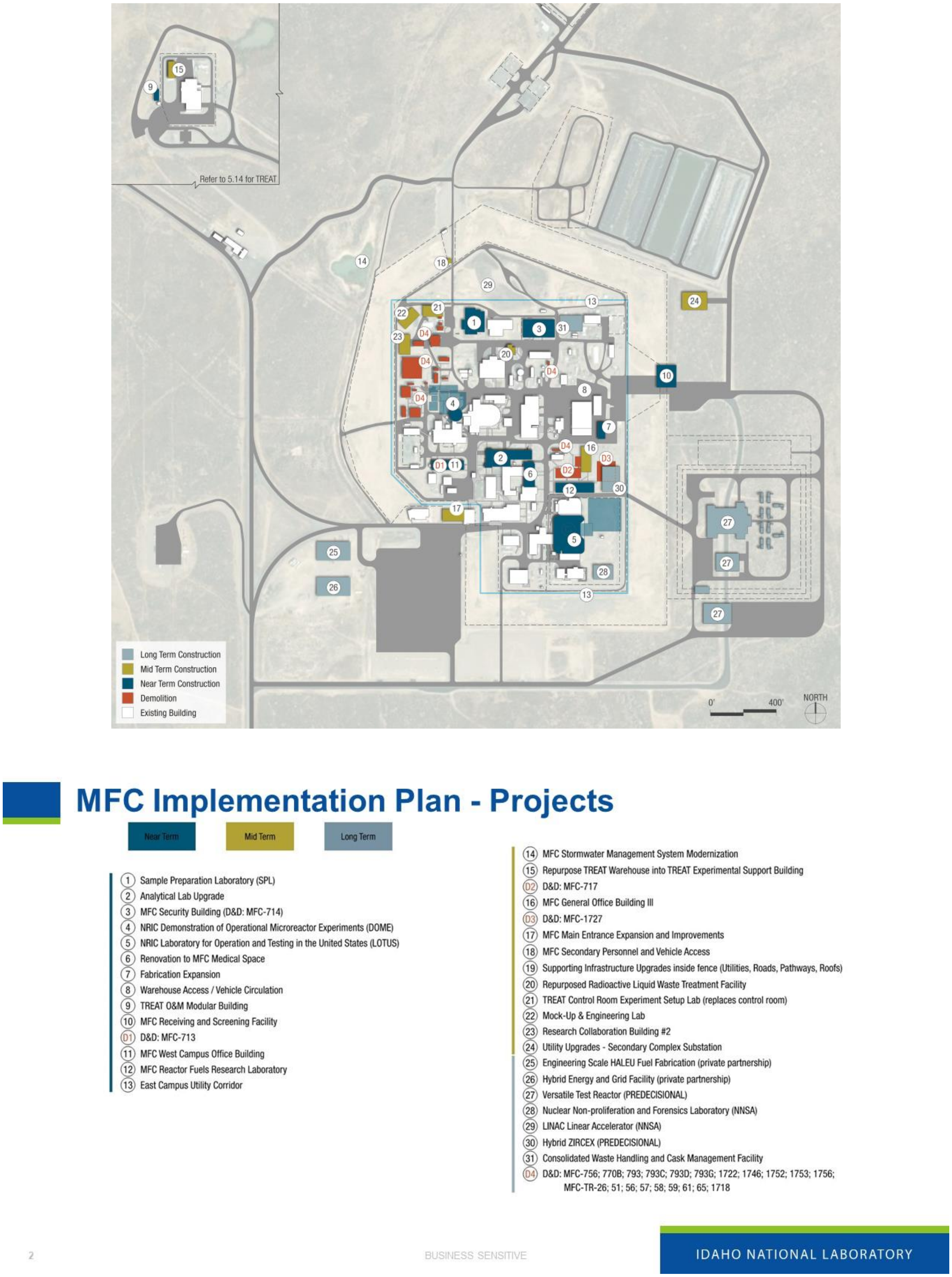



Figure 4. MFC Campus Vision Conceptual Time Frames for Test Bed and Demonstration Platform Development.

## 4.1 Sample Preparation Laboratory

**Description**

The Sample Preparation Laboratory (SPL) is focused on analysis of irradiated structural materials. It closes an identified nuclear energy research capability gap by greatly increasing sample throughput and nanoscale research capability. SPL will provide a central hub for DOE-NE research collaborations because of its world-class instrumentation and ability to prepare, analyze, and ship alpha-free materials to universities, industry partners, and other DOE user facilities for research. This network provides specialized capabilities and access to a greater portion of the national intellectual capital.

**Benefit**

The proposed laboratory will include capabilities that will allow high-hazard materials to be routinely prepared and tested in a safe, secure, and environmentally controlled environment. SPL provides a key link between DOE-NE's core research functions at MFC and ATR and the broader nuclear energy research community. Materials free from alpha contamination can be sized appropriately, packaged, and transported to other national user facilities, universities, commercial, and international sites. In addition, this laboratory will complete the suite of facilities fulfilling near-term advanced post-irradiation examination (along with HFEF and IMCL) needs that will serve as a center for advanced fuels and materials characterization, as well as development of new processes, tools, and instruments to further research.

**Facility Risk**

This facility is needed to continue test bed expansion in line with NRIC. RD&D capabilities associated with non-alpha mechanical testing of nuclear materials cannot be established without new hot cell space that this facility will provide. SPL will provide world-class structural material analysis capabilities focusing on non-fuel sample preparation, mechanical properties and failure modes, and micro/nano structural materials characterization. This capability is crucial to growing the DOE-NE test bed capabilities, to support advanced reactor RD&D up through demonstration, and to ensure LWR life extension.

**Estimated Cost:** $166M.

**Status:** Construction underway.

## 4.2 MFC Analytical Laboratory Upgrades

**Description**

The Analytical Laboratory (AL) was constructed in the late 1950s and has been operational since that time. The facility was expanded in the 1970s to add sodium chemistry and nondestructive analysis capabilities. There was a major refurbishment of the hot cells in the early 1990s. Throughout its history, AL has been primarily focused on providing chemical and isotopic analyses in support of experimental programs. In addition, AL supports the analytical infrastructure needs of other MFC facilities. While additional capabilities have been added over the years, the support infrastructure and scientific instrumentation has not kept up with current technology. AL has several single-point failures that could have a major negative impact to MFC's mission if they occurred. The current effort remodels separate laboratories within the AL to include replacing aging or out-of-service fume hoods and refurbishing cabinets and floors. An exterior insulation finishing system and new windows were installed in FY-20/21 to support regulating interior temperature and pressure which had historically impacted operations. The major capital asset effort focuses on replacing the aging HVAC system and upgrading the system to support current and future research capabilities.

**Benefit**

Growing test bed needs will continue to impact mission support operations and limit efficient response to these needs. Given its current infrastructure and space limitations, AL will be unable to address the needs associated with its position as a central part of the DOE-NE test bed and future growth associated with capabilities at MFC unless its analytical capabilities and infrastructure are expanded. Expanded footprint coupled with re-purposing and refurbishment enables AL to incorporate modern infrastructure technologies and install state-of-the-art analytical capabilities that would address upcoming mission needs while attracting world-class talent and users.

**Facility Risk**

A recapitalization program has been implemented to ensure the laboratory is able to meet its near-term mission by addressing critical infrastructure needs. This proposed effort addresses several current potential single-point failures and alleviates the need to continue in a high-maintenance mode using scavenged and harvested parts. It also lessens the facility reliability risks associated with single-point failures and production bottlenecks that jeopardize the production and efficiency of MFC. However, it does not expand the facility footprint to support additional analytical capabilities to meet anticipated advances in the nuclear mission.

**Estimated Cost/Status:** AL HVAC upgrades are underway. Efforts are being carefully integrated and coordinated to minimize RD&D mission support impacts. Current estimate for all the combined efforts is $15-18M with the GPP portion estimated at $16.6M TPC.

## 4.3 MFC Security Building

**Description**

Funding for a new MFC security building was identified in FY-20 within the NE Safeguards and Security appropriation.

**Benefit**

MFC-714 is the current MFC security building. It is a temporary modular office acquired in 1992 and in poor condition. A new MFC security building is required to replace the existing building MFC-714 to house necessary female and male security personnel at MFC. The project will demolish and replace the MFC-714 building and tenants have been temporarily relocated. The new building will include both female and male sleeping quarters, showers, and locker rooms. This solves providing facilities of equal quality and access that were not available to female Pro Force personnel. Also included will be Special Response Team (SRT) and Security Police Officer (SPO) storage rooms; muster/classroom; classified storage and communications; kitchen and weight room; and office/computer stations.

**Facility Risk**

The current security building is a converted temporary office building never intended to house security personnel overnight. It is less than 700 square feet and not suited for the security mission at MFC as operations increase and the test bed continues to grow and mature. This can impact the effectiveness of security personnel at MFC.

**Estimated Cost:** The current estimated TPC is $15.6M.

**Status:** The MFC-714 removal subcontract was awarded January FY-22. The construction (new building) design is being revised with plans to finalize design (new building) this summer and award late in FY-22.

## 4.4 NRIC Demonstration of Operational Microreactor Experiments (DOME)

**Description**

A key component of the NRIC strategy is to provide by the end of 2024 a network of independent test beds and sites (research infrastructure) that can accommodate a wide variety of experimental reactors. Based on its unique capabilities (i.e., containment dome, configuration, location at MFC), the EBR-II facility has been identified as one of the NRIC test beds. Specifically, the NRIC Demonstration of Operational Microreactor Experiments (DOME) EBR-II facility has been identified as a facility for testing of reactor concepts up to 10 MW thermal, using Safeguards Category-IV fuels. To support advanced reactor demonstration activities, the containment capabilities of the EBR-II structure must be re-established to include the freight access door, personnel airlock, and support system penetrations. Re-establishment of containment functionality of the dome is consistent with its original function. Pre-conceptual design of the re-established EBR-II test bed was completed in FY-20 and is documented in the NRIC EBR-II Test Bed Pre-Conceptual Design Report (INL/EXT-20-59733). Initial design activities were conducted based on preliminary discussions with potential reactor demonstrators. Further specification of capabilities needed to support possible reactor demonstrations will occur throughout the design process.

**Benefit**

Re-establishing reactor demonstration test bed capabilities at NRIC is foundational to the goals of providing research infrastructure to promote scientific progress and enable users from academia, the National Laboratories, and the private sector to make scientific discoveries relevant for nuclear, chemical, and materials science engineering; and enabling the private sector to partner with the National Laboratories to demonstrate novel reactor concepts.

**Estimated Cost:** This facility has a conceptual design Class 5 point estimate of $38M.

## 4.5 Laboratory for Operation and Testing in the United States (LOTUS)

**Description**

The Office of Nuclear Energy (NE) has a mission need to establish a Safeguards Category I demonstration test bed capability to support the development and deployment of advanced reactor concepts. NRIC has identified a test bed capability known as LOTUS.

The purpose of the test bed capability is to enable and support the development and deployment of advanced nuclear systems by providing the infrastructure for advanced reactor developers to test and operate demonstration and experimental reactors that utilize Safeguards Category I materials. The capability would also provide necessary support systems and components (e.g., reactor cooling, backup power, instrumentation and control, material handling) for safe operations and testing.

LOTUS repurposes existing space at MFC. Multiple missions are being considered for the former ZPPR reactor cell. The reactor and ancillary support systems were removed several years ago. This created several thousand square feet of Hazard Category 2 research space available to repurpose to support new advanced reactor development and demonstration. The ZPPR facility consists of a workroom, cell area, and material storage vault. The ZPPR cell is cylindrical in construction with a useable 40-ft diameter and 25-ft height. The facility can provide safety-class confinement supporting the operation of nuclear reactors. Current facility activities are material inspections and packaging in the workroom/vault, National and Homeland Security testing and detection training in the cell area, and material storage in the vault. Demonstration of reactor concepts has not been conducted since the early 1990s.

**Benefit**

Re-establishing reactor demonstration test bed capabilities at NRIC is foundational to the goals of providing research infrastructure to promote scientific progress and enable users from academia, the National Laboratories, and the private sector to make scientific discoveries relevant for nuclear, chemical, and materials science engineering; and enabling the private sector to partner with the National Laboratories to demonstrate novel reactor concepts.

**Estimated Cost:** This facility is pre-conceptual design, and no cost estimates are available at this stage.

**Status:** CD-0 was approved in March 2022. This capability has a Class 5 point estimate of $55.5M.

## 4.6 MFC Old Cafeteria Conversion to Medical Facility Replacement

**Description**

The former cafeteria in MFC 752 has been deemed the most suitable location for the space needed to relocate the MFC Medical dispensary. The current medical unit does not have space sufficient for current staff and services proportional to our large growth in population.

Scope includes refurbishment of the old cafeteria space to accommodate a medical unit that will meet the increasing needs of the medical unit at MFC. This will include demolition and new office space to be created.

**Benefit**

The future layout of the space is in the final design stages and includes areas not available in the current medical facility such as; an EAP office, laboratory, additional doctor's offices, men's and women's restrooms, and space for physical therapy. The section of roof above this area will be replaced and 50+ year old HVAC serving this are will also be replaced as part of this comprehensive renovation. There will also be a new compliment of equipment that will be needed and procured under this work-scope.

**Facility Risk**

MFC will continue to struggle to provide the space necessary for medical staff and medical services without expanding the footprint of medical services. Key footprint available for repurposing will go unleveraged.

**Cost Estimate:** ROM estimate of $3.5M.

**Status:** Currently in design.

## 4.7 MFC Fabrication Space Expansion

**Description**

The work at Building 796 is projected to be accomplished in FY-21 – FY-23. This consists of modifications to the facility to convert from warehouse to a manufacturing shop. No new equipment will be purchased as the equipment from Building 782 will be relocated to Building 796.

Fabrication expansion will be a multi-year effort SSPSF materials out of the northside of Building 796 up to the Security Building 736 on the hill. That scope will happen this year. In order to accommodate storage in MFC-736, disassembly of the MFC-736 scanning equipment will occur and new shelving and warehousing type of storage will be installed. The MFC-796 wall divider will be removed and life safety systems, HVAC power drops, and an overhead crane with approximately 2 ton capacity will be added There will be a modular office inside of the Warehouse Building 796 for fabrication personnel. We will install modern quality storage racks, material handling equipment, and a laser cutter and other sizing machinery. The fabrication and assembly area in the current fab shop will be moved out into that warehouse making space for new mills and lathes.

**Benefit**

Additional fabrication capabilities are required to keep up with increasing demand. Additional footprint is needed to accommodate new capabilities. This expansion will position MFC Fabrication to support fabrication needs for test-train assemblies and projects lab wide as well as enhancing delivery and turn-around times to customers.

**Facility Risk**

Without the additional fabrication capabilities, MFC's ability to meet commitments to researchers will be impacted.

**Estimated Cost/Status:** Class 5 cost estimate of $3.2M/Demolition inside MFC-796 is complete, design is underway and procurement of equipment is commencing.

## 4.8 MFC Warehouse Access and Vehicle Circulation

**Description**

The existing warehouse loading dock configuration provides for a north south semi-truck access now. The new East gate will now have vehicles traveling east west right in front of that warehouse. The new loading dock configuration will have trucks parking facing west backing up to a new loading dock jetty that will allow for that. This project will also correct drainage issues in front of the loading dock and a bad low spot in the road that is being exacerbated by all of the traffic coming in that East gate now

**Benefit**

Reconfiguring MFC warehouse access optimizes traffic flow into MFC from the new East Gate. This enhances safety and operational efficiency.

**Facility Risk**

The loading dock for the existing MFC warehouse (MFC-781) is configured such that trucks are parked in a north-south orientation, blocking the roadway in front of the building. This configuration makes it difficult for the large trucks to maneuver into the dock parking and results in congestion and blocks the flow of traffic on the road in front of the docks. With establishment in FY-21 of the East Gate at MFC as the primary access point for in-plant vehicle access, the road in front of MFC-781 now serves as the primary ingress/egress roadway for MFC with an average of 125 vehicles accessing the facility on a daily basis.

The existing configuration of the MFC-781 loading dock creates not only a logistical issue with routine flow of traffic, but it also presents a safety hazard for personnel supporting operations at the warehouse as well as personnel accessing MFC. With continued growth and construction activities at MFC, it is anticipated that the impacts of the current loading dock configuration will continue to increase. Additionally, the grading of the existing dock configuration results in drainage running directly into the dock parking spaces, creating muddy/icy conditions that represent further hazards to employees.

**Estimated Cost/Status:** ROM of $1.5-$3M**.** Design is underway with the goal of landing services to the modular first of the FY-23, and occupancy by Spring FY-23.

## 4.9 TREAT O&M Modular Office Building

**Description**

Treat O&M Modular Office Building will provide space for TREAT operators and maintenance personnel as well as micro-reactor staff to be added as use of the TREAT area expands, accommodating approximately 36 to 40 people. The building will be located northwest of the treat guard station and will have full services; water, power, fiber, life safety systems.

**Benefit**

Current operations are impacted by a lack of space to house staff. Staff are forced into double or triple occupancy in some cases during research mission execution. Additional facility space can more effectively house current TREAT staff as well as new microreactor staff supporting MARVEL and future initiatives. This will improve living conditions and operational efficiency for all personnel located at TREAT. Existing MFC-721 office space is above reasonable capacity with the available space optimized to the furthest degree possible to hold current staff. In addition to current TREAT staff, we are hiring operators and maintenance staff for the MARVEL, PELE and MCRE micro-reactors who will be assigned to the TREAT division. These additional personnel will only exacerbate the current space issues.

**Facility Risk**

There will be no available expansion capability to house additional micro reactor staff. Substandard conditions will continue to exist for TREAT personnel affecting employee morale and productivity. A lack of training and conference room space will result in delayed qualifications. Further hiring, required to support TREAT programmatic goals, means doubling up the remaining 3 manager's offices with additional workstations. Conditions will affect the TREAT experiment schedule and will force us to slow hiring for micro reactor programs.

**Estimated Cost/Status:** Design is underway with the goal of landing services to the modular first of the FY-23, and occupancy by Spring FY-23.

# 4.10 MFC Receiving and Screening Facility

**Description**

The MFC warehouse (MFC-781) was built in the late 1960s to support the EBR-II mission. It is now insufficient to support the diverse needs of MFC's current and anticipated mission, programs, and facility maintenance. MFC is also lacking adequate NQA-1 controlled storage space to support the growing number of research activities requiring more stringent management and control of material associated with nuclear facilities and research. MFC-781 does not have sufficient warehousing space and functions primarily as a receiving and distribution facility.

**Benefit**

This facility creates more space in and around the research corridor to support test bed growth, reduces pedestrian interaction with heavy equipment movement, and recapitalizes aging infrastructure eliminating the end-of-life maintenance issues associated with it. It will be integrated into the MFC East Gate so that deliveries do not have to enter the secure area to drop off freight. This facility will also provide limited NQA-1 secure storage. This supports the campus vision of collocating industrial functions to the northeast quadrant of MFC, separating them from the research corridor areas and freeing up campus space in the research corridor for test bed growth. This also reduces traffic within the MFC campus that will further limit truck congestion and interaction with pedestrians.

**Facility Risk**

Inadequate storage creates operational inefficiencies because there is no environmentally controlled storage for mission- and maintenance-critical parts, equipment, and supplies. Unnecessary double handling, additional manual material handling risk, increased material storage and labor costs, and increased damage risk occur due to the present West One warehousing arrangement for all the materials, supplies, equipment, and instruments needed to support the MFC mission. Temporary environmentally uncontrolled storage in SeaLand containers has been adopted due to inadequate storage space to support facilities' needs to stage and retain critical components, one-of-a-kind fixtures, hot cell support equipment, spare parts, and programmatic equipment for efficient retrieval. The cargo containers are located throughout MFC, creating an industrial/construction atmosphere versus a campus atmosphere. Quality storage is implemented *ad-hoc*, often resulting in less-than-optimal arrangements that increase quality risks. Items and materials are pigeon-holed throughout the facilities, resulting in multi-handling, housekeeping and safety issues, and less than optimal storage and handling of expensive, delicate, and quality-designated items. Interim radiological storage is lacking across MFC, and West One does not allow storage of contaminated or suspect contaminated items, so SeaLand containers are being used for this purpose. Waste boxes and other containers could be stored in a central location while awaiting shipment, and incoming shipments needing temporary overnight storage could be accommodated if space were available. Storage of suspect and contaminated items should be accommodated.

In many cases, roads and grounds maintenance equipment is improperly stored in the weather (trucks, plows, mowers, sprayers, sweepers, and other implements), because enclosed storage space is not available. Programs inefficiently use valuable space that could be repurposed for essential mission functions. For example, one MFC division maintains multiple storage buildings at MFC and INTEC for equipment storage. These components could be consolidated into central controlled storage for more efficient operations and free up valuable real estate. MFC fabrication shop experiences fabrication inefficiency because there is no room for bulk-source material quality-controlled storage. Semi-trucks delivering to MFC-781 perform six- and eight-point turns to access the loading dock in its current configuration. This blocks the street for lengths of time that will be untenable when the new east gate is operational.

**Estimated Cost:** This facility is pre-conceptual design, and no cost estimates are available at this stage.

**Status:** Aspirational pre-conceptual design.

## 4.11 MFC West Campus Office Building

**Description**

Modernizing the MFC Test Bed Campus remains a priority for INL. INL recently completed construction of a new office building including a new cafeteria in 2021. A second office is needed to replace aging modular office infrastructure. This ensures here are facilities available to support the anticipated growth of research and technical support staff. Ensuring adequate office space also supports attracting and retaining personnel critical to support the growth of the test bed. A second administrative building has been designed to replace capabilities that are well past their design life. This building is a key component of a modern nuclear energy research test bed at INL.

**Benefit**

Many MFC personnel are still housed in aging modular offices. Some without basic necessities such as plumbing. Code compliance is also at risk with this aging infrastructure. Completion of the proposed second administrative building will greatly enhance large capacity meeting capability and provide for more professional office capacity for MFC employees, tour groups, and visiting dignitaries. This facility will also provide at least 60 additional office spaces that will support mission growth as well as replace the aging modular facilities that are approaching 40 years old.

**Risk**

New support infrastructure is required to replace aging and less than adequate modular structures currently exceeding capacity to house existing staff. MFC is currently over 100% capacity for office space. Many of the office buildings are decades beyond their intended design life. For example, MFC-717 was acquired in 1985, MFC-713 was acquired in 1978, and MFC-714 was acquired in 1977. There are also numerous smaller trailers such as MFC-TR-56 and MFC-TR-57, located at MFC in the mid-2000s that were originally leased and used by the Idaho Cleanup Project contractor to support operations at MFC. None of these degrading facilities were ever intended to provide long-term permanent offices for MFC personnel and do not have water or sewer.

Expected RD&D growth at MFC will further burden housing that is over capacity. There is no room for the additional personnel required to support the growing mission at MFC.

**Estimated Cost:** TBD. The targeted cost is in the range of less than $25M.

**Status:** Design

## 4.12 Reactor Fuels Research Capability

**Description**

The Reactor Fuels Research Capability will provide a reconfigurable, long-term solution for meeting DOE, small business, and commercial needs for development of demonstration-scale quantities of fuel for licensing in current and advanced reactors. This supports the concept of working alongside industry as part of the NRIC test bed.

**Benefit**

A new demonstration-scale fuels research capability will be needed to support demonstration of advanced reactor technology. Demonstration articles must be fabricated using prototypic fabrication processes that produce fuel with reproducible characteristics. As the hub of NRIC, fuel demonstration capability is critical to support test bed demonstrations of advanced reactor designs. Significant investment is being made in advanced and rapid fabrication capabilities in industries with regulatory and risk profiles similar to the nuclear industry, including the aviation industry.

Currently the domestic NRC-licensed nuclear power industry is regulated to less than 5% enriched uranium and is only licensed for commercial reactor uranium oxide fuels (with only one exception). The advanced reactor design options that can capitalize on enrichment levels above 5% and below 20%, known as high assay low-enriched uranium (HALEU), are extensive and need to be exploited to develop advanced carbon free nuclear energy options. The existing facilities within the DOE complex are currently limited to research quantities of materials, generally less than one kilogram. There is a gap in capabilities for advanced fuel demonstration in the United States for fabrication of test-bed or engineering scale quantities of fuel focused on demonstration and process validation. To fill this gap requires a flexible and reconfigurable Nuclear Hazard Category-2 fuel development facility within the DOE complex that can handle large quantities of HALEU. This facility would allow the fabrication of lead test rods, lead test assemblies, microreactor cores, and the demonstration of new fabrication processes using many kilograms of material.

In addition to the direct fabrication capability, an important aspect of this study is to evaluate the extent of the quality assurance needed in the facility to foster reduced overall time required to produce a fully inspected fuel product. A critical quality component to nuclear fuel is elemental and isotopic analyses; as a result, this study needs to strongly evaluate the need for a fresh fuel analytical laboratory that may be included as a part of this facility.

**Facility Risk**

There is a gap in flexible capabilities for engineering scale fuel fabrication in the United States for advanced reactor fuel with enrichments higher than current commercial reactors incorporating potential advanced fuel fabrication and manufacturing technologies. Addressing this gap is critical to ensure that advanced reactor technology is able to move up the technology readiness scale from basic research through demonstration.

**Estimated Cost:** This facility is pre-conceptual design and no formal cost estimates are available at this stage, but the estimated range is $100 – $200M.

**Status:** This facility is in the pre-conceptual design stage.

## 4.13 East Campus Utility Corridor

**Description**

As the MFC campus continues to mature and grow, infrastructure must also expand to support the test bed. This effort will be similar to the work done on the West Campus Utility Corridor several years ago that enabled the NW quadrant research corridor growth.

**Benefit**

Planned expansion of the MFC test bed in the NE and SE quadrants will require expansion of the existing utility corridor that has not been modified for decades. Electrical, firewater, and potable water, communications, and sewage utilities will need to expand to handle planned new construction including a reactor fuels research capability and east gate receiving and inspection facilities.

**Risk**

The current utility capabilities along the eastern borders of MFC are not adequate to support expanding needs as the MFC test bed continues to grow.

**Estimated Cost/Status:** Project is pre-conceptual design and costs are TBD.

## 4.14 Stormwater Management System Refurbishment

**Description**

The current stormwater management system is largely the same system that has existed at MFC for decades. It is generally outdated and needs to be refurbished to address the growth at MFC and limit impacts to existing facilities

**Benefit**

Current maintenance activities continue to address optimizing the current system but campus growth requires a more substantial effort to support efficient campus operations.

**Risk**

Managing stormwater and snow run off ensures MFC campus operations remain effective and efficient. Recent intrusion of run off into research facilities has created increased expenses and resources required to address run intrusion. Additional maintenance was required to address the HFEF truck lock and FMF intrusion of runoff into research facilities. The current system is not able to ensure new facilities are also protected and overall refurbishment of the stormwater management system is necessary to support effective base operations.

**Estimated Cost/Status:** Project is pre-conceptual design and costs are TBD.

## 4.15 TREAT Experiment Support Building

**Description**

Additional equipment is needed to support experiment assembly at the Transient Reactor Test (TREAT) facility at MFC. Experiment assembly is needed for nearly all TREAT test programs, including those funded by NASA, DOE-NE for advanced fuels and accident tolerant fuels, NSUF projects, NNSA projects, and possibly DOD and DARPA. INL is repurposing an existing building for installation of an initial complement of experiment assembly equipment, including an inert atmosphere glovebox for closure of inerted experiment capsules.

**Benefit**

To address the experiment preparation bottleneck, the TREAT Experiment Support Building (TESB, MFC-723, the repurposed TREAT Warehouse) is being prepared for additional work associated with TREAT experiments. A glovebox and experiment assembly equipment have been purchased for installation into the facility, but the building still lacks basic infrastructure to allow year-round and full utilization of the equipment in an appropriate work environment. The upgrade/betterment associated with this request includes the following:

- New radiological monitoring equipment to support glovebox activities
- Installation of a new heating, ventilating, and air conditioning (HVAC) system to support year-round operation
- Facility improvements such as repair of insulation on the building ceiling; repair of roll-up doors to prevent moisture ingress in the building; installation of new data transmission capability (phone and internet) to and within the facility; installation of a new fire alarm panel to allow additional input to the alarm system; and modification of the electrical panels to accommodate equipment additions.

**Risk**

Existing capabilities and space are not sufficient to support the TREAT experiment assembly workload. TREAT experiments are currently assembled in a number of INL facilities including HTTL, AFF, EFF, and the TREAT reactor building. Each of these facilities support multiple missions and at times bottlenecks in experiment assembly have threatened the TREAT testing schedule. Equipment purchased for TREAT experiment support activities in the TESB cannot be fully utilized, particularly during inclement months, without building improvements that provide modern communications infrastructure and heating and cooling. With the TESB unable to meet experiment support needs, TREAT will continue to rely on an *ad hoc* collection of multi-mission facilities to prepare TREAT experiment, with a high potential to impact the TREAT testing schedule for some future priority experiment.

**Estimated Cost/Status:** Final TPC is TBD; ROM estimates are $1.2M – $2M.

## 4.16 General Office Building III

**Description**

Modernizing the MFC Test Bed Campus remains a priority for INL. A third office building is needed to continue replacing aging modular office infrastructure. This ensures there are facilities available to support the anticipated growth of research and technical support staff. Adequate office space supports attracting and retaining personnel critical to support the growth of the test bed. A second administrative building has been designed to replace capabilities that are well past their design life. This building is a key component of a modern nuclear energy research test bed at INL.

**Benefit**

Modernizing the MFC infrastructure for the future provides advantages to attracting world class talent. Many MFC personnel are still housed in aging modular offices. Some without basic necessities such as plumbing. Code compliance is also at risk with this aging infrastructure. Completion of a third administrative building will greatly enhance large capacity meeting capability and provide for more professional office capacity for MFC employees, tour groups, and visiting dignitaries. This facility will also provide at least 60 additional office spaces that will support mission growth as well as replace the aging modular facilities that are approaching 40 years old.

**Risk**

New support infrastructure is required to replace aging and less than adequate modular structures currently exceeding capacity to house existing staff. MFC is currently over 100% capacity for office space. Many of the office buildings are decades beyond their intended design life. For example, MFC-717 was acquired in 1985, MFC-713 was acquired in 1978, and MFC-714 was acquired in 1977. There are also numerous smaller trailers such as MFC-TR-56 and MFC-TR-57, located at MFC in the mid-2000s that were originally leased and used by the Idaho Cleanup Project contractor to support operations at MFC. None of these degrading facilities were ever intended to provide long-term permanent offices for MFC personnel and do not have water or sewer.

Expected RD&D growth at MFC will further burden housing that is over capacity. There is no room for the additional personnel required to support the growing mission at MFC.

**Estimated Cost:** TBD.

**Status:** Aspirational. No design work has commenced.

## 4.17 MFC 701 Refurbishment and MFC Front Entrance Improvements

**Description**

This effort will upgrade and modernize MFC-701 and replace the current chain link and barbed wire front entry into MFC with modern securiscaping, eliminating the dated and imposing military look of the entrance to MFC. This will include replacement of fencing with more modern barriers seen around other secure facilities such as concrete planter barriers and more decorative style barriers such as the modern ornamental type fencing seen around the entrance to FCF.

**Benefit**

Commercial designs to secure the MFC front entry will provide a much more modern research facility-oriented look to the test bed and still maintain critical secure access control.

**Risk/Estimated Cost/Status**

This effort is in the conceptual developmental stage and more details will be provided as planning proceeds.

## 4.18 MFC North Gate Improvements

**Description**

The north gate is currently used to support construction of SPL. In the past it provided interim access to MFC on an as-needed basis.

**Benefit**

Enhancement of the NW gate will allow future ingress/egress directly into the northern research corridor. This allows quick access to SPL, IMCL, and HFEF as well as a future mock-up/engineering/testing facility.

**Risk**

More direct access to a critical research hub at MFC increases overall mission efficiency providing increased footprint for and accelerating mission support.

## 4.19 MFC Mock-Up Facility Replacement

**Description**

The current mock-up capability occupies critical Hazard Category II research footprint within FCF. Mock-up, engineering, and testing needs continue to grow every year with no ability to increase footprint to support these activities. A new mock-up capability is proposed to be located in the NW quadrant co-located near the primary research facilities IMCL, SPL and HFEF. This enhances mission execution by providing co-located resources and more efficient mock-up and testing capabilities closely aligned with the research facilities.

**Benefit**

Providing additional non-radiological footprint in the NW research corridor supports more effective integration. This co-locates important engineering, development, and mock-up functions increasing mission integration efficiency.

**Facility Risk**

Access to the mock-up area is needed by multiple facility and engineering personnel creating traffic within FCF that is not productive for FCF operations. The size of the mock-up area is not adequate to support current MFC mission execution creating delays in mock-up and testing that impact mission execution progress. The need for mock-up capabilities is increasing every year as the MFC mission continues to grow.

**Estimated Cost/Status:** This is pre-conceptual design and no estimates are available at this time.

## 4.20 MFC NW Quadrant Engineering Laboratory

**Description**

This building will provide essential laboratory and collaboration space supporting engineering initiatives at MFC.

**Benefit**

Increasing use of MFC research facilities requires additional space to execute engineering efforts that support research. Dry lab and wet lab space to develop and assemble research related systems and equipment as well as plant health and other related facility systems enable research throughput and facility reliability.

**Risk**

More laboratory space is essential to support both research and plant health related efforts. Increased utilization of test bed capabilities requires footprint to perform engineering and

**Estimated Cost/Status:** This is pre-conceptual design and no estimates are available at this time.

## 4.21 TREAT Control Room and Office Building Update

**Description**

This project updates or replaces the TREAT Control Room and Office Building to support the TREAT mission.

**Benefit**

Updating the TREAT Control Building and Office Building will enable INL to support the TREAT mission into the future. The control room sits in a modular building installed in the early 1980s, and updated during the recent TREAT restart project. The Office Building is undersized for its current and anticipated personnel usage supporting a TREAT test program, which is growing to include users and experimenters from DOE-NE, NASA, NNSA, and industry seeking a variety of test types. This deficiency will only be exacerbated by the increasing complexity of upcoming TREAT tests and increasing on-site participation by TREAT experimenters. Furthermore, the most recent addition to and upgrade of the TREAT Office Building was completed in the early 1980s, such that the building systems consist of components of different vintage, many requiring frequent maintenance or replacement.

This project will begin with an evaluation of different options for updating or replacing the current Control Room and/or Office Building in a manner that best supports the merging and future mission. Details to be assessed through trade studies include an update-or-replace decision and location for any new construction.

**Risk**

If the TREAT Control Room and Office Building are not updated or replaced, the TREAT test program will be impeded by the inefficiencies of not being able to accommodate all necessary program personnel at the TREAT location. Impacts could include cessation of, or not being able to perform certain TREAT test campaigns.

**Estimated Cost/Status:** This is pre-conceptual design and no estimates are available at this time.

## 4.22 Repurposing Existing MFC Facilities to Support Growth of the Test Bed and Demonstration Platform

MFC is evaluating facilities within the existing campus footprint and determining if they can be repurposed. Repurposing existing MFC space can be a viable alternative to investing in new infrastructure if a new mission for these facilities can be economically established within existing footprint. Several candidate facilities are currently in execution and others are being investigated for repurposing. Actual execution of activities to repurpose these are dependent upon available funding and emergent mission need. Examples of existing footprint that might be converted to support new mission areas include:

- Removal of tanks and ancillary equipment from the Radioactive Liquid Waste Treatment Facility will provide additional footprint available to support the expanding test bed mission. A replacement system is, being designed and installed elsewhere as part of overall plant health efforts is currently underway and planned to complete in FY-22. This system will provide drum filling stations for AL, FCF, and HFEF supporting offsite disposition.
- Removal of systems within FCF including the Inter-Building Cask and gloveboxes inside Room 20 is currently underway and planned to complete in FY-22.
- The EBR-II dome and ZPPR cell are discussed earlier. Repurposing to support NRIC is completing conceptual designs for both and moving into design in FY-22.
- Repurposing MFC-768 Power Plant. This is the original power plant structure that supported the EBR-II reactor and is approximately 51,000 $ft^2$. This multi-story facility currently houses some of the electrical infrastructure for MFC and includes office and lab space. Some mock-up activities are also housed inside. This area is being evaluated for best use of the available office and lab space within the existing footprint.
- Relocation of the Mock-Up Shop now located in FCF is being considered. This would free up significant footprint in a HC-2 nuclear RD&D facility to support mission expansion of the test bed. No clear path forward has been determined but options range from using a portion of MFC-768 to construction of a new basic metal sided facility.
- Repurposing of parts of FCF areas in support of NRIC has been initiated. FCF is a HC-2 nuclear facility that has a high security posture. The building houses a large inert atmosphere hotcell and an air atmosphere hotcell. Part of the strategic focus for the facility is to move missions that do not require the facility’s security or radiological capabilities to other locations. The goal is to maximize the space available for research missions.
- The MFC-752 cafeteria is no longer needed to support food services now that the new multi-purpose office building is completed. This will provide additional footprint available for repurposing. MFC will utilize the space to provide a larger area for occupational medicine personnel and convert the current medical facility into training classrooms.
- The TREAT Warehouse (MFC-723) is currently underutilized, other than for storage of equipment and supplies. An effort is underway to repurpose the building to support demonstration platform expansion. The vision is repurposing this facility into the TREAT Experiment Support Building that will support experiment preparation and assembly.
- Expanding the fabrication footprint at MFC. MFC fabrication expansion can occur by repurposing the metal stock control building MFC-796 (4,600 sq. ft.) and the no longer utilized vehicle inspection station building MFC-736 (4,800 sq. ft.). The Space Nuclear Power and Isotopes technology division currently stores fixtures, casks, and other mission equipment in MFC-796. This material will be moved to the vehicle inspection station, which is being repurposed for general storage. This allows MFC-796 to be renovated for fabrication material receipt and quality storage, material sizing and preparation, and test train/other experiment fabrication.

## 4.23 Versatile Test Reactor (Pre-decisional)

The VTR project is a capital asset project governed by DOE O 413.3B. It received CD-1 approval in September 2020. It is in the project planning phase. The VTR's purpose is to fulfill the U.S. need for a capability to irradiate materials and fuels in the fast neutron spectrum. A sodium-cooled fast test reactor design is intended to provide a unique research capability to improve the understanding of nuclear fuels and structural materials for the development of advanced nuclear energy systems. The VTR will provide the physical means of fuel and materials testing in a user facility analogous to testing in DOE's thermal test reactors. Experimental inserts and tests loops are included in the project, but power production and thermal storage are outside of the project's scope.

The draft environmental impact statement identified the Idaho National Laboratory (INL) as the preferred site with Oak Ridge National Laboratory (ORNL) as a second choice. Fuel for the VTR would be constructed using capabilities at Savannah River National Laboratory (SRNL), or at the INL. For planning and cost estimating purposes, the VTR project has assumed the VTR would be located at the INL as the preferred alternative. Location and scope decisions will be finalized with the release of a record of decision (ROD) under NEPA. VTR's draft environmental impact statement (EIS) was released in December 2020 and public comments have been resolved. A ROD of decision is anticipated in 2022.

VTR received capital funding in FY-21 and began expenditure of those funds in Summer 2021. A VTR siting investigation will include boring, trenching, and seismology measurements. Current appropriation language for FY-22 did not include new funding for VTR, Preliminary design, final design, and construction timelines dependent on appropriations and are on hold for now.

## 4.24 Long Term Aspirational Program Funded Facilities

Various research programs have expressed a desire to construct programmatic facilities at MFC. These facilities are aspirational in nature and may be line items within other areas of the NE budget. Examples of these facilities are listed below with no time frames or cost estimates due to the aspirational level of detail:

- The Materials Recovery and Waste Form Development Program has identified a desire to construct a hybrid ZIRCEX facility. The hybrid ZIRCEX (short for zirconium removal prior to extraction) process recovers highly enriched uranium (HEU) and downblends it to create High-Assay Low-Enriched Uranium (HALEU), defined as uranium containing between 5% and 20% U-235. This would provide HALEU feedstock to support fuel development for advanced reactor designs.
- The long term vision for the NE test bed includes the possibility of industry partnering with DOE by co-locating facilities near the MFC campus. Examples include advanced HALEU fuel fabrication and hybrid energy facilities.
- A Nuclear Non-Proliferation and Forensics Laboratory has been discussed with homeland security personnel. This laboratory would enhance current National and Homeland Security RD&D capabilities at INL.
- A linear accelerator (LINAC) uses electricity to generate high energy beams of X-rays or electrons to support materials research and isotope production for nuclear forensics, medical, and emergency response applications. Locating a LINAC at MFC has been proposed by NHS programs. This capability could also provide critical support research of needs for the microstructural characterization of fuel.

## 4.25 MFC Consolidated Waste Management, Disposition, and Cask Management Facility

**Description**

The current waste management capabilities of SCMS are limited and do not support an effective overall waste management and disposition capability. The MFC vision includes a new waste management and disposition facility in the northeast industrial area of MFC. MFC needs this capability to provide a foundation for an effective strategy to address legacy materials and the anticipated growth in newly generated waste streams resulting from increased and varied RD&D activities. This will provide a capability to more effectively consolidate, store, and stage waste and legacy materials and prepare this material for offsite disposition, reducing the environmental liability at MFC. This building will have limited treatment capabilities and be RCRA-permitted similar to SCMS.

This facility will also provide a climate-controlled area where casks and supporting equipment, instrumental in completing MFC's missions, can be stored and maintained in a controlled environment. This facility and those casks used for inter-facility and intra-INL transport activities would fall under the ownership of the Waste Management Integration and Transport Operations organization. This will provide clear roles and responsibilities, enable balancing of priorities, and enable hazard controls that can be tailored to the specific work being performed (storage and maintenance) and not subject to conflicting facility priorities and missions

**Benefit**

This facility reduces risk by reducing the footprint of outdoor storage of waste and material and optimizes waste- and material-management activities. This aligns with the vision of the research corridor expanding into the NW portion of the campus with industrial functions located in the northeast quadrant.

Providing single-point control of all casks and related support equipment, their use, storage, and maintenance follows the tenets of the ISMS process. This would also provide seismic stability for storage of casks. The work management and maintenance process will be enhanced when the currently dispersed cask and equipment storage and maintenance is under the ownership of a single organization.

**Facility Risk**

MFC must meet the growing waste management demands that will be associated with the NE test bed. This facility is necessary to support consolidation of waste management activities from across the test bed, reduce internal waste container transportation distances, open more campus space at MFC from this consolidation as well as addressing legacy materials, and ensure that MFC has a consolidated capability to address current and future growth in waste management needs.

Casks and support equipment will continue to deteriorate and pose the risk of contamination to the environment. The casks are currently stored outside, and the required maintenance is performed in HFEF or FCF using valuable mission space and resources.

**Estimated Cost:** This facility is pre-conceptual, and no cost estimates are available at this stage.

**Status:** Pre-conceptual.

# Appendix A

# Detailed Descriptions of Plant Health Activities

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# 1. Replace or Upgrade the AL HVAC System

**Description**

The Analytical Laboratory (AL) ventilation system has been operating at or near (within a few percent) maximum capacity at all times with the current configuration. Some existing equipment including HEPA banks are degraded and shut down or cannot be connected because the suspect exhaust system cannot support the ventilation requirements. The result is an inability to be efficient in our processes and creates delays in sample processing. General laboratory area airflow direction and pressure differentials are difficult to maintain as desired to limit migration from zones of higher to lower potential contamination (hot cell pressure differentials are maintained). AL's mission is continuing to grow and evolve with an anticipated increase in throughput and precision and sensitivity for radiochemical measurements. Reheat/Room heaters intended to maintain lab temperatures within a tighter band are currently steam heaters, which cannot provide the precision and control needed for current technology instrumentation.

**Benefit**

Control of differential pressure within the AL is currently extremely difficult with the analog equipment installed. Research activities are regularly suspended due to air flow concerns. This upgrade will provide digital pressure differential control technology for control of building ventilation, enhancing safety for personnel within the facility and improving efficiency of research activities.

As uncertainty of measurements gets reduced, the data produced gets more accurate. This also increases the availability of AL as fewer ventilation-failure induced shutdowns. Improved flow and pressure control reduces the risk of contamination migration.

This effort increases reliability and operational safety of the AL ventilation system. This also increases capability when the new system is complete and able to better accommodate increasing research capabilities.

**Facility Risk**

Control of building air flow from areas of least contamination to areas of higher contamination is a fundamental principle for protecting workers in nuclear facilities. The current AL ventilation DP control is analog and segmented in approach. AL staff is required to regularly suspend research activities and adjust the ventilation system to achieve minimum air flows. The current system limits the addition of scientific capability within the AL as new instrumentation has a negative impact by exceeding the limits of the current HVAC system. This upgrade will provide enhanced air flows and minimize research interruptions. Failure of key blowers, dampers, or control system components would result in several weeks down time for key AL lab spaces.

**ROM Cost Estimate:** $17M.

## 2. Manipulator Replacement Campaign in HFEF, FCF, and AL

**Description**

This project procures a new manipulator system for replacement of the obsolete manipulators in HFEF, FCF and AL and commences an extended manipulator replacement campaign. Replacement manipulators are not currently available and will need to be developed by the supplier. To fully test manipulator capability prior to implementation, two complete units need are being procured with additional slave arms of varying length to simulate the implementation in cell. The concept is a modular manipulator with a standard seal tube. Heavy duty master/slave and medium duty master/slave would utilize the same seal tube and allow for maximum cell configurability. Additionally, several slave arms of varying length would be balanced to a master configuration to allow in-cell configuration as needed for each workstation. This concept would minimize the total number of manipulator arms needed. Scope includes procurement of a set of manipulators for the mockup, testing and evaluation followed by optimization prior to procurement of a complete set of manipulators in each facility. The mockup manipulators will remain for use in qualification of equipment.

**Benefit**

This project provides replacing the aging manipulator fleet with new manipulators increasing reliability across all hot cells. This includes new models from the current provider as well as Wallischmiller models. The implementation of manipulators can be scaled back based on funding but should provide one or more operating station replacements per year as funding allows.

**Facility Risk**

Current manipulators are obsolete. Spare parts are no longer available from vendor and increased usage is resulting in increased breakage. Many are out-of-service and cannot be repaired. Prototype manipulators are being tested with the vendor now. Delays in completing this campaign adds to the risk that cessation of mission work that could span months at critical hot cell windows if old manipulators fail and impact facility availability.

**ROM Cost Estimate:** $17.9M.

## 3. Window Replacement Campaign in HFEF, FCF, and AL

**Description**

Main hot cell windows at HFEF, FCF, and AL use mineral oil to provide clarity between windowpanes. Several windows have developed mineral oil leaks into the hot cells. HFEF window 1M is currently leaking approximately 2 gallons per month. Operators currently have to periodically clean up the oil manually. This project involves evaluating the condition of the windows and providing a means to restore the windows to their intended function. This is not considered a standard maintenance item due to the complexity of the repair and the need to breach the hot cell containment in order to implement the repair. This project will include significant interruption of facility availability. Each window replacement will require fabrication or refurbishment of a replacement A-slab (outer layer of a multi-layer hot cell window unit) with oil collection and management capability, installation of the new/refurbished A-slab, fabrication or refurbishment of replacement window tank unit extracts, and installation of the replacement/refurbished tank unit. There are a total of 3 leaking windows in HFEF, 2 in FCF, and 2 in AL that require replacement.

**Benefit**

Mitigates oil leaks by establishing a leak tight A-slab and allowing for periodic draining of accumulated oil between the A and B slabs. It also corrects the source of the oil leak and establishes the original integrity of the system. Additionally, the fabrication of the replacement tank unit minimizes the downtime on the facility with the facility hot and argon filled. AL will also investigate using oil-free windows in its hot cells.

**Facility Risk**

The hot cells are aging, and additional window failures are anticipated. Failure to provide the additional window replacements may jeopardize hot cell operations due to the extensive planning and lead time associated with the evolution. A catastrophic window seal failure would cause unacceptable mission impacts on the order of months to over a year.

**ROM Cost Estimate:** $25.5M.

## 4. FCF Multi-Function Furnace

**Description**

The electrometallurgical treatment process used to neutralize the sodium component of irradiated EBR-II elements includes a salt distillation step as part of the process. Currently, the 25-year-old Cathode Processor (CP) is the only means of performing this salt distillation requirement from uranium dendrite or other process materials in the FCF argon cell. When maintenance needs arise, repairs to this unit must be performed remotely which results in extended treatment process downtime. This is a single point failure that limits process treatment rates. The addition a secondary distillation capability via a new high temperature vacuum atmosphere furnace in the FCF argon cell will enable salt distillation requirements to continue when maintenance occurs on the Cathode Processor and will help to alleviate the bottleneck at this process step associated with higher throughput rates. Additionally, this new furnace will be designed to support expanded missions beyond salt distillation to include cladding hull consolidation, sodium contaminant distillation, as well as uranium consolidation.

**Benefit**

Increase in overall treatment system reliability and process rate efficiency, while expanding capability in enhancing uranium product and process waste stream disposition

**Facility Risk**

The single point failure associated with the current treatment system limits the rate of treatment. Past operational conditions provided some flexibility to store dendrite on an interim basis until the Cathode Processor was available, however future operating requirements will significantly restrict this capability, resulting in shutting down the process until repairs can be made.

Workload at the CP is increasing, while equipment availability has been decreasing in the recent past due to unplanned component failure related to the age of them.

**ROM Cost Estimate:** $7.5M.

## 5. Radioactive Liquid Waste Treatment Facility Process/Storage Tanks Replacement

**Description**

RLWTF has four 1,000-gallon tanks, one of four tanks has evidence of recent leaks that has not been repaired and the two other tanks have been previously patched. These tanks need to be permanently removed from service and a suitable replacement system will be installed.

**Benefit**

The replacement system will utilize commercial products and eliminate RLWTF process equipment O&M costs. This also reduces radiological risks.

**Facility Risk**

Facility risk is reduced by installing a low maintenance alternative to existing RLWTF system. Eliminate consequences of failure of this system that would entail stopping manipulator repairs in HFEF and FCF (as there would be no water reservoir for drain water from manipulator decontamination work). This would rapidly shutdown programmatic work in these hot cells.

**ROM Cost Estimate:** $3M.

## 6. HFEF Small and Large Transfer Lock Drive Control System Replacement

**Description**

The large and small lock drive controls are old and prone to failure. This project replaces the existing controls with new modern controls. The small transfer lock is used to transfer small materials between the main hot cell and decontamination cell. It is used to support both programmatic and in-cell maintenance. Hinges and sealing surfaces have degraded. These doors maintain argon cell containment control and limit contamination release between the two hot cells. These doors are safety significant.

**Benefit**

Replacement of the drive controls with modern components will increase reliability of lock door operations. Small lock door replacement will return the physical hot cell boundary to the original condition. This action minimizes the risk of future material transfer delays due to system inoperability.

**Facility Risk**

Failure to replace the controls would expose program work to increased schedule risk should the locks become inoperable due to control issues. Failure to perform this work increases the risks to perform material efficient material transfers to support programmatic work. The door repair is a long-lead activity with an estimate of 6-9 months to obtain, modify, and install a replacement.

**ROM Cost Estimate:** $800K.

# 7. HFEF and FCF Electro-Mechanical Manipulators, Cranes, Hoists, and other In-Cell Handling Equipment Refurbishment and Replacement

**Description**

In-cell handling equipment in the HFEF and FCF hot cells is often single point failure threats to all or parts of hot cell operations supporting crucial research missions. These include electro-mechanical manipulators (EMM), hoists, cranes, and transfer locks. These are critical components to hot cell operations and how research material and equipment are moved around inside the hotcell. These are also how critical in-cell maintenance is performed. Most of these important systems are beyond design life and are experiencing accelerated failure rates with a direct impact on facility reliability and research equipment availability. Addressing these risks will require a multi-year campaign similar to manipulator and hot cell window replacement. Specific near-term targets are described below

HFEF Repair Hoist Access Improvements – Observations during previous repair hoist entries, transitioning from run to failure maintenance strategy to the performance of periodic maintenance/inspections, as well the future installation of a second manipulator repair enclosure in room 318 warrant repair hoist enclosure access improvements.

HFEF Crane and EM Component Replacement – Several components for the crane and EMM's are no longer available as direct replacement. Engineering must be performed to ensure compatibility and configuration of replacement components. This includes:

- Crane Hoist Brake/Lubrication
- Crane Hoist Motor
- Crane Trolley Drive Assembly
- EM Hoist Drive Assembly
- EM Rotate Drive Assembly
- EM Carriage Drive Assembly
- EM and Crane Bridge Motor.

HFEF Repair Hoist Control System Upgrade – The repair hoist control cabinet has numerous outdated components and controls. Recent activity to restore repair hoist control have been successful in maintaining operability. Replacement of the internal of the control cabinet internals allows for maintainable system and adds monitoring capability to the system for evaluating system performance.

Crane/EM Power Feed Replacement – The power feeding the two in-cell cranes and two Ems has had issues and has been wired to spare conductors to maintain operations. Power is supplied through a wall feedthrough with in-cell wiring extending up to the wall mounted bus bars. The wall feedthrough is suspected to have had current failures but cannot be easily tested.

Replace FCF Blister Hoist and Controls – The Blister Hoist is 5-ton capacity hoist whose purpose is to remove and replace the argon cell crane trolleys and the EMM carriage-bridge drives when these devices need repair or maintenance. This hoist is within an enclosure which is a carbon steel tank connected to the top of the argon cell concrete roof. The blister-hoist enclosure is included as a safety significant Argon Cell Confinement System Passive Components. Shielding is provided by a shielding plug attached to the hoist chain so that when the chain is withdrawn, the plug nearly fills the roof through-tube. The Blister Hoist operates with no known issues but is beyond end-of-life usage, has not been inspected since the early 90s, and repair components will be difficult if not impossible to locate for procurement. The equipment is original to the facility.

Replace FCF Air Cell Exit Cell Crane and Controls – The exit cell houses a 5-ton crane whose purpose is to remove and replace the air cell crane trolleys and the EMM carriage-bridge drives when these devices need repair or maintenance. The exit cell crane is located over a hatch in the air cell that has sliding doors to allow items to be hoisted or lowered between the air cell and the exit cell. A door between the exit cell and the cart area was sealed shut for security purposes as part of the HRA restoration work. The Exit Cell Crane operates with a potential future problem with bus bar insulation and is beyond end-of-life usage and repair components will be difficult if not impossible to locate for procurement. The equipment is original to the facility. Replacing the Exit Cell Crane will include modifying the door between the exist cell and old Decontamination Spray Chamber (DSC) roof to allow access for inspection.

**Benefit**

The general benefit of executing in-cell handling equipment refurbishments and replacements is increasing research capability availability. Since these systems are critical to cell operations, all aspects of operations, maintenance, and execution of various research missions depend on them.

Refurbishing and replacing HFEF and FCF in-cell handling equipment link directly to facility reliability and research capability availability. Any movement of materials or equipment into, out of, or within the hotcells rely on these critically important tools. Recent down time associated with the FCF transport lock and HFEF repair hoist failures significantly impacted research capability availability for extended periods of time. This adversely impacted progress on important research program milestones, HALEU production, and regulatory support of the Idaho Settlement Agreement. Certain failures of handling equipment also reduce availability of functioning equipment to protect remaining capabilities and limited availability of research capabilities within the hot cells. For example, the HFEF repair hoist failure eliminated the ability to reduce manipulator repairs which impacted progress on research.

**ROM Cost Estimate:** Multiple annual funding increments of $3-4 M.

# 8. Replace FCF SERA/DSC Crane and Update Control Equipment

**Description**

The Suited Entry Repair Area (SERA) allows maintenance of large equipment items that require hands-on servicing. It has a 5-ton-capacity overhead bridge crane which connects with the crane bridge above the DSC; the crane hoist trolley can carry a load from one bridge to the other, between the SERA and the DSC. The SERA Crane is essential to move EMMs, Cranes, Process Equipment, Waste, and Manipulators to and from the repair enclosure which is critical to maintaining capability of performing EBRII Fuel Processing and HALEU Production program mission commitments.

The SERA has experienced control system failures at an increase frequency and problems with crane bridge latching at the interface of the SERA and DSC.

Replacing the SERA/DSC Crane will include Bridge Latch Limit Redesign & Rebuild, developing a replacement plan for Crane and controls, initiate advanced procurement, and execute replacement of the Exit Cell Crane.

**Benefit**

Reliable capacity to perform Material/Equipment transfers and needed maintenance on Argon and Air Cell Manipulators, EMMs and Cranes to ensure availability for project/program missions.

**Facility Risk**

Without additional funds mission commitments are at-risk of completing on time as we have committed.

The SERA/DSC Crane is evaluated as a single point failure piece of equipment. Its failure would significantly and adversely impact EBRII Fuel Processing and HALEU Production program commitments.

**ROM Cost Estimate:** $500K 2023, $3.5M 2024, $4.0M 2025.

# 9. New SCRAPE Cathode Module for FCF Electrorefiner

**Description**

The electrorefiners in FCF are used to separate the EBR-II used fuel and irradiated blanket materials into individual components as part of the treatment process to neutralize the sodium used in constructing the elements. As part of the process, the separated uranium is recovered on a cathode mandrel and removed from the vessel for potential re-use in other nuclear fuel cycle applications, including high assay low enriched uranium for proposed fast spectrum research reactors. Removal of the cathode with accumulated uranium dendrite is time consuming and occurs 4 to 6 times (on average) during a treatment batch. Implementation of the scraped cathode concept is intended to reduce the frequency of cathode withdrawal via accumulation of uranium dendrite in a co-located product collector and use of an integrated compaction plate to increase the amount of uranium dendrite removed from the electrorefiner each time the cathode is withdrawn.

**Benefit**

Increase in overall treatment system reliability and process rate efficiency.

**Facility Risk**

The task of removing the electrode assembly and connected cathode mandrel from the ER is one of the more time-consuming aspects of the treatment process. The frequency of handling electrode assemblies to remove the cathode is manipulator intensive and disruptive to processes occurring in the adjoining workstations, thus concepts that could lead to a reduction in the frequency with which this operation is conducted could yield significant overall efficiencies to the treatment process.

**ROM Cost Estimate:** $2.8M.

# 10. Replace FCF Facility Control System

**Description**

The facility and process monitoring and control systems in the Fuel Conditioning Facility (FCF) were designed, constructed, and installed by in-house MFC engineers and technicians. The backbone of these systems consists of three integrated component types. These components are:

1. Programmable Logic Controllers (PLC)
2. Small Logic Controllers (SLC)
3. Operator Control Stations (OCS)

These components were last replaced in the 1990s and are past obsolescence. The old components operate under the Windows XP platform that is no longer supported or maintained by Microsoft. The individual PLCs and SLCs within the systems use modules that are no longer available from the vendor. The vendor is requiring replacement of these older system components with new, up-to-date hardware in order to provide vendor support. Migrating to new hardware involves porting the existing PLC/SLC application software to a modern, vendor supported, operating system. The OCS human machine interface (HMI) was developed using the FIX32 (Supervisory Control and Data Acquisition software system) will not run on platforms running Microsoft Windows' versions newer than XP. Fortunately, the Fix32 HMI software can be converted to a new version, iFIX, that will operate under current Windows operating system platforms (and should be supported for many years to come). All the components within a system must be upgraded simultaneously to maintain proper system functionality.

As the older components continue to fail in service, the FCF has experienced unscheduled system outages that have delayed facility operations while repairs are made. Replacement of these system components, under crisis management methods, has not proven timely or cost effective. This project will replace the obsolete components, repair or replace the networking backbone of the systems, update all components to run on supported Microsoft Windows operating systems, and do so in a series of scheduled facility outages that will be coordinated with other facility operations and schedules. In this way, high facility reliability and availability can be sustained.

**Benefit**

1. Increased facility availability and reliability
2. Network security of systems is reestablished
3. New hardware will be supported
4. Commercial spare parts readily available

**Facility Risk**

The FCF monitoring and control systems have reached end of life. The systems in question provide critical data and control functionality to/from various processes and systems throughout the facility. Equipment failure has had a detrimental impact on FCF's daily operations and overall mission. The impairment caused by the failure of this equipment has resulted in facility outages that have prevented facility activities from being performed (such as EBR-II fuel processing). This equipment must be upgraded in order for FCF to operate through its anticipated life.

**ROM Cost Estimate:** $12M.

## 11. Analytical Laboratory Lab Room Renovations

**Description**

The Materials and Fuels Complex Analytical Laboratory (AL) provides high-quality processing, analysis and characterization of radiological materials. The AL laboratory rooms house sample preparation and examination equipment and analysis instrumentation. The majority of the lab rooms are located in the B-wing and Sodium wing of the AL. The B-Wing and Sodium Wing were put into service in 1957 and 1969 respectively with little to no updating since being put into service. Damaged asbestos based floor tiles and work surfaces are present in many of the lab rooms. Windows are single-pane with aluminum framing which provide marginal insulation value. Additionally, modern instrumentation detection limits are so low that background radiation levels within some of the rooms interfere with new instrument capabilities. Therefore, laboratory rooms need to be decontaminated and new sample preparation fume hoods and work surfaces need to be installed.

**Benefit**

Clean and modern work environment with more efficient equipment and use of lab space will optimize performance of personnel in their workspaces. Updated work areas and equipment will reduce the amount of emergent maintenance required.

**Facility Risk**

The conditions can be less than ideal for operating equipment. Inefficient layout of workspaces present challenges for personnel when preparing samples for analysis. Personnel output is reduced both in volume and quality when working environments are not satisfactory. Background levels are interfering with the lower detection limits required by programmatic work and capabilities of current instrumentation being installed in the AL.

**ROM Cost Estimate:** $750K/lab room.

## 12. HFEF Argon Regeneration Valves

**Description**

The regeneration system in HFEF provides heated dry air and argon for regenerating the purification system dryers. The regeneration valves are old and need replacement. The summary of work for this project is the procurement and replacement of the HFEF argon cell regeneration valves. This includes design of components to ensure proper interface of the new valves with existing piping.

**Benefit**

Replacement of the regeneration valves will increase the reliability of the regeneration system.

**Facility Risk**

The risk to the facility if the regeneration valves are not replaced is the increased chance of the regeneration system failure which in turn would impact the facility capabilities to support programmatic work.

**ROM Cost Estimate:** $500K.

## 13. Design, Fabricate, and install New FCF Feedthrough to Support $CO_2$ Cold Jet Decontamination System

**Description**

The SDI Select 60 Cold Jet $CO_2$ Blast Unit (Cold-jet) has been tested for contamination removal of materials (e.g., manipulators & EMMs) in the FCF Decon Spray Chamber (DSC). The use of the Cold-jet was demonstrated to significantly reduce surface contamination in some conditions and thereby further achieve ALARA objectives. To support the permanent installation and effective use of the new cold-jet decon system at FCF, a new feedthrough needs to be designed, fabricated, and installed in the DSC. We will modify an existing feedthrough to fit the needs of the cold-jet system.

**Benefit**

The use of the Cold-jet was demonstrated to significantly reduce surface contamination in some conditions and thereby further achieve ALARA objectives. The feedthrough will facilitate more efficient and effective use the cold-jet system.

**Facility Risk**

Without this new feedthrough the use of the Cold-jet system in the temporary non-routine procedure process requires multiple Suited Entry Repair Area and DSC entries which is not in alignment with ALARA objectives and causes measurable delays in the decontamination process.

**ROM Cost Estimate:** $350K.

# 14. HFEF MetBox Refurbishment

**Description**

The met cell is a small, shielded, inert gas-filled hot cell (located in Room 123). The cell houses a Leitz Model MM-5RT gas-sealed metallograph, a LECO AMH55 Micro-Hardness Tester used for microhardness testing, and a Leica DMi8 Advanced Microscope used for microscopic examination of prepared samples. The cell maintains the inert atmosphere required for loading and examining samples and shields personnel from radiation from the samples. The atmosphere control system maintains an inert gas atmosphere (< ppm O2 and H2O) in the loading cell. It is maintained at negative pressure with respect to Room 123, and is regulated by its own controls located on the north wall of Room 123. The met-cell atmosphere is automatically controlled by the feed and bleed, analytical instrumentation, cell-exhaust, purification, and nitrogen/Argon systems.

**Benefit**

Restoration of full capabilities optimized RD&D support efficiency and reduces rework on samples.

**Facility Risk**

The only atmospheric control that is currently functional is pressure and thus there is no information for the purity of the atmosphere in the Met Box. Not controlling the atmosphere allows oxygen and moisture into the atmosphere which causes oxidation of the Met mounts and degradation of susceptible system components.

**ROM Cost Estimate:** $1M.

# 15. HFEF Containment Box Lid Seal and Hoist

**Description**

The HFEF Containment Box, along with its associated support equipment, is located in the HFEF main hot-cell. The containment box is an enclosure that isolates the station from the main cell atmosphere. The purpose of the containment box is to isolate an area for use in preparation of metallographic specimens for optical microscopy and hardness testing. This enclosure is necessary because metallographic operations require the use of liquids that could be harmful to the system used to purify the main cell argon. Additionally, head-end operations prior to sample preparation (grinding and polishing) require sawing operations that produce fines that also need to be isolated from the main cell environment for contamination purposes. Issues related to the containment box that require attention include a lid and doors that no longer seal properly, aging controls and cooling systems that require upgrade, and aging hoist capabilities within the enclosure.

**Benefit**

Correcting the previously mentioned issues will improve isolation of the containment box interior from the main argon cell as well as improve reliability of the containment box functions.

**Facility Risk**

The risk to the facility is delay of program work should the door and lid seals completely fail or should the box controls or cooling system fail. It is estimated that containment box down time would exceed 9-12 months should complete failure occur.

**ROM Cost Estimate:** $500K.

## 16. Fabricate Replacement Parts for HFEF Transfer Lock Ram

**Description**

The HFEF transfer lock is used to move equipment and material into and out of the argon cell. The recent failure of the transfer lock at FCF shut down operations for several months. Lessons learned from the FCF failure will be applied to the HFEF transfer lock.

**Benefit**

The benefit to the facility is the ability to respond quickly to a similar failure. Having the parts and engineering experience on hand will support a quick response in the event similar issues are encountered at HFEF.

**Facility Risk**

The transfer lock between the argon cell and air cell is the primary portal to transfer material and equipment into or out of the hot cell. Failure of this equipment would effectively shut down hot cell operations with the exception of ongoing work currently in the hot cell.

**ROM Cost Estimate:** $2M.

## 17. FCF In-Cell Lighting

**Description**

FCF In-cell lighting in a highly degraded condition. After determining the failure locations of many of the lighting circuits we have determined that they cannot be repaired remotely in the argon cell. As a manned entry for repair is also not possible our most logical alternative is to utilize other conductors to provide power to the in-cell lighting. Currently there are spare feedthroughs currently installed, available and capable of supplying the necessary power for in-cell lighting. Original ballasts and light fixtures will be reused. Ballasts were replaced in the last decade and these are still serviceable items. Some lighting fixtures will need to be replaced on as-needed basis.

**Benefit**

In-cell lighting directly impacts the ability to perform work in the argon cell. Many times supplemental lighting in the form of handheld spotlights are being used to augment the low light conditions in the argon cell. The use of the handheld spotlights increases the quantity of personnel required to perform work at the cell windows as 1 person is often shining the light while the other operator(s) perform the task in cell. The increased lighting will reduce the risk of mistakes performed during in-cell operations that are caused by inadequate lighting.

**Facility Risk**

Reduced lighting in the argon cell will increase the risks associated with in-cell operations. Incorrect identification of containers, unintentional striking of other items with remote overhead handling equipment, increased time for all in-cell tasks will be all negatively impacted with low light conditions.

Efficient critical mission work in the argon cell will continue to be impacted or will not be able to be completed.

**ROM Cost Estimate:** $750K.

## 18. Replace TREAT Loop Handling Cask Winch System

**Description**

The TREAT Loop Handling Cask is used to transfer test loops containing previously irradiated fuel from a shipping cask, such as the HFEF-15 cask that will be used to move loaded loops from HFEF to the TREAT Reactor building, to the test location in the TREAT reactor core. The winch located on the cask is used to pull to raise and lower the loop into or out of the Loop Handling Cask. A new winch system is needed because spare parts are no longer available for the current winch, original in 1982.

**Benefit**

The replacement system will improve Loop Handling Cask reliability and will also have a higher load capacity, which is believed necessary for supporting upcoming projects using the BIG-Buster containment.

**Facility Risk**

Facility risk (schedule interruption due to winch failure) will be reduced because the new winch will be less prone to wear-induced failure and will be more readily maintained with spare parts available through suppliers.

**ROM Cost Estimate:** $0.075M.

## 19. TREAT Dedicated Microprocessor Tester Installation

**Description**

Prior to reactor operation, changes to TREAT reactor trip point settings and other functionality require microprocessor testing to ensure set points were entered correctly and trip systems are operate as intended. A new Dedicated Microprocessor Tester (DMT) is proposed to replace outdated computer systems and software, similar to the recent Automatic Reactor Control System (ARCS) replacement (but with less scope for a simpler system).

**Benefit**

The new DMT will provide hardware and software that is more efficiently maintained and updated. The new DMT is also expected to reduce the turnaround time needed to complete the microprocessor tests.

**Facility Risk**

As with any outdated computer and software, the current DMT presents a vulnerability and rick for schedule impact, should the system fail and require hardware maintenance with parts that are difficult to find or software revision using computer languages unfamiliar to today’s personnel.

**ROM Cost Estimate:** $0.15M.

## 20. TREAT Radio Signal Booster

**Description**

The radios used by the TREAT Building Emergency Director and the MFC Emergency Response Organization do not receive signal when inside the TREAT Reactor Building. This project will place a signal booster in or near the TREAT Reactor Building to improve reception.

**Benefit**

Procurement and installation of the signal booster will allow emergency personnel inside the TREAT Reactor Building to reliably communicate over the INL emergency response radio frequencies.

**Facility Risk**

Facility risk (inadequate communication during emergency response) will be reduced by ensuring the TREAT Building Emergency Director and other MFC Emergency Response Organization personnel can reliably communicate with the MFC Emergency Control Center when in the building.

**ROM Cost Estimate:** $0.1M.

## 21. Experiment Data Acquisition System (EDACS) Installation/Upgrade

**Description**

The TREAT Experiment Data Acquisition and Control System (EDACS) is a non-safety system used to monitor and record signals from an experiment and to control experimental systems, such as heaters or pumps. The primary interface is the EDACS console in the TREAT Control Room, although the system allows control and monitoring from inside the Reactor Building. The current EDACS was assembled and installed during TREAT restart and provides the minimal functionality needed for tests and experiments to date. However, an expanded capability will be necessary for more complex TREAT experiment systems and vehicles, such as for the Hydrogen Test Loop and the Sodium Test Loop. The EDACS Installation/Upgrade project will update hardware and software to provide an expanded and more-robust control capability and an increased number of data signal channels for monitoring and recording.

**Benefit**

The EDACS Installation/Upgrade project will provide the expanded capability necessary to operate more complex TREAT experiment systems.

**Facility Risk**

Completion of this project will ensure that TREAT has the capability needed to accommodate increasingly complex and evolving needs of experimenters and users, reducing risk of not being able to adequately control testing conditions or of missing data due to an inadequate signal processing capacity. The upgrade to separate controllers similar to those used in other TREAT systems will enhance EDACS maintainability by TREAT personnel.

**ROM Cost Estimate:** $0.48M.

## 22. Replace TREAT Control Rod Segments

**Description**

A recent discovery of an unusual-looking end-plug welds in two segments of TREAT reactor Control/Shutdown rods (1 instance in each of two rods) prompted an investigation into the condition. The end result of the evaluation was the determination that the control rod segments (and any others that might unknowingly be in the same condition) are Operable but Degraded. The determination was made primarily as a conservative action for a condition that may have been adequate and possibly even accepted as-is with justification during early TREAT operation in 1960; however, unless or until additional information from 1958 can be found or the weld condition can be better characterized, it is prudent to move toward replacing any affected control rod segments with new parts. The engineering evaluation demonstrated that the affected rods are not likely to fail, based on their nearly 40-year operational history to date, so replacement can be pursued in parallel with TREAT operation. This project will procure and install new control rod segments wherever needed, removing any question about component reliability.

B**enefit**

Ensuring that this safety-related component meets today's manufacturing and inspection criteria will establish confidence in TREAT component quality.

**Facility Risk**

An unexpected component or failure of a control rod might arguably be sufficiently severe to prevent control rod insertion, which, though anticipated in the TREAT SAR, would have a negative impact on the TREAT operations schedule.

**ROM Cost Estimate:** $0.9M over FY-22 and FY-23 (rough estimate; to be improved in FY-21).

## 23. Fire Barrier Refurbishment for MFC Nuke and Rad Facilities

**Description**

Fire barriers within MFC facilities serve two functions: 1) protect life; and 2) protect property, including research equipment and experiments. There is no documentation that alterations that have occurred to the fire barriers over time are compliant with NFPA 221. The work scope involves penetrations and seals in fire rated walls that need to be repaired or replaced. The scope also includes door repairs, wall joint repairs, and window & door replacements.

**Benefit**

Inspections of the barriers have identified gaps that would affect the barriers' performance in a fire. As a result, it is uncertain that adequate protection would be provided to property, personnel, and equipment if a fire were to occur in one of these MFC facilities.

**Facility Risk**

The barriers will continue to be potentially non-compliant with NFPA requirements and weaknesses in the fire protection system will continue to pose a potential threat to MFC property and personnel.

**ROM Cost Estimate:** $1M.

## 24. Refurbish HFEF Precision Gamma Scanner

**Description**

The precision gamma scanner's (PGS) gamma detector has surpassed its expected useful life by 3 years and is showing signs of failure. The system is using ~4x the coolant it once did, indicating that it is no longer running optimally. The PGS gripper has experienced significant down time in recent months. Further equipment failure is likely, which would shut down production for weeks or months to procure replacement parts. These delays could affect program milestones. The control components within the PGS electrical cabinet are old, and drop-in replacements are not commercially available.

**Benefit**

The PGS is considered a "portal" instrument supporting almost every nuclear fuel research effort. This is considered a base R&D capability and refurbishment is essential for mission execution.

**ROM Cost Estimate:** $3M.

## 25. Replace MFC Fire Protection and Potable Water System

**Description**

Approximately 1.2 miles of underground piping and two deep well pumps that were installed as part of the original EBR-II infrastructure in the 1960s. This piping is cast iron and has surpassed service life. Recent piping failures (4) in the past 15 months that have cost over $2.5 million to replace.

**ROM Cost Estimate:** $15M spanning 4 years. IRA Funding.

## 26. Replace MFC Industrial Waste Water System

**Description**

Current system was installed in the 1970s with approximately 1,500 ft of asbestos cement underground piping and about the same linear footage of open ditches.

**Benefit**

Enables protection of the aquifer.

**ROM Cost Estimate:** $10M spanning 4 years. IRA Funding.

## 27. Emergency Shower/Eyewash Compliance Updates

**Description**

The emergency eye wash and showers in the Analytical Laboratory are currently compliant only because they were installed so long ago. The do not meet current ANSI standards, which says they must provide 20 gpm at 30 psi for 15 minutes between the temperatures of 60 and 90 degrees.

Providing for tepid water by installing an electric water heater/storage tank to provide hot water, to be mixed with cold water, to provide 80°F (median required water temperature) is required. Assuming cold water is 50°F, and 140°F hot water storage temperature, 100 gallons of hot water would be required to mix with cold water to provide 300 gallons at 80°F. A mixing valve will be needed, and they require annual maintenance and testing. A return line and circulating pump should also be installed from the storage tank to each lab (parallel to existing supply piping) to ensure the tepid water supply is nearly instantaneous in the event a shower is activated.

**Benefit**

Installation of a new system to provide warm water to the shower and eye washes throughout the facility meets ANSI standards. Additionally, it also provides comfort to individuals in dire circumstances to be able to rinse for the recommended time and prevent further harm. Currently, with the temperatures where they are, if something were to happen, individuals could not stay under the shower for enough time to fully mitigate the hazard of the chemicals.

**Facility Risk**

The Analytical Laboratory currently is operating at risk due to the shower and eye wash. The safety of the technicians in the lab is compromised. It would be hard for anyone to stand under a 65 degree shower for 15 minutes to rinse during an abnormal event when there is already chaos.

**ROM Cost Estimate:** $750K.

## 28. Roof Repairs to Nuclear and Radiological Facilities

**Description**

This covers maintenance activities associated with repairs and/or replacements of sections of roofs that cover the nuclear research facilities.

**Benefit**

Steady funding for ongoing maintenance activities on nuclear research facility roofs ensures that facilities remain available to support research missions and that the vital research capabilities are protected from damage. An ongoing roof maintenance campaign of targeted replacements of sections of these aging roofs ensures that research operations are not disrupted.

**Facility Risk**

Roof leaks in nuclear facilities put facility and research equipment at risk from infiltration of water. It can disrupt operations and poses a risk of damage to facilities, systems, and research equipment.

**ROM Cost Estimate:** $20M over 4 years. IRA funding.

## 29. AL Ultra Pure Water Stations

**Description**

Ultra-pure water stations deliver on-demand water that has been purified and de-ionized to a conventional standard and that ensures native elemental species in supplied water do not interfere with the quantification of elemental and isotopic analytes in solutions under investigation. To maximize the efficiency of laboratory operations and take full advantage of the ultra-pure water characteristics, these water stations should be installed wherever sample preparation occurs in the laboratory, typically those rooms with benchtop areas and fume hoods for preparative work.

**Benefit**

The majority of the AL's elemental and isotopic analyses require the use of ultra-pure water in all steps of the sample and standards preparation processes to prevent the introduction of contamination that will alter the results of the analyses. The sensitivities of the mass spectrometers, for example, are so high that low concentrations of samples are used to achieve increasingly lower detection limits of analytes. Native elements present in the water used to prepare the dilution acids could skew measurement or result in false-positive detection. Ultra-pure water is therefore necessary to ensure accuracy in challenging measurements.

Because sample preparation, including dilutions, takes place in each benchtop laboratory space in the AL, it is necessary to have local ultra-pure water stations in each of the pertinent rooms. The need to access ultra-pure water rapidly arises with sensitive analytes and acids. In addition, the need to reduce the handling of the water by, for instance, transporting it from one room to another, is critical because increased handling results in greater probabilities of introducing contaminants. Ultra-pure water stations at each benchtop increases the AL's sample throughput and improves quality control and assurance.

**Facility Risk**

The absence of ultra-pure water stations at each benchtop (or one per laboratory room) limits the accuracy and precision of the AL's results and jeopardizes the AL's ability to meet ultra-low detection limits in its characterization of low levels of impurities in experimental fresh fuels. It also reduces the precision in the characterization of used fuels during post-irradiation characterization. Both of these functions are critical mission areas for the AL.

**ROM Cost Estimate:** $300K.

## 30. HFEF Decon Cell Fire Suppression System

**Description**

Current fire suppression in the HFEF Decon Cell (air atmosphere) consists of external $CO_2$ fire extinguishers plumbed through the wall and relies on operators to manually activate the fire extinguishers while using manipulator arms to hold and point the nozzles at a fire. Given historical manipulator availability and challenges with holding erratically moving hoses with a manipulator, this system does not provide the reliability needed for future mission work.

MFC Fire Protection recommends clean agent systems because they are designed for flooding applications and leave no residue after discharge. HFEF facility engineering has concerns with total flooding fire protection systems as total flooding systems require ventilation to be secured; if ventilation is secured in the Decon Cell, then the negative differential pressure is lost on an unsealed hot cell. This project needs a feasibility study prior to design to ensure that nuclear and radiological concerns are balanced with fire protection concerns.

**Benefit**

Installing an automatic fire suppression system in the HFEF Decon Cell would provide reliable fire suppression to support new mission activities, including fuel pin re-fabrication with welding, and assembly and disassembly of TREAT sodium loops. This project will assess feasibility, installation, acceptance testing, operation, as well as inspection, testing, and maintenance requirements.

**Facility Risk**

Existing fire suppression may not be adequate for new mission activities planned for the HFEF Decon Cell such as fuel pin re-fabrication with welding and TREAT sodium loop assembly and disassembly. If adequate fire suppression is not available, these mission activities may not be approved.

**ROM Cost Estimate:** $4.5M.

## 31. MFC Plant Cooling Water Systems Refurbishment

**Description**

The MFC plant cooling water system is a chemically-treated closed-loop cooling-water system that supplies cooling to vital loads in buildings MFC-768 (Power Plant), -765 (Fuel Conditioning Facility - FCF) and -787 (Fuels and Applied Science Building - FASB).

The system includes a cooling tower at the power plant and a piping network and pumps within the power plant that travels to FCF and FASB above ground and then returns to 768 via underground piping. The system cools various loads; HVAC equipment, air compressors, process equipment, with the most vital load being the FCF argon chillers which serve as the heat sink for the FCF hot cell.

This system is comprised of mostly original piping of which approximately 500 linear ft is buried 1960-era cast iron on the return side. The piping within FCF has had numerous sediment issues and leaks, and the line has had multiple underground failures (3) in the past 4 years. The system is largely oversized as system loads have been systematically taken out of service since EBR-II was deactivated.

The proposed system modification would be to separate FCF and FASB loads from the main system through the design and installation of self-contained facility specific cooling systems. These new systems would be properly sized for current loads and provide for expansion as needed. The original system would be re-routed and appropriately downsized to provide cooling to power plant (768) loads only. Due to the latest piping failure, cooling is being supplied to FCF via a cross connect with the potable water system and just being dumped to industrial drains until repairs can be made.

**Benefit**

New dedicated systems for FCF and FASB would likely be above ground in controlled environments eliminating the potential for underground piping failures that are difficult to locate and then require a significant project to repair/replace the failed components.

**Facility Risk**

Given the condition of underground return piping, if replacement is not completed negative mission impacts from failed piping will increase in frequency and the associated cost of repairs will be absorbed accordingly. It is not improbable that a break in a bad location could force an extended FCF shutdown due to effects on the hot-cell heat sink.

**ROM Cost Estimate:** $10M.

## 32. HFEF Cell Chiller Replacement

**Description**

The HFEF cell chillers were replaced around 2010. Since then, the chillers, while functional, have never performed as desired. The HFEF cell chillers continue to experience repeated failures due to a hybrid controller system, excessive start/stop sequences, and unbalanced run times. The hybrid control system does not allow start/stop sequences and unbalanced run times to be remedied. The current cell chillers do not have the correct duty cycle and are not the correct type of unit to maintain the required atmosphere inside the HFEF hot cell. Multiple repairs and partial replacements have been conducted since the units were installed, but the underlying problem remains, requiring increased cell chiller maintenance due to failures. Over the last several years nearly every mechanical component has failed and has been replaced without effectively solving the problem. This project will replace the current HFEF cell chillers with process type chiller that is designed for extended operating cycles.

This project will be a 2-year effort with 1 year of design, including issue of procurement, and 1 year for implementation and close-out.

**Benefit**

The benefit to the facility is increased chiller reliability resulting in reduced maintenance costs (now roughly cumulated to ~200K), less schedule delays to accommodate the repairs as well as less potential for cell down time and impact to programmatic work.

**Facility Risk**

If the replacements are not procured and installed and the main cell chillers fail, there will be a complete stop work of all the activities in the main cell, including containment box, metbox, and purification system. The main cell would be in a feed and bleed style for pressure (would fluctuate between -1" and 4" of $H_2O$) and be unable to control the moisture and oxygen content of the cell. If not corrected in a timely manner will lead to experiments becoming degraded and potentially completely damaged beyond recovery.

**ROM Cost Estimate:** $1.9M.

## 33. IMCL Laboratory House Chiller System

**Description**

Heat loads in laboratory have continued to increase due to additional new equipment. In particular the number of air-cooled chillers, computers, research instruments and other sources of heat. The existing HVAC unit for cooling the laboratory can no longer keep up with the heat loads. There are now fourteen (14) air cooled chillers that expel heat into the laboratory that have been added to cool scientific instruments: these include the SEM, TEM, EPMA, FIB, PPMS, TPC Instruments, G4-FIB, Atom Probe LEAP, SEM-6500, PXRD, etc. Additional equipment heat sources also include vacuum pumps and lighting.

**Benefit**

An upgraded chiller system can support increased research throughput and enhances facility reliability.

**Risk**

Research is halted and impacts scheduled commitments and milestones. Temperatures during the summer months are when laboratory temperatures are highest. Temperatures can reach into the 80+ degree F ranges, and the result is that scientific equipment is either shut down, or in some cases overheat and can result in costly repairs and down time

**ROM Cost Estimate:** $1.5M

## 34. TREAT Transient Rod Drive Controller Replacement

**Description**

The Transient Rods Control system in TREAT uses MTS-450 analog controllers, which were installed in 1988. These controllers and the parts for them are now obsolete and unavailable.

**Benefit**

Direct benefits include reducing risk of failure and operations shut down. Modernizing reactor control systems support facility reliability and increased research throughput.

**Risk**

Not updating the Transient Rod Driver controller leaves TREAT vulnerable to a component failure that leaves us unable to operate our transient control rods, with resulting consequence of significant program schedule delay (but no safety impact).

**ROM Estimated Cost:** $0.03M

# 35. NRAD Fuel Procurement

**Description**

NRAD reactor in the 64-element configuration has $0.96 of excess reactivity at full power. The banked critical rod heights at full power are at 80% of core height. $0.54 is required to reach equilibrium xenon conditions, leaving $0.42 of available reactivity for experiments and associated in-core hardware before the experiment irradiation schedule becomes restricted due to xenon preclusion. Several proposed irradiation fixtures (e.g., NRAD pneumatic transfer system [NPTS] and large drywell heater) have reactivity penalties estimated to be ≥$0.50 depending on core position. Regardless of the future vision of NRAD, NRAD will need additional fuel to compensate for burnup.

Makeup fuel: ROM Cost Estimate $3.6M

- 2022 – 4 sticks 30/20 + 8 graphite
- 2023 – 4 sticks 30/20 + 4 graphite
- 2024 – 4 sticks 30/20 + 4 graphite

Experiment enabling Fuel: ROM Cost Estimate $1.7M

- 2025 – 6 sticks 30/20 + 2 instrumented elements

**Benefit**

Makeup fuel will extend the life of the reactor. Experiment enabling fuel quantities will allow NRAD to reconfigure the core to compensate for larger negative reactivity experiments, tailor the core flux in the vicinity of an experiment and maintain the flux profile to protect the fuel.

**Facility Risk**

TRIGA Fuel International fabricates TRIGA fuel on a campaign basis. If NRAD misses the next fabrication campaign then NRAD will shut down permanently before the following campaign which could be 25 years or longer away, or never.

If a commitment is not made to purchase makeup fuel, then soon NRAD will reach a point that excess reactivity available will not allow extended reactor runs due to xenon preclusion to support projects such as TRISO, aU furnace LDRD and molten salt LDRD or perform large negative reactivity irradiation experiments.

If experiment enabling fuel is not purchased, then NRAD will not be capable of configuring the core to compensate for high negative reactivity experiments, limiting the reactor value as a multifunction research platform.

**ROM Cost Estimate:** $5.3M spanning 4 years.

## 36. MFC Glovebox Oxygen Monitors

**Description**

The Servomex MonoExact DF310E (formerly Delta-F 310E) oxygen analyzers are installed on gloveboxes in FMF, ZPPR, IMCL, AL and EFF. The original Delta-F 310E oxygen analyzers have been discontinued and the company, Servomex, has purchased the rights to the Delta-F product lines and replaced it with the Servomex MonoExact DF310E. Getting a replacement analyzer (Servomex MonoExact) or parts has become increasingly difficult, and the lead time is 12+ weeks. Currently, there is one Delta-F analyzer available at the warehouse and it was purchased for the AFCI glovebox in FMF. The AFCI glovebox oxygen analyzers are Safety Significant SSC's per SAR-404. There are two Servomex MonoExact analyzers currently in testing with I&C but they have erratic performance and one is no longer functioning and awaiting parts/repair from Servomex.

The Ntron Senz-Tx oxygen analyzer is currently being evaluated as a potential replacement for the Servomex MonoExact analyzers at MFC. Pending a successful evaluation, the MonoExact analyzers will be replaced with the Ntron analyzer at the critical facilities (FMF & IMCL). This will require glovebox, piping, and software modifications to implement into existing gloveboxes. A commercial grade dedication of the Ntron's will also be required for use in the AFCI glovebox (in FMF).

**Benefit**

The bench-top testing at MFC have shown the Ntron Senz-Tx analyzers have quick response times, short stabilization times, high accuracy, low variations to pressure and flow fluctuations and no failures (with a statistically small sample of eight units). The Ntron's also have a lower cost ($2,000 per sensor, $6,000 per sensor/analyzer combination) and lower lead times (approx. 8-week lead time). They also are available in two mounting configurations (flow-through and KF-40). The KF-40 option allows the analyzer to be installed directly into the glovebox atmosphere, eliminating the need for a sample loop to draw glovebox atmosphere through the analyzer.

**Facility Risk**

A Servomex MonoExact analyzer may fail on an existing glovebox while the evaluation and design work for incorporating the Ntron's is being implemented. The evaluation may reveal that the Ntron's do not meet MFC's design specifications which would re-start the selection process for a new analyzer. INL also does not have experience with the long-term reliability of the Ntron analyzer.

**Estimated Cost/Status**

The estimated total cost for replacing the Servomex MonoExact analyzers in FMF (qty. 5) and IMCL (qty. 5) is $558K. The bench-top and in-situ testing of the Ntron analyzer is completed and engineering has begun the equivalency evaluation.

## 37. Procure Transfer Container for Large Liners at RSWF

**Description**

There are 267 Larger Liners located at RSWF which require transfer to the Remote-Handled Low-Level Waste Disposal Facility for final disposal. A Modified Facility Transfer Cask (MFTC) was originally proposed as the transfer cask of choice however this cask can only accommodate one large liner at a time resulting in a long, prolonged campaign to accomplish final disposal for the full inventory. Opportunities for container transfer efficiency exist and it has been proposed and accepted to evaluate an Interim Storage Container (ISC) design which can accommodate the transport of 2 or 3 large liners in a single ISC to improve operational efficiency and reduce the overall schedule for RHLLW Disposal Facility.

This request will support facility planning and required analysis revisions as well as design and fabrication of at least two ISCs to support transfer of this inventory for final disposal.

**Benefit**

Developing the capability necessary to accomplish multi-liner transports will ensure disposal continuity of legacy remote-handled low-level waste in storage at RSWF, reduce schedule impacts with other planned shipments at RHLLW Disposal Facility, and improve inventory reduction efficiency and greater economy of scale for MFC.

**Facility Risk**

Failure to procure a transfer cask which can accommodate transfer of the large liner or multiple large liners of legacy RH-LLW from RSWF to RHLLW Disposal Facility will inhibit MFC from meeting its yearly commitment to reduce the overall RH-LLW inventory which is also identified as an INL environmental liability.

**ROM Cost Estimate:** $5M.

## 38. RHLLW Maintenance Bldg. Overhead Door Replacement

**Description**

The original doors have continued to sustain significant damage for various reasons over the years including rail deformation, broken support systems, motor burnout, keyway damage, etc. The doors are far too large and too heavy to replace with similar overhead doors and will continue to break in the same manner due to sheer weight during operation of the system.

A contract was let in the summer of 2021 to perform the initial diagnosis of the north door for repair. As a result, a write-up with repair/replacement options was provided indicating varying levels of repairs that could provide functionality but with a caution that due to the size of the doors would only last so long and the doors would continue to break in the same fashion time and time again. The third option was to replace the doors with sliding doors that are better suited for the opening size of the maintenance building. The replacement of the overhead doors would include removal of the old doors and associated hardware and installation of 2 new doors with equivalent R-value, and electrical operation options.

**Benefit**

Reliable capacity to perform critical maintenance and material handling The Overhead doors (North & South) function is imperative for Operations to support pulling casks/trailer in and for cold weather repairs to Vault Shield Plugs and Cask-to-Vault Adapting Structure as issues arise, and other cask/materials required to ensure availability for program mission.

**Facility Risk**

Mission commitments are at-risk of completing on time as committed.

**ROM Cost Estimate:** $500K.

## 39. Refurbish FCF Air Cell Transfer Hatch Ram

**Description**

A large floor hatch located in the northeast corner of the air cell is used to transfer equipment and materials to and from the transfer tunnel, decontamination spray chamber (DSC), argon cell, and SERA in the basement. The transfer hatch is served by the Air Cell Ram a 5-ton capacity hydraulic lift located in the basement for material movement between the air cell and the basement facilities.

The Air Cell Ram operates with no known issues but has not been inspected since the early 90's. The equipment is original to the facility. The Argon Cell Ram, with the same history, had seals fail in 2020 requiring over a month outage to repair.

**Benefit**

Reliable capacity to perform needed maintenance on Air Cell EMMs, Manipulators, and Cranes to ensure availability for program mission.

**Facility Risk**

Without additional funds mission commitments are at-risk of completing as scheduled.

The Air Cell Ram is evaluated as a single point failure piece of equipment. Its failure would significantly adversely impact EBRII Fuel Processing and HALEU Production program commitments.

**ROM Cost Estimate:** $1M.

## 40. MFC-720 Replace Roll-up Doors

**Description**

During the FY-20 test of the roll-up doors in the TREAT Reactor Building (MFC-720), the southeast roll up door failed its brake test. The braking system was inspected and fixed. However, this motor and braking system is obsolete and replacement parts are not available. Currently, the roll up doors are function but continue to age with no replacement parts. The door in question that has already has issues is one of three roll-up door entrances/exits for vehicles into the TREAT High Bay. Any one of these failing would cause a disruption in work, depending upon on how major of failure depends on impact of the facility. A minor failure that leaves the door operational by manual devices would allow operators to manually open and close the doors. A major failure that leaves the doors permanently closed would result in a major disruption in the TREAT mission.

**Benefit**

Replacing the roll-up doors in the TREAT Reactor Building would remove this vulnerability for potential schedule impact to the TREAT mission.

**ROM Estimated Cost:** $450K.

## 41. Replace FCF Decon Spray Chamber Chiller Unit

**Description**

The DSC system is used to decontaminate manipulators, EMM's, and various materials/equipment used in the FCF hot cells. Decontamination is needed to mitigate the high dose rates. The chiller unit that reduces fogging of the shield window at the DSC Control station has been failing and parts are not readily available due to the age of the equipment. Without the DSC Chiller fully functional productive decontamination spray activities cannot be performed. Need to replace Current Chiller System with a

**Benefit**

Reliable capacity to perform the facility decontamination of manipulators, waste, or other process equipment. This avoids downtime in the facility as the materials/equipment requiring decontamination cannot be performed until the chiller unit is repaired and the subsequent potential for missed mission commitments and milestones.

**Facility Risk**

Without additional funds mission commitments are at-risk of completing on time. Currently, the interim actions have been to replace components (fuses, capacitors, etc.) on the compressors as needed. However, due the age of the equipment, some parts are not easily replaced and finding equivalent parts is time consuming.

**ROM Cost Estimate:** $2M.

## 42. HFEF Intrafacility Pneumatic Sample Transfer Systems Overhaul

**Description**

The HFEF pneumatic transfer systems (PTS) are at their end-of-life, have components that are antiquated, and are exhibiting more frequent failures. Specifically, there are two systems of focus, (1) the highly-used interfacility PTS, which moves valuable research samples between HFEF and the Analytical Labs via FCF, and (2) the 6D PTS, which moves various items between the Decon Cell at window 6D and the glovebox in room 130. Crucial components for these systems are no longer available; therefore, redesign and system upgrades are needed to ensure these systems are available for use. There are very limited spare parts for these systems with some components having no replacements or replacement parts. The interbuilding PTS, a single-point failure, is crucial to getting research samples to the Analytical Laboratory and has some components that are difficult to access. System upgrades to include redesign and fabrication of crucial components is imperative to support research operations at HFEF.

**Benefit**

Greatly increase reliability, better efficiency of system operations, and reduced downtime in both frequency and duration with corresponding confidence for movement of valuable research samples. Upgrades will reduce the risk of mission impacts. Crucial components include:

- Updated motorized ball valve assemblies
- New solenoid operated valves
- Updated vacuum pumps
- Updated instrumentation (pressure switches, indicators)
- Replacement of piping runs as required.

**Risk**

The interbuilding system from HFEF to FCF is highly used to move valuable research samples between HFEF and FCF and the Analytical Laboratory and is a single-point failure for this capability. The loss of use of this system greatly inhibits the capability to make sample transfers to the Analytical Laboratory. Some components are not repairable, can be long lead acquisitions from suppliers, and require a redesign process as well as fabrication prior to installation. This combination of processes could result in significant and extended downtimes leaving the systems out of service for several months, thus stranding valuable research samples; creating unsustainable delays to a vast majority, if not all, of the projects executed in HFEF; and jeopardizes various programmatic work and mission milestones. Without system overhaul, failures are expected to increase, resulting in loss of mission research.

**ROM Cost Estimate:** $1.5M.

## 43. Compressed Air Supply Systems for Research Facilities

**Description**

The MFC Compressed Air System was designed to supply HFEF, FCF, and AL with compressed air for process, instrument, and breathing-air purposes. Currently, two large air compressors (with dedicated air dryers) located in the MFC-768 power plant run continuously with standby air compressors at FCF and HFEF to augment the system upon low pressure. The smaller standby air compressors are not large enough provide adequate volume for full operation if more than one of the large compressors in MFC-768 is out of service. The air compressors in MFC-768 are frequently out of service due to breakdown creating costly and timely repairs that have adversely effected HFEF and FCF mission planning. Currently, only FCF and HFEF utilize breathing air. None of the current compressors are breathing air rated, breathing air is qualified by dryer/filter systems and local quality monitoring. Local breathing air systems at FCF and HFEF that can also provide process and instrument air needs would provide a more cost-effective supply of breathing air than a site wide system that is only periodically used for breathing air. Newly designed systems that provide for individual facility needs with the ability to be manually cross connected should be engineered. Individual air compressor systems would be provided at MFC-768, FCF, HFEF and AL.

The MFC protected area Instrument Air (IA) System is used by multiple facilities including EML, FMF, SSPSF, and ZPPR. Reliability of the IA system has been decreasing over the past 8 years indicating multiple IA components are approaching end of life. System outages are reoccurring, maintenance costs are increasing, and facility availability is decreasing; all resulting in negative trend impacts to multiple existing programmatic milestones. Instrument air supports various systems and equipment important to security and to defense-in-depth safety features.

**Benefit**

Having a facility-specific, decentralized compressed-air system will allow nuclear and non-nuclear facilities to have reliable compressed air that is adequate for their own individual load. Additionally, individual facilities will not be affected by preventative maintenance and outages being completed on other facilities. This will allow for more nuclear facilities to have more uninterrupted work towards mission critical deliverables.

**Facility Risk**

The current compressed air system at MFC is unreliable and outdated. Without an updated compressed-air system, we continue to risk untimely outages at FCF and HFEF and not being able to stay ahead of compressed air needs to support MFC facility expansion.

During periods where instrument air is unreliable, the PIDAS facilities will experience increased cost due to: Increased maintenance costs ($900/week for compressor rental); Increased security costs ($1500/day for extra guards); Decreased facility availability; New mission support with increased IA demands is not sustainable with the current available system capacity; Running to failure increases system recovery costs.

**ROM Cost Estimate:** $10-12M.

## 44. HFEF Hot Cell HEPA Replacement

**Description**

The HEPA filters in the HFEF hot cells (argon and decontamination) have not been replaced since the facility started operations in 1975. This project will design, fabricate, and test the tooling and equipment necessary to replace the in-cell HEPA filters. In addition, this project will replace the HEPA filters. This project will take 3-4 years (1 year of design, 1 year of fabrication and testing, and 2 years of implementation) to complete. The filters for the HFEF main cell are located under the false floor where programmatic work is performed; in addition to temporarily relocating program work, a significant amount of waste in the cells will need to be removed in order to access the filter housings.

**Benefit**

The benefit to the facility is that replacement of the filters will reduce the risk of filter failure due to seals or a media breach and subsequent contamination of the fixed (non-replaceable) secondary filters and associated ducting.

**Facility Risk**

If the filters are not replaced, the facility risk continues to increase with the potential for filter failure (seal or media) and subsequent contamination of the fixed secondary filters and associated ducting in turn causing difficulty in future filter change operations. The importance of changing these filters will continue to increase as the age of the filters increases and as the mission in HFEF continues to evolve to include more fuel furnaces.

**ROM Cost Estimate:** $5M.

## 45. New Instrument Room and Mezzanine in IMCL

**Description**

Construction of a quiet, climate-controlled room to optimize the performance of high-resolution instruments. The roof of the room would also be used as a mezzanine for storage of IMCL instrument accessories.

**Benefit**

IMCL currently houses only one climate controlled, quiet room for the operation of high-resolution instruments. Construction of an additional instrument room would allow the installation of new instruments in an environment that optimizes characterization results. High-resolution characterization allows understanding of radiation damage on the same spatial frame at which it occurs, contributing to better understanding and validation of simulations.

**Facility Risk**

There is a large demand for the high-resolution microstructural and characterization in IMCL by internal and external users. Operation of instruments with degraded performance provides less-than-adequate data and result in INL’s leadership position as a nuclear science user facility.

**ROM Cost Estimate:** $2M.

## 46. Replace McQuay HVAC

**Description**

The McQuay air-conditioning unit located on the north side of FCF supplies cool air to the first floor and SERA of FCF. It works intermittently due to the age of the unit and when the weather gets hot outside the unit cannot keep up with demand. The first-floor high bay and argon cell operating corridor temperatures can reach of 85-90 degrees on hot days making working conditions in these areas unbearable. The McQuay unit is the only air conditioning unit that provides cool air to the first floor of FCF. Currently the McQuay HVAC is performing at reduced capacity. Portable A/C units and a large swamp cooler have been brought in to provide cooler air, however the temperatures in the high bay, hot cell operating corridors, and Suited-Entry Repair Area (SERA) are unacceptably high requiring more frequent breaks and heat stress controls.

**Benefit**

Habitable work conditions are essential to productive and safe operations activities in support of project/program missions.

**Facility Risk**

Consequences of Failure to Mitigate Problem include the first-floor area becomes unbearably hot requiring more frequent breaks and the SERA of FCF has temperatures that invoke heat stress controls that severely limit our ability to perform productive work in support of multiple project/program missions.

**ROM Cost Estimate:** $1.5M.

## 47. FCF High Bay Crane Refurbishment/Upgrade

**Description**

Due to the vintage of the crane, some systems should be considered for modernization to minimize down time due to the failure of obsolete systems – when/if they occur. There are systems that would require upgrading if any modernizations were to be performed to bring the crane up to current standards. This includes the open span conductors; wooden bridge bumpers and trolley stops.

The objective is to replace components consistent with the components recently supplied on the upgrade/modernization of the 40 Ton MFC-785 Building Crane.

**Benefit**

Reliable capacity to perform needed Material Handling of shipping casks, waste boxes, and other materials required to ensure availability for project/program missions.

**Facility Risk**

The High Bay Crane is evaluated as a single point failure piece of equipment. Its failure would significantly and adversely impact EBRII Fuel Processing and HALEU Production program commitments.

**ROM Cost Estimate:** $5M.

## 48. Hoar Frost Buildup on IMCL HVAC Intake Filters

**Description**

During winter months the air intake filters on the HVAC air supply system builds up excessive hoar frost. The current design of the installed radiant heaters do not adequately to remove the frost build up, which restricts air flow into the IMCL laboratory. The restricted air flow results in increased room temperatures in the laboratory which increase to a point where research equipment is impacted, or potentially damaged, and research equipment must be shut down.

**Benefit**

Enhancing HVAC operations reduces maintenance associated with cleaning the intake. It also increases facility reliability.

**Risk**

Frost buildup can impact operation of the IMCL HVAC Laboratory research equipment is shut down or fails to operate.

**ROM Cost Estimate:** $350K.

## 49. RCL Backup Power

**Description**

Currently RCL does not have back up power. RCL has a single exhaust fan. When power is lost unexpectedly the facility is immediately evacuated due to potential radiological release from fume hoods. When this occurs, all work is stopped and placed in safe configuration.

**Facility Risk**

An emergency power system would be able to provide power in a situation like this and would prevent potential radiological release. RCL has an electric duct preheater that is the primary heat source for air coming from the outside of the facility. In the event of loss of power, the facility would have no heat available.

**Benefit**

Backup power in the Radiochemistry Laboratory would provide redundancy for the exhaust system, which in turn would allow greater flexibility and reduce risk in the event of a power failure. In addition to the reduction in risk from an exposure standpoint, there is also the benefit of better control of the heat, preventing unnecessary impact to liquid samples.

**ROM Cost Estimate:** $1.5M.

## 50. Abandoned lines and equipment (can be incrementally funded)

**Description**

Over the years, modifications in the Analytical Laboratory have left equipment abandoned in place. Though the current processes involve removing the abandoned equipment as we go, a campaign is needed to completely remove what is existing. The campaign would involve removing lines and equipment that continue to take up space for current and future projects. These lines and equipment are located throughout the facility and will involve extensive work up front to identify all the lines that need removed.

The casting lab glovebox in B147 is an inert-atmosphere glovebox that is approximately 250 $ft^3$. The inventory in the glovebox represents a large portion of the material inventory for the lab. Additionally, it is one of the highest risks to the analytical laboratory (AL) due to material processing, operational challenges and continual issues. The box is in B147 of the analytical laboratory but operated by the fuel fabrication division. The fuel fabrication division has plans to add the capability to complete the work in their facility with hazard category 2 limits of materials, which is not able to be performed in the AL. Once the capability is installed in FMF, there will be no need for the glovebox in the AL.

**Facility Risk**

The glovebox will continue to be an operational risk due to outdated equipment and obsolete parts that impact the availability of the glovebox and increased the cost to maintain. Additionally, the amount of legacy contamination within this glovebox impacts expansion of capabilities. The material limits in the facility impacts the ability to complete other programmatic work.

**Risk**

Old systems and equipment crowd lab operations and impact operational efficiency. It also limits useable footprint for additional mission support.

The glovebox will continue to be an operational risk due to outdated equipment and obsolete parts that impact the availability of the glovebox and increased the cost to maintain. Additionally, the amount of legacy contamination within this glovebox impacts expansion of capabilities. The material limits in the facility impacts the ability to complete other programmatic work.

This includes abandoned systems within AL Room B-35.

**Benefit**

The removal of the legacy equipment and abandoned piping will allow for future growth under the existing footprint of the Analytical Laboratory to meet the INL's mission. It eliminates the need to route piping around the legacy piping. The removal of the legacy piping would allow direct runs on current and future projects, ultimately reducing the costs of future installs.

Removal of the CLGB from the AL would significantly reduce the material inventory within the analytical laboratory. The greatest risk to the facility would be removed, allowing for increased operation and research capabilities and efficiencies.

**ROM Cost Estimate:** $10M Activities can be incrementally funded to make improvements when funding is available.

## 51. Cask Integration, Management, and Capability Sustainment

**Description and Benefit**

A number of casks are utilized to support movement of nuclear materials between facilities and to support disposition of wastes generated as part of R&D activities at MFC. Operability of these casks is critical to the safe, compliant operation of MFC's nuclear facilities. Focused integration and management of the casks is integral to efficient and effective nuclear operations. Inoperability of the casks can result in substantial programmatic impacts across multiple facilities and programs, representing a single point failure mechanism. This investment includes establishing a coordinated cask integration and management capability, cask sustainability actions, and development of a new cask/container for transport of legacy wastes from MFC to the new RHLLW Disposal Facility.

Legacy casks owned by INL which are in active use include the HFEF-5, HFEF-6, HFEF-14, HFEF-15, and NRAD casks. These casks do not have complete or as-built drawings. In addition, most of the analyses to support these casks are not current or have known deficiencies which need to be corrected. Procurement and fabrication of spare items to support both legacy casks and recently procured casks (such as the Outpack, GE-100, and BRR) are needed to ensure continuous operations or expedite needed preventative or corrective maintenance. This plant health investment ($1M) will support a methodical evaluation of the casks and implementation of necessary corrective actions, including modern analyses and modifications, if necessary, to support safe operations.

**Benefit**

Integration and management of casks ($300K) is critical to efficient facility operations. Coordination of use, preventative maintenance, and sustainment/refurbishment activities will help ensure that the casks are available to support program needs, when needed.

**Facility Risk**

Existing casks represent a single-point failure. Investment to procure additional casks (i.e., HFEF-5 cask) is warranted to ensure that R&D outcomes are not impacted due to operability issues and conflicting demands with existing casks. ($1.5M–$3M)

Failure to fund and implement a focused cask management and sustainment capability increases the risk that inoperability of a given cask will negatively impact MFC R&D outcomes and the potential for non-compliances due to an inability to properly maintain the physical and analytical bases for the casks.

**ROM Cost Estimate:** $3.5M–$9.5M.

## 52. Interfacility Pneumatic Shuttle Transfer System Refurbishment

**Description**

The interfacility pneumatic shuttle transfer system, also known as the rabbit system, has been in existence for decades. This system in key to moving hot samples between HFEF, FCF, and the Analytical Laboratory. Samples are prepared in HFEF and moved to FCF and AL for further analysis. This is a key transport capability between HFEF and AL. This system has not been evaluated in depth for decades and this is a single point failure for transport of hot samples.

**Benefit**

Evaluating and refurbishing this single point failure radiological sample transport system will ensure operational readiness is not impacted by a system key nuclear research facilities rely on.

**Facility Risk**

The rabbit system is a single point failure risk. Sample transfer activities between HFEF and AL will be significantly impacted if this capability is not available.

**ROM Cost Estimate:** TBD until further evaluation and advance planning is completed**.**

## 53. Analytical Lab Process Management System Upgrade

**Description**

Updating the lab management system to support the AL sample management processes.

**Benefit**

This update will provide state of the art updates for all the analytical instrumentation in the laboratory, tie-in measurement activities, and provide desktop access to individual analysts.

**Facility Risk**

The current version does not operate as effectively as needed to optimize laboratory operations.

**ROM Cost Estimate:** $1M.

## 54. TREAT Critical Spares for ARCS, DIS, and RTS

**Description**

The Dedicated Information System (DIS), the Reactor Trip System (RTS) and the new Automatic Reactor Control System (ARCS) are all necessary for TREAT operation in support of its testing mission. However, there are very few spare parts maintained in controlled inventory, making TREAT operation vulnerable to schedule impact from breakdown of one of those systems.

**Benefit**

Establishing a critical spares inventory for these three TREAT I&C systems will reduce potential downtime incurred when a component in one of these systems fails, thereby reducing mission and schedule impact.

**Risk**

Availability of spares is essential to address facility reliability risks associated with equipment failure.

**ROM Estimated Cost:** $450K.

## 55. TREAT Flex Test 40 Controllers

**Description**

The Transient Rods Control system in TREAT uses MTS-450 analog controllers, which were installed in 1988. These controllers are essential to TREAT operations but present a risk because their spare parts are now obsolete and unavailable through suppliers. This project will replace the old controllers with Flex Test 40 controllers.

**Benefit**

The replacement controllers will remove a failure vulnerability and offer expanded control capability for supporting future TREAT experiments.

**Facility Risk**

Facility risk (schedule interruption due to component failure) will be reduced because the replacement controllers will be modern and better maintained with parts available through suppliers.

**ROM Cost Estimate:** $350K.

## 56. FMF HVAC/Suspect Exhaust System

**Description**

FMF HVAC/Suspect exhaust system upgrade.

**Benefit**

The upgrades will allow fuel fabrication activities to expand throughput. This type of expansion will be needed to meet the requirements to fabricate VTR fuel.

**Facility Risk**

Increased Pu processing in FMF will require upgrades to the facility ventilation to meet Pu processing facility standards.

**ROM Cost Estimate:** $2.5M.

## 57. FCF Hot Repair Area Reactivation

**Description and Benefit**

The FCF Hot Repair Area (HRA) was abandoned in the late 1990s due to seismic and radiological confinement concerns. As the workload for FCF increases, the facility requires more maintenance for remote manipulators and cranes (that have component wear and part failure). Further, to fully utilize the hot cell space, it would be advantageous to be able to remove some components from the hotcell for interim storage and future reuse. The existing maintenance space for repair of in-cell equipment is quite limited in FCF and has become a facility schedule bottleneck. Further, a site utilization study conducted over 10 years ago did not foresee the resurgence of nuclear research for FCF (or other nuclear facilities at INL), and the Contaminated Equipment Storage Building was declared surplus and was subsequently reclaimed for other R&D purposes. No space currently exists at MFC for storage of contaminated equipment outside the hot cells.

A recent evaluation of the HRA, conducted to determine if that space could be reactivated, identified engineering and seismic analyses deficiencies that would prevent the immediate reuse of that space. The space is located over top of the FCF air and argon hot cells. It is proposed that an engineering evaluation be conducted to close out those seismic and engineering deficiencies and propose a restructuring of the HRA in a manner that will space to be reused. The proposed missions for the space would be: 1) in-cell equipment repair, 2) storage of transient in-cell equipment, and 3) insertion/removal of equipment into the hot cells. The evaluation must also consider modern radiological and nuclear safety requirements,

**Facility Risk**

Challenge to repurposing of the Fuel Condition Facility (FCF) areas in support of NRIC and other RD&D missions.

**ROM Cost Estimate:** $7.7M **-** an engineering evaluation be conducted to close out those seismic and engineering deficiencies and propose a restructuring of the HRA in a manner that will space to be reused.

## 58. TREAT Diesel Generator Replacement

**Description**

The TREAT Reactor Building electrical systems are backed up by two diesel generators, each of which is old and difficult to maintain due to limited availability of parts. The Standby generator provides 30kW of power and the Redundant generator provides 130kW of power. Theses generators and associated equipment are obsolete. Third-party parts are being used in order to maintain the units. This proposed project will procure and install a single diesel generator to replace the functions of the two older generators. The intention is to replace the generators with a brand and model that is used elsewhere on the INL.

**Benefit**

Replacement with a single diesel generator will reduce the maintenance effort currently needed for two generators. Replacing with a unit model that is used elsewhere on site will allow synergies for stocking spare parts and developing in-house expertise, each of which will reduce turnaround time and cost for responding to maintenance issues.

**Facility Risk**

The two existing generators continue to work and can be maintained, providing no key parts are needed. However, a prolonged shutdown of either unit could impact the TREAT operating schedule.

**ROM Cost Estimate:** $175K.

## 59. TREAT Filtration Cooling System VFD Replacement

**Description**

The TREAT Filtration/Cooling System is used to reduce the amount of time needed to cool the fuel assemblies after transient (power-burst) operation or steady-state operation. Forced cooling also provides cooling for test loops or experiments installed in the reactor core. Many of the components that adjust the blower motor speed and system flowrate are old and difficult to maintain due to limited availability of parts. The VFD upgrade will eliminate these parts and create a more reliable system.

**Benefit**

This project eliminates potential points-of-failure in the Filtration/Cooling System, improves efficiency, and reduces time-to-troubleshoot/time-to-repair.

**Facility Risk**

Improving the maintainability and duration of the maintenance cycle will reduce risk of operating schedule impact due to a F/CS failure.

**ROM Cost Estimate:** $300K.

## 60. He-3 Injection System Final Design and Hardware Procurement

**Description**

HENRI is a Helium-3 injection system designed to inject He-3, a neutron poison, into the TREAT core to terminate a transient pulse more quickly than the TREAT Transient Rod Drives can be inserted. The purpose is to clip a TREAT transient pulse more quickly to achieve a narrower pulse width, more consistent with those expected in postulated LWR reactivity insertion accidents (RIAs). RIAs are a class of events to be addressed in regulatory approval of new LWR fuel designs, and testing under representative conditions (i.e., time-dependent deposited energy and time-dependent her removal) is important to ensure that phenomena of interest are adequately represented. Pulses that are too wide would present a non-conservative assessment of relevant phenomena, while too-narrow pulses would unnecessarily exacerbate phenomena and possibly lead to overly-conservative interpretation of results.

**Benefit**

Completion and installation of HENRI will place TREAT as the only operating transient test facility in the world capable of providing representative LWR RIA test environments. Results from such tests will be important to regulatory approval of new fuel designs, particularly approval to operate reactors in manner that takes advantage of new fuel characteristics. These results would be one piece of the case that allows new fuel designs, such as Accident Tolerant Fuels (ATFs), to be utilized in a manner to reduce LWR fuel cycle cost.

**ROM Cost Estimate:** $1.2M.

## 61. NRS Elevator and Cask Interface Upgrade

**Description**

This project will modify the cask handling station over the North Radiography Station (NRS) elevator to accommodate additional casks, and design/build a new payload auxiliary hoist to facilitate lowering experiments onto the NRS elevator.

**Benefit**

A new design will allow a larger variety of casks to be used in the NRS along with specimens of varying diameter and lengths.

**Facility Risk**

Only the HFEF-14 and HFEF-5 loading casks, with their top and bottom features, fit on the current cask handling station. The station interfaces with the elevator in the NRS, located directly under the cask handling station in the NRS high bay. TREAT is planning on using other casks for shipment of TREAT loops (e.g., 15-cask) that will require modification to the station. In addition, the old hoist mechanism which hung from the NRS crane hook, is no longer functional and is missing parts that are obsolete. The ability to perform radiography of TREAT loops at NRAD in about 3-4 years will be jeopardized if this capability is not restored.

**ROM Cost Estimate:** $4.1M.

## 62. FCF Material Tracking System and Support Infrastructure Replacement

**Description**

The FCF material tracking system is aged and portions of the system do not lend themselves to the NQA-1 software quality rules where testing is concerned. FCF Process operators experience errors because the user interface does not clearly display process flow of the system which changed over the last 10 years and software modification of the HTML process screens is necessary. Original development team with Argonne was 15 developers. In the last 10 years this has been reduced to 2 part-time developers who have other responsibilities to the Pyro Processing project. A team of software engineers is needed to not only maintain the system, but to help update the code to meet the NQA-1 standards for regression testing and quality. The scope of this effort will be to replace the current process flow screens with new updated process flow screens to meet the current mission.

**Benefit**

The scope of this effort will replace the outdated process flow screens with new updated process flow screens and update the code to meet the NQA-1 standards for regression testing and quality and significantly improve process flow software changes to the system to make the facility process simpler and easier to follow with minimum delays to meet the current mission.

**Facility Risk**

Without this revision and update EBRII Fuel Processing and HALEU Production activities relying on MTG will be challenged to demonstrated compliance with NQA-1 standards and effective and efficient process activities.

**ROM Cost Estimate:** $6.5M.

## 63. HFEF Decontamination Spray System

**Description**

Adding a $CO_2$ spray system to the HFEF decontamination spray chamber will improve decontamination of hot cell equipment, particularly manipulators, and reduce dose to workers during repair. This project will install a $CO_2$ spray system into the existing HFEF decontamination spray chamber and associated containers for storing dry ice pellets.

**Benefit**

Adding a $CO_2$ spray system to the HFEF decontamination spray chamber will improve decontamination of hot cell equipment, particularly manipulators, and reduce dose to workers during repair. The water wash system will still be required, but less water will be used for decontamination efforts, reducing the overall radioactive liquid waste generated in HFEF. Additionally, the $CO_2$ dry spray can be used to reduce contamination on equipment that is sensitive to water and cannot currently be washed prior to repair. This improves the remote life of equipment by allowing for repair of more equipment once it can be appropriately decontaminated.

**Facility Risk**

If the new spray system is not installed in HFEF, dose to workers performing hands-on decontamination and dose to workers repairing contaminated equipment will be higher than necessary.

**ROM Cost Estimate:** $1.2M**.**

## 64. Replace FCF Argon Cell North and South Recirc Blower and Install Purification Instrument

**Description**

The argon cell recirculation and cooling system assists in the control of pressure or temperature within the argon cell by recirculating and cooling argon gas to remove heat generated by in-cell lighting, process equipment, and decay of irradiated reactor fuels and related materials.
The purification Analytical Instruments draw from the south loop recirculation and cooling system downstream of the recirculation blower and returns the flow to the recirculation loop upstream of the cooling box. The Purification Analytical Instrument provides continuous monitoring of the argon cell for oxygen, nitrogen, water vapor, and hydrogen. Failure of the South Recirc Blower would cause the Purification Analytical Instrument to be unable to accurately measure Argon Cell atmosphere. The North Recirc Blower operates with bearing temperatures abnormally high at 81 degrees Celsius and is at EOL.

The blower is in a contaminated enclosure with limited space and will involve significant planning for radiological control while facilitating material handling.

**Risk**

Failure of the South Recirc Blower would cause the Purification Analytical Instrument to be unable to accurately measure Argon Cell atmosphere. The South Loop Recirculation Blower and Purification Analytical Instrument are evaluated as a single point failure pieces of equipment. Failure would significantly and adversely impact EBRII Fuel Processing and HALEU Production program commitments.

**Benefit**

Reliable capacity to reliably perform Argon Cell cooling for pressure & temperature control and Argon Cell atmosphere monitoring to ensure Argon Cell availability for program mission.

**ROM Cost Estimate:** $1.5M.

## 65. HFEF In-Cell Compressed Argon Manifold Supply and Associated Controls

**Description**

Each window has a compressed argon manifold located in cell for using argon to run instrumentation, tooling, and general use. The solenoids that supply argon are located in control boxes under each window in the basement. Portable control stations are located on the main floor and can be moved to selected locations for controlling solenoid operation for each manifold.

**Benefit**

The operability of the compressed argon manifolds, solenoids, and controls for each window needs to be restored to a functioning capacity, standardized, and maintained to support programmatic work.

**Facility Risk**

Over time, the solenoid boxes have been modified to support programmatic work. Documentation of these mods is lacking; the boxes no longer function the same as originally designed. Several solenoids do not work, the boxes are not finger safe electrically, and at any given station manifold operability is limited. Several hoses are laid across the cell floor to supply compressed argon from a location where it is available to a location where it is needed. This is inefficient, time consuming, and costly.

**ROM Cost Estimate:** $500K.

## 66. Building Lab Exhaust Fan Replacement

**Description**

The HFEF Building Lab Exhaust system moves approximately 35,000 CFM through HFEF. This system works in tandem with the supply systems to regulate climate pressure in the building. The building lab exhaust maintains the differential pressure for the building and ensures that potential contamination does not spread throughout the building. The system also provides exhaust for the various labs and hoods in HFEF. The building lab exhaust flows through the HFEF stack and is constantly monitored in compliance with the HFEF air permit.

**Benefit**

The fans and dampers will be replaced. After 40 years of continuous operations the foils of the fan have mostly eroded; this, along with the failed damper, is causing a reduction in air flow. The vibration isolation system has also degraded over the years and often transmits a noticeable vibration through the building. The new blowers should correct the deficiencies noted. The new blowers will be capable of being operated with a variable frequency drive (VFD), allowing the differential pressure system to be upgraded at some future time.

**Facility Risk**

The flow through this system has degraded over the year and is lower than what the original documentation indicates. The dampers have been adjusted multiple times to balance flow and restore building flows. There is also a significant variation in the flow rate between the two fans, damper adjustments have no effect on this either. This is most likely a failed inlet damper internal to the ducting. Vibrations in the building reduce research quality from the optical microscopes and are restricting HFEF's ability to complete programmatic work. When any part of the system fails, HFEF enters "low flow mode" due to flows below the calibrated range of the stack monitoring system. While in "low flow mode" numerous in-cell research operations are prohibited including fission gas puncture and collection (GASR) and furnaces operations (affecting JFCS and HALEU).

**ROM Cost Estimate:** $2M.

## 67. Replace HFEF Freight Elevator

**Description**

The HFEF freight elevator is suffering from age related failures and needs to be updated. Parts are no longer manufactured, greatly increasing downtime. Failures in the mechanical, electrical and control system are occurring more frequently. In 2020 the elevator was out of service for more of the year than it was in service.

The proposed solution is to replace the elevator with a modern elevator of similar capacity. The reason for this is that the brakes for the elevator are no longer available, the motor is no longer manufactured nor are most of the components in the control system. While many of these items can be replaced with an alternate replacement items this takes considerable resources and time while only fixing that problem. This approach does not improve the long-term reliability of a 50 plus year old machine.

**Benefit**

The elevator is used to move materials throughout HFEF from items from hand carry sized things up to a 4 ton pay load. When the elevator is not available the movement of materials becomes an engineering task to develop lift plans to safely rig the item. This can significantly delay work; a functioning elevator allows crafts and operators to easily move materials as needed.

**Facility Risk**

When the elevator is out of service different methods of material movement must be utilized. This can be a simple as carrying an item up or down a flight of stairs. This increases the risk of a slip or trip while carrying the items as many times the use of both hands is required to safely carry the item. For items that are bigger than hand carry the overhead crane must be utilized. Most items are not designed to be rigged to a crane, increasing the chance for a load drop.

**ROM Cost Estimate:** $2M.

## 68. Upgrade FASB Ventilation System

**Description**

Currently FASB ventilation system is working however, it is limping along. We have outdated pneumatic controls that are no longer made (1975). We have been running on 1 fan due to this issue for 5-6 years. The air handler is on a variable speed drive however the exhaust fans are not, this causes the air handler to ramp up more than needed when any of the larger north side doors are opened. We also need to better exhaust system to hook up additional equipment currently none of the characterization equipment is going to suspect exhaust due to the limited capabilities i.e., flow.

**Benefit**

An upgraded HVAC system increases capacity for future fuel fabrication work. This also decreases risk of facility down time due to minor and major repair. This reduces the risk of contamination of suspect exhaust system, facility, and workers.

**Facility Risk**

This aging system requires increased maintenance costs to address risk of failure. Increased maintenance results in an increase in the frequency of short duration facility down time during failures. There is also a facility reliability risk associated with major facility downtime in the case of major component failure (EF-1, EF-2). Reduced performance of the existing system decreases capacity for existing equipment and new processes.

**ROM Cost Estimate:** 2M.

## 69. AL Hot Cell 5 and 6 Reconfiguration

**Description**

The Analytical Laboratory at the Materials and Fuels Complex has six interconnected hot cells for processing of high dose radiological samples. Each hot cell has a different purpose, ranging from sample receipt, gamma counting, waste processing, etc. Over the years, very few modifications and updates have been made to the AL hot cells. As a result, the equipment and instrumentation contained within each hot cell has degraded and become obsolete. It is necessary to upgrade and refurbish equipment and instrumentation to prevent delays in sample results and improvements to the processes.

**Benefit**

The reconfiguration and refurbishments to equipment and instrumentation in the hot cells will allow for efficiency gains and reduced sample processing delays and rework. The updates will support multiple programs simultaneously, increase throughput, and reduce maintenance efforts. Improvements will also provide greater ergonomic benefits and reduce the strain on the manipulators.

**Risk**

Aging equipment results in additional costs, whether through maintenance efforts or inefficiencies of processes. There is also a risk of events with wear and tear on equipment, resulting in potential spills and loss of samples.

**ROM Cost Estimate:** $5.4M.

## 70. Waste Volume Reduction Capability (A28)

**Description**

The Analytical Laboratory processes waste in cell 2. Cell 2 is also where sample preparation is performed. Only one of those activities can be performed at a time. The only way to currently keep up is to perform waste processing on overtime.

We have an empty room with a pneumatic transfer line from the hot cells that was used for ALP7 cask loading in the past. The AL would like to repurpose that room for waste processing to allow for increased efficiencies and throughput. It would require some kind of containment walls or mobile hot cell for the dose, a 2-way blower, as the current blower is only one-directional, and a sample evaporator instrument. The challenge is getting the equipment into the basement due to the size and weight.

**Benefit**

Repurposing this room allows for efficiencies in the process to allow waste and sample preparation to be performed at the same time. This would allow waste to be charged closer to when the sample analysis were complete, thereby helping with the issue of programs closing numbers and having to find funding for the waste. It would also allow us to utilize space that currently sits empty in a building where realty is hard to come by.

**Facility Risk**

The AL currently must shut down one operation, clean up, and set up the new process each time they need to switch processes. The result is a lot of wasted time and effort. Being required to complete waste processes on overtime raises the cost of an already expensive part of the process. We would be able to significantly reduce the backlog of waste waiting to be dispositioned.

**ROM Cost Estimate:** $5M.

## 71. Replace AL Backup Diesel Generator

**Description**

The current 250KW diesel generator provides adequate power to support primary safety systems in the event of a loss of power based upon current demand. However, with the forthcoming upgraded exhaust fans for the Sodium and NDA wing of the AL, conversion from steam to electric heat and numerous new research capabilities and support systems within the AL, the current 250KW generator would not support in the event of a loss of power. Additionally, the current diesel generator, while providing an essential level of backup power for safety related systems, does not provide power to help ensure that vital research systems are not damaged in the event of a loss of power.

This capital asset project replaces the AL's existing 250KW backup diesel generator with an upgraded 350KW diesel generator. The scope includes connecting all the AL's primary safety systems and vital research systems to the backup power source. It provides a pre-engineered electrical building outside of AL on a co-located concrete pad and a 350KW backup diesel powered generator.

**Benefit**

The upgraded backup power capability would provide adequate power to support the AL's primary safety systems and allow for safe and timely shutdown of sensitive research capabilities if it is necessary to do so. This minimizes damage to the AL research infrastructure housed inside this vital nuclear research facility.

**ROM Cost Estimate:** $2.5M.

## 72. AL Instrument UPS Installation

### Description

When power goes out in the Analytical Laboratory, wither planned or unplanned, there is a risk to the instrumentation. With planned shutdowns, the instruments can be shut down in a controlled manner, but there is still risk to the instrument. When the outage is unplanned, the risk is increased. In previous power bumps, we have damaged instruments. The instrumentation in the lab is very sensitive and does not take much to skew results of samples.

Addition of uninterrupted power supplies to the instrument significantly reduces the risk of damaging the equipment. The downtime on these pieces of equipment has a substantial effect on programmatic work. It is desired to add UPS's to at least 7 instruments that are both high dollar and increased risk of damage affected programmatic work. These power supplies would allow the instrument to switch to backup power during an outage. It would allow time to perform a controlled shutdown, which lowers the risk.

### Benefit

The installation of UPS's provides protection for multi-million-dollar instrumentation from damage and ultimately replacement. Reduced downtime because of damaged instruments from power bumps and shutdowns whether planned or unplanned increases the amount of programmatic work completed.

### Facility Risk

The effects of shutting down sensitive instrumentation is very volatile. There is a high probability of damage to the equipment, creating down time and possibly necessary replacement of the instrument.

**ROM Cost Estimate:** $600K.

## 73. AL Multi-Zone System Overhaul

### Description

The Analytical Research Laboratory (ARL) multi-zone system serves the lab/office space on the south side of the B-wing hallway (rooms B-102, B-116, B-120, and B-134). This area of the building was originally designed for lower hazard activities or general office space, but due to space limitations, has been converted to low hazard lab space and is separate from the main AL contaminated exhaust system. More laboratory space is needed as the ARL's capabilities are expanded and as sample throughput demand increases. This system upgrade would likely include replacement of the supply air handling unit (AHU) in the basement including DX-Cooling system (evaporator in AHU and condenser on roof) and a larger electric heater (in AHU), D&D of existing AHU and HEPAs as well as some ductwork, significant structural modifications (to safety significant SSC) to allow new exhaust ductwork to be routed into each room, new supply ductwork, an upgraded control system including new ventilation control instrumentation such as flow control valves, sensors, duct heaters, sealing the labs for pressure control, etc. The existing exhaust systems that serve other portions of the ARL (fans, HEPA banks, and ductwork) would need to be evaluated to determine if they could support exhaust demand for this additional area and exhaust stacks would require evaluation to determine if they are adequately sized for the additional air flow. If exhaust fans, HEPA banks, exhaust stacks, etc. are not sized to handle this additional load, then a complete new exhaust system would potentially be required for this upgrade.

### Benefit to ARL/MFC

- Better utilization of existing building footprint/floor space to accomplish the mission of the ARL.
- Improved area/space to use instruments that require connection to suspect exhaust, which is the vast majority of equipment used and needed at the ARL.

- Better temperature and pressure control in the affected area will provide an environment where optimal sample results can be obtained from analytical research equipment, which require an environment having steady and specific temperatures.
- Better contamination control in this section of the building, which allows the same types of activities that are performed in the other areas of the ARL to be performed in this area.

**Facility Risk**

Utilization of this area to accommodate additional R&D capabilities is not possible without these modification

**ROM Cost Estimate:** $4M.

## 74. Implement Uniform SNM Containers and Design Verification

**Description**

There are multiple designs/types of Special Nuclear Materials (SNM) containers used at MFC. Many of these are based upon old designs and have been in use for many years.

**Benefit**

Transitioning to a uniform design for SNM containers will increase operational efficiency and reduce the risk of human error. Multiple container types require slight variations in operations to address unique aspects of each container. A single type of SNM container used across all SNM operations s reduces the variation during specific material evolutions.

**Facility Risk**

This issue increases the risk of human performance errors.

**ROM Cost Estimate:** TBD until advanced planning is authorized ($3.5M placeholder).

## 75. FCF In-cell Periscope and Camera System Replacement

**Description**

There are three FCF periscopes used for in-cell viewing of small items or small print on in-cell pieces of equipment. These are early 1960s vintage. These periscopes are mechanically operated, and the operating gears are very worn and replacement parts are no longer available. The high power/low power switches no longer operate reliably. The rubber eye pieces have deteriorated away. These represent single point failure potential. Failure would require ceasing all reprocessing operations.

**Benefit**

Improved system reliability and availability. Supports achievement of research mission.

**Facility Risk**

Current hardware is no longer vendor supported. Current operations are dependent upon these scopes to improve efficiency. Loss of periscopes and cameras would shut down processing operations for up to 12 months as upgrade components are procured and installed.

**ROM Cost Estimate:** 2.5M.

## 76. New Decon Fume Hood for Container Examination

**Description**

The FMF facility does not have a dedicated decontamination hood for use in decon of items when transferred from a glovebox.

**Benefit**

Adding this support capability will increase operational efficiency and capacity. This will also reduce risk of spread of contamination.

**Facility Risk**

The risks are essentially the opposite of benefits. This reduces the risk of personnel exposure and increases efficiency.

**ROM Cost Estimate:** $750K.

## 77. Remove RERTR Glovebox

**Description**

The RERTR Glovebox is located in FASB. It was originally placed to support the Reduced Enrichment for Research and Test Reactors (**RERTR**) Program. It was later used to support multiple research programs. This glovebox has outlived its useful life and is no longer in operation and should be removed and dispositioned offsite.

**Benefit**

Removal of this glovebox will make valuable nuclear facility research footprint available for repurposing to support other research missions.

**Facility Risk**

Leaving legacy equipment and systems in place after they are determined to be no longer useful or needed crowd current operations and requires varying levels of resources to inspect or monitor them. This impacts operational efficiency and limits valuable research space available to support current missions.

**ROM Cost Estimate:** $1M.

## 78. Install Perma-Con Containment to Replace Aging Waste Management Tent Workrooms

**Description**

The containment tents in MFC-793 and MFC-793C are aging and in need of replacement with more permanent containment structures that are better suited to long-term use and have little to no risk of degradation or failure. The current tents have been in place for multiple years and are designed to be a temporary containment. The current containment tents require repairs routinely and are becoming very difficult to pass certification. The tent in MFC-793 is connected into the building ventilation system which helps reduce cost for a permanent work space and the tent in MFC-793C has ventilation provided through a portable air handling unit. Work in both MFC-793 and MFC-793C is ongoing and consistent; however, there may be a desire to modify the dimensions of each work space based upon upcoming D&D work in both buildings which will free up floor space and add potential new work scope as well. Perma-Con structures offer the ability to easily modify the dimensions of the structure if needed and do not degrade as they are a metal structure.

**Benefit**

Replacement of the temporary tents with more current capabilities will increase operational efficiency and reduce risks associated with operations in aging containment capabilities. This will also free up additional footprint that could support other operations.

**Facility Risk**

Conducting waste management operation in degrading containment capabilities could increases risk of exposure. Additional monitoring and inspection to offset risks is required.

**ROM Cost Estimate:** $3M.

## 79. Addition of Pneumatic Transfer Line from AL Hot Cells

**Description**

Installation of a pneumatic line from the hot cell to the B-wing, most likely the radiochemistry glovebox in B137. Installation of this transfer system would reduce the dose to the workers. To remove a sample from the hot cells currently, we have to dilute the sample far enough down to make sure the dose meets the requirements for ALARA. The pneumatic line would make it so we could send higher dose samples to the B-wing, thereby reducing the efforts and dose.

**Benefit**

A pneumatic line to a glovebox in the b-wing would allow us to transfer higher dose samples for processing in the glovebox. The only options currently are to dilute the sample enough to back out and hand carry or process the sample in the high contamination area with manipulators. Cost saving from reduction in time spent and moving samples to a less contaminated environment improves the results analyses.

**Facility Risk**

Processing samples within the hot cells increases the risk of contaminating the sample due to the environment, as well as operational risk from handling the sample remotely with manipulators. The time and effort are also increase for processing this way.

**ROM Cost Estimate:** Outyears $3.5M.

## 80. IMCL Contamination Control Updates

**Description**

Recent contaminations in IMCL with the Shielded Sample Preparation Area (SSPA), Plasma-Focused Ion Beam (P-FIB) Microscope and the Electron Probe Micro-Analyzer (EPMA) exposed greater potential for local contamination events to have a greater facility impact and a potential for prolonged facility outages. Installing downdraft capability at rapid transfer ports on confinements (6 locations), provide connection from the sample chamber housing of microscope to suspect exhaust or HEPA filtered air mover and install a semi-permanent enclosure over the EPMA that facilitates maintenance on the instrument in the long term will significantly reduce risk.

**Benefit**

Implementing engineered solutions to these issues will reduce the risks to personnel and instrument availability to support research missions. These would provide an engineered, defense in depth, control to minimize effects of local contamination issues. The ability to keep contamination issues localized would keep other facility instruments at full Utilization. The costs to implement controls would pay for itself vs. loss of access to 14 (soon to be 16) instruments for programs.

**Facility Risk**

Recent events have resulted in significant loss of availability for some of the IMCL research capabilities. Corrective actions are necessary to support instrument availability and reduce costs of operations.

**ROM Cost Estimate:** $800K.

## 81. MFC Private Facility Control Network (PFCN) Critical Infrastructure, Industrial Controls Servers, and Data Repository Storage Facility

**Description**

MFC's PFCN is experiencing dramatic server, switching, data storage, and cyber-security equipment growth due to the onboarding of new research facilities, projects, and operation activities being developed at MFC. MFC's nuclear unclassified control information systems and industrial control systems (ICS) production devices have been the focus for historical retention, analytical applications, and material tracking for many years. As the requirements to support the research initiatives and mission at MFC increase, new systems for high-definition scanning and high-resolution imaging for material analysis has put tremendous pressure on the PFCN's current server, switching, and data storage systems. Such high-resolution images result in many large files requiring high-capacity storage. Recently, PFCN computer engineering, at the request of research projects, ordered a large-scale data storage platform to handle the anticipated retention requirements. This installation completes the capacity of current facility space. With new facilities being built, maturing research project needs, cyber-security requirements, and operational needs, the requirement for a new or expanded facility is warranted.

MFC PFCN shares space with information management, life-safety, and security in the INL/MFC Communications Facility building MFC-1728. There are many demands for the limited rack space currently in MFC-1728 and it is currently at capacity with no room for growth. As built, MFC-1728 is a data communications central facility and was not designed to meet the cooling requirements of a data center. With the increase of server, switch and storage systems, heat loads have become a problem and require constant monitoring. The need for a new location for the PFCN operation of a proper data storage environment is self-evident. Our proposed action is to revisit the existing plans of MFC-1728 and add a new datacenter room which would satisfy the growth requirement.

**Benefit**

Expansion of the current MFC-1728 communications facility with the addition of a data center room will help us meet the demands of physical growth allowing for additional communications equipment, environmental controls, and cooling. This physical space will provide a climate-controlled environment for server, switching, and data storage equipment to meet the demands of the MFC mission.

**Facility Risk**

If we do not act, the MFC mission risks the possibility of hardware failure due to increased cooling requirements and the inability to provide support for new hardware expansion, project opportunities, cyber-security equipment space, and data storage within the controlled environment of MFC.

**ROM Cost Estimate:** $10M.

## 82. AL Acid Scrubber Replacement

**Description**

The Analytical Laboratory has had an acid scrubber connected to the wet prep glovebox for over 10 years. We have now added a radiochemistry glovebox into the same system. The acid scrubber has been operationally down several times this year. The effect has ranged from solids within the scrubber and needing to clean it out to acid on the walls of the glovebox, causing degradation to the glovebox. While there has been no change in methods used in the gloveboxes, we have continued to have issues. The AL would like to purchase and install a new system.

**Benefit**

Collecting the alkaline components to balance pH inside of the glovebox will significantly extend the life of the glovebox. The reason for the installation of the radiochemistry glovebox is due to the degradation of the old glovebox from acids.

The maintenance issues associated with the current system will not go away and will continue to affect the ability to perform programmatic work within the wet-prep glovebox, which is the glovebox used for dissolutions.

**ROM Cost Estimate:** $2M.

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# Appendix B

# General Infrastructure Descriptions

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# 1. Replace MFC-773 Substation

**Description**

The existing 773 substation is a 13.8kV to 480V 2MVA substation that supplies power to multIndirect IPLe facilities in the northeast area of MFC. The main transformer for this substation TF-022 is showing signs of failure. Recent preventative maintenance has shown degraded test results and other abnormalities within the substation which point to shortened life expectancy.

This substation supplies power to 13 facilities: MFC-703, MFC-753, MFC- 772, MFC-773, MFC-778, MFC-781, MFC-783, MFC-789, MFC-706, MFC-790, MFC-1750, MFC-794, and MFC-782 and 796 which are part of the Advanced Manufacturing Facilities.

EWR has been submitted, walked down, engineering estimate received awaiting award.

**Benefit**

Re-designing the MFC-773 substation to remove the existing 2MVA transformer and attached switch gear and installing multIndirect IPLe smaller transformers and sectionalizing switches provides a more reliable utility distribution system.

Replacement of the substation will ensure commercial power failure at Advanced Manufacturing Facilities, FMF, ZPPR, and 13 additional support facilities is less likely. This re-design will reduce Arc-Flash Hazard as well. Additionally, the existing medium voltage option being employed at MFC is to use sectionalizing switches and facility-level transformers. This would reduce the number of facility outages necessary to perform periodic maintenance on a substation feeding multIndirect IPLe buildings/facilities.

**Facility Risk**

Providing clean reliable energy to MFC facilities is a fundamental princIndirect IPLe in ensuring important milestones can be met. Unreliable energy sources can cause increased facility down time as well as potential safety concerns due to extensive maintenance requirements (exposure to higher flash hazards. The current distribution system is becoming more unreliable and will eventually fail.

**ROM Cost Estimate:** $1.5M.

# 2. HFEF Non-Nuke/Rad Building HVAC Maintenance

**Description**

This request is to cover work scope to be completed this FY to replace aging and obsolete (in some cases 50+ years) Heating Ventilation and Cooling (HVAC) units at various MFC locations. All units listed in this INDIRECT IPL are obsolete and near complete failure. Repairs to these units have been frequent resulting in downtime during the peak summer months. Spare parts are becoming nearly impossible to obtain resulting in longer out of service delays. All units utilize R22 refrigerant which is no longer produced as of 2020. This work is above and beyond normal corrective maintenance. Specific locations and details are listed in the table and scope descriptions below.

**Benefit (ROM Estimates)**

| Priority | Project | Amount | Status | Notes |
|---|---|---|---|---|
| 1 | MFC-774 Replace AHU-1 | $1,000,000 | Design nearly complete. Indirect IPL is for execution. | 50+ year old unit that is obsolete and frequently out of service including 2021. Parts to repair are difficult to obtain. |
| 2 | MFC-710 Replace CU 1 & 2 | $615,000 | Design nearly complete. Indirect IPL is for execution. | 30+ year old unit. Frequent failures over the past two years. |
| 3 | MFC-753 AC-3 | $390,000 | Design nearly complete. Indirect IPL is for execution. | 40+ year old unit mounted to the exterior side of the building. |
| 4 | MFC-721 HVAC Replacement | $270,000 | Design nearly complete. Indirect IPL is for execution. | 40+ year old units that are obsolete and close to failure. |
| 5 | MFC-752 Replace Water Cooled AHUs | $460,000 | Design nearly complete. Indirect IPL is for execution. | Units are water cooled. One serves the dial room and the others serve office space in the basement. The MFC plant cooling loop is no longer available to support these units. Currently they are temporary supplied by a potable water cross connections that provides once through water for cooling. |
| 6 | MFC 752 HVAC Replace E&D Wings | $250,000 | Indirect IPL is for design phase. | AHU-16 serving E-wing is an obsolete 50+ year old unit that was out of service for much of the 2021 summer. D wing is served by 30+ year old fan coil units that require constant maintenance to remain functional. |
| 7 | MFC-774 Replace AHU-2 | $200,000 | Indirect T IPL is for design phase. | 50+ year old unit that is obsolete. Parts to repair are difficult to obtain. |
| 7 | MFC-752 Replace Water Cooled AHUs | $460,000 | Design nearly complete. Indirect IPL is for execution. | Units are water cooled. One serves the dial room and the others serve office space in the basement. The MFC plant cooling loop is no longer available to support these units. Currently they are temporary supplied by a potable water cross connections that provides once through water for cooling. |

**Risk**

If these projects are not completed, the current units will fail unexpectedly resulting in months of downtime due to planning requirements and the long lead times for equipment. Supply chain issues caused by the global pandemic have prolonged already long lead times to 16+ weeks. While the equipment is out of service, temporary units must be mobilized, or occupants must endure less than ideal temperatures or be sent home due to unsafe working conditions. Meanwhile, buildings risk freezing utilities and stress on other HVAC systems within the building that attempt to compensate for the loss of service.

## 3. MFC Asphalt Replacement and Roadway Maintenance

**Description**

MFC interior asphalt is significantly degraded to the point that many areas require complete replacement and in other large area require significant repair.

MFC asphalt needs include multIndirect IPLe miles of existing roadway, vehicle and equipment parking areas, pedestrian walking surfaces, and new pavement of miles of existing gravel roadways. Additionally, drainage and water flow are adversely affected in some of these areas and aesthetics are negatively impacted by the visual condition of much of our flat asphalt and gravel surfaces.

The MFC U&IS department has an interior asphalt replacement strategy document that details the condition, estimates replacement or repair costs, and breaks the areas into prioritized repair/replacement zones. The approach taken to date is to repair or replace areas in a piecemeal fashion based on annual funding allocation, however a comprehensive replacement execution strategy is preferred and should be considered when holistic revitalization made to our major support infrastructure systems (fire main, potable water, electrical distribution, sewer, etc.).

**Benefit**

Well-maintained roads are required for proper drainage control, safe pedestrian travel, efficient and effective fire and security emergency response, transport of materials and supplies including casks and other mission critical functions. Additionally, there are aesthetic impacts associated with well-maintained roadways and vehicle parking/staging areas that reflect the values of the organization.

**Facility Risk**

Most of the interior asphalt is beyond minor repairs and requires full repair or replacement. This degradation potentially increases in slips-trips-and falls, affects efficient snow removal without increasing pavement damage, is aesthetically unappealing, and will continue to degrade annually.

**ROM Cost Estimate:** $10M.

## 4. MFC Communications Network Infrastructure Maintenance

**Description**

MFC Network Infrastructure includes:

- Fiber-optic cabling, copper-wire cabling, network hardware (patch panels, servers, switches and associated communications rooms) for data computation, system monitoring and control, and alarm reporting
- Voice over internet phone (VOIP) and analog phone lines and hardware
- Fire alarm communication equipment
- WiFi internet equipment
- Cellular phone service equipment.

Much of the common infrastructure (mainlines) have been updated to provide high speed/volume capability. What remains is the update of the network infrastructure internal to the buildings/facilities themselves. For example: the majority of facility/building internal network cabling is Cat 3 which is not capable of adequate communication over the cloud of existing base computer programs, much less higher functioning programs that perform computation or have advanced graphic requirements. If the internal network cabling within the facilities/buildings were replaced with Cat 6a (current recommendation), it would provide decades of acceptable performance (ten times the speed and capacity of current data flow). Modernizing the network infrastructure becomes more urgent as technology advances, reliance on cloud based capability increase, and communication, cyber security, and data management demands accelerate.

**Benefit**

By performing the above improvements, sustainability of current infrastructure needs will be met, and it will facilitate expansion of the MFC network to accommodate future growth of projects and facilities. Replacing equipment and infrastructure will improve the performance (speed and capacity), reliability, and serviceability of the network.

**Facility Risk**

In some buildings, if updates are not made to the current components, maintenance will become increasingly difficult. When replacement parts are no longer available, restoring network service quickly will become difficult. Finally, if network revitalization is not implemented:

- Network performance will stagnate
- Innovation will be stifled
- End user expectations will not be met.

**Cost Estimate:** $20M.

## 5. MFC-781 Warehouse – Loading Dock Reorientation

**Description**

MFC warehouse loading and unloading truck traffic impacts emergency, security, and general traffic flow. The MFC East Gate was completed in 2021 and is now fully utilized as the primary entry/exit location for maintenance equipment, delivery trucks, construction vehicles and equipment, emergency response ambulance and firetrucks, and security vehicles. Typical delivery vehicles are full-size tractor/trailer (semi-trucks) that back into the loading dock to off-load their fare. Currently, we average 120 ingress/egress events through the East Gate daily. The number of events is likely to increase with expected construction at MFC going forward.

When offloading to the MFC warehouse delivery trucks execute a three point turn to back into the loading dock. When unloading these trucks are pointed north/south which is perpendicular to the ingress/egress road. While maneuvering into position these large trucks effectively block the ingress/egress road for general traffic and force security and emergency response vehicles to execute coordinated drive-arounds to respond to emergent situations. Additionally, there are two additional problems that need correction associated with the warehouse loading dock. Water has been accumulating in front of the dock for years. In the winter, this water freezes making truck offloading and pedestrian travel more hazardous. The original loading dock has spalled and cracked in many locations and has antiquated hydraulic lift mechanisms that require significant maintenance to maintain them functional.

**Benefit**

A redesigned loading dock would eliminate the need for trucks to maneuver and park perpendicular to the road, correct the water pooling situation, and would modernize the material handling hydraulic system. Overall, this effort will greatly increase the efficiency and safety of emergency and security response and daily ingress/egress of commercial traffic through the East Gate.

**Facility Risk**

Emergency and security response timeliness may be affected if trucks are in the process of maneuvering for offloading. The volume of traffic flow through the gate has exponentially increased the probability of general traffic being adversely impacted by delivery truck maneuvering. Age, degradation, and pooling water continue to adversely affect the functionality of the current loading dock.

**Estimated Cost:** $2.5M (class 5 estimate has been performed).

# 6. MFC Office/Space Maintenance

**Description**

New support infrastructure and revitalization of existing office space is required to replace aging and less than adequate modular structures exceeding capacity to house existing staff and projected growth of onsite researchers and support staff. The new administration building, planned west campus office building and future proposed consolidated mock-up, engineering, and testing facility provide, or will provide needed expansion of onsite offices and labs needed to support the research mission. Planned revitalization of current office and administration space is critical to maintain the research campus in a modern and efficient capacity. This area will provide annual targeted revitalization of existing space and limited expansion in areas where there is inadequate footprint such as the need for additional TREAT office space to support mission growth.

**Benefit**

Revitalization of existing office space reduces the need for construction of new space by providing more modern offices and amenities increasing satisfaction of staff housed in aging facilities and contributes to operational efficiency.

**Risk**

Many of the office buildings are decades beyond their intended design life. For example, MFC-717 (currently at 107% capacity) was acquired in 1985, MFC-713 (98% capacity) was acquired in 1978. There are also numerous unplumbed smaller trailers such as MFC-TR-56 (98% capacity) and MFC-TR-57 (81% capacity), located at MFC in the mid-2000s that were originally leased and used by the Idaho Cleanup Project contractor to support operations at MFC. None of these facilities was ever intended to provide long term permanent offices for MFC personnel and do not have internal bathroom spaces. This requires the provision of additional temporary bathroom trailers (comfort stations) for tenant use. Most of the large modular offices are in a degraded condition.

**ROM Cost Estimate:** This is proposed as annual incremental investments between $500K and $1.5M annually.

# 7. MFC-767 EBR-II Cathodic Protection Restoration

**Description**

A new impressed current cathodic protection system for MFC is needed to limit potential external corrosion to direct-buried metal structures and piping at MFC. Through decontamination and demolition (D&D) efforts conducted over the past two decades associated with shutdown of the Experimental Breeder Reactor (EBR)-II reactor and associated support systems, the originally installed MFC cathodic protection system has been rendered inoperable. The cathodic protection system is needed to accommodate all buried metallic materials at MFC with the exception of the steel liners at RSWF (Radioactive Scrap and Waste Facility), which are provided with their own cathodic protection system.

An impressed current cathodic protection system was installed around the perimeter of the EBR-II in 1969 with supplemental anodes installed in 1980 – 1981. Each of the installations included a dedicated transformer rectifier. Test stations and stationary zinc reference electrodes were positioned around the outer circumference of the unit and used for monitoring electrical potentials to verify the adequacy of protective current output. This system provided cathodic protection to all buried MFC metal structures and piping. The two rectifiers specific to EBR-II are no longer on site and it does not appear that any form of impressed current cathodic protection is being afforded to MFC either at this time or in the recent past. There has been significant construction work at MFC, and it is reasonable to assume that any buried conductors (i.e., positive and negative header cables as well as anode lead wires) have been impacted by excavation and are no longer intact.

With the exception of RSWF, MFC does not have a current functioning cathodic protection system for buried piping or other metallic structures in contact with the soil. The previously installed impressed current cathodic protection systems are no longer operating, and all equipment associated with the past cathodic protection system is no longer effective.

The soils at the north and northwest of EBR-II are classified as slightly to moderately corrosive to carbon steel residing between grade and 15-ft below grade. If conditions such as stray current or galvanic (dissimilar metal) corrosion exist, increased corrosion rates would be expected.

**Benefit**

A new cathodic protection system would provide corrosion protection to current underground utilities increasing the life of the systems and reducing costs for piping replacement. Additionally, cathodic protection is critical for ensuring the longevity and integrity of direct-buried metal structures such as EBR-II.

**Facility Risk**

Without the installation of a new cathodic protection system the increased corrosion rates would cause the underground metallic structure of EBR-II as well as underground metallic piping to corrode to the point of needing replaced which would be very extensive, costly and would adversely impact MFC missions. Additionally with plans of installing the new NRIC DOME reactor project in EBR-II it is crucial to maintain the structural integrity of the structure.

**ROM Cost Estimate:** $2.5M.

## 8. MFC Fire Protection and Potable Water System Piping Replacement

**Description**

The MFC Fire Protection and Potable Water System has approximately 1.2 miles of underground piping and two deep well pumps that were installed as part of the original EBR-II infrastructure in the 1960s. This piping is cast iron and is approaching the end of its service life as demonstrated by recent piping failures (4) in the past 15 months that have cost over $2.5 million to replace.

Forensic inspection is warranted to identify a preferred path consisting of select maintenance of certain sections or components or complete replacement of all 1960s era main lines (approx. 6000 ft.), 2 deep well pumps, 50 system valves, approximately 15 hydrants and building service lines. This action is proposed to alleviate the realized risk of service water delivery upsets for infrastructure and nuclear facility potable water, building HVAC systems, industrial and research process water, purified water supply, and fire protection.

**Benefit**

Replacement the end-of-life piping will provide many facilities with an improved reliability for the potable, industrial and firewater systems. Many facilities utilize potable water for processes and building cooling that is essential to keep the facilities operational. Replacement of valves will allow reliable outages for future connections and maintenance activities as well.

**Facility Risk**

If we do not act, we will continue to see facility and mission impacts through piping failures. These unpredictable failures lead to long outages, substantial flooding, and very high repair costs.

**ROM Cost Estimate:** $17.5 Million (based on the 2021 cost of approx. 1.2 million for 500 ft of piping for 713 water main project, recent hydrant, and PIV replacement, and 1 million for the replacement of each deep well pump).

## 9. MFC-786 Substation Maintenance

**Description**

The MFC-786 substation was constructed in 1971 and has seen little revitalization other then required maintenance since original installation. This substation provides the main feeds for HFEF, FCF, and FASB. For several years, the substation breakers have not been supported, replacement breakers are unavailable, and spare parts are difficult to procure. Rotating breakers during preventive maintenance allows for reduced outage time during maintenance but also introduces challenges in configuration management. A significant risk exists in the event a component within the breaker fails while in use or in testing while a replacement part is unavailable. Additionally, the south transformer has developed a significant oil leak. The original transformer manufacturer no longer supports this equipment and spare parts are unavailable. Quarterly oil sample testing results have come back with high levels of flammable gases which indicates possible internal arcing. This arcing reduces the life expectancy of the transformer and increases potential reliability issues through internal faults.

These aging components are causing significant maintenance issues and are requiring increased costs in personnel time, maintenance testing, and replacement parts.

**Benefit**

Replacing the substation with loop fed sectionalizing switches and dedicated transformers would provide for a much more robust and reliable utility distribution system. Supplying the dedicated transformers with these 480V double ended feeds would provide system redundancy and alleviate the need to take down multIndirect IPLe facilities during maintenance, which would in turn reduce facility down time during planned maintenance and unplanned faults.

Sectionalizing switches require less maintenance as recommended by the manufacturer compared to circuit breaker operated switch gear. This would reduce the cost of by reducing the amount of personnel time required to maintain the equipment. Sectionalizer switches also greatly reduce arc flash hazards.

**Facility Risk**

Providing clean reliable energy to nuclear testing facilities is a fundamental princIndirect IPLe in ensuring important milestones can be met. Unreliable energy sources can cause increased facility down time as well as potential safety concerns due to extensive maintenance requirements. The current distribution system is becoming more unreliable and will eventually fail. This revitalization would provide a more reliable and robust system which could be depended upon for future expansion capability.

**ROM Cost Estimate:** $20M.

## 10. Re-Establish Western Loop of Main Road Inside MFC

### Description

The southern loop of the western-most north/south roadway was eliminated when multIndirect IPLe trailers and associated temporary electrical distribution equipment were set in place to facilitate the installation of temporary office modular trailers. This loop is still required for normal, maintenance, construction, and emergency/security response. A self-guided work-around path has been established up and over the abandoned-in-place basement foundation of the legacy MFC-766, Sodium Boiler Building (SBB). It requires turning driving over permitted ditch culverts not designed for this traffic. Much of the area above the legacy SBB is likely to be utilized for micro-reactor support buildings and construction laydown.

This loop road is also imperative to access the water fill station for emergency response, construction, and maintenance water trucks. Currently, water trucks inside of MFC are being filled from fire hydrants that causes significant water-hammer shock to the fire protection water system when the fire-pumps automatically start on low pressure. Access to a fill station that fills from a large tank will remove that repeated water hammer of the fire main piping.

### Benefit

Re-establishing an engineered south-west loop will allow safe and redundant traffic paths for normal, maintenance, construction, and emergency/security response vehicles. It will also allow easy access to the water fill station eliminating un-necessary shock to the service water system and free up access to support buildings associated with micro-reactor projects in MFC-767, EBR-II Dome.

### Facility Risk

The MFC service water system has ruptured 4 times in the last 3 years causing considerable damage to SSCs and significant cost of repair to the system itself and related structures and components. The likelihood of continued failure remains high if there is not access to a system that fills from a reservoir. Access to the area above the SBB will continue to be encroached upon by traffic over a non-designed roadway.

**Estimated Cost:** 2 – 3M (SWAG).

## 11. MFC Storm Drain System Maintenance

### Description

The MFC storm drain system needs to be modified to properly operate. As MFC has grown with new structures, proper storm drain elevations were not required and the system is in a state that does not effectively clear storm water and snow melt out of MFC.

The proposed modification would provide for grading improvements to direct run off to appropriately designated collection areas that would include engineered catch basins and covered culverts instead of the current open ditches. MFC storm drain system currently consists of approximately 2000 ft of large open ditches. When replaced with culverts this will allow increased use of the limited space at MFC.

### Benefit

This maintenance will protect nuclear, radiological and infrastructure facilities by properly routing water away from buildings and off site. Site aesthetics will be greatly improved by this effort.

**Facility Risk**

The main risk is continued and worsening water intrusion to nuclear, industrial, and administrative structures and flooding during heavy rain events and spring snow/ice melt off.

**ROM Cost Estimate:** $15 Million Execution would include annual incremental funding.

## 12. MFC Sanitary Sewer System

**Description**

The MFC Sanitary Sewer System is comprised of 2500 ft of clay and cast-iron building drain lines, lift stations, and sewar piping mainlines that combine to exit the site and flow into the evaporative lagoon system. All buildings except TR-65 and SPL are part of the MFC sewer system that is at least 50 years old. All recent remodels of structures that contain bathroom facilities that have disturbed the sewar systems have required replacement of the piping (badly eroded yielding years of sewar leaking to ground under the buildings and out to the main lines).

**Benefit**

Replacement of failed system components will allow the system to operate as designed and not dump waste directly to ground. It will also eliminate untimely piping failures that are difficult to repair (particularly in the winter).

**Facility Risk**

If we fail to act, piping will continue to fail requiring unplanned repairs that are costly, untimely, and unfriendly to the immediate work environment.

**ROM Cost Estimate:** $8M.

## 13. MFC Industrial Waste System

**Description**

The industrial wastewater system was first installed in the 1970s and includes ~ 1500 ft of asbestos cement underground piping, and about the same linear footage of open ditches. 300 linear feet of asbestos cement piping were recently uncovered during construction and the entire length of the underground piping has failed (cracked and caved in) and is being replaced. Any remaining underground piping has likely failed and will need to be replaced as well. The lift stations are antiquated and frequently requiring repair and should be replaced. The industrial wastewater system combines with the stormwater drain system and exits MFC on its way to the Industrial Waste Pond. Industrial waste permitted ditches are monitored for flowrate and constituent concentrations. The flume and sample testing system are being updated under its own project. The industrial waste pond receives storm water in addition to industrial wastewater and is functioning properly.

**Benefit**

New lift stations and piping systems will improve flowrates and increase the accuracy of monitoring and reporting. Effluent will not be escaping underground in locations that are not monitored.

**Facility Risk**

If the system is not brought up to date and include replacement of existing failed piping/lift stations, unregulated exposure to the ground could cause non-compliance with our permits and lead to DEQ fines.

**ROM Cost Estimate:** $3M.

# 14. MFC Roofing Replacement

**Description**

MFC and INTEC facilities include more than 534K square feet of roofing consisting of 232 independent roof sections. Many of these critical roofs leak which introduces mission and personnel safety risks.

Through the DOE Department of Technical Assurance Roof Asset Management Program (RAMP) the FY-20 replacement value of the 232 roof sections was estimated to be over $34 million dollars before being normalized to INL and current supply chain costs.

Currently, the RAMP database categorizes approximately 68% of the roof sections at MFC and our INTEC facilities to be in failed or poor condition. Most of the roof sections in these categories are on our mission facilities.

Roof maintenance should be prioritized across all MFC managed buildings and funding allocated to systematically repair or replace the roof sections.

**Benefit**

Well-maintained roofs are required for safe and efficient operation and enable MFC critical mission objectives. Clean and dry facilities are also critical for the safety of staff, equipment, materials, and research activities including properly packaged nuclear and radiological materials and waste. Additionally, an aesthetic impact is realized when facilities do not leak water, contributing to our ability to attract top research candidates to our Lab and MFC.

**Facility Risk**

Data shows that 68% of roof sections inside MFC need immediate repair or replacement. Most of the sections in the “failed” to “poor” categories are on mission driven facilities or critical infrastructure facilities. Unaddressed roof degradation affects day-to-day operations, degrades underlying building structure, and could affect mission critical instruments and ultimately mission accomplishment.

**ROM Cost Estimate:** $20M.

# Appendix C

# Detailed Descriptions of Instrument Capability Activities

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# 1. Reestablish TREAT Na Loop Capability

**Description**

More-recent historic fuel safety research performed in TREAT was dominated by tests on sodium fast reactor specimens within small recirculating sodium loops. The most-recent rendition of this capable, termed the Mk-III sodium loop, will serve as a pattern for modernization of its successor, the Mk-IV sodium loop. Recent advances in materials and instrumentation, as well as loss of historic supply chain for some unique liquid metal-based component in some cases, will be address in the future sodium loop. Modern data needs and next generation sodium fast reactor plant designs also require a fresh look at innovating the next generation sodium loop capability for TREAT.

**Benefit**

This recirculating sodium device allows for irradiation under prototypic liquid metal reactor thermal hydraulic conditions and is critical to conducting tests and evaluating ‘post-failure’ phenomena, including fission product release and fuel relocation. The Mk-IV sodium loop will be crucial instrument in licensing sodium-cooled fuel designs for deployment of advanced reactors. While legacy sodium loop designs have some information that can be harvested, no earnest design efforts have been performed to date for the modernized Mk-IV loop.

**Cost Estimate:** $13.6M.

# 2. Fission Gas Mass Spectrometry

**Description**

The gas mass spectrometer (GMS) provides sensitive and precise measurement of permanent gas species. A static sample introduction system allows for grab samples of gases taken from other locations to be analyzed in the analytical laboratory (AL), even if the sample is extremely small or at low pressure. During analysis, gas species are ionized using an electron impact source and separated by their mass-to-charge ratio in a magnetic field. Detectors used in these instruments have been shown to be extremely linear over their detection ranges with fairly high sensitivities. This allows species to be reported as their mass-to-charge ratio or by the element’s isotopic composition. The analysis and reporting of gaseous species mass-to-charge ratio is not possible by any other instrument currently employed in the AL. Further specificity in the instrument design can provide multi-collection (MC), increased sensitivity, high resolution, dynamic range, and/or increased sample type (organics, entrained gases, semi-permanent gases) capabilities in addition to those listed above.

**Benefit**

The major benefit of a new instrument is an increase in the reliability of our current analytical capabilities. A new MC-GMS will provide a capability that the laboratory does not currently have by allowing for high-precision isotopic ratio measurements of noble gases. Isotopic data of fission-produced gases can provide a range of information on the process and environment in which they were generated. The proximity of the AL to the Hot Fuel Examination Facility (HFEF) also provides unique analysis opportunities for gases generated during nuclear fuel irradiation and captured using the GASR instrument in HFEF’s hot cells. In addition, the AL will be able to accept work that has previously been performed at recently decommissioned laboratories within INL, such as the Analytical Laboratory at RWMC.

**ROM Cost Estimate:** $2.65M.

## 3. Multi-program U/Pu Synthesis Glovebox

**Description**

There is currently a need to synthesize multi-Kg quantities of uranium-based fuel and plutonium-based fuel for demonstrating and testing different reactor concepts. In fact, fuel production is a key need for supporting nearly all reactor demonstration projects being considered for placement at INL, however there is no available glovebox space to meet this need. This request proposes to revise an existing plutonium glovebox conceptual design and procurement specification to incorporate multi-purpose furnace wells for general purpose, initiate the procurement, start the facility modification design, perform the necessary facility and safety basis modifications, and to install the gloveboxes. The capability could potentially serve production of any fuel type other than TRISO particle fuel. This investment would establish the glovebox capability; program-specific synthesis needs would be established in the future. With this glovebox available, any follow-on program would need to address only their specific fabrication and synthesis needs by installing the production components, consumable materials, handling equipment, and furnaces required to meet their fuel specification.

**Benefit**

The vast majority of industry reactor designs, proposed NASA concepts, proposed DARPA concepts, and designs originating from national laboratories require engineering-scale, campaign-style synthesis of significant quantities of their fuel for testing and demonstration. There is a gap across the DOE and industrial infrastructure to provide this capability. Pu capability is unavailable for this purpose, and capability for U over 5% enrichment is extremely limited. Installing the proposed multi-purpose glovebox shell would fill this gap for the near term. With planning and coordination, the glovebox would meet both uranium and plutonium needs. Future partners working under the NRIC framework, GAIN, NASA, DARPA, or the upcoming DOE Demonstration Reactor FOA would benefit through substantial schedule improvement, reduction in overall project risk, and reduction in cost uncertainty. In most cases, this would contribute to an estimated 2-year reduction in the time to demonstration for these critical experiments and reactor concepts.

**ROM Cost Estimate:** $6.4M.

## 4. In-situ Testing Stage for Titan and Talos Transmission Electron Microscopes

**Description**

Procurement of TEM (Transmission Electron Microscope) sample holder (stage) capable of exposing samples to operational environments in-situ during TEM observation. This in-situ capability is a significant in enabling rapid discovery of improved nuclear and battery materials through understanding of material behavior in environments relevant to operating conditions. In-situ testing provides information on the interaction of materials with environments as they are occurring, resulting in a much shorter time frame and higher probability of achieving mechanistic understanding of operational and failure processes. Acquisition of this capability is jointly supported by NS&T (NMDQi and NSUF programs) and MFC to help accelerate discovery of new materials and understanding and improvement of current materials. For battery development, in-situ TEM offers the opportunity for EES&T scientists to study phenomena including solid electrolyte interphase (SEI) formation and phase changes during battery operation.

**Benefit**

In-situ staging is necessary to strengthen INL's current and future lead role in nuclear (NS&T, MFC, NHS) and battery materials (EES&T). Not adopting this technology put INL at a competitive disadvantage. For example, many studies have been performed on irradiation assisted stress corrosion cracking (IASCC), and many theories exist to explain the phenomena, but a unified mechanistic understanding and designing alloys resistant to IASCC has never been achieved. Higher energy densities in batteries can be achieved by increasing battery cell capacity or cell voltage, however batteries are complex systems, subject to multiple processes during operation such as volume changes, solid electrolyte interphase layer formation, and phase transitions. Moving towards data-driven materials design and optimization, accelerated qualification of nuclear and battery materials would largely benefit from in-situ microscopy to accelerate our understanding on the role of irradiated defects, interfaces, surfaces, and phase transformations under relevant conditions. Adopting this in-situ capability at INL, with the ability to handle and study highly radioactive materials, would also be unique in the DOE complex.

**ROM Cost Estimate:** $800K.

# 5 AFF High Temperature Furnace

**Description**

Fuel is one of many essential elements of a reactor demonstration but is unique because the facilities to manufacture are both very limited and can be prohibitively capital intensive to establish. Other than modest quantities of TRISO and LALEU UO2, MFC has perhaps the only facilities in the U.S. that can produce even a single sample of the broad diversity of fuels being pursued by reactor developers. Even to reproduce MFC's limited pilot or demonstration fuel fabrication capabilities would cost time and money outside the scope of even the largest ARDP programs, let alone the various smaller microreactor or more preliminary concepts. Instead, developers continue to seek to leverage MFC facilities and expertise for this activity, yet for anything more than a modest demonstration MFC is limited by furnace capacity. Our laboratory furnaces are small, in some cases not even big enough to handle the smallest fuel article of interest, and otherwise can only process a few grams of fuel per run (which may range from a few days to weeks), so even planning 24/7 operations has in the past been schedule prohibitive.

**Benefit**

This furnace will result in diverse opportunities for INL, that have and will continue to come up routinely. The impact will benefit advanced nuclear development in general. This supports pilot scale testing, development, and development of fuel fabrication and instead reduce the substantial risk that comes with building a Hazard Category II facility and the first-of-a-kind manufacturing process inside it at full scale. Smaller microreactor programs, such as MARVEL, will continue to see their only U.S. manufacturing operation consist of INL conducting years of 24/7 operations pulling a few grams at a time out of laboratory-sized furnaces. Developers with uniquely large fuel items will continue having no viable option for even making a single fuel article for demonstration or irradiation testing. MFC will continue to have only a limited opportunity to pursue UO2 engagement, even with compelling INL-invented UO2 innovations

**ROM Cost Estimate:** $1.5M.

## 6. FASB Equipment Replacement (Red Devil Furnace)

**Description**

Replacement of current multi-mission equipment in FASB supporting multiple fuel programs and fabrication demonstrations, including the Westinghouse silicide work. Scope includes removal and disposal of Red Devil Furnace and procurement of newer model with installation. This is a table top furnace with vacuum, inert and hydrogen capability with a capacity to reach 2,000 degrees Celsius.

**Benefit**

The Red Devil furnace is frequently used and has supported many diverse fuel programs and fabrication demonstrations, including the Westinghouse silicide work. However, the furnace was originally a bare-bones system, costing less than $30K, and its functionality has been stretched as far beyond the original intent. The uniform hot zone is very small and poorly controlled, a limitation which directly led to the descoping (several times) of the silicide program commitment. Red Devil may be able to be repurposed to AFF for binder removal and other “dirty” processes.

**ROM Cost Estimate:** $600K.

## 7. Multi-program Experiment Assembly Equipment for TREAT Experiment Support Building (TESB)

**Description**

There is currently a need for additional equipment to support experiment assembly at the Transient Reactor Test (TREAT) facility. TREAT experiments are currently assembled in a variety of INL facilities including HTTL, AFF, EFF, and the TREAT reactor building. Each of these facilities support multiple missions, and at times there have been bottlenecks in experiment assembly that have threatened the TREAT experiment schedule. The TREAT warehouse (MFC-723) has been identified as being well-suited to facilitate additional work associated with TREAT experiments, and it has been renamed the TREAT Experiment Support Building (TESB) to reflect this function. New equipment is needed for the TESB to support the TREAT mission, most significantly an inert-atmosphere glovebox. The TESB glovebox would be a slight modification to the design of a glovebox currently being installed in AFF. Additional equipment needed includes a setup for helium leak testing, a micro-TIG welder, and a capsule pressurization cart.

**Benefit**

This investment establishes basic TESB experiment assembly capabilities for fresh (i.e., low radiation) samples. With this experiment assembly equipment available, TREAT experimenters and TREAT operations will be well-positioned to complete experiment assembly at the TESB in dedicated space free of conflict with other programs.

**ROM Cost Estimate:** $900K.

## 8. NRAD Imaging System Upgrades

**Description**

These upgrades include materials (e.g., optomechanics, shielding materials, camera box architecture) and labor for scientific design, engineering design, fabrication, installation, testing at NRAD, and qualification of the system for programmatic use. There are two imaging systems that will be established through this investment:

1. High-resolution nCT system covering a 3 cm field of view (FOV) and target ~20 µm resolution.
2. Interchangeable FOV digital imaging system including 10 cm, 20 cm, and 60 cm FOVs.

These two nCT systems provide capabilities that span the highest possible resolution to the largest possible FOV using NRAD's beams.

**Benefit**

Funding corrects capability gaps, namely by providing digital neutron imaging systems that accommodate a wide range of sample sizes and spatial resolution requirements to meet INL and DOE mission needs.

Potential users (e.g., INL Programs, University partners, other national laboratories, and industrial collaborators) keep asking if existing neutron computed tomography (nCT) capabilities can accommodate their applications. While the existing digital nCT system can accommodate many users' applications, others with significant scientific and mission-significant impacts are missed. This investment would provide capabilities that address scientific and material qualification programs that are currently left unanswered.

**ROM Cost Estimate:** $1.25M.

## 9. HFEF 2and Manipulator Repair Glovebox

**Description**

This will be a second glovebox to address maintenance on the manipulators in HFEF. It is functionally equivalent to the current repair glovebox.

**Benefit**

The existing slave manipulator repair glovebox/containment is limited to the number of remote manipulators it can accommodate. The addition of a new repair box will increase maintenance capability to increase the number of remote manipulators available for replacement, thereby decreasing facility downtime and increasing R&D productivity

**ROM Cost Estimate:** $2M.

## 10. Upgrade NRADS North Beam Shutter to Include Aperture and Filter Drum

**Description**

Replace the current neutron beam shutter of NRAD's north neutron beam. The new shutter will be more robust to attenuate the neutron beam to nearly-zero when closed and include a filter drum and wheel to condition the neutron beam. Radiation transport modeling will inform the geometry and materials of the new shutter, and engineering will address the structural, motion, control system, and interlock issues. The materials will be purchased, and components fabricated according to the designed specifications and installed. Beam parameters (e.g., neutron energy & flux, gamma content) will be measured before and after installation of the shutter.

**Benefit**

This will enhance the NRAD beam line capabilities to support higher resolution and mission support efficiency.

**ROM Cost Estimate:** $1.3M.

## 11. Sample Preparation Equipment for IMCL

### Description

Equipment will improve sample preparation capabilities at IMCL. Use of a cryogenic sample stage and transfer eliminates hydride artifacts introduced during preparation of zirconium alloy fuel cladding samples with the FIB. Preparation of samples in the FIB, if not performed at cryogenic temperatures, leads to introduction of hydrogen artefacts that confuse analysis of uptake, precipitation, growth, and reorientation mechanisms. The hardness tester is necessary to obtain crucial mechanical data for most structural and fuel materials at IMCL. These instruments will be used all work at IMCL, including FCRD (Fuel Cycle Research and Development) and NSUF (Nuclear Science User Facility); LDRD projects, university collaborations, and work for others.

The list of instruments to be added in IMCL includes a cryostage and transfer for FIB, a sample rotator for PPMS, and a hardness tester

### Benefit

The rotator for PPMS is crucial to study magnetic samples when we study the effect of magnetic field. Actinides materials have shown strong anisotropy in their physical properties such as resistivity, magnetoresistance and magnetic torque. By rotating the single crystals along different crystallographic orientation in magnetic field, several fundamental properties can be understood in detail. Sample preparation of irradiated zirconium cladding using the FIB allows detailed characterization of microstructural features such as hydride precipitates whose density and orientation determine cladding mechanical properties and lifetime.

**ROM Cost Estimate:** $450K.

## 12. EFF X-Ray Diffractometer

### Description

The Panalytical X-Ray Diffractometer (XRD) is a basic material science characterization tool that serves as a workhorse, supporting nearly all of the research programs in our division and providing critical data for numerous scientific publications. In the best of times there can be a sample backlog, but failure of the equipment can slow or stop progress on projects or require workarounds that create project risk and diminish opportunities to publish. A recent XRD outage has lasted months in the face of ongoing frustrations with the vendor unable to promptly perform a repair and has impacted at least seven different projects. While similar capabilities exist in other facilities, the facility/equipment capabilities, the process of performing sample transfers, and scheduling the analyses has at times made such options either impossible or presented a cost/schedule burden that could not be overcome. This is a multi-program capability that will increase efficiency and research output for the development of new fuel alloys as well as the verification of sample form after processing.

The Rigaku MiniFlex 6F benchtop X-ray diffractometer would provide a similar capability to that provided by the instrument currently in FASB. It is a basic but capable unit and cost competitive with any other comparable solution. Its small footprint would allow for its placement on a lab bench.

### Benefit

The best way to assure continuous availability of this essential capability is to expand the XRD capability with a similar instrument from a different vendor that will be placed in EFF West. A different vendor offers resilience against equipment obsolesce and long-term variability in the quality of the manufacturer's technical support.

**ROM Cost Estimate:** $200K.

## 13. Replace EML SEM (Electron Microscopy Laboratory, Scanning Electron Microscope)

### Description

High resolution analytical SEM (Scanning Electron Microscope) is essential to achieving MFC's mission. Current instrument is utilized > 150% and 11 years old. The vendor is no longer servicing the current instrument. The replacement SEM in EML will be used for multi-mission works such as United States High Performance Research Reactor program, Advanced Reactor Development Program, as well as for classified NR work. All missions require a reliable SEM outfitted with a suite of analytical detectors.

### Benefit

This instrument ensures SEM capability availability. Instrument near end-of-life (10 years old) and experiencing decrease in availability due to maintenance issues. It is one of the most utilized instruments at EML (>100%) and will have significant impact on all programs if it breaks.

**ROM Cost Estimate:** $1M.

## 14. Oxy-Gon Hot Press Furnace

### Description

Multiple programs are increasingly interested in studying material interaction experiments and characterizing material behaviors. Existing static jigs used to maintain sample pressure during heating are inadequate and cannot accommodate thermal expansion of the samples. A hot press furnace equipped with the ability to apply a consistent pressure on samples during heating is a far superior approach to this kind of experimentation. In addition, INL is experiencing an increase in demand for furnaces. This combined with supply chain and repair issues leads to numerous situations in which there are not enough furnaces for the current and expected workload. This furnace expands on research capabilities, powder manufacturing techniques, and provides redundancy to further help relieve demand for existing furnaces. This furnace is in addition to the "red devil" replacement furnace that has already entered the procurement process.

### Benefit

The benefits of this system include improving process efficiency for diffusion couple testing by eliminating steps in the experiment assembly process. This system provides redundancy for high temperature testing of materials in a controlled atmosphere environment, improving the ability to meet multiple programs goals. This versatile system is also of interest for a variety of programs as an efficient alternative for small-scale powder manufacturing applications. Hot pressing methods improve on the handling and manufacturing of ceramic, metal, and composite materials that utilize powder feedstock. Hot pressing can produce higher density samples than the cold-press and pressure-less sintering methods currently used.

**ROM Cost Estimate:** $250K.

## 15. EFF Radiological EDM Capability Upgrade

**Description**

As the existing EDM continues to serve as a workhorse for many programs, its continued use increases the chances of it failing to a point beyond repair. Procurement and installation of a new wire EDM (electrical discharge machine) with fourth axis, and disposal of existing wire EDM. The existing wire EDM system has outlived its useful life and is experiencing more downtime requiring FFNMM staff to adapt on the fly to troubleshoot and repair the system or consider alternative processing schemes. The nature of the radiological work performed within the EDM precludes significant maintenance activities given the equipment is contaminated itself and also that it resides within a contamination area. That is, refurbishment or any repair beyond basic repair is not a viable option for the current EDM system.

**Benefit**

This is a critical capability for which there is not an available substitute for approximately 90% of the work performed on it. Majority of metal fuel development and fabrication efforts utilize the EDM as does a majority of space propulsion research efforts for processing of its fuel forms. If a replacement EDM is not installed there is a significant risk of being unable to perform research and development in support of these major programs, among other more incidental work.

**ROMK Cost Estimate:** $700K

## 16. Laser Powder Diffractometer

**Description**

Procurement and installation of a new wire particle size analyzer. The existing particle size analyzer system has outlived its useful life and is experiencing more downtime requiring FFNMM staff to adapt on the fly to troubleshoot and repair the system or consider alternative processing schemes. This is due to the age of current particle sizing equipment, and unreliability of other particle size verification methods. It has been deemed necessary to replace the existing equipment with a new laser-based system. Particle size analysis is a beneficial metric for characterizing feedstock powders used for a variety of experimental processes.

**Benefit**

The following are benefits of the new machine:

- Utilizes laser diffraction to measure a wide range of particle sizes (0.04 μm – 2500 μm)
- Highly flexible design allowing for particle size measurement of both dry and wet samples in the same machine (example being reactive powder in liquid suspension, while a larger particulate could be analyzed in a dry state (milling media, non-reactive granules)
- Easy to access and maintain
- Capability for highly accurate, repeatable particle size runs, while also allowing for quick turnarounds if necessary
- The new laser powder diffractometer will allow the lab to provide high quality world class data for feedstock powders and address the growing demand for research-grade particle size analysis within our facilities.

**ROM Cost Estimate:** $150K.

## 17. ZEISS X-ray Source Upgrade

**Description**

ZEISS X-ray Microscopy has recently developed an upgrade to their Versa X-ray microscope product line with a new X-ray source that offers faster imaging times (capable of reducing imaging times by 150%) and finer resolution (down to 500 nm resolution) than what was previously available. INL's current ZEISS 520 Versa X-ray microscope (XRM), equipped with the previous generation X-ray source, is a versatile, nondestructive system that provides spatially-resolved 3D imaging of internal defects, inclusions, cracks, and voids.

**Benefit**

Throughput and quality of 3D X-ray imaging at INL will significantly advance. Programs, both internal and external, are increasingly requesting methods that both decrease the imaging time and increase data quality (this has been of particular interest to GA for developing characterization methods for SiC fiber-reinforced SiC tubing development). Advancing this capability supports capturing future work scope as other governmental, industrial, and academic laboratories begin to either upgrade their XRM systems or purchase new XRM systems (the previous generation X-ray source is no longer commercially available). For commercially available, laboratory-based XRM, increasing both throughput and data quality can only be achieved through hardware upgrades. Investing in this capability will be required in order to maintain a competitive advantage over the next 5-10 years.

**ROM Cost Estimate:** $750K.

## 18. CNC for experiment disassembly and sample preparation throughput increase at Window 3M

**Description**

This will address procurement and in-cell installation, including engineering modifications and qualification, of a computer numerical controlled (CNC) device.

Current experiment disassembly and complex-geometry samples are achieved with the use of a manually operated conventional mill. The current system relies heavily on operator skills, hence it is time consuming and more prone to errors that could jeopardize the integrity of the experiments.

**Benefit**

The upgrade of the equipment to a CNC-based machine would remove some of these hazards and increase throughput exponentially. DOE fuel qualification programs, NNSA fuel qualification programs ARDP awards, DOD material qualification programs, work for others contracts are current and potential customers that will benefit from this capability upgrade. This replaces labor-intensive and error-prone equipment and will support increasing demand and timeline acceleration requested by the customers.

**ROM Cost Estimate:** $1M.

## 19. AL B-wing ICP-OES (non-rad)

**Facility:** Analytical Laboratory

### Description

The ICP-OES located in B-148 still functions but has required large amounts of maintenance and replacement parts. Since this instrument is no longer supported by manufacturer service agreements it has gone long periods of time awaiting repairs. Furthermore, this instrument is several generations behind the current models and requires special manufacturing of some consumable parts essential for its use. Current analysis provided by this instrumentation is limited to Si and B elementals in non-irradiated fuels.

### Benefit

It is recommended this instrumentation be upgraded to a current generation instrument with high resolution capabilities, inside of a walk in hood. Use of a HR-ICP-OES would allow for the analysis of halogens and improve the resolution and sensitivity to the elements generally analyzed. The addition of a hood to enclose the instrument would allow for higher activity samples to be analyzed and reduce the load on the A-wing OES, eliminating the tedious process of transferring samples, standards, and checks into Hot Cell #6 before being transferred into the ICP glovebox. A HR-ICP-OES could afford improved data and lower data analysis time as many of the interferences the plague the current instrument would be eliminated by the improved optics of a HR.

**ROM Cost Estimate:** $500K.

## 20. Improved Electronic Interface for Hot Cell Scales and Balances

### Description

The balances and scales in the HFEF cells are still using the MTG. The balances and scales need an improved electronic interface with facility software to support improved material tracking in-cell.

### Benefit

An improved capability to interface more directly with facility material management software will increase operational efficiency and reduce opportunities for error. The current system requires manual entry of data into the material tracking system after measurements are taken. This slows work progress and introduces risks of error.

**ROM Cost Estimate:** $400K.

## 21. Visual Mount Inspection System in the HFEF Containment Box

### Description

The primary function of the containment box in the Hot Fuel Examination Facility (HFEF) is to prepare mounted ceramic or metallic samples for materialography. Materialographic sample preparation involves subsequent steps of mechanical material removal of each deformation layer from the previous step to reveal the true microstructure of the mounted material. Prior to proceeding to the next step of mechanical material removal the mounted sample must be inspected to ensure the surface finish is free of deformation from the previous material removal step and that the sample is free of preparation artifacts (i.e., scratches, smearing, edge rounding, etc.).

If the surface finish of the mounted sample is not properly inspected prior to materialography and is determined to be unacceptable during light microscopy, costly rework, scheduling, and material transfers must occur. It is estimated that each mounted sample with an unacceptable surface finish costs approximately 20 man hours of operations time to rework the preparation steps. Currently, this inspection is accomplished by the use of a Kollmorgen Model 894 Hot Cell Periscope.

**Benefit**

A visual system to inspect mounts during sample preparation is necessary to ensure the efficiency of containment box operations.

The Kollmorgen Model 894 Periscopes were procured and installed in HFEF in the mid-1970s. The Kollmorgen Model 894 Hot Cell Periscope has performed satisfactorily for the purpose of inspecting mounted samples, though it is experiencing intermittent failures from age and extensive use. Repairs to the periscope were completed in 2008, but the repairs have not restored full system capability. Kollmorgen has ceased manufacturing of hot cell periscopes and a very limited supply of replacement parts is available. The inspection of mounted samples during sample preparation is key to efficient materialography operations. Failure of the Kollmorgen Hot Cell Periscope would leave containment box operations at HFEF in a vulnerable state.

**ROM Cost Estimate:** $1.5M.

## 22. Automated Sample Prep/Dissolutions

**Description**

Update AL capabilities to include automated sample preparation and sample dissolutions.

**Benefit**

Automatic sample preparation and dissolution capabilities increase laboratory operations efficiency and reduce the number of personnel required for these steps. This frees up personnel to run and monitor research equipment and provide data analysis.

**ROM Cost Estimate:** $750K.

## 23. Multi-Function Furnace #2

**Description**

The electrometallurgical treatment process used to neutralize the sodium component of irradiated EBR-II elements includes a salt distillation step as part of the process. The Cathode Processor (CP) is 25-years old and the only means of performing this salt distillation requirement from uranium dendrite or other process materials in the FCF argon cell and is experiencing failures indicative of the end of its useful life. When maintenance needs arise, repairs to this unit must be performed remotely which results in extended treatment process downtime. The addition a second distillation capability via a new high temperature vacuum atmosphere furnace in the FCF argon cell will enable salt distillation requirements to continue when the Cathode Processor is unrepairable and will help to alleviate the bottleneck at this process step associated with higher throughput rates. Additionally, this new furnace will be designed to support expanded missions beyond salt distillation to include cladding hull consolidation, sodium contaminant distillation, as well as uranium consolidation.

**Benefit**

Increase in overall treatment system reliability and process rate efficiency, while expanding capability in enhancing uranium product and process waste stream disposition

**Facility Risk**

The single point failure associated with the current treatment system limits the rate of treatment. Past operational conditions provided some flexibility to store dendrite on an interim basis until the Cathode Processor was available, however future operating requirements will significantly restrict this capability, resulting in shutting down the process until repairs can be made.

Workload at the CP is increasing, while equipment availability has been decreasing in the recent past due to unplanned component failure related to the age of them.

**ROM Cost Estimate:** $2.5M.

## 24. Develop NRAD Neutron Diffraction Capability in HFEF

**Description**

This project designs and installs a neutron diffraction system that will quantitatively improve irradiated material characterization. The diffractometer will be installed at NRAD (Neutron Radiography reactor) north beam line.

**Benefit**

Neutron diffraction is a powerful tool that is complimentary to e-beam methods for the characterization of nuclear materials. At the INL, advanced microscopy techniques are used to characterize the crystal structure of irradiated nuclear fuel and materials. These methods provide detailed microstructural information on a very small sample, but require difficult sample preparation. Neutron diffraction provides more precise information on lattice parameters, atomic positions, and the stress state in a bulk material. Neutron diffraction and data analysis can generally be conducted in less time than electron microscopy. The use of neutron powder diffraction at NRAD has the potential to significantly enhance the basic and applied science of nuclear fuels for current DOE programs as well as scientific and commercial customers.

The capability for neutron (or x-ray) diffraction of high activity materials and irradiated fuels does not exist in the United States, and only at a few places in the world. Current neutron diffractometers rely on high flux sources (the HFIR and NBSR reactors and the SNS, for example) at user facilities that do not accept high activity materials or fuel. Since neutron flux at the sample location of NRAD north beam line is low relative to these reactors, a polychromatic (white) beam diffraction approach has been selected in consultation with neutron scattering scientists at ORNL and MIT. The use of a white beam provides many diffraction events simultaneously and uses an analyzer crystal to select the specific neutron wavelengths that are collected by the detectors.

Neutron diffraction coupled with simultaneous neutron imaging will provide closely correlated information about material structure and performance.

The feasibility and system design of neutron diffraction using the NRAD reactor is currently being explored with MIT and ORNL. Design concepts and feasibility studies will be completed in FY-17.

**ROM Cost Estimate:** $2.5M.

## 25. AL HR ICP-MS

**Description**

Adding a new high resolution ICP-MS to the AL RD&D capabilities

**Benefit**

The sensitivity of the HR-ICP-MS can be up to 50x higher when compared with the Q-ICP-MS, and the instrumental uncertainty can be as low as 0.025% which, in many instances, is a requirement in the development and certification of new and advanced nuclear fuels. The instrument will also help the ARL maintain its high sample throughput, help maintain high data quality as programmatic needs increase, and keep pace with technological advances in chemical and analytical metrology.

**Risk**

The HR-ICP-MS is used for the quantification of isotopes that do not require higher resolving power, but require a more sensitive or more precise technique.

**ROM Cost Estimate:** $1.5M.

## 26. IMCL High Throughput Sample Preparation Capability for Nuclear Fuel (Laser)

**Description**

Sample machining technology based on femtosecond lasers provides the opportunity to rapidly and precisely prepare intermediate-scale samples (50 micron to millimeter) for characterization. This project couples commercially available laser sample preparation capability with a radiological contamination control system and light shielding, and installs the system in IMCL.

**Benefit**

Micro-scale samples for characterization and mechanical testing are currently fabricated using FIB (Focused Ion Beam) instruments. FIBs are dual-purpose instruments, used for both sample analysis and sample preparation. FIB sample preparation is extremely precise, but time consuming. Commercially available laser-based sample preparation tools have been demonstrated to produce high-quality samples much more rapidly than FIB. These systems are also capable of producing larger-scale samples, which provide material property data more representative of bulk material. Use of a less expensive, dedicated laser-based system for sample preparation allows FIB instruments to focus on sample analysis instead of sample preparation, increasing data generation and contributing to shorter nuclear technology development timelines.

**ROM Cost Estimate:** $1M.

## 27. Shielded Experiment Preparation and Inspection Cell (EPIC) – Procurement and Installation Into TESB

**Description**

This hot cell will provide functionality to support LWR fuel testing, and perhaps fast reactor fuel testing. This will include procurement and installation of a shielded cell and glovebox, named the Experiment Preparation and Inspection Cell (EPIC) for remote installation of instrument sensors onto previously irradiated fuel rods intended for irradiation the Advanced Test Reactor (ATR) and transient testing in TREAT.

### Benefit

EPIC will form the foundation of a key capability for backfilling the loss of the Halden Test Reactor.

**ROM Cost Estimate:** $8M.

## 28. Design & Install a Rotation Stage in the ERS Elevator to Enable Neutron Tomography of Fuels

### Description

Design, build, and test a rotation stage for the East Radiography Station (ERS) elevator at HFEF to enable neutron tomography of specimens inside the HFEF main cell. The stage should include an encoder for reliable and repeatable positioning. Control system for the rotation stage should be user-friendly and capable of being interfaced with the neutron imaging system control software. The rotation stage should be able to accommodate virtually any specimen inside the HFEF main cell that can fit into the ERS elevator. The rotation system would build upon the experience of the AFIP-7 tomography fixture designed and used in 2015, and the imaging techniques developed in the TREAT SETH program in the north radiography station.

### Benefit

Neutron computed tomography (nCT) is now available for imaging low-activity specimens in NRAD's North Radiography Station. However, to examine highly-radioactive specimens, a nCT system must be installed in the ERS to have access to specimens in the main cell via the elevator. For nCT to work, the specimen must be able to rotate and the angle be controlled by the imaging control system. Such a rotation stage does not currently exist, but would enable nCT of irradiated fuel, which is of vital interest to fuel R&D programs.

**ROM Cost Estimate:** $750K.

## 29. AFF multi-purpose Uranium powder glove box chain

### Description

AFF multi-purpose Uranium powder glove box chain

Demand for fuels development work continues to increase. These increases are for a wide range of fuel types, many of which utilize powder processing in some form. A major example is additive and advanced manufacturing which uses powder as a feedstock. A multi-purpose uranium based glove box chain to allow for more powder handling in a safe and efficient manner while maintaining powder quality would be impactful well into the future.

### Benefit

Increased capability and glovebox space for new or existing program users. Will give the division some redundant capabilities and surge capacity if needed to meet program goals. Increases capability to support reactor development and demonstrations.

**ROM Cost Estimate:** $3-4 M over 2 years.

## 30. HFEF ECP/EBLM Refurbishment

**Description**

The Element Contact Profilometer/Element Bow and Length Measurement instrument is original equipment to HFEF. Multiple failures have occurred, the bow and length measurement function is not operable, and the system is unreliable, requiring increasing repair. Some functions cannot be repaired or replaced in-situ due to age and obsolescence. This project will refurbish the instrument, restoring full functionality and updating to modern components.

**Benefit**

This refurbishment will restore full functionality and improved reliability to a PIE instrument that is part of routine, baseline non-destructive examinations. This is a key measurement for medium- and full-size fuel pins which will be more common as we look towards industry partnerships.

**Facility Risk**

Without this project, HFEF will not be able to offer a key PIE technique for light water reactor fuel PIE and other medium- to full-size fuel pins and will lose work to laboratories who can complete this measurement.

**ROM Cost Estimate:** $1M.

## 31. Powder Bed Additive Manufacturing

**Description**

Powder bed additive manufacturing.

**Benefit**

The INL currently does not have a powder bed 3D printing apparatus for use with uranium based metals. This capability would give us an expanded number of options available to fabricate fuel using additive manufacturing techniques. Expanded fabrication options for advanced fuels. This expanded capability will allow us to be more competitive in attracting new fuels work.

**ROM Cost Estimate:** $2M.

## 32. HFEF/NRAD Digital Imaging Studio

**Description**

Convert Photolab space (Room 121 and 124) into digital imaging laboratory. Modification would include PFCN ties for high speed data collection and transmission, high resolution scanners and processing computers in room 121, and a large viewing display for presentations in room 124. A new access to the NRS Highbay may also be included to allow quick access to imaging equipment in the basement and NRS Highbay workspaces.

**Benefit**

Image processing equipment to enable neutron CT, Tomography, and diffraction real-time data analysis. More presentation-worthy display equipment for PIs and professional-looking tours in room 124.

**Facility Risk**

Without digital imaging equipment space, time will be lost transferring information to other data analysis spaces, and reactor run time is wasted if rework is required for imaging.

**ROM Cost Estimate:** $500K.

## 33. NRAD NRS Elevator Replacement

**Description**

The NRS elevator, originally designed to radiography large TREAT loops, is non-functional and needs to be replaced. The replacement would require a more precise specimen positioning stage and accommodate larger diameter specimen.

**Benefit**

The NRS space is ready to demonstrate neutron diffraction, neutron CT, TREAT experiments, and is slated to perform TREAT loop radiography in a few years. An elevator replacement would allow better remote positioning of specimen for radiography and neutron CT of full TREAT loops. In addition, new business opportunities could be developed if the design doubles as a diffraction sample stage, and is wide enough to accommodate barrel-scanning operations using X-ray or neutron beams (e.g., waste characterization).

**Facility Risk**

The current system is degraded, requiring operator workarounds such as manual placement of specimen and test radiographs to confirm positions prior to program radiography. Elevator vertical movement, rotation, clamping, and carriage motion components and associated position indications are all currently non-functional. Upgrade would consider system redesign to accommodate larger specimen since current conceptual TREAT designs are too large for the elevator to accommodate.

**ROM Cost Estimate:** $1M.

## 34. NRAD Sample Preparation Glovebox

**Description**

Set up a sample preparation glovebox at NRAD for preparing fresh and lightly irradiated fuel samples for in-core irradiation. The targeted place for this equipment is in room 029 (old argon compressor room) in the basement of HFEF.

**Benefit**

The single largest use of small research reactors worldwide is neutron activation analysis. Instrumental NAA (INAA) offers such benefits as low detection limits, minimal sample preparation, and the possibility of measuring analytes that are prone to interferences in more traditional techniques, such as mass spectrometry and optical emission spectroscopy. Developing and enhancing NRAD's sample preparation and in-core irradiation capabilities will take advantage of its co-location with the HFEF hot-cell. It would allow for researchers to use INAA to look at the composition of materials, to explore the behavior of small amounts of materials in a neutron flux, and to perform basic nuclear measurements to improve knowledge of cross-sections or half-lives. Several programs across INL who are working to develop the next generation nuclear materials would be able to take advantage of this technique to measure analytes that do not currently have established methods, with the appropriate detection limits and precision, available in the Analytical Laboratory (AL), such as bromine and chlorine. An in-house sample preparation and counting area would minimize transfer paperwork and manual material handling of fueled material.

**Facility Risk**

The NRAD reactor currently does in-core irradiations inefficiently. Each sample is prepared in another nuclear facility and must be transferred individually and hand-loaded into the core.

**ROM Cost Estimate:** $500K.

## 35. Argon Atmosphere Capability in the IMCL Shielded Sample Preparation Area

**Description**

The SSPA (Shielded Sample Preparation Area), a small hot cell used for mounting and polishing of irradiated samples in IMCL (Irradiated Materials Characterization Laboratory) will be converted from an air atmosphere to an inert argon gas atmosphere.

**Benefit**

The SSPA is currently limited in its ability to prepare air sensitive metallographic samples. This lack of capability results in a continued backlog of samples, extra sample transfers, higher net operational cost, and lack of efficiency that contribute to long nuclear material development cycle times.

Sample preparation is a bottleneck in the characterization of nuclear fuels and materials that is important to understanding irradiation behavior. This SSPA works in concert with the HFEF (Hot Fuel Examination Facility) containment box to provide these samples. Converting SSPA to operate in an inert argon atmosphere will expand the range of samples that can be prepared and help to reduce the time required for analysis, decreasing development and qualification cycle time.

**ROM Cost Estimate:** $1.5M.

## 36. NRAD NRS Control Console Replacement

**Description**

NRS neutron shutter, gamma shield, beam shaping components, and aperture have been returned to service. However, the control system is obsolete and degraded and needs a replacement like the ERS control console.

**Benefit**

The NRS space is ready to demonstrate neutron diffraction, neutron CT, TREAT experiments, and is slated to perform TREAT loop radiography in a few years. An upgraded control system PLC would ensure reliability of the beam and transporter control equipment and remote monitoring capability.

**Facility Risk**

The current system is obsolete and degraded. It is composed of early 1980s chips and circuitry that are no longer available. Failure of the system jeopardizes all new work in the NRS.

**ROM Cost Estimate:** $500K.

## 37. NRAD Automated Computed Tomography System

**Description**

Design and install an automated neutron computed tomography system in the east radiography station (ERS). The system would require modification of the beam stop in the ERS cell and adjacent Subcell area to accommodate equipment. The system would tie the ERS elevator, rotation stage, beam tailoring, and shutter controls into a single automated system.

**Benefit**

An automated neutron computed tomography system would make NRAD the only system in the world that could offer neutron computed tomography of irradiated material and subsequent 3D reconstruction as a standard PIE practice for highly irradiated specimen. During installation of this system, a side benefit could be realized to optimize the shielding inside the ERS Cell to eliminate neutron streaming and resultant radiation areas in the normally occupied spaces of the HFEF basement.

**Facility Risk**

Neutron CT is an advanced capability for highly irradiated fuels. The ERS can function without this equipment.

**ROM Cost Estimate:** $2.4M.

## 38. Laboratory Robotics/Automation for Analytical Research Laboratory (ARL) Processes

**Description**

Currently, there are no processes in the ARL that are fully automated or utilize robotics. The scope of this will prioritize and add these capabilities to the processes that are the most likely to benefit from robotic automation. There are many applications that would benefit from robotic automation including remote handling of samples and reagents via manipulators. Weighing and labeling of sample bottles, heat treatment and sampling of dissolutions, and performing auto sampling/loading for analytical instrumentation.

**Benefit**

Laboratory robotics is the practice of using robots to perform or assist in the laboratory tasks. While laboratory robots have been applied in diverse industries and sciences, pharmaceutical companies have used them more than any other group. Many laboratory processes are suited for robotic automation as the processes are composed of the repetitive movements. Robots can pick/place the liquid & the solid additions, they can heat/cool, mix, shake & test.

One of the most rapidly growing areas in the laboratory automation is the use of the robotics for sample preparation as the manual preparation of samples has remained a time-consuming problem. Advanced laboratory robotics can be used as auto-samplers as their main task is to provide continuous samples for the analytical devices. Laboratory robots have arms, hands, and fingers. These components can be programmed to repeat sample preparations previously performed by laboratory technicians. These robots can be programmed to perform many different tasks such as sample preparation and handling. Laboratory robots can dispense acids, mix, heat, centrifuge, filter, and weigh samples.

Laboratory robotics offer high speed, high efficiency, minimal wastage, task reproducibility, and enhance safety of laboratory personnel. Laboratory robotics can withstand adverse environmental conditions. Because sample preparation requires the use of hazardous chemicals, robots minimize the human exposure to these chemicals. Robots provide consistency in sample preparation and they improve the precision of the data. The repeatability and the reproducibility are improved as the automated systems are less likely to have the variances in the reagent quantities and less likely to have the variances in the reaction conditions. Efficiency will be improved as the robots can work continuously and they can reduce the amount of reagents that are used to perform the reaction. This also reduces the amount of waste produced in a process. Automation can establish safer working environments since the hazardous compounds do not have to be handled. The automation also allows staff to focus on other tasks which are not repetitive.

**Risk**

The physical space constraints within the ARL and the ever increasing workload requires significant change to the traditional way of performing laboratory work. Many routine, repetitive tasks can be improved upon by utilizing robotic automation. Human constraints and errors will always exist when a person is performing these tasks. Costs will continue to increase and productivity from human based work cannot match that of automated processes. Automation will also improve data precision and repeatability.

**ROM Cost Estimate:** $5M.

## 39. AL Liquid Scintillation Capabilities

**Description**

The AL currently houses 2 liquid scintillation counters that are key to the success and efficiency for gross alpha and beta samples. One of the instruments is about 9 years old and will require replacement over the next few years, as the instrument bearing typically wear out around year 10-12.

**Benefit**

Liquid Scintillation Counters are the instruments that are constructed to hold a magazine of samples and rotate them through the counting apparatus. Liquid Scintillation is a counting technique that measures light that is generated when radioactivity interacts with special organic molecules. The amount of light, or photons, that are generated is directly proportional to the energy of the radioactive particles that cause it, so can be translated into a spectra and quantified. This measurement can approach 100% efficiency. Use of this capability streamlines laboratory operations and increases efficiency and reduces variation.

**ROM Cost Estimate:** $600K.

## 40. Integrated Gas Supply, Collection, and Distribution System in HFEF for Mechanistic Source Term and Component Pressure Testing at HFEF

**Description**

As the laboratory moves forward with goals for developing numerous advanced reactor and advanced fuel concepts the need for testing reactor and fuel components in transient heating and high-pressure environments will greatly increase. Rather than each development project developing its own unique system it makes sense for INL to invest institutionally in a system that can support the needs of multiple programs.

The gas system will be designed to be able to couple with existing and new furnaces in HFEF to enable either the supply of high-pressure inert gas for pressure/burst testing of irradiated structural components, or the collection of fission gas from transient heating furnace which can be used to determine mechanistic source term release fractions. The time frame for execution is approximately 3 years including design, HFEF modification and equipment procurements, and deployment. DOE fuel qualification programs, ARDP awards, NRC licensing activities, and commercial work for others are potential customers.

**Benefit**

If not funded this could result in significant delays of numerous advanced nuclear technologies or in the application of unnecessarily restrictive limits placed upon their operation impacting their cost competitiveness. Individual programs may invest in similar systems that are limited to their specific program. This would place an unnecessary burden on the engineering, hotcell space, and waste management resources at INL through the proliferation of numerous (and nearly redundant) systems instead of addressing the testing need holistically.

**ROM Cost Estimate:** $6M.

## 41. ZPPR multi-purpose uranium processing and synthesis glove box chain

**Description**

There is a continuingly increasing need to handle and synthesize multi-Kg quantities of uranium-based fuel and plutonium-based fuel for demonstrating and testing different reactor concepts. Fuel production remains a key need for supporting nearly all reactor demonstration projects being considered. This request proposes to build on the existing multi-purpose glove box design and procurement. Then install this new glovebox chain in the ZPPR work room. This new glove box would expand the functionality of the ZPPR work room and would provide more options for large quantity fuel processing.

**Benefit**

Would provide processing capability in ZPPR facility, branching outside of SNM disposition, NHS projects, and nuclear material management increasing overall value and usage of the ZPPR facility. Increases capability to support HALEU material availability and reduce our capability to support reactor demonstrations.

**ROM Cost Estimate:**$5-6 M over 2 years.

## 42. FMF multi-purpose glovebox and fume hood combination

**Description**

There is a continuingly increasing need to synthesize multi-Kg quantities of uranium-based fuel and plutonium-based fuel for demonstrating and testing different reactor concepts. Fuel production remains a key need for supporting nearly all reactor demonstration projects being considered. This request proposes to build on the existing multi-purpose glove box design and procurement. The addition of a single glove box section with an attached fume hood. Would position FMF to be able to adapt to a number of conceived future expansions. With this glovebox available, any follow-on program would only be required to address specific fuel fabrication and fuel synthesis needs by installing program specific production components, consumable materials, handling equipment, and furnaces required to meet the program’s needs. This new glove box and attached ventilation hood would fill the FMF south work room and complete the vision started years ago when D&D efforts were taken to improve the facility.

**Benefit**

The vast majority of industry reactor designs, proposed NASA concepts, proposed DARPA concepts, and designs originating from national laboratories require engineering-scale, campaign-style synthesis of significant quantities of their fuel for testing and demonstration. The lack of this capability causes a gap across the DOE and industrial infrastructure. This capability for Uranium fuels with an enrichment over 5% is extremely limited and is completely unavailable for Plutonium fuels. Installing the proposed multi-purpose glovebox shell in the Fuel Manufacturing Facility would allow upcoming projects to fill this gap for the near term. With planning and coordination, the glovebox would meet both uranium and plutonium needs. In most cases, this would contribute to an estimated 2-year reduction in the time frame typically required to demonstration for these critical experiments and reactor concepts. Increases capability to support reactor demonstrations.

**ROM Cost Estimate:** $4-5 M over 2 years.

## 43. Multi-Purpose U Glovebox FASB multi-purpose uranium glove box chain

**Description**

The RERTR glove box chain in FASB is over 20 years old, has surpassed its useful service life and needs replacement to ensure continued availability of high purity inert environment processing. The RERTR box is expensive, time consuming to maintain and has difficulty holding atmosphere. Additionally, the configuration of the box no longer meets mission needs. The box has a relatively small interior space and does not allow many of the core capabilities needed for ongoing and future programmatic work. Currently, the PCG glovebox is utilized by other programs requiring increased height, well space, or length that the RERTR box cannot support. This significantly impacts other programmatic work in the PCG box and increases risks to experiments. The RERTR box is compartmentalized with small transfer ports limiting its functionality and movement of samples, materials and equipment between compartments.

A new glove box chain replacing the RERTR box would increase the divisions capability to address current mission needs and adapt to future programmatic work. Instrumented lead irradiation tests and engineering scale irradiation tests require larger gloveboxes for both experiment assembly as well as fuel specimen fabrication. Currently, engineering scale fabrication effort space within gloveboxes is very limited or non-existent depending on fuel type. Removal of the rolling mill and other antiquated equipment will also provide additional facility space to accommodate a much longer glovebox line which would make a new glovebox suitable for large development activities. Replacement of the RERTR box with a larger box designed to support current and future mission needs will continue our efforts to modernize and upgrade our research infrastructure and provide a core capability to process an array of test and reactor designs which require larger specimens to ensure prototypic irradiation behavior.

**Benefit**

This is a modern glovebox, capable of maintaining atmosphere and quick recovery after glovebox shutdowns. It expands capability for controlled experiment assembly and increases capability to support R&D activities for metallic fuel experiments and out of pile testing during removal and installation.

**ROM Cost Estimate:** $3-4 M over 2 years.

## 44. NRAD Fuel for 1 MW Upgrade

**Description**

The additional fuel increases the power of the Neutron Radiography Reactor (NRAD) from 250 kW to 1 MW proportionally increasing the neutron intensity in both the NRAD core and its neutron beams. The higher beam intensity increases the neutron signal to the instruments using NRAD's beams improving data quality.

**Benefit**

The higher neutron intensity in the NRAD core will enable in-core, low-burnup irradiation experiments like those at the Advanced Test Reactor (ATR) but with direct access to post-irradiation examination capabilities at the Hot Fuel Examination Facility (HFEF). NRAD's direct proximity to HFEF enables fast and cost-efficient transfers to the hot cell. This also allows access to short-lived fission product behavior that is currently unavailable from experiments shipped from ATR. The new capabilities enabled by increasing NRAD's power to 1 MW will accelerate the discovery, development, and qualification process for new nuclear fuels and materials.

**ROM Cost Estimate:** $5.1M.

## 45. Replace CNOH Glovebox and Instrumentation

**Description**

The CNOH instruments within the CNOH glovebox are near end of life and well past their recommended life cycle. The instruments were brought over from FASB and have been in the Analytical Laboratory for about 5 years. The modifications made to the glovebox for the specific instruments were extensive. All of the feedthroughs and connections were modified for the current instrumentation.

**Benefit**

There is a large backlog of samples waiting to be processed through the instrumentation within the glovebox. Additionally, there is a lot of programmatic work expected for the next 10 years to be processed through these instruments.

**Facility Risk**

The analyzers within the glovebox are past their life expectancy. Any disruption to the ability to process samples would effect programmatic work and cause delays.

**ROM Cost Estimate:** $5.5M.

## 46. Inert Glovebox Installation in B147

**Description**
B147 currently houses the casting lab glovebox. It is intended to tear out the glovebox once the capability is installed in FMF, which is on the 5 year plan. The glovebox contains a large portion of the facility material inventory and operationally creates the highest risk within the facility.

The Analytical Laboratory is need of an additional inert glovebox for processing samples due to the environment. The casting lab glovebox is set up for the instrumentation that is currently in there and the glovebox and associated gaskets, etc. are antiquated. Therefore, simply removing the instrumentation would still not allow for the glovebox to be used.

**Benefits**

The Analytical Laboratory continue to receive requests for samples and programs requesting analyses that cannot be processed anywhere other than in an inert environment due to pyrophoric and reactive materials. Installation of an inert glovebox with space for processing sample would be of great benefit to the programs and the AL.

**ROM Cost Estimate:** Outyears $4,000

## 47. Inert Glovebox Install in A-102

**Description**

The Analytical Laboratory has seen an increase in request for processing pyrophoric and reactive samples. These samples can only be processed in an inert atmosphere glovebox. A-102 houses the special projects and does not get used very often, and most of the work completed there could be completed anywhere. It is only used because there is space. The piping and ventilation is mostly in place and would only require minor modifications. The cost includes the waste disposal costs for the special projects glovebox.

**Benefit**

The ability to process samples that are both pyrophoric and reactive would help programs that are requesting the analyses. Installation of the glovebox would increase the capabilities of the analytical laboratory.

**ROM Cost Estimate:** $4.5M.

## 48. Replacement of the AL Thermal Ionization Mass Spectrometer (TIMS)

**Description**

The ability to perform precise and accurate analyses for Material Control and Accountancy (MC&A) samples is a vital part of several processes at MFC. The traditional method of performing those types of measurements at the INL and across the DOE complex is the TIMS. The instruments are simultaneous isotope ratio instruments that use very well characterized spike material (by New Brunswick Laboratory, NBL) and isotope dilution mass spectrometry to perform assays on Uranium and Plutonium. The total assay of a TIMS analyses for U and Pu is < 0.5 %, which is consistent with the international target values.

The current Triton TIMS unit has been in operation since 2009. While the instrument is currently functioning, it is nearing the end of its support from Thermo, the instrument manufacturer. In addition, new advances in detectors, ion optics and filament temperature controls make the current state of the art superior to the currently installed instrument. As the need for improved detection capabilities increases, and multi-laboratory exercises within the DOE complex continue, it is vitally important that the AL have equivalent instrumentation and capability to perform on the same level as the other national laboratories. In addition, for programs that want data consistency, by consistent analyses since the 1980s, it is important to have the TIMS capability available. Hence, the replacement of the Triton TIMS units is necessary.

**Benefit**

The replacement of the TIMS unit will allow for better, timely, and consistent MC&A measurements for U and Pu. Another direct benefit of the addition will be the use of the Triton instrument for method development and fundamental research activities (while the instrument is functioning). The addition of another instrument will give flexibility for research activities that are not currently allowed because the instrument must be maintained for the MC&A activities. These could include advancements in sample introduction, method development for low level detection and modification of ion optics and detector assemblies for improved performance.

**Status:** A rough order of magnitude cost estimate has been developed. Lead time on the instrument is approximately 6 – 9 months after placement of the order.

**ROM Cost Estimate:** $3M.

## 49. Upgrade the Visual Examination Machine (VEM) Camera Controls

**Description**

The Visual Examination Machine (VEM) represents a new in-cell high resolution imaging capability at the Hot Fuels Examination Facility (HFEF). There are currently two controls for the VEM, the camera position (magnification) and the focus, and each is controlled by a momentary switch. To improve the quality and reproducibility of imaging results gathered with this system, it is proposed that the camera controls be upgraded.

The camera in the VEM essentially uses a “prime” lens, which means that the focal length, which determines magnification, is fixed. This means that the size or magnification of subjects is determined by both the distance of the subject in-cell from the VEM feedthrough and where the camera is physically located on its “track” within the VEM feedthrough. The camera magnification momentary switch controls this latter function. The distance to a subject from the feedthrough wall in-cell may be estimated. However, the current controls give no way to determine where on the “track” the camera is located, beyond a lack of movement if the camera is at either “limit” of travel. Given that quantitative analyses is desired from this new system, consistency in imaging is desirable. An upgrade to this control that provides a user with an indication of the current location of the camera within the feedthrough is proposed such that imaging can be conducted at a consistent magnification.

The switch that controls the focus of the VEM camera is coarse while the depth of field, what is in focus, is narrow, resulting in a tedious, iterative exercise to focus the camera on small features (~50 µm in diameter). The control for the focus will be upgraded to include a “coarse/fine” toggle switch to alternate between coarse and fine focusing step sizes.

**Benefit**

This will significantly improve the speed and consistency of focusing the VEM camera. Without an indication of the camera’s position within the feedthrough, magnification can only be consistent by operating at the limits of camera travel, defeating the purpose of having a variable camera position control. Additionally, retaining the current coarse camera focus controls increases the difficulty in focusing on fine features, as the instrument was designed.

**ROM Cost Estimate:** $250K.

## 50. High Capacity, High Temperature Furnace

**Description**

A high capacity and high temperature furnace significantly expands capabilities to process a wide variety of fuel forms. This includes sintering and heat treatment of fuel forms in support of NASA, AFC, and other DOE and industry-driven advanced fuel concepts. Potential fuel forms include UO2 and UZrH (TRIGA).

This furnace has a 1,000 $in^3$ uniform hot zone that can operate at temperatures up to 1,900°C. It can also operate at a variety of atmospheres including vacuum, inert gas, and hydrogen, both flowing and static. This project will install this furnace in AFF with a new glovebox in support of kg to multi-kg scale fuel processing.

**Benefit**

This furnace represents a step change in MFC's capability to sinter, heat treat, and otherwise process fuel for multi-kg and up to LTA-scale fuel fabrication campaigns. This closes a significant gap between MFC's current capabilities and ongoing and upcoming demands from industry, DOE, and other potential partners. This gap is currently leaving MFC behind, failing to capitalize on the other fabrication capabilities, facilities, fuel materials handling infrastructure, and human capital that have been built over decades as the industry strives towards dozens of demonstration reactors that need more fuel than MFC can make.

While the lab-scale powder blending/milling, pressing, and other process equipment is modest in scale, the long cycle times for thermal treatments make a larger furnace the single best way to extend MFCs reputation, build expertise, and position MFC with a minimal but credible demonstration-quantity fuel fabrication capability and support the coming generation of advanced nuclear reactor demonstrations. Notably, such a furnace need only be run a handful of times to capture these benefits of this leap and justify the investment, yet will offer an enduring and unique capability and bridge to an RFRL.

**Facility Risk**

With the growing interest and demand for MFC to fabricate fuel for advanced reactor concepts, current facility capabilities are limited to smaller volume and less capable furnaces. This addition to the FFNMM equipment portfolio would allow for greater throughput with the large internal volume. This has obvious efficiency advantages, but it also will also decrease risks associated with research quality or consistency by minimizing the amount of furnace runs required for a given fabrication campaign. While this furnace provides enhanced capabilities, it could also accept some of the work currently performed in the EFF HDF furnace, thus minimizing single-point-failure risks associated with the HDF furnace.

**ROM Cost Estimate:** $3M.

## 51. EFF Radiological Machining Capability Enhancement

**Description**

This project would upgrade several of the machining capabilities currently located within EFF. EFF has both warm-machining capability to machine fuel-containing specimens, and also hot-machining capabilities to machine fuel specimens themselves. This project would upgrade several pieces of equipment in both the hot-machining and warm-machining areas including: centerless grinder, Trak mill, CNC lathe, and CNC mill.

This upgrade includes removal and disposal of existing equipment, and engineering, installation, and commissioning of the new equipment.

**Benefit**

This represents an important investment in staying current with equipment technology advancements and the growing demand for fuel machining work, which has and will continue to increase in proportion to the demand for nuclear energy. Each of these pieces of equipment serve unique functions that often cannot be substituted for with another piece of equipment or process. Each upgraded piece has specific benefits, but where these capabilities are complimentary, the most benefits are realized upon a significant capability investment. Specific benefits include increased precision and significantly decreased risk of equipment failure or its inability to meet throughput or tolerance requirements. Equipment upgrades also enhance our ability to machine unique geometries and the new technology on equipment allows for more efficient machining operations and tooling changeouts.

This is a substantial upgrade that will help MFC to maintain this important capability to support the current and future portfolio of nuclear fuel R&D needs for nearly all uranium-based reactor fuel concepts ranging from ceramic, to metal, to cer-met fuel forms.

The increased demand on aging equipment that is not duplicated anywhere else at INL leads to significant risk to a wide variety of programs and projects. NASA, AFC, aLEU, multiple ARDPs, LDRDs, and other advanced fuel concepts and their development and production efforts rely upon these machining capabilities to produce or prepare feedstock, interim fuel forms, or process final fuel forms.

The increased demand for fuel machining work has increased throughput thus accelerating machine aging. The precision required of the fuel outputs has also increased, in some cases beyond the ability of the equipment. The failure of any single piece of equipment in this list will have catastrophic effects to at least several programs, which would only be compounded through failure of multiple pieces of equipment.

**ROM Cost Estimate:** $5.5M.

## 52. AFF Weld Characterization Suite

**Description**

This item stages several pieces of equipment in AFF to maximize throughput of projects relying upon the laser welding glovebox located in AFF. This includes mechanical property testing capability, along with additional optical analysis capability of weld samples. A tensile testing system and bend testing system would be located in AFF to qualify weld specimens, and additional microscopy and weld sample preparation equipment would be installed to allow for evaluation of welds during development iterations.

**Benefit**

An increase in ATR and TREAT irradiation tests in support or a wide variety of nuclear fuel systems, both for the current fleet of LWRs and for advanced nuclear reactor concepts, has resulted in a higher demand for specimen assembly via welding. Additionally, materials being welded as part of these efforts has expanded beyond historically standard materials, resulting in increased weld development efforts. These equipment additions would facilitate a significant increase in efficiency by staging all requisite development and qualification equipment adjacent to welding systems. It would also allow for more thorough characterization of weld samples to understand fundamental material behaviors.

The primary risk associated with not pursuing this equipment is related to the timescale to develop adequate welds and the overall quantity of work that can flow through the laser welding system. A robust weld characterization and evaluation capability is the main limiting factor in weld development timelines. Without this equipment in AFF, personnel time is spent performing characterization using less than ideal equipment or at areas outside of MFC.

**ROM Cost Estimate:** $300K.

## 53. FASB Arc Melter Replacement

**Description**

This is a replacement of the arc melting system currently in the RERTR glovebox located in FASB. The arc melting system is in high demand across most metallic fuel programs and is beginning to experience increased component failures.

**Benefit**

A replacement arc melting system would increase the uptime of the system significantly. Obvious benefits of this include high program throughput and decreased worker time spent performing equipment maintenance and repairs, thus reducing unnecessary dose and fatigue.

The current system has experienced a significant number of component failures and at this point, most of the components that are subject to replacement have been replaced. The system is exhibiting initial indications of incipient structural failure. Ongoing component failures waste program resources on failed runs and destroyed samples and have resulted in limited schedule availability dedicated to system repair and re-work instead of research.

**ROM Cost Estimate:** $80K.

## 54. Cold Hearth Furnace

**Description**

This adds capability with a new furnace that would be installed in AFF. The cold hearth furnace allows for crucible-free casting of fuel material that have either high melting points or high potential interaction for standard crucible materials.

**Benefit**

This furnace represents a unique and niche capability to fabricate high-melting point fuel or fuel compositions that otherwise interact with typical crucible materials using existing capabilities. It is particularly ideally suited to high-Zr U-Zr alloys that are otherwise very difficult to fabricate with high purity and represent a notable gap in MFC's metal fuel capabilities. This capability would offer new and unique research opportunities to broaden MFC's and the industry's fuel composition portfolio.

This furnace would expand MFC metallic fuel fabrication capabilities beyond those that currently exist. Continuing to operate with the existing metallic fuel fabrication capabilities results in limitations on accepting work associated with high melting point fuels.

**ROM Cost Estimate:** $1M.

## 55. AFF Envelope Pycnometer

**Description**

An envelope pycnometer would be installed in AFF in support of particle size characterization. This pycnometer fills a gap by adding capability to measure density of samples containing >5% porosity and of irregular geometry.

**Benefit**

This pycnometer complements the existing He pyrometer and offers density measurement capability in AFF, reducing sample transfer requirements. Density is a critical parameter in fabricating ceramic and additive materials, however not samples are amenable to accurate geometric density measurements (e.g., SNP fuel) and He pycnometry can falsely report very high density in samples that are actually porous, an error of physical parameter conflation that can be difficult or impossible to reconcile ex post facto.

This capability fills a gap that currently exists at MFC in characterization of feedstock powder. Not addressing this gap increases R&D risks associated with powder-based fuel systems as feedstock cannot be fully characterized, potentially leading to development or qualification challenges.

**ROM Cost Estimate:** $75K.

## 56. AFF Muffle Furnace

**Description**

This furnace operates at a range from 800°C to 1200°C with an air or inert gas atmosphere and will be used to bakeout ceramic binders, resins, or other processing materials used in various fuel fabrication processing schemes. This furnace allows for an intermediary step before additional specimen processing in a high temperature furnace, which protects the insulation components, heating elements, and other components of the high temperature furnace from damage from specimen off-gassing.

**Benefit**

This muffle furnace benefits the longevity of high temperature furnaces through preventing their exposure to processing materials that are burned out of fuel specimens during their sintering or processing. Maintaining these high-temperature furnaces that are required for final fuel processing in as pristine of a condition as possible also ensures the highest quality of R&D throughput and minimizes risk of performance issues during processing large batches of fuel specimens.

The addition of a muffle furnace to AFF decreases risk of damage to high temperature furnaces by allowing an intermediary bakeout step in a furnace designed to accommodate offgassing. The risk of a fuel fabrication scheme that does not include this furnace is damage to the heating elements, insulation, or other components of the more precise and sensitive high temperature furnaces necessary for sintering or other final processing of fuel forms.

**ROM Cost Estimate:** $400K.

## 57. High Capacity Press

**Description**

This multi-station, hydraulic-actuated, numerically encoded press supports rapid and consistent pellet pressing in multi-kg batch sizes. This high-capacity press serves as a complimentary capability to the numerous furnaces being installed, or proposed, to expand our capacity.

**Benefit**

The primary press supporting pellet fabrication efforts is staged in the HDF glovebox within EFF and is only capable of pressing a single pellet at a time after manually loading powder into the die. This high capacity press would allow for an order of magnitude increase in pellet pressing throughput over the current press in the HDF glovebox in EFF.

The primary risk of not increasing pelleting capabilities is the limited throughput and consistency of pellets pressed using the system currently in the EFF HDF glovebox. This results in the inability to produce high quantities of pellets (i.e., LTR or LTA quantities) in support of advanced nuclear fuel applications in a timely manner.

**ROM Cost Estimate:** $1.5M.

## 58. FASB SEM Light Element Analysis Capability

**Description**

A new advanced EDS detector with a spatial resolution of 10 nm and that can detect light elements such as nitrogen and lithium would be installed on the SEM in FASB. The current detector in FASB fails to be able to quantify light elements and create such high spatial resolution. The proposed detector improves sensitivity to low energy x-rays by 10x the current detector. It is also compatible with existing software optimization to correct for peak overlap and improve accuracy. Due to the short working distance this detector provides, it can collect EDS data at very low voltages which also reduces sample damage. This detector is compatible with the current SEM and software in FASB

**Benefit**

Currently, FASB has no capabilities to detect light elements in samples. This limits the ability to study ceramic fuels, waste forms, oxidation, and contaminant elements. With the Ultim Extreme EDS detector, light elements and small sample features can be evaluated easily and quickly within the same facility. This speeds up the manufacturing research and reduces labor costs

**ROM Cost Estimate:** $150K.

## 59. FASB Optical Microscope Replacement

**Description**

A new optical microscope would replace the aging Zeiss inverted microscope in FASB. This new optical microscope would include multiple lenses that support enhanced material optical microscopy.

**Benefit**

The Zeiss inverted optical microscope in FASB has outlived its useful life. As an older piece of equipment, vendor support is limited, along with the microscope capability and reliability. This replacement system would provide a robust optical microscope system in FASB in support of the wide variety of optical analyses performed by a multitude of programs. This capability is necessary to perform basic sample analysis and compliments SEM analysis as well. This new microscope would increase image quality both in resolution and ability to perform detailed analyses, as well as, increase the ability to perform quality significant measurements.

The risk of not replacing the current optical microscope in FASB is related to image quality and also overall system uptime. Not having access to a reliable optical microscope in FASB would require samples be transferred to other labs for analyses, essentially straining equipment that is not used to its full potential in these alternate locations.

**ROM Cost Estimate:** $150K.

## 60. FASB HIP Upgrade

### Description

This item upgrades the current IPS Hot Isostatic Press (HIP) located in FASB. The existing system has outlived its useful life and is in need of significant repair to make it operational. This item replaces the HIP with a new unit, including removal and disposition of the existing system. This work is supported by aLEU as part of the programs fuel development efforts.

### Benefit

The HIP currently in FASB is not operational, and there are no other HIP systems at MFC. This item adds hot isostatic pressing as a capability to the MFC fuel fabrication portfolio.

**ROM Cost Estimate:** $700K.

## 61. Replace IMCL SEM 7600

### Description

For post irradiation examination (PIE), a high-resolution analytical SEM (Scanning Electron Microscope) is essential for bridging the information gap between the typical metallograph (from HFEF) and atomic scale resolution instruments such as atom probe and transmission electron microscope in IMCL. The SEM in IMCL is an integral part of the PIE characterization instrument suite for achieving important MFC missions such as nuclear fuel development/qualification and irradiated material performance evaluation. Several major DOE programs, including the United States High-Performance Research Reactor project (USHPRR), NSUF, AFCI, as well as industrial users such as Westinghouse and TerraPower, rely on this SEM for their microstructure characterization and chemical analysis needs. The current SEM in IMCL (JEOL JSM-7600F) has been utilized extensively and has exceeded the typical ten-year service life (11 years as of July 2022). The vendor no longer produces spare parts for the current instrument and has warned that if a major breakdown happens, replacement parts may not be available (i.e., on the JEOL legacy instrument list). The vendor also has the right to reject the service contract renewal simply based on their business considerations. A new unshielded EPMA will ensure that the IMCL (and INL) continues to provide governmental and industrial users uninterrupted support for their irradiated material characterization needs. This new EPMA will provide basic SEM functions to meet programmatic needs, and also has the abilities to detect and quantify light element analysis (e.g., Li, Be, B, C) that are critical for battery research and nuclear fuel qualifications.

### Benefit

This instrument supports major programs from different DOE offices such as NE (FCRD, AGR, NSUF, LDRD), NNSA (USHPRR), Office of Science (TETI), and industrial projects such as Natrium. A reliable, uninterrupted SEM service at IMCL will ensure these programs meet their PIE mission needs and accomplish their milestones in a timely manner.

The current instrument is near end-of-life (11 years old, on the JEOL legacy instrument list) and experiencing a decrease in availability due to maintenance and stability issues. It is one of the heavily utilized instruments at IMCL and will have a significant impact on all major programs if it breaks. The whole replacement process (including biding, ordering, manufacturing, delivering, installing, performance accepting, procedure approving, and operator training) typically takes at least 6 months (for example, it took more than 9 months for the recent Focus Ion Beam (FIB) replacement process in EML).

**ROM Cost Estimate:** $2.5M.

## 62. Replace IMCL Shielded Ga FIB

**Description**

The IMCL Shieled Ga FIB is one of the most critical and utilized instrument for every program. It is primarily used to conduct sample preparation for TEM and APT, and micromechanical testing. The service contract expires in 2023, and there will be no parts or power supply available afterwards.

**Benefit**

The Ga FIB is a critical instrument for all programmatic work at IMCL.

Failure to replace this instrument will have detrimental impact on all programs, and all subsequent characterization and testing such as TEM, APT, micromechanical testing may be stopped.

**ROM Cost Estimate:** $2.5M.

## 63. IMCL Simultaneous Thermal Analyzer (STA) Mass Spectrometer (MS) Replacement

**Description**

Throughput of measurements has drastically increased in the previous FYs. The rapid pace of measurement leads to significant exposure to radiation to the instrument components. Additionally, we expect higher burnup samples in the future, which will accelerate the degradation of instrument components. The STA instrument has modular components designed for replacement due to the high radiation fields it is exposed to. The primary failure modes include the mass spectrometer and components related to the furnaces experiencing radiation damage, individual component failures will occur as soon as 2023, and are expected to occur continuously on a 2-year basis going forward.

Funding requested for this instrument will be used to replace the Mass Spectrometer and/or related components (currently the mass spectrometer is out of service), a mission critical component that allows the measurement of fission product release in heated fuel samples.

**Benefit**

The STA at IMCL is one of the premier instruments at INL for engineering scale measurement of specific heat and mass spectrometry of irradiated fuel materials. The hot cell STA is uniquely suited for measurement of one of the important thermal properties used for qualifying new and existing nuclear fuels. The measurements from the Differential Scanning Calorimeter are used to determine the specific heat of the fuels, which informs our understanding of the thermal diffusivity and thermal conductivity of the fuel as it’s temperature changes, an important quantity to understand for fuel qualification and performance modeling. The mass spectrometer is an important instrument for determining what elements are released as the temperature of irradiated nuclear fuels changes – giving information for how safely the fuel operates in nominal and adverse conditions. There are no backup instruments at MFC for measuring the engineering scale thermal properties of irradiated nuclear fuel, making the continued performance of the STA mission critical.

Without these upgrades to the STA components their continued use will cause significant increases in uncertainty of measurements and will leave the instruments inoperable. The requested use of the STA is continuing to increase as it is uniquely capable of critical measurements for nuclear fuel design and qualification. Given the expected increase in nuclear fuel research, we must upgrade the instruments to match current demand increases and prepare these instruments for the future to keep up with future demand.

**ROM Cost Estimate:** $300K.

## 64. IMCL Thermal Conductivity (and Diffusivity) Microscope (TCM) Upgrade

### Justification

High throughput of samples with an increase in measurements and improvement in data collection techniques have led to longer, unavoidable radiation exposure times for the instrument. Many components have suffered radiation damage which reduces the sensitivity of the instrument. Currently the thermal conductivity measurements are inaccurate due to the accumulated radiation damage. Multiple components need to be upgraded to return the TCM back to original specifications. Additionally, shielding for the instrument and samples to reduce radiation exposure for the TPC and TCM will be implemented.

The software used for the TCM was designed in lab along with the instrument and is severely outdated. There are multiple bugs and flaws in the software that have been found to slow down operation of the instrument. If the instrument is to keep up the current pace of measurements and adjust to the increased amount of projects interested in use of its measurements, it will need to be brought up to date with modern programming and operational standards.

The other instruments located in the TPC – the LFA and STA – are capable of providing measurements at different temperatures using furnaces. However, for the TCM is currently only capable of measurements at room temperature at the moment, despite being designed with heated measurements in mind. To address this, it will be necessary to implement a heating stage in the TPC, which will require safety reviews.

Funding will be used to replace critical components to restore the TCM to full operation along with additional protection from radiation. Due to the open nature of the TCM configuration, samples contribute significantly to the TPC background radiation dose rate. To reduce exposure of personnel, it is best to implement shielding partially isolating the instrument from the TPC. The software for the TCM is outdated, which limits the capabilities of the instrument and the speed of data analysis. To improve throughput and data analysis quality on the TCM, it is necessary to spend time bringing the software up to modern standards. Finally, the heating stage needs to be tested and needs to pass a Management Safety Assessment.

### Benefit

The TCM at IMCL is the primary instrument at INL for engineering scale measurement of irradiated fuel materials. The TCM at IMCL in the TPC confinement is uniquely suited for localized spatial measurement of the microstructural thermal properties used for qualifying new and existing nuclear fuels. The thermal conductivity and thermal diffusivity measurements dictates the critical fuel safety margins including the fuel centerline temperatures. Additionally, the thermal diffusivity and thermal conductivity measurements are used to determine fission gas swelling, release and rod pressurization – all of which are critical to the operation of nuclear fuel rods. There are no backup instruments at MFC for measuring the microstructural scale thermal properties of irradiated nuclear fuel, making the continued performance of the TCM mission critical.

Without these upgrades to the TCM, its continued use will cause significant increases in uncertainty of measurements and will leave the instrument inoperable. The requested use of the TCM is continuing to increase as it is uniquely capable of mission critical microscale measurements of thermal diffusivity and thermal conductivity for nuclear fuel design and qualification. Given the expected increase in nuclear fuel research, we must refurbish and improve the instrument to match current demand increases and prepare these instruments for the future to keep up with future demand.

**ROM Cost Estimate:** $350K.

## 65. IMCL Laser Flash Analyzer (LFA) Laser and Power System Replacement

### Description

The laser flash analyzer is one of the most well-renowned instruments in IMCL, used for bulk measurement of thermal diffusivity of irradiated samples. The LFA has very high throughput of sample measurements and produces consistently reliable results. However, these measurements require the detector to be exposed to the full surface of irradiated samples with little protection. The high individual sample radiation fields and throughput of samples in the LFA is leading to an increase in radiation exposure from previous years. The laser and power components are experiencing declining sensitivity, with individual component failures occurring as soon as 2023, and are expected to occur continuously on a 2-year basis.

Funding for this instrument will be used to purchase a replacement for the vital laser and power systems. Without these components the instrument will be nonfunctional, as such these components are of the highest priority. The funding will also be used for the installation of the new systems and obtaining the necessary vendor support.

### Benefit

The LFA at IMCL is uniquely suited for measurement of the most important thermal properties used for qualifying new and existing nuclear fuels. The thermal diffusivity measurements from the LFA are used to dictate the critical fuel safety margins including the fuel centerline temperatures. Additionally, the thermal diffusivity measurement and resulting thermal conductivity calculations are used to determine fission gas swelling, release and rod pressurization – all of which are critical to the operation of nuclear fuel rods. There are no backup instruments at MFC for measuring the engineering scale thermal properties of irradiated nuclear fuel, making the continued performance of these instruments mission critical.

Without these upgrades to the LFA laser components their continued use will cause significant increases in uncertainty of measurements and will leave the instruments inoperable. The requested use of the LFA is continuing to increase as it is uniquely capable of mission critical measurements for nuclear fuel design, qualification, and performance modeling. Given the expected increase in nuclear fuel research, we must upgrade the instruments to match current demand increases and prepare these instruments for the future to keep up with future demand.

**ROM Cost Estimate:** $250K.

# 66. Analytical Lab Laser Flash Analyzer (LFA) Laser and Power System Replacement

**Description**

The laser flash analyzer is one of the most well-renowned instruments in IMCL, used for bulk measurement of thermal diffusivity of irradiated samples. The LFA has very high throughput of sample measurements and produces consistently reliable results. However, these measurements require the detector to be exposed to the full surface of irradiated samples with little protection. The high individual sample radiation fields and throughput of samples in the LFA is leading to an increase in radiation exposure from previous years. The laser and power components are experiencing declining sensitivity, with individual component failures occurring as soon as 2023, and are expected to occur continuously on a 2-year basis.

Funding for this instrument will be used to purchase a replacement for the vital laser and power systems. Without these components the instrument will be nonfunctional, as such these components are of the highest priority. The funding will also be used for the installation of the new systems and obtaining the necessary vendor support.

**Benefit**

The LFA at IMCL is uniquely suited for measurement of the most important thermal properties used for qualifying new and existing nuclear fuels. The thermal diffusivity measurements from the LFA are used to dictate the critical fuel safety margins including the fuel centerline temperatures. Additionally, the thermal diffusivity measurement and resulting thermal conductivity calculations are used to determine fission gas swelling, release and rod pressurization – all of which are critical to the operation of nuclear fuel rods. There are no backup instruments at MFC for measuring the engineering scale thermal properties of irradiated nuclear fuel, making the continued performance of these instruments mission critical.

Without these upgrades to the LFA laser components their continued use will cause significant increases in uncertainty of measurements and will leave the instruments inoperable. The requested use of the LFA is continuing to increase as it is uniquely capable of mission critical measurements for nuclear fuel design, qualification, and performance modeling. Given the expected increase in nuclear fuel research, we must upgrade the instruments to match current demand increases and prepare these instruments for the future to keep up with future demand.

**ROM Cost Estimate:** $250K.

# 67. IMCL TPC shielding for reducing exposure to personnel

**Description**

The due to the high concentration of instruments in the cell and the engineering scale measurements performed in the TPC there is a nearly constant high radiation background in and around the cell. To address this, we want to implement intracell shielding that will allow modular separation of instruments during measurements. This will reduce effective dose to instrument scientists and operators, as well as protect instruments from radiation fields that can lower the instrument lifespan. The funding will be used to request engineer designs for shielding that can be moved using manipulators, and to fund the purchase and installation of the solution.

**Benefit**

This will reduce effective dose to instrument scientists and operators, as well as protect instruments from radiation fields that can lower the instrument lifespan.

**ROM Cost Estimate:** $100K.

## 68. User-facility Data Analyses Station for FIBs, SEM, TEM, XRD, PGS, Thermocalc, and Aviso license

**Description**

Data and imaging processing require licensed software and high-speed computing resources. As the PIE users continue to grow, the availability licenses and computational resources become very limited. It is more efficient to establish a center stations with high speed computing clusters and all licensed software to perform data and imaging analysis. This center station can be linked to the center data storage for rapid data transfer and reduction.

**Benefit**

The center station will provide better user experience and will reduce cost to purchase individual licenses and computers.

**ROM Cost Estimate:** $400K/year initial, then $100K/year.

## 69. Remote Control and Advanced Data Analytics for PIE and Advanced Characterization

**Description**

Advanced characterization of irradiated nuclear fuel, cladding, and structural materials creating valuable microscopy and spectrum data collected at a speed of ~ 10 gigabytes every day. Enormous amount of information is stored in the collected data, but the full usage of data remains yet to be achieved. The analyzing capability is significantly limited by the time and resource of staff scientist and the efficiency of data transfer and management. Utilization of machine learning and artificial intelligence models will increase the efficiency of data collection, boost the security of data management, and enhance data analysis efficiency. Most importantly, with the involvement of experience research staff at INL, Machine Learning and Artificial Intelligence models will provide quantitative and unbiased assessment of nuclear material's behavior.

**Benefit**

Remote Control and Advanced Data Analytics will put INL at the cutting edge for nuclear fuel and materials development and qualification. While other national laboratories are actively investigating the application of ML/AI models into their daily operation, INL will lose the advantages on nuclear materials research if such capabilities are absent. All the science programs including the emerging capabilities INL is trying to establish will have significant setbacks.

**ROM Cost Estimate:** $3-5M.

## 70. Replace IMCL Shielded Electron Probe Microanalyzer (EPMA)

**Description**

An electron probe microanalyzer (EPMA) shielded to 3 Ci of 0.75 MeV is integral to post irradiation examination of highly irradiated fuels and other reactor materials. The demand for the present shielded EPMA is such that the instrument is already booked out for the next 14 months – into February 2024.

INL is unable to meet this demand because of the current shielded EPMA is not reliable, having been down 50% of CY 2022. A new shielded instrument is sought to provide irradiated fuel analysis for Natrium, NSUF, AGR, BANR, LDRD, and other programs projected to have future quantitative post-irradiation examination needs. This capability will replace the current shielded EPMA, and to the extent possible, interface with the present glovebox and external shielding system. No service contract will be provided for the current EPMA after 2030. Giving the long lead time to install a shield EPMA, the acquisition should start as early as FY-25.

**Benefit**

EPMA is an essential instrument to generate qualitative chemical composition and fission product data to support nuclear fuel qualification. Due to the current EPMA's unreliability, it is impossible to assure a client or program that milestones can be met, or to secure new work, because we cannot promise that we can deliver. Additionally, parts for the current EPMA are not guaranteed to be available beginning in 2030. Failure to replace this instrument will likely result in the loss of significant programmatic funding, external funding, and will be a vital capability that INL will have lost.

**ROM Cost Estimate:** $6M.

## 71. IMCL LEAP5000 APT Major Components Replacement

**Description**

The major components such as laser source, power supply, and detection system for LEAP5000 needs to be replaced typically every 4 years.

**Benefit**

The IMCL LEAP5000 system is the most advanced APT used for nuclear fuel and materials research, and is being utilized nearly 100%, supporting all science programs and NS&T programs. Any failure of those components may cause the system inoperable for a significant period of time, and the impact to programs cannot be recovered.

**ROM Cost Estimate:** $500K.

## 72. Replace IMCL Shielded G3 PFIB

**Description**

The IMCL Shieled G3 PFIB is recognized by everyone at INL as the most critical and utilized instrument for nuclear fuel and materials research for every program. It is primarily used to conduct sample preparation for TEM and APT, and used as SEM with analytical capabilities such as EDS and EBSD for highly irradiated fuels and materials. The service contract is expected to continue at least 5 years to 2027. After that, we need to replace this PFIB with a new PFIB. In addition, this is one of its kind instrument used for highly irradiated nuclear fuel and materials research, and the impact of radiation on its lifetime can't be accurate estimated.

### Benefit

The IMCL Shielded G3 PFIB is recognized by everyone at INL as the most critical and utilized instrument for nuclear fuel and materials research for every program. Failure to replace this instrument is not acceptable as it will have detrimental impact on all programs for INL.

**ROM Cost Estimate:** $2.5M.

## 73. IMCL ZEISS X-ray Microscope X-ray Source Replacement

### Description

The X-ray source typically lasts about 5 years so it is due replacement in FY-28. The X-ray microscope is expected to be operated and serviced until FY-32. INL's current ZEISS 520 Versa X-ray microscope (XRM) provides spatially-resolved 3D imaging of internal defects, inclusions, cracks, and voids. By investing in this capability, INL has been able to provide critical 3D, nondestructive information for both internal and external R&D programs that would otherwise require destructive characterization methods.

### Benefit

The ZEISS Versa XRM in IMCL has been used to image a variety of nuclear fuel and materials, such as U-10Zr, U-10Mo, TRISO, SiC cladding, graphite, and a variety of non-nuclear materials such as bio-fuels, batteries, fossils, coal, etc. It is one of most advanced PIE technique IMCL developed in the past couple years, leading the NDE community for fuel PIE. If not funded, the x-ray source may be serviced by the vendor and if it fails all program work has to stop and the lead time to procure a new x-ray source may take up to 12 months.

**ROM Cost Estimate:** $500K.

## 74. PI-98 Nanoindenter Upgrade for Micro-mechanical Testing for IMCL

### Description

PI89 gives us future access to XPM (high speed indentation), SPM imaging, 1000C high temperature heating stage, advanced Rotation/Tile stage, and 3.5N high load stage (sold separately based on our need in future). The upgrading to pi89 takes $68,360. Pi88 and pi89 share several core components. The upgrade could build our nanoindenter into a multifunctional platform.

### Benefit

This new nanoindenter will replace the current PI-85 and all programs will benefit from the high throughput characterization and expanded temperature testing range.

**ROM Cost Estimate:** $70K.

# 75. IMCL TITAN TEM 4D STEM Detector Upgrade

**Description**

The characterization of atomic point defect and associated strain of crystal lattice is essential to understand the irradiation and materials degradation mechanism. The current STEM capability at Titan instrument can't deliver such knowledge due to instrumental and detection limitations. The scanning electron nanobeam diffraction technique, also known as 4D-STEM, coupled with atomic resolution high angle annular dark field (HADDF) STEM imaging capability at Titan will allow the mapping of point defects and accurate measurement of lattice strain at atomic resolution. Furthermore, the data collection efficiency of 4D-STEM will generate a large amount of experimental data, if coupled with machine learning/artificial intelligence modeling, 4D-STEM will allow fast assessment of radiation damage on nuclear materials.

**Benefit**

This capability will allow the mapping of point defects and accurate measurement of lattice strain at atomic resolution and couple with ML/AL for high throughput fuel performance assessment. Both PNNL and ORNL are maturing in the application of 4D-STEM in the field of nuclear materials research. Failing to invest in this dynamic and developing capability will impact INL advanced characterization, program work and scientific research.

**ROM Cost Estimate:** $500K.

# 76. High Temperature Laser Flash Apparatus

**Description**

The nuclear fuel community need thermophysical property data at a very high temperature range such as thermal conductivity, capability, emissivity, and melting point.

**Benefit**

Benefit for major programs cannot be realized, such as ATF and space reactor fuels.

**ROM Cost Estimate:** $600K.

# 77. Micro-XRD Analyses Upgrade

**Description**

The chemical and structural change of nuclear fuel and reactor cladding materials tend to be heterogeneous in very small scales, on the order of micrometer and nanometer. High-quality observations of these micro-features are critical to nuclear technology development and nuclear safety. Microbeam techniques such as the Transmissive Electron Microscopy (TEM) helps with our understanding of these heterogeneity at the scale of a few nanometer to 20 micrometer, while bulk X-ray Diffraction (XRD) analysis (what we are equipped with at IMCL and FASB currently) provide information at the scale of 10-15 millimeter. There is a lack of analysis capability at INL for obtaining chemical and crystal structural information the range of 100 micrometer to 5 millimeter, which is critical to a whole-picture understanding of nuclear materials.

**Benefit**

The proposed additional of microbeam capability on the XRD will be able to provide high resolution structural and chemical information of nuclear materials at 100um to mm range. With the ongoing development to analyze irradiated fuel samples at high-temperature in-situ on the XRD, micro-beam capability will enable analysis of regional phase and structural transition during the high-temperature experiments. This capability is not available in any other research laboratories in North America. Therefore, this upgrade will strengthen our capacity as a user facility, as well as better facilitate the cutting-edge research that is critical to the innovation of nuclear technology that is much needed in our rapidly changing world.

**ROM Cost Estimate:** $100K.

## 78. Atomic Force Microscope (AFM)

**Description**

There has been increasing interest to study the surface science of nuclear materials. Because most material degradation initiates at the surface of a material, it is incredibly important to understand how these processes occur at the outermost atomic layers of the surface. This field of study has historically been very underrepresented in the field of post-irradiation examination. Within the U500 division we realized this and started to initiate a program in surface science. To advance this program a base set of instrumentation is needed and one of these is an atomic force microscope (AFM). An AFM is capable of imaging material surface topography by rastering a probe over the material. In this way it generates a 3D image of a materials outermost surface with a lateral resolution down to the atomic scale. In addition to topography there are many other modes of operation that can provide information on a materials surface electronic, magnetic, thermal, and mechanical properties within a single instrument. The addition of this instrument to INL will put us in a unique position to provide first of a kind measurements on fundamental mechanisms of material degradation at surfaces. These measurements will be of tremendous importance to the development of advanced reactors, where materials will be subjected to new environments and degradation mechanisms may change.

**Benefit**

With the increased rate of development of small modular and micro reactors this AFM capability is very important. Without this instrument INL will be lacking in its ability to provide data on material degradation at surfaces. This instrument will help jump start INL in the field of surface science as applied to irradiated material.

**ROM Cost Estimate:** $1M.

## 79. HC#6 Glovebox ICP-AES

**Description**

The Analytical Research Laboratory (ARL) purchased and installed a replacement Teledyne Leeman Labs Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) glovebox system in FY19. The instrument purchased and installed was “like for like” replacing the original install dating from approximately 2008. The glovebox is a harsh environment for the instrument to operate in. The original install began experiencing issues in approximately 2017 resulting in frequent failures preventing sample analysis. Failure to maintain the ICP-AES glovebox system makes the lab vulnerable to loss of sample throughput, which in turn affects several programs at the INL. With this knowledge, the ARL anticipates needing to replace the glovebox ICP-AES within the next 5 – 6 years.

### Benefit

Purchase and install of a new ICP-AES glovebox system will ensure the latest technology is incorporated into the instrument and allow uninterrupted processing of samples using this capability. A “like for like” replacement instrument ‘s lead-time for manufacture, test, install, and startup is 8 – 10 months. Replacement prior to intermittent failure will allow continuous reliable functionality and reduce the risk of irreparable issues occurring that impact programmatic needs.

**ROM Cost Estimate:** 1M.

## 80. ICP-ToF-MS

### Description

The ARL purchased and installed a TOFWERK GmbH Time-of-Flight Mass Spectrometer (ICP-ToF-MS) in FY19. Where typical mass spectrometers must calibrate in different mass ranges, the ICP-ToF-MS simultaneously measures all isotopes. This enhances sample throughput and decreases sample preparation; analysis times and produces less waste.

Currently, the ARL has coupled the ICP-ToF-MS with LA-LIBS. The laser ablates a material of interest to generate a plasma plume. ARL researchers then use argon as a sweep gas to carry the plume to the ICP-ToF-MS for isotopic analysis.

To mitigate negative impacts to programs the ARL has a replacement schedule for this instrument. Deferring replacement will increase risk of instrument failure. Maintaining this capability in the ARL is critical to meeting programmatic needs and a leading role in nuclear research.

### Benefit

The ICP-ToF-MS instrument records a complete mass spectrum that doesn’t miss an analyte or interference signal. The instrument is high resolution allowing for separation of interfering ions. The ICP-ToF-MS has a robust sample introduction interface allowing for multiple sample introduction techniques. In addition to the LA-LIBS, the ICP-ToF-MS can also couple with gradient polymer elution chromatography (GPEC), multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS), high-performance liquid chromatography (HPLC), etc., enhancing the R&D capabilities of the ARL. Surface profiling using the LA-LIBS as the sample source to the ICP-ToF-MS gives information on homogeneity of how the composition of a substance varies by depth.

**ROM Cost Estimate:** 1M.

## 81. Single Quadrupole ICP-MS

### Description

The Analytical Research Laboratory (ARL) purchased and installed two PerkinElmer single quadrupole Inductively Coupled Plasma Mass Spectrometers in FY21. The ICP-MS is the most requested sample analysis capability by programs sending samples to the ARL for analysis. Most samples processed through an ICP-MS instrument require only a bench-top configured instrument. However, approximately 10% require more robust containment such as an instrument coupled with a fume hood or physically located within a fume hood environment. Therefore, the first instrument was installed in a bench-top configuration and the second was placed into an oversized fume hood. Given the volume of samples processed using the ICP-MS instruments, the instruments begin to experience intermittent failures. The ARL anticipates the need to replace the individual ICP-MS instruments every 8 – 10 years due to obsolescence of components, user interface software becoming unsupported and/or because of heavy use of the instrument. Currently there is redundancy in this capability allowing for a staggered replacement schedule.

**Benefit**

Purchase and install of a new ICP-MS instruments will ensure the latest technology is incorporated into the instrument and allow uninterrupted processing of samples using this capability. Maintaining this capability in the ARL is critical to meeting programmatic needs and a leading role in nuclear research.

**ROM Cost Estimate:** 1M.

## 82. LA-LIBS

**Description**

The ARL purchased and installed an Applied Spectra Laser Ablation-Laser Induced Breakdown Spectrometer (LA-LIBS) in FY19. The LA-LIBS is capable of isotopic and elemental surface profiling of irradiated fuels and cladding. ARL researchers designed a sealed sample chamber allowing the instrument to be installed and operated on a bench top with connection to suspect exhaust.

Currently, the ARL has coupled the LA-LIBS with ICP-ToF-MS. The laser ablates a material of interest to generate a plasma plume. ARL researchers then use argon as a sweep gas to carry the plume to the ICP-ToF-MS for isotopic analysis.

To mitigate negative impacts to programs the ARL has a replacement schedule for this instrument. Deferring replacement will increase risk of instrument failure. Maintaining this capability in the ARL is critical to meeting programmatic needs and a leading role in nuclear research.

**Benefit**

Surface profiling using the LA-LIBS as the sample source to the ICP-ToF-MS gives information on homogeneity of how the composition of a substance varies by depth. Additionally, the LA-LIBS system allows for a near layer-by-layer reconstruction be performed and compared to theoretical gas generation predictions that are currently utilized by reactor design models. The LA-LIBS provides an expanded capability for nuclear research programs and avenues for INL research publications.

**ROM Cost Estimate:** 1M.

## 83. Plasma 3 MC-ICP-MS

**Description**

The Analytical Research Laboratory (ARL) purchased and installed a Nu Instruments, LLC Plasma 3 Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS) in FY19. The Plasma 3 instrument was installed in room B-159 with a fume hood interface. These instruments have an approximate 8 – 10-year life expectancy. Technology advancements rapidly make the instruments obsolete. As the instrument ages there is risk of increased downtime for repairs because parts become difficult to find and interface software being no longer supported. To mitigate negative impacts to programs the ARL has a replacement schedule for this mission critical instrument. Maintaining this capability in the ARL is critical to meeting programmatic needs and to maintain a leading role in nuclear research.

**Benefit**

Purchase and install of a new MC-ICP-MS will ensure the latest technology is incorporated into the instrument and allow uninterrupted processing of samples using this capability. A replacement instrument's lead-time for manufacture, test, install, and startup is 12 – 18 months. As the current multi-collector reaches end-of-life, having the ability to operate both instruments at the same time gives ARL research personnel opportunity to qualify the new instrument prior to taking the old out-of-service.

**ROM Cost Estimate:** 2M.

## 84. Gas Chromatograph

**Description**

Gas chromatography (GC) coupled with a range of possible detection techniques, such as thermal ionization, flame ionization, and mass spectrometry, provides the ability to measure gaseous elements and compounds, as well as volatile liquids and solutions of solids. GC instrumentation is standard in most analytical laboratories and provides access to measurements currently outside the capabilities of the Materials and Fuels Complex Analytical Laboratory (AL). The GC chromatograph consists of one or more coiled separations columns that are housed in an oven providing the temperature control necessary to fine tune separations and maintain the gaseous state of the species under investigation. The columns themselves are highly customizable, also contributing to the ability of GC to effect difficult separations. The separated analytes, as they elute from the column, are then identified and characterized by the detection techniques mentioned above.

**Benefit**

The AL currently operates a high-resolution gas mass spectrometer (GMS), some of whose functions overlap with those of a GC. There are some important differences, however, that make having both types of instruments advantageous. For example, the GMS requires an additional, expensive heated inlet system for the measurement of volatile liquids, and the introduction of these types of samples presents technical challenges. On the other hand, rapid introduction of volatile liquids to a GC is straightforward because of its simple oven apparatus and preheated columns. Furthermore, the measurement of solutions containing solids with molecular masses up to c. 300 daltons is possible in GC instruments but not possible for the GMS. The ability to measure such solutions provides a powerful tool that the AL does not currently possess for the characterization of small molecules. The ability to measure small molecules by GC opens opportunities for collaborations on research and development on speciation studies, particularly pertaining to the complexation of actinide elements critical for environmental remediation and decontamination efforts.

Measurement of species in the GC mass range fills a gap in capability between atomic species, currently measured by a suite of inductively-coupled-plasma (ICP) instruments in the AL, to molecules heavier than 300 daltons, which are able to be characterized by the AL's high performance liquid chromatograph (HPLC).

**ROM Estimated Cost:** $400K.

# 85. MKS VISION 2000-P XD

### Description

The MKS model Vision 2000-P XD is a high sensitivity, low resolution gas mass spectrometer. This spectrometer is a compact piece of equipment which utilizes the small size of a quadrupole and its oscillating electric fields to quickly separate gas ions based on their mass to charge ratio. This technology is robust and has been well developed within the field of analytical chemistry. With a minimal power requirement and lack of moving parts, the instrument is mounted on a mobile cart and can be moved to a process or gas source requiring analysis with minimal efforts.

### Benefit

The combination of mobility and gas analysis capabilities is something that the Analytical Laboratory has not previously possessed. A mass range of 1-300amu and ppb detection levels make this an ideal instrument for analysis of noble gases such as xenon and krypton. A mass unit resolution will allow for isotopic analysis of these gases and is a complementary method to the newly installed gas chromatograph in the AL. An eleven order of magnitude detection range gives the instrument the flexibility to measure pure gases as well as sub-ppm impurities and a 10-150torr inlet pressure range gives it similar sampling capabilities to previous gas instrumentation in the AL.

**ROM Estimated Cost:** 100K.

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# Appendix D

# Detailed Descriptions of TREAT Instrument Capability Activities

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# 1. Transient Testing Experiment Preparation and Handling

**Description**

TREAT experiment vehicles are complex systems that require dedicated equipment to support assembly and checkout, post-test disassembly characterization of low-activity experiments, preparation of high-activity experiments for transfer to INL PIE facilities, and remote loading and assembly of experiment vehicles in the Hot Fuel Examination Facility (HFEF).

Repurposing of and modifications to the TREAT Warehouse (MFC-723) are underway to establish the TREAT Experiment Safety Building (TESB), co-located adjacent to the TREAT Reactor Building (MFC-720), ideal for cross-cutting TREAT experiment support. TESB facility projects include:

- Installation of a building HVAC system and sealing of building doors to provide building climate control for year-round use and to reduce dust entry into the facility
- Reinforcing selected locations on the building floor (a concrete slab), construction of a separately ventilated confinement room for installation of heavy equipment, and establishment of the TESB as a Hazard Category 3 nuclear facility, to allow experiment preparation with previously irradiated fuel rods.

TREAT experiments continue to grow more complex, as expected, and require specialized skills and equipment for assembling experiment vehicles. Experiment assembly and disassembly equipment is proposed to be acquired in a manner to add increasing functionality at the times when developing experiment programs will need it. Specific equipment acquisitions proposed for multi-mission experiment capability include:

- Procurement and placement of equipment needed for simple experiment assembly of fresh fuel tests, including an inert atmosphere glovebox
- Procurement and installation of equipment, including a tall inert-atmosphere glovebox, for closing and assembling larger fresh fuel tests, such as would go into the TWIST capsule or TWERL loop for simulated LOCA testing of LWR fuel
- Procurement and installation of equipment needed for closure of experiment capsules requiring light contamination control.

Functionality to support LWR fuel testing, and perhaps fast reactor fuel testing, includes:

- Procurement and installation of a shielded cell and glovebox, named the Experiment Preparation and Inspection Cell (EPIC) for remote installation of instrument sensors onto previously irradiated fuel rods intended for irradiation the Advanced Test Reactor (ATR) and transient testing in TREAT (a key capability for backfilling the loss of the Halden Test Reactor)
- Design, fabrication, procurement, and assembly of the fuel rod instrumentation bench that will be located inside EPIC for instrumenting previously irradiated fuel rods.

Other capabilities supporting multiple programs and sponsors are being established or are proposed. The TREAT Neutron Hodoscope is a unique capability that allows time-dependent sensing of fuel motion during transient tests, and further investment in modern hardware and imaging techniques will allow better information to be obtained from tests. That capability is being brought up to 1980s functionality, but with modern instrument electronics and computer data acquisition. Additional work is proposed to push the hodoscope techniques and hardware to greater functionality, allowing experimenters to obtain higher-resolution images of real-time fuel motion. Other work underway and proposed seeks to apply new sensing technologies to TREAT experiment instrumentation so that experimenters can obtain all the measurements possible and monitor all the phenomena possible.

**Benefit**

Many TREAT experiments will be conducted on low activity samples (fresh fuel or small samples) that will require minimal shielding during post-transient handling. Within the TESB, a specialized test train assembly facility supporting TREAT, similar to the Advanced Test Reactor (ATR) Test Train Assembly Facility (TTAF), built and equipped in Phases 1 through 3 will provide equipment and space for rapid assembly, modification, and repair of test rigs prior to installation in the reactor. Currently, assembly of TREAT experiment vehicles is performed ad hoc in temporary spaces in the Experimental Fuels Facility (EFF) or the Advanced Fuels Facility (AFF) and in part on the TREAT operating floor. A dedicated space adjacent to the TREAT Reactor Building will allow timely and efficient experiment preparation and will reduce opportunity for experiment damage due to transfer from facilities inside the main MFC fence.

The installation and equipping of EPIC will provide a key component of INL Halden replacement capability. Again, co-location of this area within vicinity of MFC fuel fabrication facilities is important to timely and efficient support of experiments and integration of system design and performance testing with ATR and TREAT operations staff.

Investments in experiment monitoring and instrumentation, as described above, will enable increasing amounts of information to be gleaned for transient tests, maximizing the value of the value obtained from resources spent on transient testing.

**ROM Cost Estimate (TESB modifications and experiment prep equipment):** Based on conceptual and pre-conceptual designs available to date, for FY-21 to FY-25 (to be proposed from multiple funding sources).

- TESB Building Modifications $5.1M
- Multi-mission experiment assembly/disassembly equipment $3.9M
- EPIC procurement and installation $8.1M
- EPIC instrumentation equipment $5M.

**ROM Cost Estimate (Next-Generation Hodoscope and In-Pile Instrumentation):** $12.7M, for FY-21 to FY-25.

# 2. LWR/ATF Fuel Testing

### Description

Equipment needed to test current and developmental LWR fuel designs, including Accident Tolerant Fuels (or ATFs) is distinguished from other TREAT test equipment by providing static or flowing water environments. The targeted temperatures in such testing, typical of LWR accident conditions, are lower than in testing of other fuel types (e.g., fast reactor fuel designs), so the experiment hardware is not usually challenged temperature but is necessarily designed to maintain internal pressure typical of water and water-steam mixtures at those temperatures.

Because nuclear fuels are most susceptible to failure in their degraded end-of-life condition, access to and use of this material type is crucial to the success of any transient testing program. Testing of irradiated LWR fuel samples in TREAT (or ATR) requires removal and resealing of samples extracted from full-length fuel pins irradiated in commercial power reactors. Because LWR fuel rods are typically 10 to 12 feet long, the capability to shorten the fuel rods to fit into TREAT and ATR test vehicles is a necessary. Testing plans also call for incorporation of instrumentation into the previously irradiated test rods, which requires a small, shielded hot cell equipped for remote attachment of instrument sensors and leads to fuel rods and experiment vehicles. Although this capability is expected to be requested for testing of fast reactor fuels in flowing sodium loops as well, at this time only the LWR test program requires this capability.

Devices of this type have been developed for use by virtually all peer nuclear testing institutes around the world and can be procured for use. Two versions of these specialized devices are planned to enable this process at INL, which is essential for INL to fulfill its mission to test accident-tolerant fuel design and high-exposure fuel designs for LWRs. The first device targeted for HFEF, the **Re-Fabrication Bench**, simply allows for rod sectioning, extraction of excess fuel pellets, installation of new end plugs, and re-pressurization of the pin. A second device, the Fuel **Rod Instrumentation Bench** intended for the EPIC cell in the TESB, provides equipment for the installation of instrumentation necessary for scientific studies and fuel qualification testing.

Facility assessment and cost estimates for the shielded instrumentation capability were completed in FY-17 and are documented in TEV-3093. Design and acquisition of this equipment is currently supported by the Advanced Fuels program. Equipment and irradiation vehicles needed for LWR fuel testing, including equipment needed for post-irradiation examination and for fuel rod refabrication in HFEF, have been designed and procured (to date) using funds from DOE-NE programs. Similarly, the tests use to commission the experiment vehicles have been funded by DOE-NE programs. However, other funding sources might be appropriate for selected test capabilities that will support multiple users, and specific instances of test hardware will be funded by individual test sponsors.

Other needed capability includes design, first assembly, and commissioning of LWR experiment vehicles and the fixtures and equipment needed to load and unload the vehicles in HFEF. Specific experiment vehicles include:

- **Transient Water Irradiation System in TREAT (TWIST)** – Adaptation of the MARCH-SERTTA vehicle to allow testing of single fuel rods under loss-of-coolant accident (LOCA) conditions. Will have the capability to perform Loss of Coolant Accident’s (LOCA’s) and Reactivity Initiated Accident’s (RIA’s) with side loading of fuel capability to remove interference of the cable heaters and TC support arms.
- **TREAT Water Environment Recirculating Loop (TWERL) –** Based on systems used in INL’s Power Burst Facility in the 1970s and 1980s, this loop will accommodate small bundles of fuel rods up to 1.2m in active fuel length for testing under full forced convection. The test layout enables in-situ heat balance measurements for increased confidence in core-to-specimen power coupling for

high-value pre-irradiated specimens where uncertainties in end-of-life isotopic composition can increase uncertainty in nuclear heating predictions. Will have the capability to perform Loss of Coolant Accident's (LOCA's) and Reactivity Initiated Accident's (RIA's) with prototypic coolant flow conditions, necessary for assessing time-dependent phenomena and post-failure fuel behavior.

Reestablishing TREAT loop handling testing capability will require an assembly and checkout station to support water and sodium loops in HFEF. Flow tube assembly will be performed at HFEF Stations 5D and 4D. Loop assembly will be performed directly into the cask container. The loop station will support full operational testing of the loop before shipment to TREAT for transient testing.

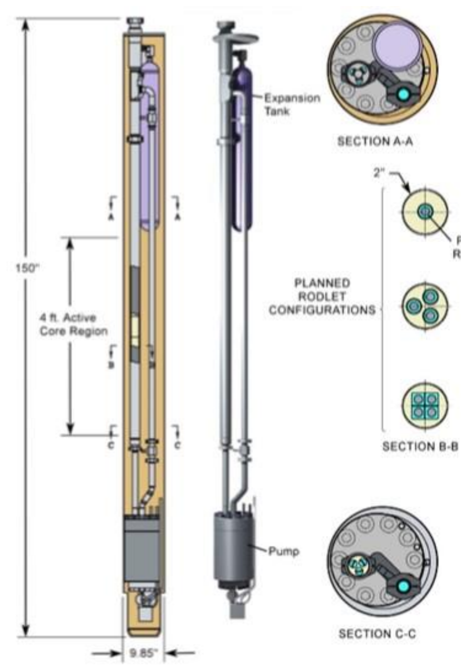
Another important experiment system needed to simulate LWR accident conditions is a $^{3}$He injection system, used to clip TREAT transient pulses more quickly than possible with the TREAT Transient Rod Drives. The **Helium-3 Enhanced Negative Reactivity Insertion (HENRI)** system is being designed to provide pulse width (full-width half-maximum) narrowing to as low as 40 msec, enabling power pulses of the type expected for PWR and BWR Reactivity Accidents (RIAs).

**Benefit**

Testing of new and advanced LWR fuel designs, including ATFs, was one of the objectives that motivated TREAT restart. The collaboration between DOE and industry in the ATF program has successfully brought forward several designs with prospect for greatly improved behavior in severe accidents and for possible burnup extension (which would improve LWR fuel cycle economics by increasing fuel utilization). Establishing beneficial behavior during design basis accidents and postulated severe accidents is key to claiming the benefit of new fuel designs, and TREAT offers what could well be the best transient testing capability for that purpose, augmenting the capabilities provided by ATR and other steady state irradiation reactors in backfilling the loss of the Halden Test Reactor. Completion of the infrastructure needed for LWR fuel testing will allow INL and TREAT to provide test data and to meet key expectations that motivated restart.

Further, the irradiated fuel rod instrumentation capability is needed for fuel testing I-loops being built for insertion into ATR, and will thus comprise part of INL's post-Halden capability.

**ROM Cost Estimate:** Roughly $33M over FY-21 to FY-25.




**TREAT Water Environment Recirculating Loop (TWERL)**

# 3. Fast Reactor Fuel Testing

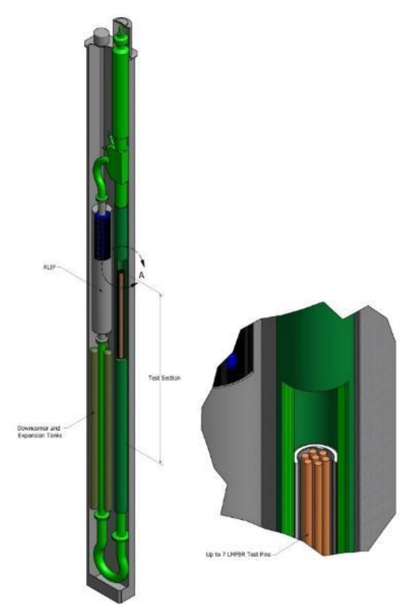
**Description**

Equipment and irradiation vehicles needed to test fast reactor fuel designs is distinct for providing high-temperature testing environments that can simulate the time-dependent temperature experienced by fast reactor fuel rods in either static capsules or flowing coolant loops. Targeted test temperatures are relatively high, 500 to 700°C for sodium cooled fast reactor (SFR) fuel and higher for other coolants such as lead or molten salt. Test vehicle pressures for these coolants, with their relatively high boiling temperatures, are near ambient. Currently, only static capsules and flowing sodium are planned for transient testing of fast reactor fuel designs, and those capabilities are adaptable to investigate some aspects of fuel behavior for fuel designs intended for lead-cooled fast reactors and gas-cooled fast reactors. But environmental effects and higher test temperatures would require differently designed loops. Design and commissioning the sodium loop capability is supported by three DOE-NE offices, but specific applications of the capability and expendable components are funded by individual test sponsors.

The experiment vehicles planned for testing of fast reactor fuel design include

- **Temperature Heat-sink Overpower Response module (THOR) -** Simulates fuel temperature response during early stages of overpower transients in SFRs. The device will be used for Fast Reactor safety research, phase-based properties measurement, and power-to-melt studies for enhanced thermal conductivity fuel
- **TREAT Flowing Sodium Loop (Mk-IIIR Loop) -** Updated version of the historic TREAT Mk-III sodium loop design with forced convection, for testing small bundles of fast reactor fuel rods in flowing sodium coolant. This capability is essential for assessing time-dependent safety-related fuel behavior and fission product release under design-basis accident conditions, for assessing consequences of post-failure phenomena, and for demonstrating certain passive safety features of metal fuel designs (such as transient axial expansion that inserts negative reactivity during a transient overpower event).

Other projects are underway or planned to establish the infrastructure at INL to support sodium test loops (i.e., test loops for testing and calibrating instruments, sodium loading and unloading) and to load and unload experiments from the Mk-IIIR loop inside the Hot Fuel Examination Facility (HFEF).




**TREAT Mk-IIIR Sodium Loop**

**Benefit**

Testing of new and advanced Fast Reactor fuel designs, particularly for advanced reactor concepts under development such as the Traveling Wave Reactor or Natrium (both by TerraPower) or GE Hitachi's PRISM, was another objective that motivated TREAT restart. The U.S. DOE, and its predecessor agencies, invested considerably in sodium-cooled fast reactors over many decades, and now industry is pulling that technology from the labs and DOE and configuring it in new plant designs to bring to market. Demonstrating safety-related reactor and fuel behavior remains a key need for license approval by regulators. TREAT testing can resolve key issues and quantify fuel failure thresholds to inform those licensing decisions at relatively low cost.

**ROM Cost Estimate:** Roughly $17M over FY-21 to FY-25.

# 4. Other Program Investments

**Description**

Early in its restart life TREAT has been enlisted to assist fuel development and demonstration for nuclear thermal propulsion (NTP) reactors intended for space vehicles. Testing already underway (in the Sirius-2 test series) is assessing the ability of fuel designs to retain form and integrity through expected power-duty cycles, using the Minimal Activation Retrievable Capsule Holder (MARCH) irradiation vehicle system and a capsule design unique for the Sirius test series.

The Sirius-4 test series calls for prototypic testing in a flowing hydrogen test loop, something new for TREAT. The test loop is being designed by a collaborative team of INL and NASA personnel. Specific expertise provided by each organization include INL's expertise in experiment vehicle design and nuclear operations and NASA's expertise in hydrogen safety. The gaseous hydrogen (H2) supply and exhaust system for experiments in TREAT, referred to here as the "Loop," is a flow-through system supplying H2 to experiments and releasing exhaust gases to atmosphere. The Loop will be separable into three major sections: H2 supply, inert gas supply, and experiment exhaust. Each experiment that uses the Loop and the connections that integrate the Loop with an experiment will be in the design of the experiment. The Loop system consists of hydrogen and inert gas storage, gas control panels for the hydrogen and inert gas, and the gas lines connecting supply to the panels, and the exhaust lines from the experiment. The Loop design and assembly is funded by NASA and is scheduled to be available in FY-23.

Other investment is needed to modify the TREAT Reactor Building to support micro-reactor demonstrations. The proposed project will equip the TREAT micro-Reactor Experiment Cell (T-REXC, the North High Bay 10-ft pit) with basic infrastructure needed for small (kilowatt range) micro-reactors. This includes installation of shield blocks for the north storage pit, installation of industry standard I&C infrastructure, electrical power infrastructure, control room infrastructure, a T-REXC HVAC system, a fire suppression system, and a Reject Heat/Load Bank system. These permanent modifications are required to support any small micro-reactor testbed installed in T-REXC. This project excludes scope for specific reactor systems.

**Benefit**

Completion of the hydrogen test loop and its installation in TREAT for testing will address many open questions about fuel and material behavior during service while exposed to flowing hydrogen There is currently no reactor with a flowing hydrogen capability to perform these tests.

The TREAT facility provides operating infrastructure needed for the quickest possible accommodation of shorty-lived, very small micro-reactor demonstrations and tests. Adding the basic infrastructure listed will complete the test bed and minimize the facility work needed for a successful demonstration project. NRIC is pursuing similar, though much larger, modifications to the EBR-II Dome and the ZPPR Reactor Cell for the same purpose of establishing rapid demonstration test beds to facilitate development of new reactor technologies.

**ROM Cost Estimate (Hydrogen Test Loop):** Roughly $12M over FY-21 to FY-25 (complete in FY-23).

**ROM Cost Estimate (Hydrogen Test Loop):** Roughly $12M over FY-21 to FY-25 (complete in FY-23).