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Materials and Fuels Complex
FY-18–FY-23 Five-Year Investment Strategy

July 2018

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July 2018

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ACRONYMS

AES	Atomic Emission Spectroscopy
AL	Analytical Laboratory
ANL	Argonne National Laboratory
BCS	Building Control System
CAMS	Continuous Air Monitoring System
CAS	Criticality Alarm System
CH	contact-handled
CLG	Casting Laboratory Glovebox
D&D	decontamination and decommissioning
DDC	Direct Digital Controls
DM	Deferred Maintenance
DOE	Department of Energy
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	Electro-mechanical manipulators
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
FFTF	Fast Flux Test Facility
GAIN	Gateway for Accelerated Innovation in Nuclear
GASR	Gas Assay Sample and Recharge
HFEF	Hot Fuel Examination Facility
HVAC	heating, ventilating, and air conditioning
IA	Instrument Air
IASCC	irradiation assisted stress corrosion cracking
ICP	Inductively Coupled Plasma
ICP-MS	Inductively Coupled Plasma Mass Spectrometer
INL	Idaho National Laboratory

LA	laser ablation
LFTD	laser-flash thermal-diffusivity
LLW	low-level waste
MEITNER	Modular Examination Instrument for Transportable Nuclear Energy Research
MC-ICP-MS	Multi-Collector Inductively Coupled Plasma Mass Spectrometer
MFC	Materials and Fuels Complex
MLLW	mixed low-level waste
NE	Office of Nuclear Energy
ORNL	Oak Ridge National Laboratory
PIE	post-irradiation examination
RAMS	Radiation Area Monitoring System
RD&D	research, development, and demonstration
RDD&D	research development, demonstration, and deployment
RH	remote-handled
RLWTF	Radioactive Liquid Waste Treatment Facility
RN	Repair Needs
ROM	rough-order of-magnitude
SC-ICP-MS	Single Collector Inductively Coupled Plasma Mass Spectrometer
SEM	Scanning Electron Microscopy
SPG	Special Project Glovebox
SSC	structure, system, and component
SSPSF	Space and Security Power Systems Facility (at MFC)
TCM	Thermal Conductivity Microscope
TEM	Transmission Electron Microscopy
TIMS	thermal ionization mass spectroscopy
TREAT	Transient Reactor Test Facility
TRIGA	Training, Research, Isotope, and General Atomics
VFD	variable frequency drive
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) mission is to provide the research, development, and demonstration foundation to extend the lives of the current operating reactor fleet, develop the next generation of nuclear reactors, and provide integrated nuclear fuel cycle solutions. This document is a complimentary document to the Materials and Fuels Complex Integrated Five-Year Science Strategy (INL/EXT-17-41117, Rev. 1) that defines specific implementation strategies for increasing research capability and throughput through targeted investments in research facilities, research instruments, and research staff.

Refer to INL/EXT-17-41117, Rev. 1 for details about MFC, its capabilities, and the overall science strategy for the Materials and Fuels Complex.

1.1 A Strategy for the Materials and Fuels Complex

MFC will continue its support of current research, development and demonstration (RD&D) missions while enabling new projects and missions working with DOE-NE partners, industry and academia. The strategy described in this document will guide 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 the existing MFC nuclear infrastructure. The strategy also anticipates and guides the preparations necessary for demonstration of advanced nuclear energy technologies in support of DOE (as envisioned by the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative and Idaho National Laboratory (INL) Strategic Plan.

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

- Nuclear fuels and cladding
- Radiation damage in core structural materials
- Advanced manufacturing for nuclear fuel and cladding
- Chemical separations and fuel recycling
- Focused basic research that advances the applied technology mission
- Nuclear nonproliferation and nuclear forensics
- Space nuclear power and isotope technologies
- Transient testing of reactor fuels.

The strategy for MFC entails building and improving on these core competencies, introducing new and revitalized RD&D capabilities. MFC is also implementing new business and operations models to help transform MFC into a complex capable of supporting 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 features of this strategy include the following:

- RD&D Capability Development, Optimization, and Integration – This emphasizes research and capability development in areas where MFC has a core strength. Collaborating with NS&T and NHS, prioritizing and pursuing funding for construction of needed capabilities where national gaps exist and leveraging the key GAIN partnerships with 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 fills capability gaps that will not be added to MFC. Improving or establishing relationships with U.S. universities to further extend MFC's research network, provide a pipeline for recruiting future staff, and positively influence educational programs whenever possible and providing additional collaboration pathways with the international community through INL's recent designation as an International Centre based on Research Reactor (ICERR) by the International Atomic Energy Agency (IAEA) are also key components.

- Base Operations, Plant Health, and RD&D Capability Sustainment – This emphasizes executing efficient base operations as a core foundations to RD&D execution excellence. A portion of this includes reviving and improving historical MFC capabilities that support demonstration-scale activities of nuclear systems. This supports DOE-NE programmatic objectives by maintaining, improving, and constructing new support infrastructure, as needed, to ensure the safe operation of MFC
- Implementing A New MFC-Wide Operating Model – Implementing an operations model that improves the efficiency, reliability, and safety of MFC operations sustains and advances RD&D execution excellence. Transitioning to a user facility-like model that increases research capacity and allows improved access to nuclear RD&D capability at MFC; this model will ensure that a cadre of expert staff and state-of-the-art research capabilities are available to support effective implementation of a test bed capability described by GAIN, including extending the user-facility model to DOE-NE's extended research network, as appropriate

This strategy will position INL and its sponsor, DOE-NE, to deliver an effective nuclear RD&D capability in support of current programs and further 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 experiment infrastructure support needs in Section 3
- A forward-looking vision for development of the MFC campus in Section 4
- Details of specific maintenance and instrumentation target areas in Appendix A and B.

1.2 Anticipated 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 will result in the following outcomes:

- Increased facility and equipment reliability and availability, reducing the experiment lifecycle of RD&D critical to DOE-NE 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 support the Nuclear Energy R&D Test Bed concept in a reliable manner.

MFC performance metrics will focus on factors important to supporting MFC's nuclear energy RD&D mission. Metrics (current or being developed) will 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.

- **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.
- **Instrument/equipment utilization –** Utilization 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.
- **Expanded Research Staff to Enable the R&D Test Bed –** This measures increases in scientific staff needed to provide comprehensive growth of scientific support of test bed capabilities.
  - MFC has hired over 20 R&D and post-doc researchers since FY-16 in critical areas such as radio-analytical chemistry and post-irradiation examination PIE.
  - Intern hires have increased nearly four-fold over the past four years (FY-13 through FY-17) demonstrating MFC's commitment to growing tomorrow's research talent pool.
- **Critical position turnover** – Retaining talent is critical to growing the expertise needed to successfully execute the NE mission. Annual employee turnover at MFC has decreased by over 50% from FY-13 levels and based on headcount has decreased from 12% to 4% annually, a three-fold decrease in FY-17.
- **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:
  - Completion of MFC mission outcomes
  - Number and quality of peer-reviewed publications and reports
  - Number of external users relying on MFC RD&D capabilities
  - Positive feedback from customers (e.g., NS&T, NHS, and external industry, small business, and university users).

A baseline for many of these metrics was established in FY-16. A primary goal will be to double MFC research throughput over its current level by the end of FY-22, as measured by instrument utilization and research output metrics.

1.3 Funding

MFC is the hub of the DOE-NE test bed. 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 and position this new technology for deployment into the commercial sector as a safe cost competitive carbon free energy source.

Figure 1 provides a diagram of the proposed funding strategy. Elements shaded blue are proposed to be funded by the IFM program and the green shaded element should be supported by NE RD&D programs. Overall funding levels to build an effective test bed and to re-establish DOE-NE as the world leader in innovative nuclear energy technology are identified in Figure 2. FY-18 proposed levels diverge slightly from the FY-18 budget request to account for increases in facility use as capabilities increase at MFC.

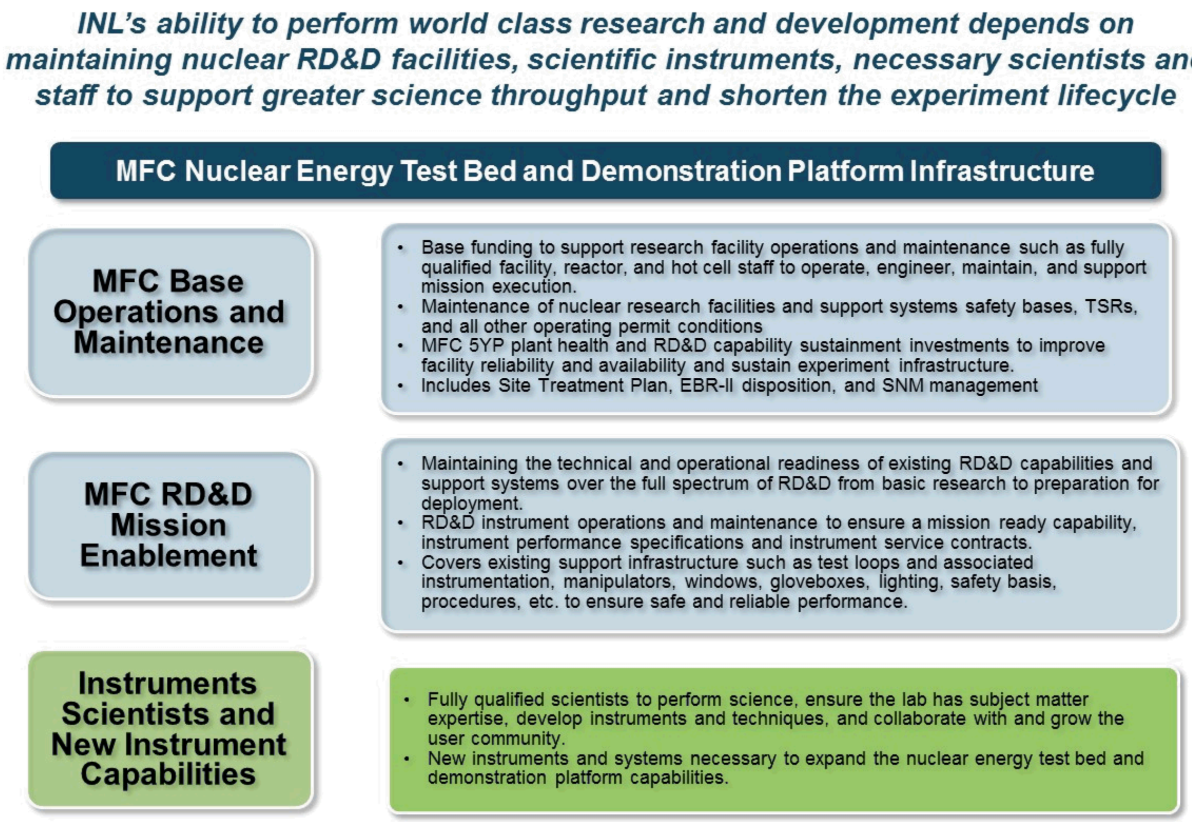
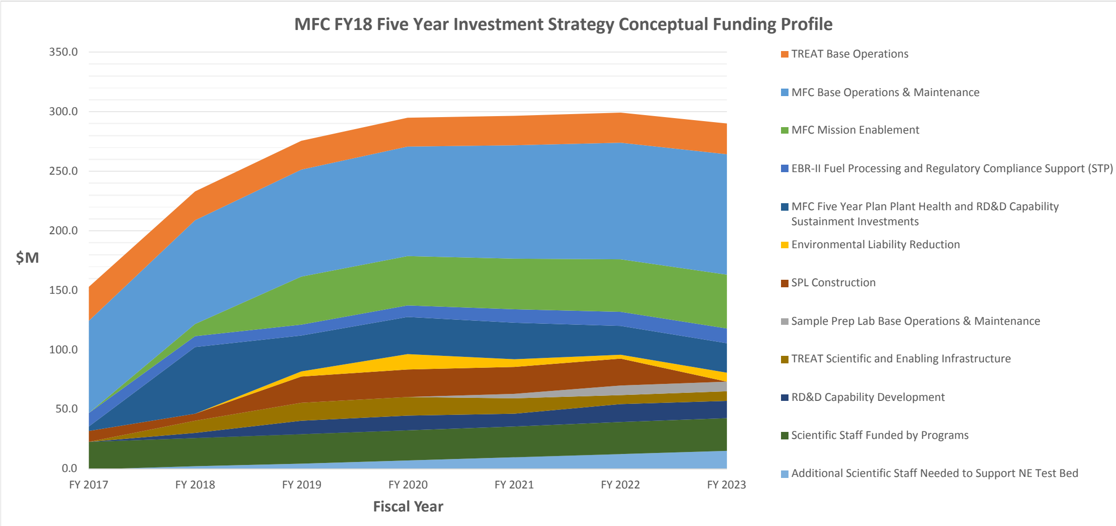


Figure 1. DOE-NE Test Bed and Demonstration Platform Funding Strategy.



Program Area	Crosswalk to Proposed Funding Model Figure 1	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	Comments	Section
TREAT Base Operations	**MFC Base Operations and RD&D Mission Enablement**: Nuclear research operations including fully qualified staff to operate, engineer, maintain, and sustain the test bed. This includes sustained operatonal and research infrastructure reinvestment and growth to support a nuclear energy test bed and demonstration platform	29.0	24.4	24.0	24.0	24.7	25.2	25.9	Resumption complete in FY17. Base operations and maintenance only.	
MFC Base Operations & Maintenance		77.2	86.9	89.5	92.2	95.0	97.8	100.7	Includes MFC Base, NRAD, SNM management, and RH-LLW OPC (one-time). Includes O&M for RH-LLW FY17 on.	
MFC Mission Enablement			10.0	40.3	41.5	42.8	44.0	45.4	Funding that supports RD&D capability sustainment/development (instruments) including support systems and equipment above compliance level within R&D facilities	2.2
EBR-II Fuel Processing and Regulatory Compliance Support (STP)		11.4	9.1	9.5	9.7	11.5	11.7	12.1	From Table 3	2.4
MFC Five Year Plan Plant Health and RD&D Capability Sustainment Investments		3.7	56.1	30.1	30.9	30.3	24.2	24.9	FY18 Omnibus and FY19 draft House mark	2.3
Environmental Liability Reduction				4.3	13.1	6.6	3.7	7.6	Proposed in Waste Management Table Section 2.4	2.4
SPL Construction		8.8	6.0	22.0	23.2	22.5	22.2		TPC (TEC+OPC)	4.1
Sample Prep Lab Base Operations & Maintenance						4.0	8.0	8.2	Emerging SPL base operations scope. FY 20 ramp up and readiness for FY 22.	2.1
TREAT Scientific and Enabling Infrastructure	**New Instrument Capabilities:** Scientific instruments, test vehicles, procedures, etc. A steady and reliable funding stream to maintain and grow the test bed and expand demonstration support capability	0.0	10.4	14.8	15.5	12.5	7.5	7.7	From Table 9 provided by Transient Testing Scientific Coordinator. This is programmatic funding managed by Nuclear Science and Technology.	3.2.2
RD&D Capability Development			3.8	11.4	12.2	10.8	15.5	14.6	Proposes funding beginning in FY 18. Expands test bed and demonstration platform capability broadening TRL support	3.2.1
Scientific Staff Funded by Programs	**Instrument Scientists:** Acquire, develop, and retain scientists and staff to operate, maintain, and expand research capabilities	23.2	23.9	24.6	25.4	26.1	26.9	27.7	Base resources already funded by programs escalated at 3%	
Additional Scientific Staff Needed to Support NE Test Bed			2.5	4.9	7.4	9.9	12.5	15.2	Additional Programmatic FTEs to support ~10% growth in NE test bed/demo platform support	3.1
Currently Funded or Requested in IFM ($M)		130.1	192.5	219.6	234.6	237.3	236.8	224.8		
Additional NE Program Investment Totals ($M)		23.2	40.6	55.7	60.4	59.3	62.4	65.2	Additional NE investment above historical levels/areas needed to support a user facility test bed	
Total Conceptual Funding Profile ($M)		**153.3**	**233.1**	**275.3**	**295.0**	**296.6**	**299.2**	**290.0**		
Laboratory investments in support of this initiative are not included										
Revised 06/12/18										

Figure 2. Proposed MFC funding profile.

2. FACILITY INFRASTRUCTURE

Facility Infrastructure is made up of four primary components:

1. **MFC Base Operations and Maintenance** – This area provides compliance level support to maintain MFC nuclear and radiological facilities at 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 RD&D Mission Enablement** – This area provides the funding above compliance level that supports operating, maintaining, and sustaining the current RD&D instruments and support systems at a mission readiness level to be ready to support RD&D mission execution. (Subsection 2.2)
3. **MFC Five-Year Strategy Plant Health and RD&D Capability Sustainment Investments** – These are investments into plant systems and infrastructure above historical levels of corrective and predictive maintenance. These investments are focused on refurbishment and replacement of aging infrastructure and plant systems that can impact facility reliability and availability and negatively affect mission execution and RD&D outcomes. (Subsection 2.3)
4. **Waste and Materials Management** – Activities executed to support meeting regulatory agreements between DOE and government entities such as the Idaho Settlement Agreement 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. Facility infrastructure funding summary.

Area	FY-18	FY-19	FY-20	FY-21	FY-22	FY-23
MFC Base Operations and Maintenance MFC O&M including NRAD and SNM management plus the addition of RH-LLW Disposal Facility and SNM management.	$86,900	$89,507	$92,192	$94,958	$97,807	$100,741
MFC Mission Enablement	$10,000	$40,300	$41,509	$42,754	$44,037	$45,358
MFC Five-Year Strategy Plant Health and RD&D Capability Sustainment Investments	$56,100	$34,675	$31,265	$30,710	$24,550	$25,287
TREAT Base Operations Includes completion of resumption activities	$24,400	$24,000	$24,000	$24,700	$25,200	$25,900
Waste and Materials Management Includes Site Treatment Plan CH-MLLW & RH-MLLW, Nuclear Materials Management, and EBR-II Disposition	$10,435	$13,763	$22,792	$18,079	$15,378	$15,840
Total Facility Infrastructure Funding ($K)	**$187,835**	**$202,245**	**$211,758**	**$211,201**	**$206,972**	**$213,125**

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. Very little of this base workscope is 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. Proposed changes to base operations includes investments in facility and instrument enablement discussed in Subsections 2.2 and 2.3.

Execution within the base operations framework includes managing the operations, maintenance, and support of nuclear facilities and resources 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 related to health and safety, 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 and upgrades necessary to ensure safety and functionality
- Enabling specific activities such as establishing an equipment reliability program, improving configuration management and plant health monitoring that efficiently ensures reliability of SSCs and the efficiency and safety in which maintenance and engineering changes are performed.

In addition, targeted major maintenance and repair is performed to address SSC degradation in order to ensure facility availability and throughput. Targeted major maintenance and repair efforts (described in Section 3) include hot cell window replacements, manipulator upgrades, and Analytical Laboratory (AL) HVAC replacement. These upgrades will result in a reduction in MFC deferred maintenance (DM) and key repair needs (RN). This funding will allow these facilities to sustain multiple shifts and to handle the increased maintenance burden as they are operated at increased capacity. Additional engineering and other technical support resources will be needed to address the technical issues associated with operating multiple shifts into aging facilities to meet mission demands.

2.2 MFC RD&D Mission Enablement

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 Enablement 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 enablement 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
- 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, windows, gloveboxes and lighting to ensure safety 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 cranes, feedthroughs and process instrumentation
- Maintaining inter-facility transport capabilities
- Operating and maintaining data and control networks.

Establishing a robust, direct-funded mission enablement 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 enablement 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 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 will be instrumental in reestablishing U.S. leadership in advanced nuclear energy technologies and research techniques.

2.3 MFC 5-Year Plant Health and RD&D Capability Investments

2.3.1 MFC Plant Health

MFC plant health investments are a key aspect of a healthy and efficient NE RD&D test bed model and require dedicated and sustained funding to address MFC's plant health needs. 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 deferred maintenance (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 request is $120M from FY-18 to FY-23 and will result in increased facility reliability, increased research throughput, expanded test bed capacity, and a reduction of $25M in DM over this time period.

Table 2 provides a list of activities necessary to implement the strategy to increase the reliability of MFC mission-enabling infrastructure and identifies those DM items that will be completed in priority order. Appendix A provides specific descriptions of each project in priority order. Subsection 2.5 lists the current inventory of MFC DM. Table 4 provides the MFC DM master list as of September 2017.

MFC is implementing a disciplined process to identify and assign a relative priority to plant health issues through the MFC Complex Health Committee (CHC) prioritization process. 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 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 higher RD&D throughput and mission execution success.

Two of MFC's flagship facilities, HFEF and AL, have repair needs and deferred maintenance that are key to DOE's overall mission accomplishment. Some aspect of most of the research executed by MFC is dependent upon the capabilities located in these two facilities. HFEF and AL are where the initial focus on plant health began. These activities will be integrated with other current priorities or emergent issues in the other research facilities.

HFEF is DOE-NE's core PIE facility. This five-year strategy will address deficiencies in HFEF systems that currently limit research throughput and will ensure 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. Systems such as the argon supply for the HFEF hot cell have not been refurbished since the facility opened and are single point failure risks to RD&D operations. Equipment such as the 40-ton high bay crane exhibits a variety of age-related issues, such as trucks climbing up on rails due to crabbing of the trolley and an obsolete control system that exhibits frequent failure is being refurbished to address risks to facility reliability. Key equipment such as the HFEF polisher/grinder, a "gateway" piece of equipment supporting sample preparation for all in-cell microscopy is being replaced, as is the Gas Assay Sample and Recharge (GASR) system, which is an aging, unique, and critical piece of R&D process equipment.

The HFEF main cell pressure/temperature, purification, and compressed argon systems use obsolete technology. Key components are exhibiting increasing failure rates 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 impact.

HFEF electrical systems have, for the most part, remained unchanged and have only had minor modifications performed since HFEF was constructed in the1970s. 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.

AL is MFC's principle 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 ever since. AL is a Hazard Category 3 Nuclear Facility with approximately 10,000 ft^2 of laboratory space. The AL HVAC system is no longer capable of supporting additional research or analytical capability, and currently operates at maximum capacity. The near-term focus for plant health for AL is a significant renovation of the AL HVAC system required to ensure facility reliability is maintained and AL has the ventilation capacity to support MFC R&D missions.

The HFEF, FCF, and AL master/slave manipulators and electro-mechanical manipulators (EM) are they key systems that move equipment and material 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. An overall strategy to address manipulators across MFC is detailed in PLN-5568, "MFC Manipulator Strategy." This plan is phased over several years and will eventually result in replacement of all manipulators with reliable next-generation equivalents.

The hot cell windows at HFEF and FCF were fabricated over 50 years ago. These windows are 4-ft 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 efficiency of operations. An ongoing window replacement campaign staged over several years targets HFEF, FCF, and AL hot cell windows.

Four of the gloveboxes in use at AL (casting lab, special projects, waste form testing, and radiochemistry) need either replacement or significant overhaul. Part of the comprehensive plant health strategy includes addressing these gloveboxes to ensure the facility is in the best possible condition to support new fuels development in its pre- and post-irradiated forms, fuel separations, and waste form development.

The TREAT Automatic Reactor Control System was placed in service in 1986. The system underwent limited refurbishment during the Resumption of Transient Testing activities. However, the system still runs on antiquated computer hardware using outdated programming languages such as assembly code. There are currently vendors for some components and spares are on hand for many others, but, as vendors retire these production lines, sources for new parts will disappear. Additionally, staff with the knowledge and skills to maintain the hardware and programs are nearing retirement age. While still operational, this system is well past its designed service life and needs to be replaced to ensure continued reliability.

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. The MFC private facility control network (PFCN) is a primary aspect of maintaining secure cyber systems across MFC. 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.

FCF priorities include addressing the facility control system for hot cell operations. This includes replacement of the programmable logic controllers for the system. These are producing spurious failure notifications decreasing facility reliability and requiring significant time and effort to troubleshoot and address. Planning is currently underway to address these in FY-19. The reliability of the high bay crane and replacement of the Truck Lock Industrial Waste Holding Tank will also be addressed in the future.

FMF and ZPPR facilities need replacement of the current criticality alarm system (CAS) as well as roof repairs. FMF CAS replacement is scheduled for FY-18/19. The FMF HVAC system also needs refurbishment. FMF and ZPPR roofs are aging and requiring significant resources to address infiltration of precipitation during different parts of the year and planning is underway to address these as early as FY-19.

Many legacy items in the research facilities and support areas can be removed and dispositioned. This increases overall mission execution efficiency and frees up additional critical nuclear facility RD&D space critical to support test bed growth. This FMF Waste Characterization Glovebox, AL Waste Form Glovebox, and AL Cell #1 Glovebox could all be removed and dispositioned providing critical additional RD&D space. A separate funding source (limited DOE-EM funding to address D&D of INL systems and facilities) is addressing the FMF Waste Characterization Glovebox and FASB East Development Glovebox in FY-18 while other areas have not yet been prioritized within current funding.

A sustained plant health campaign 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 matures.

2.3.2 MFC RD&D Capability Sustainment Investments

MFC RD&D capability sustainment investments are focused on sustaining RD&D capabilities through instrument replacement, refurbishment, and occasionally enhancement as analytical capability within the industry matures and develops. This is a new area of focus with limited investment commencing in FY-18. This area recognizes the DOE-NE commitment to sustaining world-class nuclear RD&D capabilities across MFC's current areas of expertise. This is in contrast to investment into research and development of prototype analytical or PIE systems that will be referred to in this strategy as RD&D

Capability Development and expected to be funded by DOE-NE research programs investment or laboratory investment.

Some notable variations that make up this five year strategy include two areas of investment IFM committed to lead. These are supporting completion of the IMCL thermal properties cell and installing the first suite of instrumentation; and establishing the first suite of advanced fuel fabrication capabilities. This decision establishes essential new RD&D test bed capabilities that no single research program is able to fund.

Sustainment areas within AL focus on replacement and addition of mass spectrometry capability to support AL operations. This strategy includes replacement of an aging, single-point-failure risk ICP-MS that is considered a “work horse” instrument 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.

HFEF RD&D sustainment activities include refurbishment of the East Radiography Station elevator which is still original equipment installed in 1980 and has no commercially available spares. Several functions are out of service and an upgraded elevator and control system provides more efficient and reliable support for this non-destructive PIE capability. Another area is restoring and upgrading the north beam line in HFEF. The North Radiography Station is also 1980 original equipment with several out-of-service functions. This effort includes removal of old, out-of-service HFEF equipment increasing the available footprint to support expansion of beam line mission support of RD&D.

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.

Subsection 3.2 provides a detailed list of MFC five-year RD&D needs and identifies areas of capability development and sustainment targets.

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

MFC Overall Priority	Asset Name	Name	DM	FY-18	FY-19	FY-20	FY-21	FY-22	Outyears	Est. Total Cost (FY-18 $)
1	AL	Replace or Upgrade the AL HVAC System	No	$10,000						$10,000
2	AFF	AFF Modifications (HVAC)	No		$2,000					$2,000
3	HFEF/FCF/ AL	Manipulator Replacement Campaign in HFEF, FCF, and AL	No	$3,000	$3,000	$2,500	$4,000	$4,000	$2,200	$18,700
4	HFEF/FCF/ AL	Window Replacement Campaign in HFEF, FCF, and AL	Yes	$2,500	$2,000	$2,000	$2,000	$2,000	$2,000	$12,500
5	HFEF	Argon Cell Temperature and Pressure Controls	No	$1,500						$1,500
6	FCF	Replace FCF Facility Control System (PLC Replacement)	Yes		$3,000					$3,000
7	FMF/ZPPR	Replace the Criticality Alarm System (CAS) in FMF and ZPPR	No	$2,000				$2,300	$600	$4,900
8	HFEF	Facility Out-of-Cell 40-Ton High Bay Crane	Yes	$2,500						$2,500
9	HFEF/ IMCL	Compressed Argon Supply System	Yes	$700						$700
10	FCF	Multi-Function Furnace	New	$6,000						$6,000
11	HFEF/FCF/ AL	Radioactive Liquid Waste Treatment Facility Process/Storage Tanks Alternatives Analysis and Replacement	Yes	$3,000						$3,000
12	Sitewide	Refurbish MFC-Wide Drainage System	No		$2,100					$2,100
13	TREAT	ARCS Replacement	No			$3,000				$3,000
14	Sitewide	MFC HVAC Replacement Campaign	No		$400	$400	$400	$400		$1,600
15	FMF/ZPPR	Roof – Replacement	No		$3,000	$3,000				$6,000
16	AL	AL Lab Space Renovation	No		$440	$400	$400	$400	$400	$2,040
17	IMCL	Noise Reduction Modifications	No		$350					$350
18	HFEF/FCF	Electro-mechanical Manipulator Refurbishment	No	$2,000						$2,000
19	Sitewide	MFC Paving Repairs/Replacement	Yes		$2,100					$2,100
20	Sitewide	Radiation Monitoring (CAMs/RAMs) Updates	No		$3,070					$3,070
21	EML	IMCL/EML Critical Spares	No		$200					$200
22	HFEF	Small Transfer Lock Doors	Yes	$600						$600
23	HFEF	Small and Large Transfer Lock Drive Control System Upgrade	Yes	$500						$500

MFC Overall Priority	Asset Name	Name	DM	FY-18	FY-19	FY-20	FY-21	FY-22	Outyears	Est. Total Cost (FY-18 $)
24	HFEF	Containment Box	No		$500					$500
25	MFC	Legacy Materials Disposition	No	$2,000	$500	$500	$500			$3,500
26	HFEF	Decontamination Spray System	Yes						$1,200	$1,200
27	ZPPR	ZPPR Control Room Rip Out (DOE-EM funded)	No							$ –
28	HFEF	Radioactive Drain System Piping/Valves/Tanks	No				$350			$350
29	FCF	New SCRAPE Cathode Module for FCF Electrorefiner	No	$2,500						$2,500
30	FCF	Integration of Bottle Inspection w/ Wire Removal Process Improvement	No	$1,500						$1,500
31	MFC	Cask integration, management, and capability sustainment	No		$2,000	$3,500				$5,500
Not Prioritized	Multiple	Lab-wide UPS backup installation	No							TBD
Not Prioritized	IMCL	IMCL Communications Infrastructure				$300				$300
Not Prioritized	IMCL	IMCL Material Transfer Optimization				$200				$200
Not Prioritized	IMCL	IMCL DSA Rewrite				$250				$250
Not Prioritized	IMCL	Fixed Air Sampling System				$250				$250
Not Prioritized	IMCL	IMCL facility ventilation system optimization				$300				$300
Not Prioritized	IMCL	IMCL facility manipulator repair capability				$500				$500
Not Prioritized	FCF/ ZPPR/ SSPSF	Compressed Air Supply System	No					$1,000		$1,000
Not Prioritized	FMF	FMF Ventilation System – HVAC	No				$1,750			$1,750
Not Prioritized	HFEF	Facility Building Chiller Units	No				$400			$400
Not Prioritized	HFEF	Facility Electrical Distribution System	No					$2,000	$1,000	$3,000
Not Prioritized	HFEF	Facility Standby Diesel Generators	No				$3,000			$3,000
Not Prioritized	AL	Replace Casting Lab Glovebox (FMF)	No				$2,500			$2,500
Not Prioritized	AL	Replace Cell 1 Glovebox	No					$1,500		$1,500
Not Prioritized	AL	Hot Cell #2 Redesign	No				$1,000			$1,000
Not Prioritized	HFEF	Pneumatic Sample Transfer Control System Upgrades	No				$275			$275
Not Prioritized	FASB	Upgrade FASB Ventilation System	No				$500	$500		$1,000
Not Prioritized	FMF	Pu R&D Glovebox	No							$ –
Not Prioritized	FMF	PU Stabilization Glovebox	No			$500	$2,500	$1,500		$3,000

MFC Overall Priority	Asset Name	Name	DM	FY-18	FY-19	FY-20	FY-21	FY-22	Outyears	Est. Total Cost (FY-18 $)
Not Prioritized	EFF	Fixed Air Sampling System	No			$350				$350
Not Prioritized	HFEF/FCF /EBR-II	480V Critical Switchgear Replacements	No			$1,000	$1,000	$1,000		$3,000
Not prioritized	All	Enhance IFM base operations inventory	No			$500				$500
Not Prioritized	FCF	In-cell Periscope and Camera System	No						$925	$925
Not Prioritized	Sitewide	Replacement Optical Comparator for QA	No			$250				$250
Not Prioritized	Sitewide	Computed Tomography for QA	No			$750				$750
Not Prioritized	FASB/RCL	Stack Monitoring System	No			$500				$500
Not Prioritized	Sitewide	Safety and Health Fall Protection Equipment	No			$150				$150
Not Prioritized	Sitewide	Radiofrequency identification labelling system for mixed waste and other inventories management	No			$300				$300
Not Prioritized	AL	ENU Piping from Sink Drains	No						$1,000	$1,000
Not Prioritized	AL	AL Hot Cell Lighting Upgrade	No						$1,500	$1,500
Not Prioritized	AL	Rabbit Xfer from HC to B-wing	No						$1,500	$1,500
Not Prioritized	AL/RCL	Remove Steam - convert to Mech. Heat	No						$250	$250
Not Prioritized	AL/RCL	RCL Backup Power	No						$450	$450
Not Prioritized	AL	Ultra Pure Water Stations	No						$240	$240
		TOTALS		**$40,300**	**$24,660**	**$21,400**	**$20,575**	**$16,600**	**$13,265**	**$135,300**
Shaded rows represent lab investments		**Less Lab Investments (NE Funding Only)**		**$40,300**	**$20,060**	**$21,000**	**$20,175**	**$16,200**	**$13,265**	**$129,500**

2.4 Waste and Materials Management

2.4.1 Newly Generated Waste Management

MFC manages various newly generated and legacy research related materials and wastes as part of their environmental stewardship responsibility and compliance with DOE O 435 requirements. Detailed treatment and disposition paths as well as alternative disposition paths being evaluated have been established.

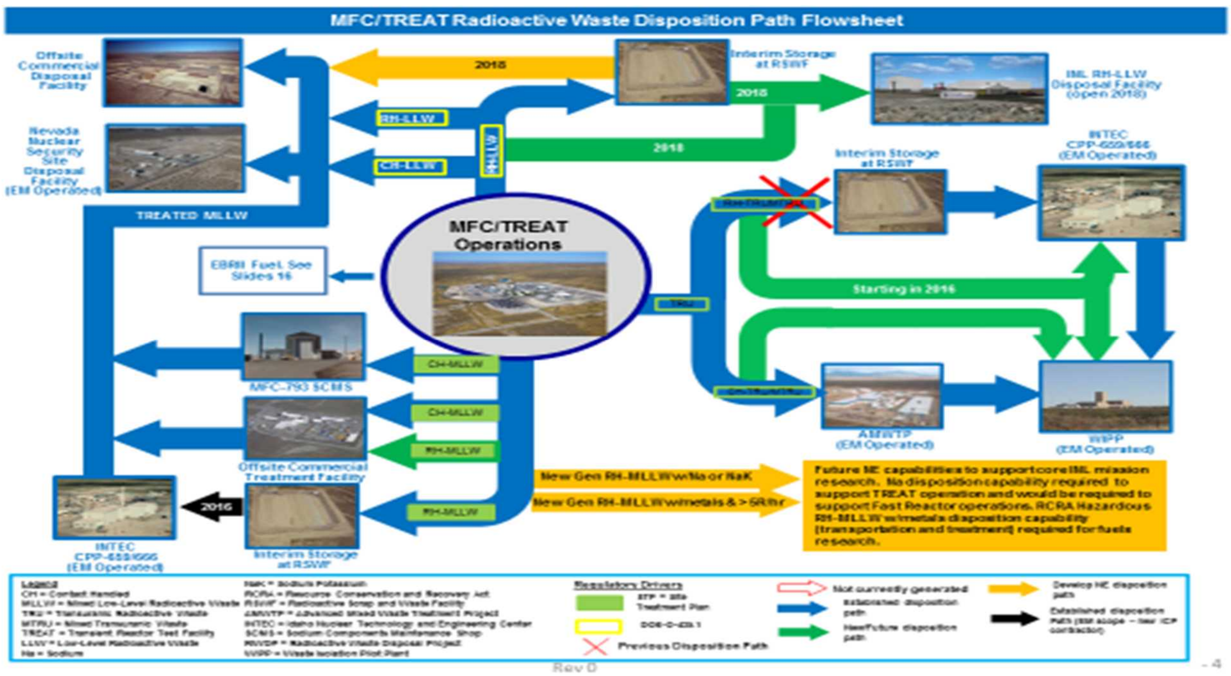


Figure 3. MFC/TREAT Radioactive Waste Disposition Path Flowsheet.

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 two 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 establishes disposition paths for new waste streams prior to generation. The INL remote-handled (RH) Waste Service Center collects revenue for newly generated RH waste that will be dispositioned when the INL RH-low-level waste (LLW) Disposal Facility opens or when the backlog at WIPP is eliminated after reopening.

Currently BEA is using the EM contractor capabilities and Waste Isolation Pilot Plant (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 thru May 2021. BEA is developing a plan to establish a TRU program to support ongoing newly generated TRU.

2.4.2 Legacy Materials Management

The Department of Energy (DOE) is responsible for the storage, management, and disposition of a number of legacy waste 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), and CH-MLLW. These items are all managed under the INL Site Treatment Plan (STP) as directed by the consent order between the DOE and the Idaho Department of Environmental Quality (IDEQ).

A strategic plan has been developed for establishing a path for off-site treatment capabilities for the CH-MLLW, and portions of the RWDP backlog, with the potential for application of the treatment capability against future reactive waste or materials on a case-by-case basis.

Identifying off-site treatment as the preferred approach considered 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 the INL. This plan also provides the key activities, preliminary cost estimates, and high level schedule that are required to implement the preferred approach.

MFC is also in the process of repackaging legacy RH-TRU waste located in the HFEF and FCF Hot Cells in a manner compatible with characterization capabilities located at INTEC CPP-659 (e.g., externally clean 55-gallon drums). Characterization using Real-Time Radiography and Non-destructive Assay techniques will be used in INTEC CPP-659 to certify the waste containers prior to shipment to WIPP.

The funding profile associated with the various inventories is outlined below.

Table 3 summarizes investments on treating the irradiated EBR-II elements, as well as, waste and materials management from multiple fund sources across the laboratory.

Table 3. MFC Materials and Waste Management Funding Profile.

Activity	2018	2019	2020	2021	2022	Total (K)
Inventory	**Cost**	**Cost**	**Cost**	**Cost**	**Cost**	**Total (K)**
Driver Fuel Treatment (7) Batches 14 receipts	$7,755	$7,988	$8,227	$8,474	$8,728	**$41,172**
R&D for treatment alternatives & efficiency improvements	$980	$1,605	$1,645	$1,685	$1,730	**$7,645**
SCMS backlog (STP)	$600	$1,500	$1,500	$3,000	$3,000	**$9,600**
Fermi Drums (Lab Funded)	$5,800	N/A	N/A	N/A	N/A	**$5,800**
CH-MLLW Treatment Alternatives	$750	$750	$1,500	$1,500	$1,500	**$6,000**
RH-TRU/MTRU Repack	$350	$420	$420	$420	$420	**$2,030**
RWDP Backlog – DOE-EM funded		$700	$700	TBD	TBD	**$1,400**
RWDP Backlog – DOE-NE funded	N/A	$1,500	$9,500	$3,000	N/A	**$14,000**
Total DOE-NE Funding	**$10,435**	**$13,763**	**$22,792**	**$18,079**	**$15,378**	**$80,447**
Total Laboratory Funding	**$5,800**	**N/A**	**N/A**	**N/A**	**N/A**	**$5,800**
Total DOE-EM Funding	$700	$700	$700	TBD	TBD	**$2,100**
Total (K)	**$16,935**	**$14,463**	**$23,492**	**$18,079**	**$15,378**	**$88,347**

2.4.3 Strategy to Accelerate Production of High Assay Low-Enriched Uranium (HA-LEU) Material

The irradiated sodium-bonded uranium-based material from the EBR-II reactor includes ~60 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 for evaluation and treatment.

The current treatment 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 separating the components of the used fuel and successfully neutralizing the bond sodium; however, improvements for efficiency and/or alternative treatment technologies will be necessary to successfully meet the 2035 deadline agreed to in the Idaho Settlement Agreement (ISA). Accordingly, INL has initiated investigations aimed at identifying potential treatment alternatives, as well as possible process enhancements to the current system. The goal of the investigation is to identify new technologies/methods for efficiency improvements and cost reductions in order to successfully achieving the 2035 ISA deadline.

FCF is currently operated 10 hours/day, 4 days/week under current funding of approximately $8M. The current funding includes support for 25 FTEs and a production rate of 6 batches of driver fuel treated per year. To reach the desired production rate of 19 batches per year (1 MT HA-LEU) to support the 2035 milestone, requires a tripling of the normal annual product output. In order to achieve this, FCF would need to: add staff and transition to a 24/7 operating schedule, complete security upgrades, and complete equipment reliability upgrades. A total of 75 FTEs would be required for this effort. It is estimated that the time necessary to ramp up operations to the desired production rate (1 MT HA-LEU) would take 18 months from the date in which work was authorized and funding was provided.

Security upgrade construction activities are already in progress and will complete in FY-18. Implementation of security enhancements related to zone inventories may impact treatment throughput; these constraints are currently being evaluated. It is expected that security constraints will not impact the production assumptions in this evaluation.

The age of the facility 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, refurbishment of the through-wall tele-manipulators and overhead electro-mechanical manipulators will be completed prior to ramp up in operations at a cost of approximately $3M. Installation of a new, redundant cathode processor (multi-function furnace) to eliminate the single point failure for processing equipment will cost approximately $5M and could be completed after production ramp up has started.

2.4.3.1 Funding and Schedule Estimate to Achieve Desired Production Rate

The estimated **additional cost** to support the increased personnel and resource requirements is approximately **$21-$23M/year**. Approximate total estimated costs for production of 1 MT HA-LEU annually is = **$31M per year**.

As discussed previously, a one-time investment of $8M is required to address reliability improvement needs.

The production schedule provided in the table below assumes funding begins at the start of FY-19.

Table 4. Proposed Schedule for Accelerated HA-LEU Production.

Estimated Accelerated HA-LEU production from FCF		
	Direct Ship from CPP-666 to FCF	Retrieve from

							RSWF	
	2018	2019	2020	2021	2022	2023	2024	2025
Batch/yr	6	7	15	19	19	19	19	12
HA-LEU/yr (MT)	0.326	0.381	0.816	1.034	1.034	1.034	1.034	0.653
Cumulative Inventory (MT)	3.826	4.207	5.023	6.057	7.091	8.125	9.159	9.812
				Total from EBR-II Driver (MT)				9.812

2.5 Deferred Maintenance Listing

Table 5 below is the current full list of deferred maintenance as of September 2017 for MFC. Deferred maintenance addressed as part of the plant health initiative is identified in Table 2.

Table 5. MFC DM Master List as of September 2017.

ID	Requirement - Asset Name	Requirement Name	Est. Cost ($)
CPP-1634	CPP-1634 - Technology Dev. Facility	Repair roof section CPP-1634-RF01	$3,411
CPP-1634	CPP-1634 - Technology Dev. Facility	Replace Restroom Receptacle	$63
CPP-1674	CPP-1674 - Central Alarm Station	Repair Old security gate	$46,530
CPP-651	CPP-651 - Mat'l Security & Consolidation Fac.	Vault Berm	$517,000
CPP-651	CPP-651 - Mat'l Security & Consolidation Fac.	LaNai Doors	$413,600
MFC-1729	MFC-1729 - Irradiated Materials Characterization Lab	Repair roof sections MFC-1729-RF01 & RF02	$188
MFC-1731	MFC-1731 - Quonset #2 Storage Building	Support frame corrosion.	$1,560
MFC-701	MFC-701 - Security Building	Deteriorated Raised Floor Tiles	$11,373
MFC-701	MFC-701 - Security Building	Replace Exterior Windows	$11,166
MFC-701	MFC-701 - Security Building	Deteriorated Vinyl Composition Tile	$1,938
MFC-707	MFC-707 - Fire Pump House	Replace roof section MFC-707-RF01	$50,224
MFC-709	MFC-709 - Safety Equipment Building	Replace roof section MFC-709-RF01	$82,225
MFC-725	MFC-725 - MFC Fire Station	Repair Leaking Windows	$88,068
MFC-751	MFC-751 - Space Systems Building	Replace roof section MFC-751-RF01	$58,633
MFC-752	MFC-752 - Lab & Office Bldg.	Refurbish Leaking Window in Hot Cell 5	$413,600
MFC-752	MFC-752 - Lab & Office Bldg.	Refurbish Leaking Window in Hot Cell 6	$413,600
MFC-756	MFC-756 - Well Pump House #2	Replace roof section MFC-756-RF01	$19,220
MFC-758	MFC-758 - Electrical Substation Building	Replace roof section MFC-758-RF01	$56,413
MFC-759	MFC-759 - Emergency Reentry Building	Replace roof section MFC-759-RF01	$167,020
MFC-765	MFC-765 - Fuel Conditioning Facility	Replace Hot Cell Windows "A1"	$2,208,438
MFC-765	MFC-765 - Fuel Conditioning Facility	The truck-lock drain tank has been removed from service due to severe corrosion issues.	$206,800
MFC-765	MFC-765 - Fuel Conditioning Facility	Replace Facility Control System	$3,257,100
MFC-765	MFC-765 - Fuel Conditioning Facility	Replace Hot Cell Windows "P1"	$2,208,438
MFC-768	MFC-768 - Power Plant	Replace Roof Section MFC-768-RF04	$54,114
MFC-768	MFC-768 - Power Plant	Replace Roof Section MFC-768-RF06	$256,953
MFC-768	MFC-768 - Power Plant	Cooling water system	$1,654,400
MFC-768	MFC-768 - Power Plant	Replace Roof Section RF02	$127,192
MFC-768	MFC-768 - Power Plant	Deteriorated Exterior Windows	$36,904
MFC-768	MFC-768 - Power Plant	Water Intrusion in Cable Tunnel	$13,241
MFC-768	MFC-768 - Power Plant	Damaged Concrete Block Wall	$37,412
MFC-768B	MFC-768B - Water Chemistry Laboratory	Replace roof section MFC-768B-RF01	$55,502

ID	Requirement - Asset Name	Requirement Name	Est. Cost ($)
MFC-770B	MFC-770B - Sodium Component Storage Building	Leaking Roof Penetration	$5,182
MFC-771	MFC-771 - Radioactive Scrap and Waste Facility	Cathodic protection EOL.	$1,292,500
MFC-772	MFC-772 - EBR-II Engineering Lab	Replace roof section MFC-772-RF01	$111,004
MFC-774	MFC-774 - ZPPR Support Wing	Clean Air Conditioning Ducts	$6,332
MFC-775	MFC-775 - ZPPR Vault-Workroom Eq Rm	Replace roof section MFC-775-RF01	$945,588
MFC-776	MFC-776 - ZPPR Reactor Cell	Replace roof section MFC-776-RF01	$220,067
MFC-780	MFC-780 - Quality Level A & B Storage Building	Replace roof section MFC-780-RF01	$43,333
MFC-781	MFC-781 - Materials Handling Bldg	Corroded Loading Dock Equipment (North)	$28,145
MFC-785	MFC-785 - Hot Fuel Examination Facility	Refurbish Leaking Hot Cell Window - 20M	$1,477,142
MFC-785	MFC-785 - Hot Fuel Examination Facility	Refurbish Leaking Hot Cell Window - 5M	$1,477,142
MFC-785	MFC-785 - Hot Fuel Examination Facility	Refurbish Leaking Hot Cell Window - 6M	$1,477,142
MFC-785	MFC-785 - Hot Fuel Examination Facility	Refurbish Leaking Hot Cell Window - 4D	$1,477,142
MFC-785	MFC-785 - Hot Fuel Examination Facility	Correct deteriorated exterior walls, leaking foundation wall, and sealed flooring.	$454,698
MFC-785	MFC-785 - Hot Fuel Examination Facility	Facility Out-of-cell cranes 40 ton high bay	$1,551,000
MFC-785	MFC-785 - Hot Fuel Examination Facility	Argon compressors	$1,292,500
MFC-785	MFC-785 - Hot Fuel Examination Facility	Small transfer lock doors and structure	$356,951
MFC-785	MFC-785 - Hot Fuel Examination Facility	Decon spray system	$152,919
MFC-785	MFC-785 - Hot Fuel Examination Facility	NRS Exhaust	$361,900
MFC-785	MFC-785 - Hot Fuel Examination Facility	Air Conditioning Ducts	$7,321
MFC-787	MFC-787 - Fuels & Applied Science Building (FASB)	Replace roof section MFC-787-RF01	$275,707
MFC-790	MFC-790 - Equipment Storage	Replace Deteriorated Roof Insulation	$429
MFC-791	MFC-791 - Instrument & Maintenance Facility	Deteriorated Concrete Block Walls	$67,972
MFC-794	MFC-794 - Experimental Fuels Facility	Replace Damaged Steel Beam	$1,994
MFC-798	MFC-798 - Radioactive Liquid Waste Treatment Facility	MFC-798 holding tanks leak	$1,551,000
		Total	$27,107,436

3. INSTRUMENT SCIENTISTS AND NEW INSTRUMENT CAPABILITIES

Experiment infrastructure supports dedicated instrument science teams and a funding line for new instrumentation that, when coupled together, push the boundaries of nuclear energy research. Dedicated predictable funding is required to ensure this capability is available to accept current mission work and provide the ability to fully support the growing industry need for research.

3.1 Instrument Science Teams

A dedicated cadre of scientists, engineers, and technicians is critical to ensuring the efficient generation of high-quality information that moves innovative concepts up the scale of technology readiness. Instrument scientists and engineers are responsible for:

- Ensuring that each research tool is performing at its peak level and seeking world leading innovations in data analysis and instrument hardware
- Performing great science as part of collaborative teams and serving the user community as a subject matter expert on instrument techniques and data analysis
- Helping build the user community by seeking opportunities to apply instrument techniques in unique and innovative ways to materials and fuels challenges.

These scientists, engineers, and technicians require a specialized skill set to operate sophisticated research instruments, interpret data, and safely and effectively conduct research in nuclear facilities. Instrument science teams publish extensively to ensure dissemination of knowledge gained from their instrument.

These skills are acquired and honed by training and experience over several years. As MFC research facilities extend capabilities and operating hours to deliver on increasing requests for research, additional instrument scientists and support staff will be required. In order to be effective in helping drive innovation, these staff must be able to focus in a manner that allows them to be world-leading experts. MFC is experiencing a steady increase in research requests that have exceeded the existing staff's ability to support. A user facility-like model for developing personnel must be cultivated that allows both hiring in advance of the need and more efficiently and effectively increasing, introducing, and reinforcing the core principals and critical skills required to build competence.

Part of the instrument science function (great science) is currently supported by DOE programs; however, these programs are focused on fuels and materials. Stable funding for instrument scientists allows focus on instruments, measurement techniques, and analysis methods enabling existing characterization and post-irradiation examination instruments to meet user needs and provide world-class data.

A wide range of instruments and techniques are required to execute the nuclear technology development cycle, including skill sets that are not typically represented at instrument-focused user facilities. Fabrication material scientists, for example, provide fuel and material specimens that are a necessary part of the development cycle.

Proposed instrument scientist teams include the following instrument and technique areas:

- Nuclear fuel fabrication research
- Nuclear fuel and cladding system assembly
- Visual examination
- Neutron and x-ray radiographic and tomographic imaging

- Gamma spectrometry
- Eddy current analysis
- Metrology (the science of dimensional measurement)
- Fission gas measurement and analysis
- Optical microscopy (including sample preparation and micro-hardness testing)
- Mechanical property testing
- Fuel accident testing
- Thermal property measurement
- Scanning Electron Microscopy (SEM)
- Electron Probe Micro-Analysis (EPMA)
- Focused Ion Beam (FIB)
- Transmission Electron Microscopy (TEM)
- Neutron and x-ray diffraction
- Analytical chemistry sample preparation
- Inductively Coupled Plasma (ICP) Methods (Atomic Emission Spectroscopy, Mass Spectroscopy, Multi-Collector)
- Thermal Ion Mass Spectroscopy (TIMS)
- Gas Mass Spectroscopy
- Radiochemistry
- Alpha Spectroscopy
- Beta Spectroscopy
- Gamma Spectroscopy
- Wet chemical separations
- Data analysis and visualization
- Statistical analysis of data.

Instrument science teams consists of lead instrument scientists, engineers, and technical specialists. Program funding currently supports existing team members at approximately the level shown in the first column of Table 6. The remainder of Table 6 provides additional staffing needs by year given new instruments, additional responsibilities of instrument scientists, and the increasing MFC research workload.

The funding profile provided in Table 8 is proposed to transition to the instrument scientist funding approach described in Section 1.3 to accelerate development and implementation of state-of-the-art instruments and capabilities that are essential for MFC's function as a national nuclear R&D test bed.

Table 6. Proposed staffing profile for instrument science teams.

Facility Instrument Team Staffing (FTE)	**Current Staffing**		**Additional Instrument Team Staff Increases Needed per Year (additive)**									
	FY-18		**FY-19**		**FY-20**		**FY-21**		**FY-22**		**FY-23**	
	IS/E	**Tech**	**IS/E**	**Tech**	**IS/E**	**Tech**	**IS/E**	**Tech**	**IS/E**	**Tech**	**IS/E**	**Tech**
HFEF/NRAD	7	20	3	2	2	1	5	1	3	1	1	1
IMCL/EML/SPL	14	9	2	2	1	1	1	1	1	1	5	4
AL/RCL	17	10	2	2	1		1			1		
EFF/FASB	2		2		1		1					
TREAT	1		1									
Data/Stats	1		1									
MFC Instrument Team Total FTE	**39**	**39**	**10**	**6**	**5**	**2**	**8**	**2**	**4**	**3**	**6**	**5**

Table 7. Proposed funding profile for instrument science teams.

Instrument Teams Funding ($K)	**FY-18**	**FY-19**	**FY-20**	**FY-21**	**FY-22**	**FY-23**
Base Instrument Teams (current DOE-NE support)	$23,080	$24,234	$25,446	$26,718	$28,054	$29,457
Additional Instrument Team Hires		$4,862	$7,066	$10,320	$12,401	$15,636
Total Instrument Science Funding	**$23,080**	**$29,096**	**$32,512**	**$37,038**	**$40,455**	**$45,093**

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 researcher and development teams to ask and to 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 times, 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 upon 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 Research Instrumentation Strategy

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 instrumentation needs from 2018 – 2023 include:

- High spatial resolution thermal conductivity measurement system to measure the change in thermal conductivity across a fuel pellet.

- High-resolution multi-collector inductively coupled mass spectrometers that provide extremely accurate isotopic analysis in a fraction of the time of previous technology. This is needed for improved fuel burnup analyses and fission product measurements.
- Electron Energy Loss Spectrometer (EELS) and precession diffraction system (e.g., the ASTAR system) installed on an existing transmission electron microscope that provides elemental composition and chemical state at the atomic scale and grain orientation on the nanometer scale.
- A second shielded cell for performing irradiation assisted stress corrosion cracking (IASCC) growth rate measurements.
- Femto-second laser that allows rapid and quantitative chemical and isotopic analysis of nuclear materials without chemical dissolution.
- 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.
- 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 to increase over the next five years as major maintenance issues are retired. The total proposed funding level from 2018 through 2023 is up to $122M. This is generally identified in the funding table in Subsection 1.3. 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. Beyond FY-22, a steady state funding level of $15–$20M per year will expand the DOE-NE test bed capability and ensure that the suite of instruments remains current, reliable, and upgraded to meet user needs.

Table 8 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 B.

Table 8. Summary of FY-18–FY-23 instrument development strategy and ROM cost estimates ($K, FY-16 dollars).

Number	Facility Name	Capability	Sustainment/ Development	FY-18	FY-19	FY-20	FY-21	FY-22	Outyears	Total
1	IMCL	Install Thermal Properties Cell and Glovebox (laser flash, DSC, thermogravimetric, and dilatometry)	Development	$3,500						$3,500
2	AFF	Expanded Fuel Fabrication Capability	Development	$3,500						$3,500
3	AL	Mass Spectrometers for AL (Quad/ToF-MS/LA-LIBS)	Sustainment	$3,800						$3,800

Number	Facility Name	Capability	Sustainment/ Development	FY-18	FY-19	FY-20	FY-21	FY-22	Outyears	Total
4	HFEF	Complete GASR and Polisher/Grinder Refurbishment	Sustainment	$1,500						$1,500
5	HFEF	TREAT Experiment Handling Support at HFEF	Sustainment	$1,000						$1,000
6	FASB	Install new 'workhorse' SEM into FASB	Sustainment	$500						$500
7	HFEF	East Radiography Station Elevator Repair	Sustainment	$1,000						$1,000
8	HFEF	North Radiography Station Neutron Science Readiness	Sustainment	$1,000						$1,000
9	IMCL	Titan TEM upgrades (EELS)	Development		$1,300					$1,300
10	HFEF	Replace Leitz Metallograph in MetBox	Sustainment		$500					$500
11	IMCL	Titan TEM probe upgrade	Development		$750					$750
12	NRAD	NRAD neutron diffraction capability	Sustainment		$385	$565	$485	$500		$1,935
13	IMCL	In-situ thermal, mechanical, and micro isotopic measurement using FIB	Development		$700	$250	$250			$1,200
14	IMCL	Atom probe tomography instrument	Development						$4,500	$4,500
15	MFC	Qualify International Sample Transport Cask (Flying Pig)	Sustainment			$900				$900
16	HFEF	ECP/EBLM refurbishment	Sustainment							$ –
17	AL	B-wing ICP-OES (non-rad)	Sustainment		$300					$300
18	HFEF	Install and test visual examination system	Sustainment		$500					$500
19	Various	Expanded fuel fabrication capability	Development			$700	$500	$1,000	$2,000	$4,200
20	All	Research data management and visualization system	Development			$250	$1,000	$1,000		$2,250
21	NRAD	NRAD digital neutron radiography/tomography	Development		$500	$1,000	$1,000			$2,500
22	HFEF	Shielded multi-instrument non-destructive PIE capability	Development		$955	$1,000	$3,000	$5,000	$7,000	$16,955
23	FASB	IASCC shielded cell #2 (FASB)	Development						$8,500	$8,500
24	AL	Replace TIMS	Sustainment			$1,000	$1,000			$2,000
Not prioritized	IMCL	Develop robotic capabilities for advanced PIE	Development							$ –
Not prioritized	IMCL	Redesign of the IMCL DSA	Sustainment							$ –
Not prioritized	IMCL	Additional IMCL user-defined shielded instrument	Development						$4,000	$4,000
Not prioritized	ATR	In-canal non-destructive PIE system	Development						$7,800	$7,800

Number	Facility Name	Capability	Sustainment/ Development	FY-18	FY-19	FY-20	FY-21	FY-22	Outyears	Total
Not prioritized	AL	Gas flow proportional counters, series 5 LB5500 (Canberra) or WPC-1150 model (Protean)	Development						$75	$75
Not prioritized	AL	Agilent or Thermo triple quad ICP-MS	Sustainment						$700	$700
Not prioritized	AL	High performance liquid chromatograph	Sustainment						$200	$200
Not prioritized	AL	Gas mass spectrometer	Sustainment							$ –
Not prioritized	AL	High Resolution ICP-MS (B-154)	Sustainment						$1,400	$1,400
Not prioritized	AL	Quad ICP-MS	Sustainment						$1,400	$1,400
Not prioritized	BEAMS	NRAD Automated Computed Tomography system	Development		$500	$850	$850	$200		$2,400
Not prioritized	BEAMS	NRAD Beamline Upgrades	Development		$550	$600	$400			$1,550
Not prioritized	BEAMS	NRAD Power upgrade to 1 MW	Sustainment						$7,500	$7,500
Not prioritized	BEAMS	High Energy X-ray Diffraction System	Development						$1,325	$1,325
Not prioritized	BEAMS	Transmission Mode XRD Development	Development			$700				$700
Not prioritized	BEAMS	X-ray Micro-CT System	Development		$800					$800
Not prioritized	FIB	Replace EML Quanta FIB	Sustainment		$1,000					$1,000
Not prioritized	Fuel Performance Science	NDE of Fuel Microstructure Using X-ray Computed Tomography (HFEF)	Development						$3,000	$3,000
Not prioritized	Fuel Performance Science	Develop High Spatial Resolution (micron) In-Cell Elemental Measurements for Fuel (HFEF)	Development			$450				$450
Not prioritized	Fuel Performance Science	Develop Elastic Modulus Measurement Capability (HFEF)	Development			$200	$300	$250		$750
Not prioritized	Fuel Performance Science	In-cell Machining of Cladding (HFEF)	Development			$300				$300
Not prioritized	Fuel Performance Science	Separate Effects Furnace (HFEF)	Development			$200	$250			$450
Not prioritized	Fuel Performance Science	Develop General Purpose Oxide Thickness Measurement System (HFEF)	Sustainment			$500	$500			$1,000
Not prioritized	Fuel Performance Science	Develop Capability to Examine Thermometry Packages (IMCL)	Development				$200			$200
Not prioritized	Fuel Performance Science	Laser-based pulsed neutron source (HFEF)	Development							$ –
Not prioritized	TEM	In-situ Mechanical Testing for Titan TEM (IMCL)	Development						$200	$200
Not prioritized	TEM	Ion Mill (PIPS-II) for Sample Preparation (IMCL)	Development						$170	$170

Number	Facility Name	Capability	Sustainment/ Development	FY-18	FY-19	FY-20	FY-21	FY-22	Outyears	Total
Not prioritized	TEM	Replace EML TEM (EML)	Sustainment						$1,875	$1,875
Not prioritized	TEM	ASTAR system (IMCL)	Development		$360					$360
Not prioritized	EML	Replace EML SEM (EML)	Sustainment		$750					$750
Not prioritized	SEM	Upgrade Energy Dispersive Spectrometers (JEOL 700, JEOL 7600)	Sustainment		$165					$165
Not prioritized	SEM/EPMA	Upgrade Electron Microprobe (EPMA) to Field Emission Gun (IMCL)	Development						$2,000	$2,000
Not prioritized	SEM/EPMA	In-situ Mechanical Property Testing	Development				$400			$400
Not prioritized	Thermal	Adiabatic calorimeter	Development							$ –
Not prioritized	Other	Shielded Multi-Instrument non-destructive PIE Capability MEITNER (HFEF)	Development						$16,000	$16,000
Not prioritized	Other	Physical Property Measurement System(IMCL)	Development						$800	$800
Not prioritized	Other	Qualify International Sample Transport Cask 'Flying Pig' (HFEF, IMCL)	Development						$900	$900
Not prioritized	Multiple	Acquisition of new BRR cask	Sustainment						$2,800	$2,800
Not prioritized	AL	Capillary Electrophoresis	Development			$200				$200
Not prioritized	AL	Ion Chromatography	Sustainment			$200				$200
Not prioritized	AL	Liquid Scintillator	Sustainment						$150	$150
Not prioritized	AL	3 Mobius gamma detectors	Sustainment						$400	$400
Not prioritized	AL	Multi-Collector ICP-MS	Sustainment						$1,600	$1,600
		Annual Totals		**$15,800**	**$10,015**	**$9,865**	**$10,135**	**$7,950**	**$76,295**	**$130,060**
		Mission Enablement		$9,900	$40,300	$41,509	$42,754	$44,037	$45,358	
		Grand total		**$25,700**	**$50,315**	**$51,374**	**$52,889**	**$51,987**	**$121,653**	

3.2.2 TREAT Reactor Instrumentation Development Strategy

INL-LTD-15-33324 provides an overview of the capabilities required for conducting experiments in TREAT. These capabilities are introduced sequentially as the complexity of transient testing increases and fuel types range from LWR to advanced fuels. The objective over the last several years has been to establish the baseline capsule testing capabilities in time to coincide with resumption of TREAT reactor operations. These baseline capabilities are necessary for providing the initial transient testing services required for projects and programs with near-term needs (e.g., the NTRD Accident Tolerant Fuels Program). The baseline capability includes equipment, facilities, and expertise to perform basic transient tests using static capsules. These capabilities will need to advance significantly to include prototypic environments (pressure, temperature, and recirculating coolant) and state of the art in-pile instrumentation over the following 5-year period (FY-18–FY-22) to continue to meet the nuclear fuel technology development objectives.

Additional TREAT capabilities are required for experiment handling, experiment vehicles, experiment instrumentation, and PIE functions.

TREAT instrument funding needs are provided in Table 9. The descriptions of each instrument or support system are provided in Appendix C.

Table 9. Summary of FY-18–FY-22 Transient testing scientific and enabling infrastructure development strategy and ROM cost estimates ($K, FY-16 dollars).

Number	Facility Name	Capability	FY-18	FY-19	FY-20	FY-21	FY-22	Total
1	TREAT	Low Activity Experiment Handling Bench	1,500	1,700				3,200
2	HFEF	HFEF Capsule Experiment Handling Capability	2,000	1,500				3,000
3	HFEF	HFEF TREAT Loop Handling Capability			3,000	3,000		6,000
4	TREAT	TREAT Hodoscope	1,400	1,400	1,000	1,000	1,000	5,800
5	HFEF	Remanufacturing Bench for Irradiated Fuel Pins	500	700	1,000	1,500		3,700
6	TREAT	Transient Science Modular Irradiation Vehicle (MARCH System)		1,000	1,000			2,000
7	TREAT	Recirculating Sodium Transient Irradiation Loop (Mk-IV Sodium Loop)	2,500	3,000	2,500			8,000
8	TREAT	Multi-Capsule PWR Transient Irradiation Vehicle (Multi-SERTTA)	1,000	1,500				2,500
9	TREAT	Large-Capsule PWR Transient Irradiation Vehicle (Super-SERTTA)	500	2,500	3,000			6,000
10	TREAT	Recirculating PWR Transient Irradiation Loop (TWERL)			1,000	4,000	3,000	8,000
11	TREAT	Enhanced Reactivity Clipping System (HENRI)						5,000
12	TREAT /HTTL	Advanced In-Reactor Instrumentation for TREAT	1,000	1,000	2,000	2,000	2,000	8,000
13	TREAT	Advanced Radiography Examination Station for TREAT		500	1,000	1,000	1,500	4,000
Research Instrument Total ($K)			**$10,400**	**$14,800**	**$15,500**	**$12,500**	**$7,500**	**$65,200**

4. MFC CAMPUS VISION

MFC is a central part of the NE test bed and demonstration platform and the future growth associated with this concept. To support advanced nuclear technology development, the nuclear energy technology RD&D must progress further up 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 provide these new capabilities along with a strategy to replace and relocate capabilities to support the growing test bed needs. These new facilities are described below and range in maturity from planned construction and line-item critical decision (CD) progress 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 the NE test bed and demonstration platform. Additional capabilities such as a large scale demonstration and deployment capability (e.g., expanded fabrication, mock-up, and testing) will be identified with input from the research community and industry.

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, including the proposed new Research and Engineering Center, are focused in the NW quadrant of MFC sited near HFEF and IMCL. Current and future fuel fabrication RD&D facilities are located in the SE quadrant near FMF. Current and potential future analytical laboratory research and support capabilities will remain in the central or SW portions of the campus to support all research areas. Industrial support services will move to the NE quadrant. Traffic will be rerouted around the perimeter of MFC to reduce vehicle and equipment interaction with research and support staff and provide more direct access to research and industrial portions of MFC.

Additional issues 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 the 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 will be addressed as funding allows. Deferred maintenance backlog and repair needs will be targeted. Transportation flow and general roads and grounds will be reviewed with respect to the future campus design. Sustainability activities such as xeriscaping and LED light replacement will be 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 funded nuclear infrastructure 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; and
3. Laboratory-funded investments include general-use buildings, structures, and support infrastructure. Examples here are building roofs and skins, electrical and HVAC, lighting replacement, sidewalks and pavement, and other sustainability efforts.

4.1 MFC Capital Asset and Direct Nuclear Infrastructure

Two new capital asset construction projects are the MFC Research Collaboration Building GPP (in construction) and the line item Sample Preparation Laboratory (in design). Both are described in the following sections. Other facilities in much more conceptual phases are also generally described. None of the conceptual facilities have been estimated for cost and are all pre-mission need. These are identified below in Figure 4 and are described generally in the following sections.

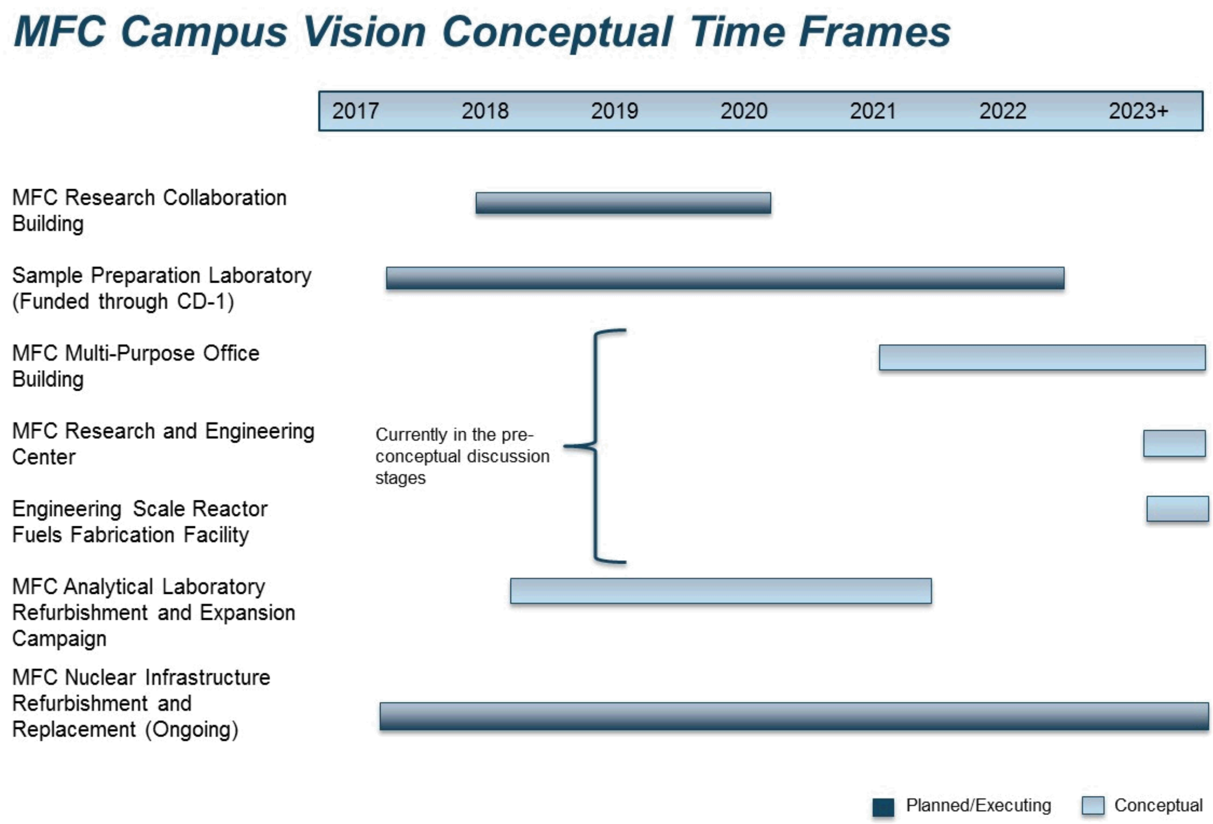


Figure 4. MFC Campus Vision Conceptual Time Frames for Capital Asset and Direct Nuclear Infrastructure.

4.1.1 MFC Research Collaboration Building

Description

A major role of DOE-NE in advancing nuclear technology is to bring the best and brightest scientists together in a cooperative manner to resolve technical challenges in nuclear energy. The interaction of scientists and engineers at the working level ensures that innovative ideas, supported by data, can be translated to workable technology solutions.

Benefits

This facility provides much needed collaboration space and will enable close interaction between INL researchers and technical staff with visiting users from outside the INL and the United States. This allows technical staff to support key experiment discussions, design, and logistical activities at a location adjacent to the test bed without having to travel away from their work locations and provides visiting users close proximity to MFC.

Facility Risk

MFC office space is currently nearly 100% occupied. As use of IMCL grows and SPL achieves operational status and the number of outside researchers using MFC is projected to grow beyond 200 per year in approximately 2022, additional collaborative research space is needed where research teams, consisting of INL researchers, visiting researchers and engineers, and other key technical support can collaborate and use advanced data analysis and visualization tools to resolve technical challenges.

Estimated Cost: $9.5M TPC.

Status: Planning and design began in FY-17 with CD-0 approval with facility completion planned in FY-19.

4.1.2 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.

Benefits

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 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: Project costs reflect upper end of the cost range approved at CD-1 is $98.2M TPC.

Status: SPL currently has an approved CD-1 facility design and CD-2/3 is occurring during FY-18.

4.1.3 MFC Research and Engineering Center

Description

The MFC research corridor is expanding into the NW quadrant of MFC. The addition of IMCL and the planned SPL adds a host of new RD&D capability alongside HFEF. This new facility will house the researchers and engineering support for these facilities and provide space for design and planning of the critical RD&D conducted within them. The design of the facility is also proposed to support access through a new security portal with adjacent parking outside the facility fence line. This provides effective access to this major portion of the MFC research corridor and collocates

Benefits

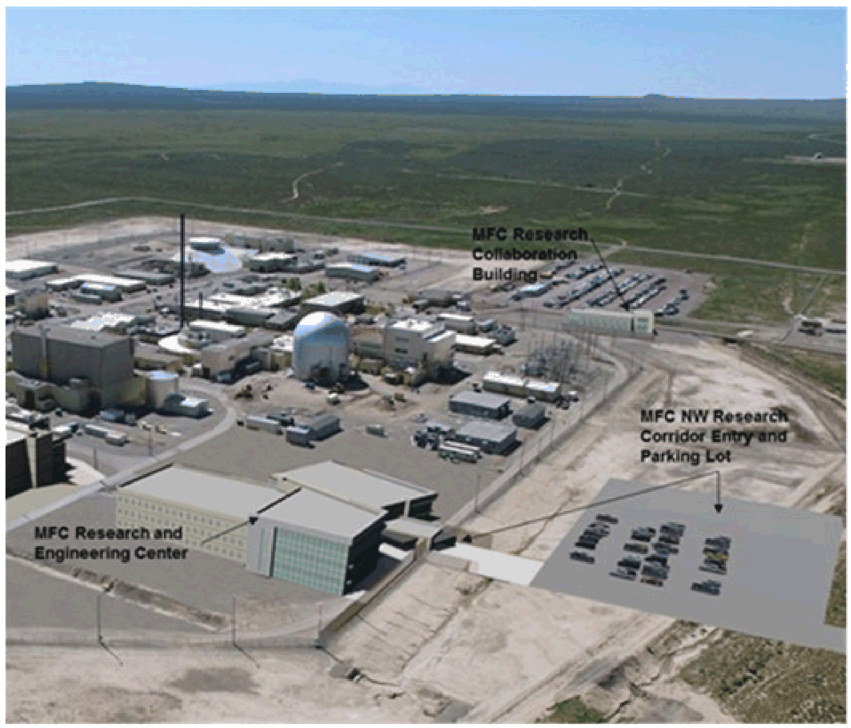
This facility will provide crucial capacity to collocate research staff and technical personnel close to the NW portion of the test bed research corridor providing critical support functions next to the key RD&D facilities needing this support. This also provides an ability to vacate many modular office buildings constructed in the late 70s and early 80s and significantly past their intended service life. Along with the recent decontamination and decommissioning (D&D) of MFC-718, this will support footprint reduction with the ability to now D&D MFC-713 built in 1978, MFC-717 built in 1985, and several other trailers near HFEF.

Facility Risk

This facility is needed to support efficient execution of mission operations in the research corridor located in the NW quadrant of MFC and house the research and technical support staff needed to support the test bed. This will also enable D&D of aging facilities to reduce the mortgage associated with maintenance on facilities well past their design life.

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

Status: Pre-conceptual



4.1.4 Reactor Fuels Fabrication Laboratory

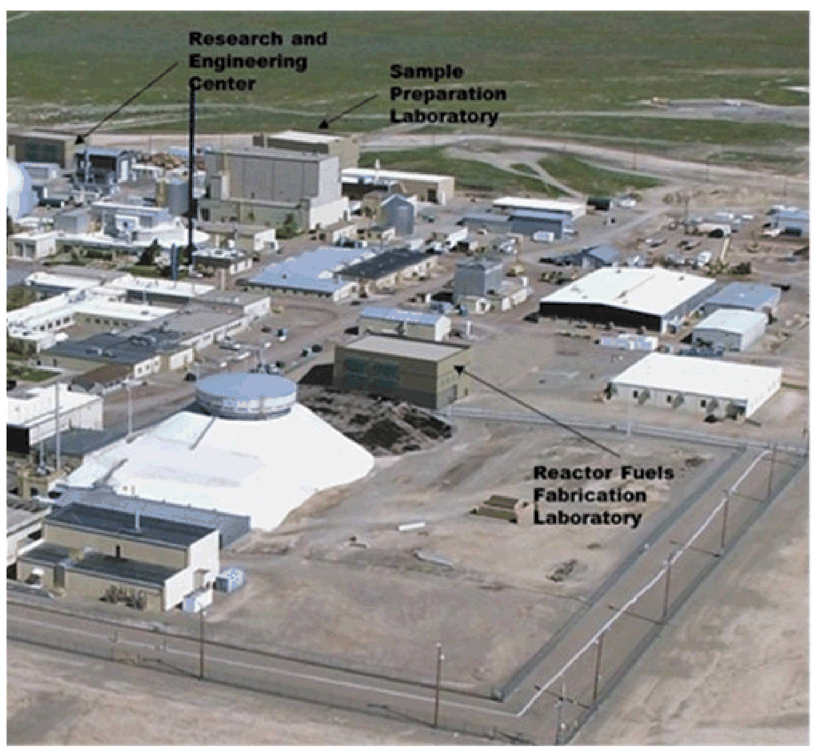
Description

The Reactor Fuel Fabrication Laboratory provides a reconfigurable, long-term solution for meeting DOE, small business, and commercial needs for manufacturing demonstration-scale quantities of fuel for licensing in current and advanced reactors that benefits DOE and industry.

Benefits

An important part of reducing the fuel development time for commercial fuel deployment is the ability to rapidly fabricate large enough quantities of fuel to validate fabrication techniques as well as have enough fuel to fully analyze performance. To fully implement GAIN, a new large-scale fuel fabrication facility will be needed to allow demonstration of new fuel systems. Demonstration articles must be fabricated using prototypic fabrication processes that produce fuel with reproducible characteristics; doing otherwise confounds the technical understanding of fuel response and makes transitioning from research to development to licensing difficult, because fuel performance data cannot be correlated to fabrication processes and/or microstructure. 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 NRC licensed nuclear power industry is regulated to less than 5% enriched uranium and is only licensed for commercial reactor uranium oxide fuels. This limitation includes vendors such as AREVA, Westinghouse, and GE. BWXT has the capability to make fuels with higher enrichments, however, they are not licensed by the NRC to produce commercial reactor fuel in the U.S. Further, their fuel fabrication capacity is nearly fully utilized by their current customers and their business model is not well suited for this work. National Laboratories are, by their nature, geared toward this type of activity. The 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 fuel fabrication in the United States for fabrication of test-bed or engineering scale quantities (2-100kg) of fuel focused on demonstration-scale quantities of fuel. To fill this gap requires a flexible and reconfigurable hazard category II fuel fabrication facility within the DOE complex that can handle large quantities of nuclear materials with no enrichment limitations. This facility would allow the fabrication of lead test rods, lead test assemblies, micro reactor cores and the demonstration of new fabrication processes using many kilograms of material. Existing examples of customers and opportunities that could utilize this facility include Terra power, accident tolerance fuel lead test rods, specialty fuels, domestic TRIGA fuel fabrication, and any new fuel that would need demonstration in the next 15 to 20 years.



In addition to the direct fabrication capability, an important aspect of this study is to evaluate the extent of the QA 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 at the 2-100kg demonstration level and variable enrichment, 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 ladder from basic research through demonstration.

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

Status: Pre-conceptual

4.1.5 MFC Analytical Laboratory Enhancement/Expansion

Description

The 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. Since that time, however, there has been no cohesive, concentrated effort to ensure the AL maintains its ability to support the nuclear mission of INL. Throughout its history, the AL has been primarily focused on providing chemical and isotopic analyses in support of experimental programs. In addition, the 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 to ensure the facility is able to meet its nuclear mission and has several single-point failures that could have a major negative impact to MFC's mission if they occurred. Currently, the AL is functioning close to maximum capacity and floor space is at a minimum with operations moving toward multiple shifts as has occurred at other MFC nuclear facilities. Over the next five years, programmatic work coming to the AL is expected to exceed the laboratory's ability to meet mission need. While measures can be taken to ensure the AL can meet its near-future commitments by addressing such items as ventilation, the laboratory cannot keep pace with the advancements being made at MFC due to lack of space for state of the art instrumentation, personnel, and the infrastructure needed to support research activities. The AL is almost 60 years old and a feasibility study should be conducted to determine how AL can best be modernized to effectively meet it current and projected expanded mission.

Benefits

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 Risks

AL currently operates at close to maximum capacity. A revitalization program has been proposed 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 allow for the expansion of analytical capability to meet anticipated advances in the nuclear mission unless some combination of footprint expansion and re-purposing/refurbishment occurs. The growth anticipated within the MFC complex and AL cannot continue unless the infrastructure needs associated with such growth are addressed.

Estimated Cost/Status: AL HVAC upgrades ($10M) commenced in FY-18 with the first phase of AL refurbishment concluding in FY-19.

4.2 Nuclear Research Support Infrastructure Refurbishment and Replacement

Plant health investments are the investments needed in the nuclear and radiological facilities that directly support the research at MFC. Investments are needed in other crosscutting infrastructure areas to ensure they remain reliable and capable of supporting the research mission and the anticipated growth of the test bed. As the test bed matures, and use of these facilities and their current and anticipated future nuclear RD&D capabilities grow, additional investments beyond the plant health of the nuclear research facilities are needed to maintain facility reliability and availability to support increasing RD&D needs.

Additional areas being evaluated:

- Communication upgrades such as fiber optic internet cabling, high-speed wire cabling, and secure wireless internet systems
- Data collection and transmission networks
- Private Facility Control Network (PFCN) cyber security upgrades
- Backup power modernization and consolidation
- Newly generated waste treatment, storage, and disposal (TSDF) capability upgrades
- Underground utilities and support systems (pneumatic sample transfer system, steam, water, liquid waste, etc.) needed to support increased use and throughput
- Electrical distribution upgrades (e.g., switchgear replacement, transmission upgrades, etc.).

MFC is currently evaluating and planning activities in the above mentioned areas. Specific scope will be evaluated similar to the overall plant health process for prioritization. As a basis of estimate, approximately $10M per year of investment is considered an adequate and executable level. This area could be executed as specific campaigns addressing the overarching issues identified above (or other emergent issues) across the host of nuclear and radiological facilities similar to site-wide electrical infrastructure and road campaigns that are currently being executed or planned for at INL.

4.3 Laboratory Investments in MFC General Use Infrastructure

4.3.1 MFC General Use Infrastructure

MFC Facility Operations are the hub of DOE-NE's) test bed. The U&IS Group (balance-of-plant), is the hub of MFC facility support operations. U&IS Group's operations, maintenance, and subcontractor-oversight activities are associated with:

- Directly and indirectly funded infrastructure efforts such as updating or refurbishing existing support facilities and their associated structures, systems, and components (e.g., structural, electrical, or heating, ventilation, and air-conditioning (HVAC)-related activities), and efforts such as legacy material disposition
- Laboratory-funded investments for general-use buildings, structures, and support infrastructure. Examples here are building roofs, skins, interiors, electrical and HVAC, pavement and sidewalks, landscaping, lighting replacement, and other sustainability efforts, as well expansion activities.

The U&IS Group is responsible for operation and maintenance (O&M) of MFC support structures (mostly administrative buildings) and BOP utilities. The bulk of administrative-building inhabitants are employed in cross-cutting roles associated with Nuclear- and Radiological-Facility operations.

The laboratory invests every year in maintaining the general use infrastructure across the INL. Additional laboratory investment in MFC general use areas will support ensuring MFC has a reliable infrastructure to support the NE test bed and demonstration platform concepts incorporated in GAIN. Much of the support infrastructure inside the MFC fences is the original structures and systems installed many decades ago and well beyond their intended service lives. Additional support infrastructure will be needed to enable the increasing mission work being executed at MFC as well as the diverse new activities anticipated. These capabilities will extend the ability to support broader technology readiness levels. Identification and prioritization of investments is dynamic due to changing technology priorities. The estimated level of investment needed for planning purposes is approximately $10 million per year.

4.3.2 General Infrastructure Examples

As stated above more detailed planning is necessary to develop a comprehensive prioritized plan. General areas being evaluated include:

- Site electrical transmission upgrades and refurbishment to bring additional power needed for new capabilities and sustainment of the existing capabilities. This includes local utility upgrades, inter-site electrical transmission loops/corridors
- Increased high performance computing capabilities to support advanced modeling and analysis
- Site-wide wireless internet capability
- Multi-programmatic use facility re-purposing
- Roads, grounds, and general transportation refurbishment and upgrades
- Office space refurbishment and replacement
- Roofs and facility exteriors
- Telecommunications modernization (e.g., high speed, broad-band communication between MFC and the outside world).

General use areas may also be included as parts of wider direct funded "campaigns" as DOE work authorization dictates.

4.3.3 General Use Capital Investments

Some out-year general use Institutional General Plan Projects (IGPP) will be necessary to support NE test bed development and maturation at MFC. This includes investments in general use facilities across MFC and includes multi-programmatic use facilities such as support facilities at the TREAT complex. While these have not all been identified, examples are given below:

4.3.3.1 Multi-Purpose Office Building

Description

New support infrastructure is required to replace aging and less than adequate modular structures currently exceeding capacity to house existing staff. 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, and MFC-714 (233% capacity) was acquired in 1977. 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. Most of the large modular offices are in a degraded condition.

Construction will be coordinated with D&D of the aging facilities or removal of the leased facilities in order to re-purpose valuable campus footprint.

Benefit

The INL is planning a long term campaign to couple lab investment in new office construction with D&D or removal of many of these modular office facilities over a period of years beginning in 2021. Three permanent office buildings will be strategically located across the MFC campus to provide housing for RD&D personnel and support staff near the areas where resources are needed. For example, locations being evaluated include the HFEF/IMCL/SPL research corridor and the central part of the campus where a lot of the support such as administrative, planning, or business related personnel reside.

Modernizing office areas also provides intrinsic benefits relative to employee satisfaction and retention. Attracting world class talent to MFC is greatly enhanced with strategic differentiators such as modern facilities over aging infrastructure.

Facility Risk

Current capacity to house RD&D resources is at or nearly beyond limits. As missions expand at MFC additional resources will also require work space to support RD&D activities. An integrated long term strategy to update aging and failing office infrastructure and accommodate expansion is essential to support test bed and demonstration mission support.

4.3.3.2 Heavy Equipment Services and Maintenance Building

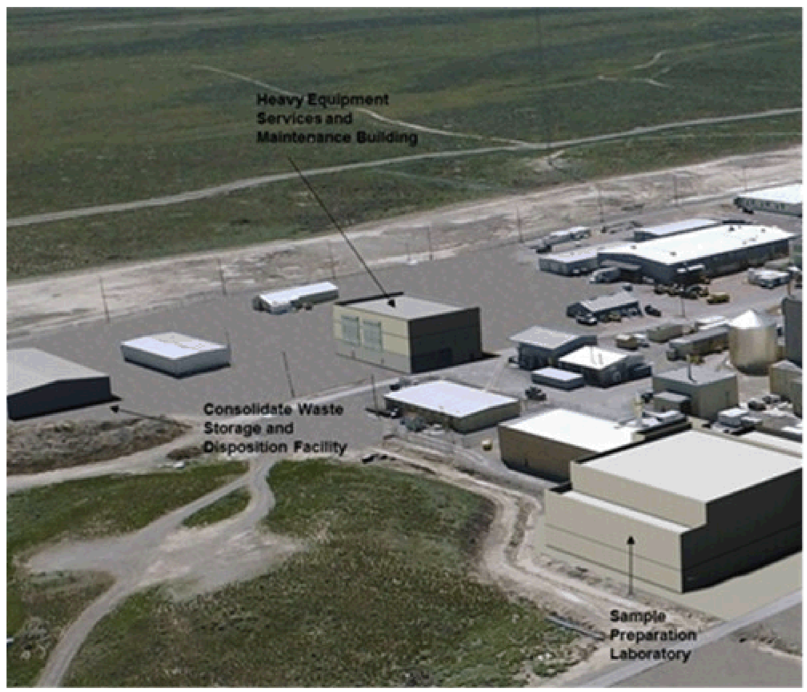
Description

The MFC Plant Services Building (MFC-753) was first constructed in 1961 and is located near the center of the expanding MFC research corridor. MFC proposes to open up the research corridor to reflect a more open campus functionality by relocating the heavy equipment services function and many of the maintenance support functions to the NE quadrant of the complex.

Benefits

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. This supports the campus vision of collocating industrial functions to the NE quadrant of MFC, separating them from the research corridor areas and freeing up campus space in the research corridor for test bed growth.

Facility Risks



More heavy equipment demands will be placed on MFC as the test bed grows and nuclear energy technology demonstrations and capabilities mature. More needs for the use of heavy equipment is anticipated, which will also increase interactions of equipment movement and research staff working in a collocated area. An aging test bed support infrastructure will impact test bed growth as needs grow and support availability is impacted from outdated beyond-design-life support capabilities.

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

Status: Pre-conceptual

4.3.3.3 MFC Consolidated Waste Storage and Disposition Facility

Description

The current waste management capabilities of the Sodium Components Maintenance Shop (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 to be located in the NE 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.

Benefits

This facility reduces risk by reducing the footprint of outdoor storage of material. This aligns with the vision of the research corridor expanding into the NW portion of the campus with industrial functions located in the NE quadrant.

Facility Risks

MFC must meet the growing waste management demands that will be associated the NE test bed. This facility is necessary to support consolidation of waste management activities from across the test bed, open up 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.

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

Status: Pre-conceptual

4.3.3.4 TREAT Control Room and Support Complex

Description

The transient testing facilities at MFC provide multi-programmatic support to an array of users from across the US and internationally. TREAT initially began operations in 1959 and, as with the rest of MFC, much of the infrastructure is antiquated and does not reflect what is needed to support modern day operations as a world class research facility. Initial planning is underway to provide modern support facilities capable of housing staff and hosting visitors in an environment that supports world class R&D collaboration and operations.

This effort refurbishes MFC-721, the TREAT office building and constructs an additional support annex to this facility. The addition to MFC-721 will include new offices, rest rooms, and collaboration space. A new septic system and parking areas are also included.

Benefits

MFC-721 was constructed in 1958. The infrastructure including the septic system has not been substantially updated since then. TREAT provides a transient testing capability in the US and plays a pivotal role in the NE test bed and demonstration platform. This upgrade provides a world class modern office building and “storefront” to the TREAT complex.

Facility Risks

The load occupancy for MFC-721 is not adequate to hold the operations and support staff needed to adequately enable RD&D at TREAT in an efficient manner. Staff is current overcrowded and doubled or sometimes tripled up in offices. Staff must be housed away from the reactor and are not able to easily support or collaborate with users in an efficient way. There is no room to house users or to effectively manage, support, and collocate experiment teams with operations and technical staff.

Estimated Cost: Class V estimate range of $4.5M–$5.5M

Status: Conceptual, no current time frame for construction.

Appendix A

Detailed Descriptions of Plant Health Activities

1. Replace or Upgrade the AL HVAC System

Description

AL suspect exhaust fans and HEPA banks are 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.

The HFEF pressure and temperature (P/T) system is used to control main cell atmospheric conditions. A portion of the P/T system was replaced in the 2016 major maintenance outage. The next phase is updating the purification system which controls the cell oxygen and moisture content. Aging components in the system have begun to cause significant maintenance issues, requiring increased costs in personnel time and replacement parts.

Benefits

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 availability of laboratory due to 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 HFEF argon cell purification system control which improves operational efficiency (reduced operational burden to maintain desired atmosphere and improved HFEF main cell atmosphere control to meet mission needs.

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 Estimated Cost: $10M.

2. AFF HVAC Modifications

Description

Similar to the prior CESB-to-EFF HVAC modifications, this effort will design, procure, and install a HEPA-filtered building HVAC system in the Advanced Fuels Facility (MFC-784).

Benefits

The current facility has no air conditioning and gets extremely uncomfortable to work in during the afternoons in the three summer months. The HEPA-filtered building HVAC system will permit installation of radiological hoods and large radiological equipment with hooded enclosures (e.g., mill, lathe, grinder, arc melter, etc.) within a Contamination Area, significantly increasing the nuclear fuel manufacturing equipment that can be installed in the available facility footprint.

Facility Risk

If INL does not install a HEPA-filtered building HVAC system in MFC-784, then radiological hoods and large radiological equipment with hooded enclosures cannot be installed in the available facility footprint. The INL will miss or delay opportunities to meet RD&D test bed and demonstration platform objectives, for external lab impact, and for funded RD&D scope. The facility will also continue to have a very hot working environment for three months of the year limiting the amount of time personnel can reasonably perform continuous work.

ROM Estimated Cost: $2M.

3. 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 work station. 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.

Benefits

This project provides 'like for like replacement' of the aging manipulator fleet. 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 Estimated Cost: $17.9M.

4. 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 window panes. 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.

Benefits

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.

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 Estimated Cost: $25.5M.

5. HFEF Argon Cell Temperature and Pressure Controls

Description

The HFEF pressure and temperature (P/T) system is used to control main cell atmospheric conditions. A portion of the P/T system was replaced in the 2016 major maintenance outage. The next phase is updating the purification system which controls the cell oxygen and moisture content.

Benefits

Increased reliability and operational safety of the HFEF argon cell purification system control. Improved operational efficiency (reduced operational burden to maintain desired atmosphere. Improved HFEF main cell atmosphere control to meet mission needs.

Facility Risk

Aging components in the system have begun to cause significant maintenance issues, requiring increased costs in personnel time and replacement parts. The major risk to the facility involves a component failure that requires feed and bleed as the only method to control oxygen and moisture levels in the cell. This may not meet operational specifications or mission needs for the cell atmosphere and would result in delays while design and repair efforts are pursued. This may affect operational milestones and mission commitments.

ROM Estimated Cost: $.1.5M

6. Replace FCF Facility Control System (Programmable Logic Controller Replacement)

Description

The facility and process monitoring and control systems in the Fuel Conditioning Facility (FCF) consists of three main systems that interact with one another. The main systems are:

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

Replacements are required to maintain FCF operability. Without these system replacements, high facility reliability and availability cannot be sustained. These replacements are needed due to equipment obsolescence and the mandate to move systems off of Microsoft Windows XP platforms. The current PLCs and SLCs use modules that are no longer available from the vendor. The vendor is requiring replacing these older systems with new up-to-date hardware in order to provide vendor support. Migrating to new hardware will involve porting the existing PLC/SLC application software. The OCS human machine interface (HMI) was developed using FIX32 and will not run on platforms running Microsoft Windows versions newer than XP. This HMI software needs to be converted from FIX32 based applications to iFIX based applications in order to run on the latest Windows operating system platforms.

Benefits

1. Increased Facility availability and reliability
2. Security of systems is increased
3. New hardware will be supported
4. Commercial spare parts readily available

Facility Risk

Facility PLC and SLC equipment has reached end of life. The controllers in question provide critical data and control functionality to/from various processes throughout the facility. Equipment failure will have a detrimental impact on FCF’s daily operations and overall mission. The impairment caused by the failure of this equipment would result in minimal or no facility activities to be performed during an outage caused by equipment failure. This equipment must be upgraded in order for FCF to operate through its anticipated life.

ROM Estimated Cost: $3.0M

7. Replace the Criticality Alarm System (CAS) in FMF and ZPPR

Description

Replace the existing Criticality Alarm System (CAS) with a new and equivalent system. CAS components are many years past their intended design life and spares are no longer available. These facilities have each experienced one to two week outages due to failed detectors. Repair was accomplished by scavenging detectors from other out of service alarm systems.

Benefits

Installation of a state-of-the-art system will ensure maximum facility availability for mission work and readily available spare parts.

Facility Risk

Failure to upgrade the CAS will result in the eventual failure of detectors or other irreplaceable components resulting in unacceptable facility downtime of up to 6-9 months as a replacement system is fabricated and installed.

ROM Estimated Cost: $1.5M.

8. HFEF Facility Out-Of-Cell 40-Ton High Bay Crane

Description

The 40-ton high bay crane is a traveling bridge crane that traverses the full length and width of the high bay. The crane is used to load and offload the majority of casks used to transport research specimens to and from the facility. Prior to installation in the HFEF, the 40-ton high-bay crane was in service at other INL locations since 1955. The crane was installed in HFEF during initial construction and has now been in service for over 60 years. The crane exhibits a variety of issues related to age that now requires upgrading. These issues include rails and trucks wearing out, trucks climbing up on rails due to crabbing of the trolley, and an obsolete control system failing frequently.

Benefits

The benefits related to repair of the 40-ton crane is significantly increased reliability as well as proper operation and operating efficiency.

Facility Risk

The facility risk (if this repair is not completed expeditiously) is the complete halt to HFEF operations and any HFEF related program work since the crane is vital in processing casks and waste containers in and out of the facility. It is estimated that a work cessation due to crane failure could span greater than a year as a replacement is obtained and installed.

ROM Estimated Cost: $3.1M.

9. HFEF/IMCL Supplied Argon System Replacement

Description

The existing HFEF argon compressors are obsolete. The existing compressors are old (1950s vintage) and obsolete; direct replacements are not available. HFEF is operating on compressor #2, compressor #1 is out of service. It is estimated that compressor replacement with a comparable system would take approximately 12-18 months and would require extensive modification to HFEF. Compressor #1failed in 2017 due to an internal water leak. The water damaged the connecting rod seals, efforts to repair the compressor failed. Now when running it raises the oxygen levels significantly in the HFEF main cell. Do to the lack of available spare parts, this compressor cannot be put back into operation. The solution to the failed/failing compressors is to replace this system with a large liquid argon storage tank. The tank will be located north or HFEF. The tank will supply all the loads that is currently carried by the compressor and will also remove portable gas bottles utilized to support various programs that require pure argon blankets, like JFCS. In addition to supplying the compressed argon system the argon tank will replace the current "emergency" argon supply system with one that can actually support the HFEF main cell for an extended period of time. The current system can supply 2000 SCFM to a cell that is 60,000 SCFM.

The system is large enough and will be located in an area that can also be utilized by IMCL to support programmatic work. IMCL has several gloveboxes that would benefit from have an argon atmosphere. Currently IMCL must use portable AR bottles to supply any programmatic need.

Benefits

The argon tank is a passive system that has no moving components. The removal of moving components greatly reduces failure mechanisms. This reduces the risk to programs in HFEF. Currently if the compressed argon system fails it will stop program work in the containment box, which also effects the METBOX. The failure of the compressors will also make the large equipment lock inoperable, if the large lock is inoperable the HFEF main cell must be placed in the standby mode. Again the lack of moving components will greatly improve reliability of HFEF. The ability to place the "emergency" argon system on the tank eliminates a potential vulnerability and provides a more extensive defense-in-depth system.

Facility Risk

This reduces the risk to programs in HFEF. Currently if the compressed argon system fails it will stop program work in the containment box, which also effects the METBOX. The failure of the compressors will also make the large equipment lock inoperable, if the large lock is inoperable the HFEF main cell must be placed in the standby mode. Currently if the compressors fail HFEF could be in the standby mode for 3 to 6 months while this modification is made. The operating compressor is due for an extensive rebuild based on hours of operation, if performed there is a potential that the compressor will not be capable of being resealed due to lack a materials or degradation of components. By not performing this maintenance there is an increased risk of compressor failure.

ROM Estimated Cost: $2M.

10. 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.

Benefits

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 Estimated Cost: $6M.

11. Radioactive Liquid Waste Treatment Facility Process/Storage Tanks Alternatives Analysis and Replacement

Description

RLWTF has four 1000-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.

Benefits

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 Estimated Cost: $3M.

12. MFC Sitewide Drainage System Upgrade

Description

The MFC Sitewide Drainage System is composed of stormwater runoff and industrial wastewater. Stormwater runoff includes the runoff from all MFC building roofs and inside the fence ground-level surfaces. There is also a small volume of monitored industrial wastewater from facilities. The highest volume of water flow occurs subsequent to rain storms and during winter snow/ice meltoff. Currently flooding occurs in the lower levels of the nuclear facilities HFEF, FCF, AL, FMF/PIDAS, and various U&IS administrative buildings due to the poor drainage. Flooding of manholes and equipment vaults also occurs and potentially causes degradation of electrical and telecommunication wiring. There is also damage occurring to facility foundation walls. At the present time, MFC does not have a drainage system specification that would be referenced when developing plans for future expansion.

Benefits

Properly engineered, graded, and maintained drainage systems greatly reduce the pooling of water from storm surge and meltoff. This reduces the likelihood of personnel injury due to slips/trips/fall hazards due to uneven surfaces or when the pools freeze. A comprehensive drainage-system specification would include the covering of open ditches, correct gradient requirements, and allow for project/facility expansion within system civil engineering specifications. Proper drainage would eliminate the flooding of facility basements and reduce damage to facility foundation walls.

Facility Risk

The risk of not improving the drainage system and allow continued flooding:

- Introduces a safety concern – currently there are electrical vaults and manholes that frequently flood and introduce the potential for water to cascade via conduit runs to switchgear in facilities
- Damage/degrade facility structure and equipment
- Leave standing pools of water that freeze in the winter
- Water infiltration into buildings can be a radiological issue
- Erosion of existing ditches and culverts further exacerbates the drainage problem
- Manual labor spent pumping down electrical manholes and vaults
- Potential to periodically shutdown facility operations
- Integration of new projects without a sitewide drainage plan

ROM Estimated Cost: $2.1M. Laboratory Investment

13. TREAT Automatic Reactor Control System Replacement

Description

The Automatic Reactor Control System (ARCS) is the computer system that facilities precise movement of the transient rod drives in fast speed, in accordance with programmed transient prescriptions. The ARCS is an aging system based on 1980s hardware and outdated software (FORTRAN, PL/M, and Assembly code). Some spare parts are no longer manufactured, contractors providing vendor support are increasingly rare, and INL personnel with programming skills in the required languages are retiring. Without a functioning ARCS system, the TREAT reactor cannot perform transients to support experiment programs.

Benefits

The new ARCS system will upgrade to a modern hardware and software platform. The new system eliminates the three risks described above and allows TREAT to continue to support transient experiment programs.

Facility Risk

The facility risk is a complete shutdown of the TREAT reactor for up to 12 months to finalize development, procurement, installation, and testing of a new system at an unplanned time. The realization of any of the three risks described above (no spares, vendor support evaporating, or INL skillsets retiring) could facilitate this complete shutdown. All three risks are also amplified as delays in procurement of the new system occur. With proper planning and timely procurement activities occurring in parallel with the current reactor operating schedule, the system can be installed in a controlled fashion within an approximately two month maintenance outage that complements programmatic goals.

ROM Estimated Cost: $3M

14. MFC HVAC Replacement Campaign

Description

The majority of administrative buildings at MFC are more than 30 years old. Infrastructure like HVAC is largely original equipment and failures are common, replacement parts are unavailable, and the units are inefficient. In the case of the L&O building, direction of air flow is important not only scientific, executive, and administrative staff, but also to the connected Analytical Laboratory. The temperature control requirements for personnel comfort are extremely challenging when relying on HVAC equipment that is in various stages of disrepair.

Benefits

Properly ventilated, heated, and cooled working environments are critical when expecting optimal performance of personnel in their workspaces. Updated HVAC equipment will reduce the amount of emergent maintenance required during the hottest part of the year.

Facility Risk

The daily temperature variance, high summer and very low winter-temperature extremes can result in very uncomfortable working conditions. The conditions can be less than ideal for operating equipment. Unreliable and inefficient HVAC equipment poses large manning requirements for personnel with specific maintenance capabilities. Personnel output is reduced both in volume and quality when working environments are not satisfactory.

ROM Estimated Cost: $400K per multi-year campaign

15. FMF/ZPPR Roof – Replacement

Description

The FMF is covered by an earthen berm that provides shielding for the nuclear material located in the building. The berm is classified as a safety system. A cellular confinement stabilization fabric is placed over this berm and serves as the roof for the building. The existing FMF roof exhibits numerous areas where the fabric anchors have backed out and the rock has fallen below the fabric. The ZPPR fabric roof is at end-of-life and requires replacement. This project will repair the entire berm area and replace the roofing material with a new, similar system. This is needed due to the general amount of deterioration between 2011 and 2013, and the accelerated deterioration in areas where water is able to penetrate (TEV-1979).

Benefits

The FMF berm serves a safety function as radiological shielding; the depth and material composition are important factors in the shielding calculations. Subsidence that significantly decreases the depth of the berm material will increase the resulting radiation dose. The ZPPR fabric and earthen covering serves a safety function as radiological shielding; the depth and material composition are important factors in the shielding calculations. Subsidence that significantly decreases the depth of the berm material will increase the resulting radiation dose.

Facility Risk

Continued degradation of the roof materials will increase the risk of external radiation dose and will compromise the ability of a credited safety system to perform its intended function. Roof replacement is estimated to take 6-9 months from procurement to installation.

ROM Estimated Cost: $6M.

16. 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.

Benefits

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 Estimated Cost: $200K/lab room.

17. IMCL Noise Reduction Modifications

Description

The Irradiated Materials Characterization Laboratory (IMCL) is the newest nuclear energy research facility at the Idaho National Laboratory's (INL) Materials and Fuels Complex (MFC). This unique 12,000 square foot facility incorporates many features designed to allow researchers to safely and efficiently prepare and conduct microstructural level investigations on materials of construction and nuclear fuels.

Since construction of IMCL, there has been an issue with acoustic noise within the IMCL facility. The noise has affected the proper operation of highly sensitive state of the art equipment and provides a noise level uncomfortable to staff and visitors in the facility. Noise emanates from the CAM (Constant Air Monitoring) system and the facility ventilation system. During testing of the ventilation system, it was found that capture velocity of gloveboxes and hoods in the facility could be maintained at a lower differential pressure, where noise is reduced. The following work will be performed to alleviate the noise issue:

1. Install a central compressed air distribution system to replace individual CAM pumps and to support installation of Fixed Air Sampling System.
2. Lower the pressure differential in the ventilation system. This involves:
   a. Documenting system testing and recommended differential pressure in a TEV (Technical EValuation)
   b. Conduct a smoke test to evaluate system performance
   c. With radiological control concurrence and facility procedures updated, implement the new differential pressure for lab operation.

Benefits

The benefits of the noise reduction within IMCL will allow for the utilization of the state of the art equipment at their optimum level, increased satisfaction for researchers and visitors to IMCL and increased knowledge for future state of the art building projects at MFC.

Facility Risk

Continued suboptimal utilization of instrument capabilities and uncomfortable noise level to researchers and visitors to IMCL.

ROM Estimated Cost: $350K.

18. HFEF and FCF Electro-mechanical Manipulator Repairs

Description

Electro-mechanical manipulators (EM) perform the majority of material intra-cell transfers to support both programmatic work and maintenance activities associated with in-cell equipment. This equipment is original to the facility and has been maintained on run-to failure basis. As such, the majority of the corrective maintenance centers around the EM carriages and bridge drives motor modules. This task ensures continued maintainability of the EM carriages and bridge drive modules as well as evaluating the bridges through the implementation of viewing equipment to perform remote inspections to identify and perform additional maintenance/upgrades necessary for continued operation.

Benefits

Operability of the EMs is directly related to the ability to complete programmatic work. This project will inspect and identify potential problems allowing correction and/or modification in a planned methodology to minimize programmatic impacts.

Facility Risk

Failure to perform this work can lead to increased failures of the EMs with significant lead times associated with planning, design/fabrication of replacement parts, and implementation. Since, many components on the EMs fabricated specifically for the end use. The delay times could be several months to restore full facility operations.

ROM Estimated Cost: $2M.

19. MFC Inside-the-Fence Pavement Upgrade

Description

MFC interior roads include 8 miles of paved and 2.6 miles of gravel road. A significant portion of pavement is driven or parked on by heavy equipment. Additionally, the paved areas support the majority of foot traffic. These interior roads and common areas need to be maintained to ensure standby-response vehicles can access all parts of the facility, materials can be delivered, and maintenance, security, operations, etc. can perform their daily duties to support the various programs.

The MFC U&IS budget can support minor asphalt work, such as pothole repair and minor crack sealing, but it is not able to fund larger-scale maintenance on the common areas, parking areas, and roads. This has resulted in the cracks in a large percentage of road surfaces going unsealed through multiple winter snow, freeze, and thaw cycles. Large portions of the interior roads have deteriorated, lost service life, and require investment in surface restoration/reconstruction. The deterioration is largely due to water infiltration that accelerates crack propagation and consequent road-base failure. Most of the asphalt surfaces at MFC are not in optimum condition: however, 9 areas have been identified as needing immediate attention. That combined area totals ~139,000 ft^2.

Benefits

Properly maintained roadways and walking paths minimize the potential for personnel injury due to slips/trips/falls from uneven/potholed surfaces and slick surfaces (ice buildup).

Facility Risk

Improperly maintained roads impact the drivability and, to some extent, the safety of the road. Increased cracking and reduced load-bearing capacity of the road leads to further degradation of the road base and increased life-cycle cost. Unaddressed road degradation affects day-to-day operations and emergency response activities.

ROM Estimated Cost: $2.1M. Laboratory Investment

20. Sitewide Radiation Monitoring Replacement Campaign

Description

Additional radiological control equipment is needed to support facility operations. Multiple facility CAMS and RAMS are obsolete and have reached their EOL. Beta and Alpha CAMS are required to be replaced because the in-service instruments are no longer supported by the manufacturer. The old units are failing at an ever increasing rate. Spares are not available. Other equipment consists of friskers, hand monitors and portable smear counters.

Benefits

The additional equipment will reduce inefficiencies associated with re-locating portable equipment within many of the RD&D facilities. In addition, locating this equipment near the point of work will reduce the risk of spreading contamination.

Facility Risk

Continued inefficiencies locating and moving portable equipment within the laboratory and limiting work activities due to un-availability of radiological equipment.

ROM Estimated Cost: $3.1M.

21. IMCL/EML Facility Critical Spares Inventory

Description and Benefits

To maintain above 100% availability and utilization of the facility research equipment there is a need for a critical spares inventory. Items for EML and IMCL include ventilation controllers and components as well as monitoring equipment and ventilation components for IMCL and their related confinements. The purchases will be IAW the remaining identified critical spares list per the EML and IMCL Facility Engineer.

Facility Risks

Failure to fund and implement this need for a critical spares inventory will increase equipment failure vulnerability, human performance risk and the risk of prolonged facility outages, resulting in reduced research equipment utilization and facility availability.

Estimated Cost: $250K

22. HFEF Small Transfer Lock Doors

Description

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.

Benefits

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 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 Estimated Cost: $600K.

23. HFEF Small and Large Transfer Lock Drive Control System Upgrade

Description

The HFEF small and large lock transfer control systems are at the end of life and are increasingly unreliable. In addition, the existing controls use 1970s technologies that are obsolete compared to current modern technologies. Based on this, modern control systems are needed to improve system reliability and repairability.

Benefits

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 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 Estimated Cost: $600K.

24. HFEF Containment Box

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.

Benefits

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 Estimated Cost: $500K.

25. MFC Legacy Materials Disposition

Description

Typically, disposition of waste is accomplished as waste is generated; however, past practices in performing mission work did not require disposition waste as it was generated resulting in a buildup of waste in the HFEF main hot cell. This waste accumulation has reduced the programmatic work space. To support GAIN and other missions, this legacy waste must be removed to provide adequate space for required facility and programmatic upgrades, and new mission-required equipment.

Benefits

Reduction in the existing quantity of legacy waste currently residing in the HFEF argon cell will increase the amount of useable floor space for installation of new programmatic equipment as well as facilitate transfer of equipment and materials within the cell.

Facility Risk

Failure to reduce the existing legacy waste backlog will inhibit new equipment installation as well as potentially delay programmatic work due to cell congestion and delays in equipment installation. Operations become severely limited and remote handling mishaps more frequent when waste items are allowed to build up in-cell.

ROM Estimated Cost: $500K per year multi-year campaign

26. HFEF Decontamination Spray System

Description

Many aspects of this system no longer function; the high pressure pump and control system is at its end of life. In addition, radioactive liquid waste from the Decontamination Cell, Transfer Tunnel, and Cask Tunnel sumps drain into the Shielded Drain Tank, TK-400, located in the liquid storage and transfer area (room 020) in the northwest corner of the HFEF service floor. The 150 gallon capacity limits the amount of decontamination that can be accomplished and significantly reduces operational efficiency. Adding shielding to an adjacent 1500 gallon tank to allow waste collection would greatly improve operational efficiency.

Benefits

Significantly increased operational efficiency since a higher capacity waste tank will allow more wash evolutions and reduce the number of drain cycles.

Facility Risk

The facility risk is a delay in program work due to the inability to transfer manipulators to the repair area because the spray system is out of service or the waste tank is full and the contents are awaiting characterization and subsequent waste disposition.

ROM Estimated Cost: $1.2M.

27. ZPPR Control Room Rip Out

Description

This effort removes old out of service reactor operating equipment from the ZPPR control room. The control is available to be re-purposed after this equipment is removed.

Benefits

Frees up additional critical footprint within a Hazard Category 3 nuclear facility to support R&D programmatic research.

Facility Risk

Reduces legacy material management costs associated with addressing this out of service equipment.

ROM Estimated Cost: $.1.5M

This work scope has been funded in FY18 through the DOE Office on Environmental Management.

28. HFEF Radioactive Drain System Piping/Valves/Tanks

Description

The instrumentation system has failed due to age related issues. The tanks have accumulated sediment over the last 40 years becoming radiological and ALARA challenges. Other aspects of this system that are a concern include: the high pressure pump is at its end of life, and the control system is as well. In addition, radioactive liquid waste from the Decon Cell, Transfer Tunnel, and Cask Tunnel sumps drain into the Shielded Drain Tank, TK-400, located in the liquid storage and transfer area (room 020) in the northwest corner of the HFEF service floor. The 150 gallon capacity limits the amount of decontamination that can be accomplished and significantly reduces operational efficiency. Adding shielding to an adjacent 1500 gallon tank to allow waste collection would greatly improve operations efficiencies.

Benefits

Significantly increased operational efficiency since a higher capacity waste tank will allow more wash evolutions and reduce the number of drain cycles.

Facility Risk

The facility risk is a delay in program work due to the inability to transfer manipulators to the repair area because the spray system is out of service or the waste tank is full and the contents are awaiting characterization and subsequent waste disposition.

ROM Estimated Cost: $350K.

29. 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.

Benefits

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 Estimated Cost: $.2.5M

30. FCF Integration of Bottle Inspection with Wire Removal

Description

Currently inspection of EBR-II fuel bottles for the presence of moisture is conducted at window 10 in the FCF argon cell. This is several workstations away from the chopping function which occurs at window 2. Movement of uninspected bottles from the air cell to window 10, and the return of inspected elements back to window 2 for chopping introduces a number of handling steps which contribute to treatment process inefficiency. Additionally, removal of wires at the same work station where chopping occurs accounts for a significant amount of the time that the fuel spends at that work station. If wire removal and cassette loading occurred in conjunction with bottle / element inspection additional handling could be eliminated.

Benefits

Elimination of lengthy in-cell transfers through multiple workstations, coupled with consolidation of the element / bottle inspection and spacing wire removal functions will increase overall treatment system reliability and process rate efficiency.

Facility Risk

Requiring elements and bottles to travel through the primary treatment workstations (MK-IV ER, CP, & CF) creates challenges in making sure the transfer paths are clear and introduces the potential for delays in the treatment process while waiting for the pathway to clear. Additionally, consolidation of multiple fuel subassemblies at window 2 challenges zone inventory limitations. Thus reduction in the amount of time fuel assemblies spend in this zone due to wire removal will help mitigate this challenge.

ROM Estimated Cost: $.1.5M

31. 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 RH-LLW Disposal Facility.

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.

Substantial issues were encountered in FY-18 associated with the HFEF-5 cask that negatively impacted RH-LLW Disposal Facility operational readiness activities and constrained waste/material movements critical to supporting R&D outcomes at MFC. These issues resulted in increased corrective maintenance costs significantly above historical averages to ensure base cask operability. Associated analyses are expected to identify modifications to the existing HFEF-5 that are required to support safe operations within a range of operating conditions that must be supported to not impact R&D outcomes. Similar deficiencies may be present with other existing casks at MFC. This plant health investment ($500K - $700K) 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.

The RH-LLW Disposal Facility is in the process of completing operational readiness. The facility includes final disposal locations for 250+ legacy waste containers stored at the Radioactive Scrap and Waste Facility at MFC. Transfer of this legacy waste for final disposal requires a cask/container system that supports the configuration of the waste canisters. This investment includes final evaluation, design, and fabrication of a cask/container to support transfer of the waste stream to the RH-LLW Disposal Facility ($1.2M - $2.0M).

Existing casks represent a single-point failure. Investment to procure additional casks (i.e., HFEF-5 cask and GE-2000 cask) is warranted to ensure that R&D outcomes are not impacted due to operability issues and conflicting demands with existing casks. ($3.5M–$4.5M)

Facility Risks

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.

Estimated Cost: $5,500K–$11,500K

Appendix B

Detailed Descriptions of Instrument Capability Activities

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Detailed Descriptions of Instrument Capability Activities

1. Completion of the Thermal Properties Cell and Glovebox in IMCL

Facility: Irradiated Material Characterization Laboratory

Description and Benefit

This effort includes completion of the installation of the thermal properties cell and glovebox, an effort that began in FY18. Completion of this will provide the support infrastructure required to house thermal properties instruments discussed further.

This project installs and qualifies thermal property measurement instruments in the IMCL thermal property shielded cell.

Thermal properties define the performance limits of nuclear fuel under irradiation. In most fuels, information on thermal conductivity as a function of burnup and temperature do not exist. This results in conservative assumptions about thermal conductivity that increase the required safety margin and decreases the reactor operating envelope. These instruments include LFTD (Laser Flash Thermal Diffusivity), DSC (Differential Scanning Calorimetry), a thermal expansion measurement system, and a thermal conductivity microscopy. Ancillary equipment for sample coating and microscopy will also be provided.

The current state-of-the art method for measurement of thermal conductivity involves three measurements; a thermal diffusivity measurement using LFTD, a heat capacity measurement using DSC, and a measurement of density as a function of temperature by one of several methods. This system provides excellent capabilities for measurements of fuels and materials that can be fashioned into regular disc shapes for the LFTD measurement. This suite of instruments provides data on thermal conductivity to temperatures of approximately 1500 C.

The thermal conductivity of irradiated fuel can be very difficult to measure using the standard laser-flash thermal- diffusivity method, because it requires a well-defined sample with specific dimensions. Irradiated fuel is often either fragmented, has the wrong diameter, or contains a center void that prevents the straightforward use of the LFTD method. In order to address these issues, INL has developed the TCM (Thermal Conductivity Microscope). Unlike the standard LFTD method, TCM allows thermal conductivity measurements to be made on fragments of irradiated fuel below 500C. The existing TCM will be installed in the IMCL Thermal Properties Cell.

The TCM method, together with LFTD must be used together to cross calibrate measurements and obtain a complete picture of thermal conductivity as a function of temperature for irradiated fuel.

Status: The LFTD, DSC, and thermal expansion system will be procured, installed, and qualified. The TCM has been developed and tested on the bench scale with radiological materials; remotization and qualification are required. Several other small pieces of equipment are required for sample handling, coating, inspection, and measurement.

Total ROM = $3,500K ($1,900K to complete the cell and glovebox, $1,600 to install the instruments
Project start: FY-18
Project completion: FY-21

2. Expanded Fuel Fabrication Capability

Facility: FMF, ZPPR, FASB, EFF, FCF, AFF, others

Description and Benefit

This strategy addresses multiple facility and process equipment upgrades to MFC fuel fabrication capabilities in several facilities in an attempt to meet continually increasing demand. The capability expansion under this strategy is intended to address our short term (5 year) RD&D Test Bed needs within existing MFC facilities and planning for possible future expansion.

1) There is a need to improve our basic science capability by providing high purity actinide materials and single crystal samples for characterization and evaluation. 2) Current applied science fuel fabrication research areas include plate fuel development, fast reactor fuels, transmutations fuels, advanced reactor fuels, and performance enhanced LWR and PWR fuels (accident tolerant fuels), all of which need to continuously improve processing techniques, including the use of advanced manufacturing techniques. 3) INL fields numerous requests to fabricate multi-kilogram quantities (engineering scale quantities) of experimental fuels including accident tolerant fuels for existing LWRs, as well as, develop fabrication processes for and build fuel in quantities sufficient for licensing of sodium-cooled fast reactors (TerraPower), demonstrate fabrication of recycled fuel (Joint Fuel Cycle Study with KAERI), and conduct a special one-of-a-kind projects for advanced and unique reactor concepts. These requests have highlighted the need for expanded fuel fabrication capabilities.

Expanding our basic science capabilities will allow the study of the fundamental properties of actinide materials that could provide valuable data for fuel performance modeling. Producing single crystals of uranium alloys and uranium doped materials will open up numerous fundamental property evaluations (including semiconductor characteristics) as well as provide unique irradiation opportunities to see how single crystals perform under irradiation and respond to irradiation damage. These capabilities will also help drive fuel development from an empirical art to a science.

In conjunction with the Lab initiative in advanced design and manufacturing, maintaining our leadership in applied fuel fabrication science requires keeping up with ever improving fabrication and manufacturing techniques. Many of these new fabrication techniques will open up fuel and cladding design options that where not possible with traditional fabrication techniques. Examples of advanced manufacturing techniques that are funded and require laboratory space to deploy are Spark Plasma Sintering (SPS), additive manufacturing, continuous metal fuel casting, metal fuel co-extrusion, and laser welding of cladding. Numerous other options are available that should be considered for applied science evaluation for use with nuclear fuel.

Many of the requests received by INL require large-scale fabrication campaigns under an NQA-1 program (Nuclear Quality Assurance) to increase the Technological Readiness Level through demonstration of fabrication and irradiation performance. These larger-sale campaigns, which cannot be conducted elsewhere, push the licensing constraints of our existing facilities and in some cases may make these activities impossible to execute in current facilities. Evaluating all of our current facilities to house engineering scale demonstrations such as these will be an on-going effort depending on the fuel fabrication process equipment needs and the quantities of finished fuel that is required.

Initially, additional capacity for RD&D can be made available by removing several obsolete glove boxes from existing facilities and repurposing several additional buildings. The objectives for individual facilities are provided below.

- **Fuels and Applied Science Building (FASB) –** Maintain as a general-purpose uranium-based fuel fabrication laboratory. Remove the obsolete “development” glove box line to make room for new Pyrochemistry glove box. Maintain characterization lab space adequate to rapidly and efficiently gauge process development.

- **Experimental Fuels Facility (EFF) –** Maintain EFF as uranium-based fuel fabrication laboratory. Improve facility process flow as needed to support RD&D needs.
- **FMF –** Primary transuranic-based (TRU) fuel development facility. Remove obsolete waste characterization glove box to allow for expansion with new glove boxes for casting and sample preparation. Evaluate the possibility for fabrication of demonstration-scale expansion to meet demand. Continue to develop and expand MOX applied research fabrication capability.
- **Zero Power Physics Reactor building (ZPPR) –** Expand work room capability to allow for higher enrichment and large quantity uranium-based fuel fabrication. Evaluate cell and alcoves for expansion of uranium-based processes.
- **AFF –** Repurpose this storage facility into a radiological facility in the same manner as EFF to allow deployment of advanced manufacturing techniques and relieve facility nuclear material quantity limits on other facilities.
- **Manufacturing Development Laboratory –** Expand capability and infrastructure to support TREAT experiment assembly and disassembly.
- **HFEF –** Develop remote fuel fabrication, as needed for the JFCS and for TREAT experiment re-fabrications.
- **FCF –** Expand capability to gravity cast FCF uranium product into molds. Evaluate further fission product removal from FCF product to foster contact handling. Support HALEU feedstock preparation.
- **RLWTF, INTEC-**651, INTEC-1634- Evaluate for repurposing into Hazard Category II fuel fabrication facilities.
- **Reactor Fuels Fabrication Laboratory-** Continue to evaluate the need for a new modern fuel fabrication facility.

Status: Scoping studies and sequential planning for an advanced fabrication capability expansion have started and will continue for some time.

ROM cost estimate: On going evaluation, initial $3.5M investment in FY18
Project start: FY-19
Project completion: FY-22

3. Mass Spectrometers for AL (Quad/ToF-MS/LA-LIBS)

Facility: Analytical Laboratory

Description and Benefit

Currently, AL owns one quadrupole ICP-MS (Elan DRC) purchased in 2005. This is essential to the support of programmatic, compliance, and waste characterization work, but its age and workload increase the probability of failure. There is an Increasing backlog of samples as more customers come to AL for analyses.

Loss of the aging Elan would delay indefinitely the majority of programmatic support. Dated hardware and software of the current instrument result in suboptimal analyses. Replacement parts are becoming more difficult to find

Limited current AL sample throughput can be significantly enhanced with a Time-of-Flight mass spectrometer (ToF-MS). Current AL mass spectrometers must calibrate in different mass ranges, increasing analysis times and producing more waste.

The AL's sample throughput is impacting the ability to meet demands as programs and programmatic scope increases. The ToF-MS also increases the ability to keep up with advancements in measurement science as technological advancements in other facilities grow. This allows AL to expand to multi-faceted capabilities as the TOF-MS can be easily coupled with other techniques.

Current AL methods for isotopic analysis lack the capability of surface profiling: only bulk material composition is measured. Surface profiling can give information on homogeneity or how the composition of a substance varies by depth. Laser Ablation-Laser Induced Breakdown Spectrometry (LA-LIBS) allows AL to take advantage of national and international collaboration opportunities, such as expanded partnerships with the Korean Atomic Energy Research Institute (KAERI), the Lawrence Berkeley National Laboratory (LBNL), and the Department of Homeland Security.

Status: A new Quadropole, ToF-MS, and LIBS along with replacement counting equipment is being procured in FY18.

Estimated cost: $33,800K
Project start: FY-18
Project completion: FY-19

4. GASR Refurbishment

Facility: Hot Fuel Examination Facility

Description and Benefit

The GASR (Gas Assay Sample and Recharge) system provides the ability to laser puncture irradiated fuel rods, measure fission gas pressure and fuel rod internal void volume, and if needed, refill/repressurize the rod with gas and weld the puncture hole closed. The GASR system also collects fission gas samples for composition and isotopic analyses. GASR data is critical for understanding the performance of all rod or pin-type fuels and contributes heavily to the licensing bases for these fuels. The GASR system has been maintained over its 30-year life, but never significantly upgraded. Many system components have become unreliable and component failure rates have increased dramatically over the last 2 years. The GASR system was inoperable for 4 months in FY-14, 1 month in 2015, and 1.5 months in FY-16. GASR failures have impacted PIE schedules for several programs. Replacement components are obsolete, and recent repairs were completed using parts purchased from eBay. Repairs have not restored 100% system capability. The GASR is scheduled for more than 1500 hours of operation in FY-17. Replacement of the system is necessary to ensure system reliability for future PIE campaigns.

Status: GASR failure rates are increasing. Upgrade and replacement of mechanical and electrical components, the GASR laser, electrical feedthroughs in the hot cell confinement boundary, and electrical control cabinets are necessary to ensure the reliability of these systems.

Estimated cost: $800K
Project start: FY-16
Project completion: FY-19

5. TREAT Experiment Handling Support at HFEF

Facility: Hot Fuel Examination Facility

Description and Benefit

HFEF is coordinating with TREAT to address restoring TREAT experiment handling capabilities in the HFEF Argon Cell. Current planning is centering around experiment handling capabilities in the 5M window.

Status: Planning has commenced in FY-18.

Estimated cost: $1,000K
Project start: FY-18
Project completion: FY-19

6. Install New 'Workhorse' SEM into FASB

Facility: FASB

Description and Benefit

This effort provides additional Scanning Electron Microscope (SEM) capability needed at MFC to meet research needs. Replaces SEM moved to IMCL. Multi-Programmatic work load required additional SEM. The accident tolerant fuels campaign, various experimental fuels under development by the DOE Advanced Fuels Campaign, and U-Zr fuels for AFC and TerraPower programs rely on SEM capability in FASB. Location in FASB ensures rapid and efficient characterization for quality assurance and research purposes. Addition of a third SEM will add additional capacity to buffer unplanned outages. Operation of the JEOL 7600 in IMCL will provide higher data quality than currently available.

Status:

Estimated cost: $500K
Project start: FY-18
Project completion: FY-18

7. East Radiography Station Elevator Repair

Facility: HFEF

Description and Benefit

Virtually all programmatic work that comes through HFEF starts with neutron radiography (nondestructive PIE). Critical decisions for destructive PIE are based on results from neutron radiography.

The ERS elevator mechanical and electrical control systems are original equipment, circa 1980. Components and spare parts are obsolete and no longer commercially available. Current controls do not allow for rotation of samples in the elevator. Tomography can only be supported with sample rotation "by hand," adding significant time and cost to research efforts.

Several functions of the elevator are out of service and can only be fixed with a complete upgrade (full up and down positioning detection, determining cable reel slack). A lack of position detection causes some images to be misaligned and requires rework, adding significant time and cost to research efforts.

Utility feed-through has failed circuits that have been bypassed with a temporary jumper.

Failure of obsolete components would result in long lead times to regain operational status, jeopardizing HFEF's ability to meet mission outcomes (if the elevator is not working, then programmatic work cannot move on from nondestructive to destructive PIE).

An up-graded elevator and control system would allow neutron radiography to become more efficient, less expensive, and provide greater reliability and repeatability to programmatic campaigns. The addition of rotational sample control will allow for Neutron Tomography to become a more cost effective nondestructive PIE capability.

Status:

Funded in FY-18
Estimated cost: $1,000K
Project start: FY-18
Project completion: FY-19

8. North Radiography Station Neutron Science Readiness

Facility:

Description and Benefit

This effort will restore and upgrade the north beam line in HFEF to support digital neutron imaging advancement, neutron diffraction, and new neutron science for irradiated fuels and materials in the North Radiography Station in HFEF. Existing out-of-service equipment occupies space that is needed to support new programmatic research on advanced neutron imaging techniques and neutron science for irradiated fuels and materials. New research equipment cannot be installed until obsolete equipment is removed. Beam line modifications are required for development of new techniques to be effective.

NRAD north beam line and elevator controls are original 1980 equipment with degraded operation and no spare part availability. When the elevator controls do not function, irradiated experiments requiring remote handling cannot be examined in the NRS.

This enables facility mission expansion by creating space for additional beam lines and instrumentation with ties to IMCL/SPL/TREAT research based on beam layout and capability. Elevator and beam controls support TREAT loop experiment and industry partner experiment examination

This also enhances spatial examination of irradiated fuels by nondestructive means, and improved understanding of behaviors in realistic conditions such as neutron tomography, neutron powder diffraction, kinetic testing with combined techniques, time-of-flight studies, X-ray scattering, X-ray μCT

Removal of legacy equipment eliminates existing liability (hazardous materials) reduces future liability.

Status:

Estimated cost: $1,000K in FY-18
Project start: FY-18
Project completion: FY-19

9. Titan TEM Upgrades (EELS)

Facility: IMCL

Description and Benefit

The addition of EELS (Electron Energy Loss Spectroscopy) to the IMCL Titan TEM (Transmission Electron Microscope) coupled with the existing Super-X energy-dispersive x-ray spectroscopy (EDS) system will provide an exceptional national capability for irradiated fuels and materials PIE. EELS is capable of measuring atomic composition, chemical bonding, valence and conduction band electronic properties, bubble pressure, and sample thickness with atomic-level spatial resolution.

Very high spatial and energy resolution makes EELS the only method for quantitative high-resolution elemental analysis in the TEM in many cases. EDS provides analysis over a wide energy range, but with an energy resolution of only ~125 eV. EELS can achieve an energy resolution of 1 eV.[a] When many elements are present, characteristic x-ray signals typically overlap in EDS, and quantification by EDS becomes difficult or impossible, especially if several light elements are present. In EELS, peak overlap occurs in few cases, because the energy resolution is much higher. One EELS spectrum, however, does normally not cover a sufficient energy range to detect all the elements present. EDS spectra are generally easier and faster to acquire and provide a broad overview of sample composition. The combination of EELS and EDS methods is therefore extremely powerful.

The intensity and position of low-energy EELS peaks are affected by pressure. Core level EELS is sensitive to all elements in the periodic table (with the exception of atomic hydrogen) but is particularly sensitive to light elements. This fact allows mapping local gas bubble pressure with ~ 1 nm spatial resolution. The determination of the pressure of fission gas bubbles in nuclear materials is of great significance in understanding the behavior of nuclear fuel. In addition, many nuclear structural materials generate He during neutron irradiation. However, neither He nor H_2 can be characterized using EDS, and EELS provides the only method to structurally characterize hydrogen and helium in materials in TEM.

EELS also provides a technique for sample thickness measurement that is general (applicable to crystalline and amorphous samples) and relatively rapid (it involves recording the low-loss spectrum, where the intensity is relatively high). It is critical to know the local thickness, t of a TEM specimen to obtain quantitative defect (e.g., dislocation density, bubble density) or elemental concentration from a TEM image or energy-loss spectrum.

The combination of EELS and EDS on the Titan TEM in IMCL will provide a unique and powerful analysis capability for nuclear fuels and materials that will lead to new knowledge of gas bubble behavior, solid fission product precipitation, and the nucleation and growth of precipitates in current and advanced nuclear fuels and materials.

Status: APIE team working on alternative program funds (NSUF) to support this effort.

Estimated cost: $1,300K
Project start: FY-18
Project completion: FY-19

a. On monochromated TEMs, energy resolution can approach 0.1 eV [1].

10. Replace Leitz Metallograph in MetBox

Facility: HFEF

Description and Benefit

Current version is experiencing failures due in large part to the current configuration of the instrument and the effects of operation in a high rad environment. The vendor is working with HFEF staff to re-design the microscope to make it more reliable in high radiation. This instrument is one of the workhorse instruments for PIE in HFEF and a new more reliable version is essential to support efficient RD&D operations.

Status: HFEF staff is working with a vendor to address instrument operation in a high rad environment and reduce the failure rate. A prototype is in development.

Estimated cost: $TBD
Project start: FY-18
Project completion: FY-

11. Titan TEM Upgrades

Facility: Irradiated Material Characterization Laboratory

Description and Benefit

The resolution of transmission electron microscopes (TEM) is limited by aberrations (spherical and chromatic) in the electron beam. A probe corrector corrects for these aberrations and improves resolution. The Titan Themis TEM installed in IMCL will be upgraded with a probe corrector to improve resolution by approximately 30%. High resolution TEM will be used to characterize extremely fine-scale features such as crack tip features produced during intergranular stress corrosion cracking.

Status: Upgrades are off-the-shelf, vendor installed items.

Cost estimate (vendor quote): $750K
Project start: FY-19
Project completion: FY-20

12. NRAD Neutron Diffraction

Facility: Hot Fuel Examination Facility

Description and Benefit

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.

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.

Status: 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: $2,500K
Project start: FY-18
Project completion: FY-20

13. In-situ Thermal, Mechanical, and Micro Isotopic Measurement Using FIB

Facility: IMCL

Description and Benefit

This project develops technology based on dual-beam Focused Ion Beam (FIB/SEM) microscope platforms in cooperation with instrument vendors focused on accelerating comprehensive characterizations of the microstructure and physical properties of irradiated fuels and materials by a factor of 5-10, and in the process, providing higher quality correlated data. This work is not only ground-breaking in the nuclear fuel and material community, but also in the much broader material science community. The resulting data streams are essential for understanding irradiation effects on materials and ideal for development and validation of mesoscale (MARMOT) models, which are necessary for the development of accurate engineering-scale (BISON) models. Detailed information on microstructural changes and mechanical properties is vital for developing predictive models and for developing new materials. Current approaches to post irradiation examination of materials are based on the use of single-purpose instruments, proceeding through a sequential process that provides incomplete characterization; multiple samples are laboriously prepared and moved from instrument to instrument in an inherently inefficient and uncorrelated process flow. Modern instrumentation with the capability for multi-modal analysis and automation offers the potential to radically improve the rate at which characterization data can be acquired, the breadth of the data streams produced, and the correlation of data. FIB instruments incorporate separate ion and electron beams and include sample micromanipulation devices and tomographic imaging capabilities that provide the unique potential for incorporation of many different characterization techniques into a single instrument. The emerging field of multiscale correlated characterization allows for the combination of insights from different techniques, from *the same region of interest* on a single sample to develop a greatly improved understanding of material response to irradiation. Extensive automation is possible through development of custom scripting.

This work will show that microstructure, nano/atomic structure, mechanical properties, thermal properties, isotopic distribution, and material chemistry analysis can all be performed and correlated. We estimate that using this platform will reduce the time required for a complete characterization by 80%, with a similar reduction in cost. In addition, the resulting multi-scale correlated data is much more useful development and validation of mesoscale models than data from isolated single-purpose measurements, resulting in direct correlation of service conditions (burnup) to microstructure and microstructure to properties.

Status: Unfunded

An FY-19 LDRD is planned to be submitted.
Estimated cost: $1,200K
Project start: FY-19
Project completion: FY-

14. Atom Probe Tomography Instrument

Facility: IMCL

Description and Benefit

Because irradiation damage occurs beginning on the atomic scale, atom probe tomography is ideal for the study of irradiation damage in materials. Atom Probe Tomography (APT) is the only material analysis technique offering extensive capabilities for both 3D imaging and chemical composition measurements at the atomic scale (around 0.1-0.3nm resolution in depth and 0.3-0.5nm laterally). We have recently pioneered the use of APT on irradiated fuels, which exhibit extremely complex behavior caused by fission; electronic energy transfer, compositional changes, and fission gas. The complexity associated with nuclear fuels, however, offers the opportunity for tailoring of fuel properties and performance, once understood. For example, the use of focused ion beam analysis has identified an association between solid fission products and fission gas that could be used beneficially to provide some control over gas-driven swelling.

Current APT technology applied to the analysis of the complex multi element structure of irradiated fuel is limited by collection efficiency. The latest generation of atom probe exhibits a 20% increase in signal, resulting in greatly enhanced counting statistics and analysis. Analysis using a newer, advanced atom probe will greatly increase our ability to understand the underlying processes associated with microstructure development in nuclear fuel and therefore apply principles of materials design where it has never before been possible.

Use of instruments not collocated with the FIB instruments in IMCL (used to prepare APT samples) results in oxidation of reactive metals and unsatisfactory analysis. This request is for an instrument in IMCL.

Status: Unfunded

Estimated cost: $4,000
Project start: FY-
Project completion: FY-

15. Qualify International Sample Transport Cask (Flying Pig)

Facility: HFEF

Description and Benefit

This supports transport of samples nationally and internationally and enhances collaboration capability with international partners, some of which possess unique capabilities that can provide important data that DOE-NE does not wish to invest in. Likewise, it may be desirable to transport material from the United States to international partners when unique capabilities exist in other nations. One of the primary difficulties associated with research within this network is the availability of shipping packages that allow rapid transport of material from ones site to another. This issue can be resolved nationally and internationally by adopting the recommendations of the international Hot Labs Working Group to develop and license an international 'Flying Pig'[b] shipping cask that allows rapid air or vehicle transport of small quantities of materials between research sites.

The 'Flying Pig' cask will allow for international shipments of irradiated fuels and materials by air and/or road. As this cask is developed, capability for direct receipt in IMCL should also be developed. Direct receipt of this small cask will reduce the cask receipt and material transfer burden on HFEF

Status: Unfunded

Estimated cost: $900K
Project start: FY-
Project completion: FY-

[b] http://hotlab.sckcen.be/~/media/Files/Hotlab/Plaquette%20FP.PDF?la=en.

16. Element Contact Profilometry (ECP)/Bow and Length Measurement (BLM) Refurbishment

Facility: HFEF

Description and Benefit

The ECP is an examination stage used to perform vertical element contact profilometry on a single fuel element. The BLM function provides an accurate measurement of the element bow in two planes and the element hanging length, which together allow for the computation of the length along the element. The existing ECP/BLM is old and increasingly prone to failure.

Upgrade or replacement of components is necessary to ensure system reliability for future PIE campaigns.

Many of the components of the ECP/BLM are unreliable and obsolete. Failure of the ECP/BLM will impact programmatic work.

Estimated cost: $750K
Project start: FY-
Project completion: FY-

17. Replacement of the inductively coupled plasma optical emission spectrometry (ICP-OES) with a High Resolution (HR)-ICP-OES

Facility: Analytical Laboratory

Description and Benefit

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. The instrument is not regularly in use, but is heavily used when analyses are required.

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.

Status:

Estimated cost: $120K
Project start: FY-19
Project completion: FY-19

18. Install and Test Visual Examination System

Facility: HFEF

Description and Benefit

TBD

Status: Unfunded

Estimated cost: $
Project start: FY-
Project completion: FY-

19. Expanded Fuel Fabrication Strategy

Facility: FMF, FCF, AFF, others

Description and Benefit

This strategy addresses multiple facility and process equipment upgrades to MFC fuel fabrication capabilities in several facilities in an attempt to meet continually increasing demand. The capability expansion under this strategy is intended to address our short term (5 year) RD&D Test Bed needs within existing MFC facilities.

Current fuel fabrication research areas include plate fuel development, fast reactor fuels, transmutations fuels, and accident tolerant fuels, all of which continuously improve processing techniques, including advanced manufacturing. INL fields numerous requests to fabricate multi-kilogram quantities of experimental fuels including accident tolerant fuels for existing LWRs, as well as, develop fabrication processes for and build fuel in quantities sufficient for licensing of sodium-cooled fast reactors (TerraPower), demonstrate fabrication of recycled fuel (Joint Fuel Cycle Study with KAERI), and conduct a special one-of-a-kind projects for advanced and unique reactor concepts. These requests have highlighted the need for expanded fuel fabrication capabilities.

Many of the requests received by INL require large-scale fabrication campaigns under an NQA-1 program (Nuclear Quality Assurance) to increase the Technological Readiness Level through demonstration of fabrication and irradiation performance. These larger-sale campaigns, which cannot be conducted elsewhere, push the licensing constraints of our existing facilities and in some cases may make these activities impossible to execute in current facilities.

Driving fuel development from an empirical art to a science also requires appropriate space to deploy advanced manufacturing and characterization equipment. Examples of advanced manufacturing techniques that are funded and require laboratory space to deploy are Spark Plasma Sintering (SPS), additive manufacturing, continuous metal fuel casting, metal fuel co-extrusion, and laser welding of cladding.

Existing MFC fuel fabrication facilities are filled with processing equipment, much of which is currently in use. As demonstrated by the recent conversion of the Experimental Fuels Facility (EFF) from a warehouse to a fully utilized fabrication laboratory, any increase in footprint is rapidly utilized by DOE programs or outside customers.

Initially, additional capacity for RD&D can be made available by removing several obsolete glove boxes from existing facilities and repurposing several additional buildings. The objectives for individual facilities are provided below.

- **Fuels and Applied Science Building (FASB) –** Maintain as a general-purpose uranium-based fuel fabrication laboratory. Remove the obsolete and unused east development glove box to make room for new process equipment. Maintain characterization lab space adequate to rapidly and efficiently gauge process development.
- **Experimental Fuels Facility (EFF) –** Maintain EFF as uranium-based fuel fabrication laboratory. Improve facility process flow. Evaluate removal of the hot isostatic press to make room for higher demand process equipment.
- **FMF –** Primary transuranic-based (RU) fuel development facility. Remove obsolete waste characterization glove box to allow for expansion with new glove boxes for casting and sample preparation. Evaluate the possibility for fabrication of demonstration-scale expansion to meet demand. Continue to develop and expand MOX fabrication capability.

- **Zero Power Physics Reactor building (ZPPR) –** Expand work room capability to allow for higher enrichment and large quantity uranium-based fuel fabrication. Evaluate cell and alcoves for expansion of uranium-based processes.
- **MFAFF –** Repurpose this storage facility into a radiological facility in the same manner as EFF to allow deployment of advanced manufacturing techniques and relieve facility nuclear material quantity limits on other facilities.
- **Manufacturing Development Laboratory –** Expand capability and infrastructure to support TREAT experiment assembly and disassembly.
- **HFEF –** Develop remote fuel fabrication, as needed for the JFCS and for TREAT experiment re-fabrications.
- **FCF –** Expand capability to gravity cast FCF uranium product into molds. Evaluate further fission product removal from FCF product to foster contact handling.

Status: Scoping studies and sequential planning for an advanced fabrication capability expansion have started and will continue into FY-18.

ROM cost estimate: $7,500K
Project start: FY-19
Project completion: FY-22

20. Research Data Management and Visualization

Facility: N/A

Description and Benefit

Focusing on increasing the quantity, fidelity, and types of data generated is a necessary, but not sufficient, condition to spur innovation. The objective must be to achieve a higher rate of knowledge generation through analysis of data. Knowledge used in context to answer a specific question provides the information that drives innovation. To accelerate innovation in the nuclear industry, the rate at which information is created must increase. Generating this information requires deployment and use of efficient experimental design and data management and analysis tools grown in parallel with reliable facilities, modern equipment and instrumentation, and efficient processes.

Current data streams range over ten orders of magnitude in length scale and include markedly different types of data (such as engineering drawings, images, linear dimensional information, tomographic data, time-resolved data on experiment operating conditions, and point data from chemical analysis). The shift to improved, three-dimensional characterization methods at both the engineering and microstructural scales will result in a further large increase in data. The capability to store, process, and analyze data must increase correspondingly. Further improvements in knowledge generation can be realized through concurrent visualization of test parameters, experimental results, and simulations. Requirements for a data management and analysis system that supports rapid generation of knowledge include the following:

Data capture and storage in a commonly accessible location in usable formats.

Data from experiments, experiment operating parameters, experiment design, and results from modeling and simulation meld seamlessly to allow the rapid validation of models and validation of hypotheses.

Visualization of multiple data streams from examination (i.e., visual exam, dimensional measurement, microstructure, and atomic structure), fabrication (i.e., pre-irradiation microstructure, isotopics, and chemistry), irradiation history (i.e., temperature, flux, and fluence), and modeling and simulation results must be available simultaneously in three dimensions over ten orders of magnitude (engineering scale to the atomic scale) to allow rapid comprehension of system behavior.

Development of effective data management, processing, and visualization tools that function seamlessly with MOOSE-based applications will dramatically increase the rate of comprehension of complex systems and validation of fuel and material performance models and codes. Effective implementation of such a system, along with implementation of improved analysis methods, provides the ability to revolutionize the current regulatory paradigm by ensuring that validated, high quality data are readily available.

Status: Development of data management and visualization is currently being investigated by INL Information Management.

ROM cost estimate: $2,250K
Project start: FY-18
Project completion: FY-20

21. NRAD Digital Neutron Radiography/Tomography

Facility: Hot Fuel Examination Facility

Description and Benefit

This project installs a digital neutron radiography system at NRAD to increase the throughput of radiography campaigns and allow routine and efficient neutron tomography.

Neutron imaging is an ideal method for rapidly evaluating fuel performance and diagnosing material and fuel failures. Tomographic neutron imaging provides a three-dimensional data stream from which detailed information of fuel and material performance and quantitative dimensional data can be acquired. Coolant channel dimensions, ^{235}U depletion, and fuel swelling data can be obtained. The currently used film transfer radiography method provides high quality radiographic images, but is time consuming, expensive, and film development generates hazardous waste. For example, even with recently improved NRAD throughput, a FY-16 tomography campaign of a four-foot long fuel element required 3 weeks to complete. Digital neutron detection can increase radiography throughput by at least an order of magnitude by eliminating the film transfer, development, and scanning process.

This project will design and deploy a digital neutron detection system for imaging irradiated objects by testing the detector response to the gamma-contaminated neutron beams at NRAD and to high gamma doses. Currently, no facility in the world has the capability for digital neutron detection of irradiated fuel and materials. Experimental digital detectors have been shown to have increased resolution and are being further developed to allow automation and reduce the time required to generate images. Neutron detectors developed at the University of California-Berkeley and supplied to other neutron imaging facilities worldwide are being tested in a high gamma field at NRAD. Initial testing resulted in the first fully digital neutron radiographs ever acquired at NRAD.

Status: Testing of digital neutron detectors and system design is currently being conducted using LDRD funding in conjunction with UC-Berkeley. Design concepts and feasibility studies will be completed in FY-18.

ROM cost estimate: $2,500K
Project start: FY-18
Project completion: FY-20

22. Shielded Multi-Instrument Measurement Station

Facility: Hot Fuel Examination Facility

Description and Benefit

This project will develop a new capability for accelerating examinations, increasing efficiency, simplifying maintenance, and providing better data quality from non-destructive post-irradiation examinations.

Traditional examination methodology requires the use of remote equipment in large hot-cell facilities, which results in high cost and long schedule duration. Remote instrument design limits flexibility in technology and geometry, and is difficult to maintain and upgrade. The MEITNER concept (Modular Examination Instrument for Transportable Nuclear Energy Research) is composed of a stack of individual shielded instruments, which would include visual examination, dimensional inspection and profilometry, surface layer composition, gamma tomography, ultrasonic examination, and eddy current testing. Non-contact measurements will be used where possible to provide flexibility in the geometries that can be examined, to speed data acquisition, and to provide three-dimensional data. This system would also be transportable, allowing measurements to be acquired anywhere with a crane, cask, and an in-floor pit, including HFEF, TREAT, and possibly ATR and commercial sites.

The shielded multi-instrument measurement station will first be developed to utilize the Neutron Radiography Reactor's North Radiography Station and/or the HFEF main cell loop insertion cell. The fuel element or component to be examined would be raised in a controlled manner into the measurement station, past multiple sensor arrays. This configuration permits use of multiple instruments mounted outside of the shielding for protection from radiation and ease of maintenance and upgrade. New instruments can easily be configured for specialized measurements. Points of interest can be marked for sectioning and gas puncturing can be accomplished using a retractable system. In this way, all engineering-scale measurements can be made simultaneously and on the same coordinate system, with the goal of increasing the PIE data acquisition rate by an order of magnitude.

Status: The feasibility of the MEITNER concept and system design is currently being explored using LDRD funding. Design concepts and feasibility studies will be completed in FY-19.

ROM cost estimate: $20,000K ($16,500 K FY-18–FY-22)
Project start: FY-18
Project completion: FY-23

23. Irradiation Assisted Stress Corrosion Cracking System Cell #2

Facility: FASB

Description and Benefit

This project installs a second Irradiation Assisted Stress Corrosion Cracking (IASCC) cell in FASB.

There is a large environmental and economic benefit to extending current commercial nuclear plant lifetimes beyond 60 years. The key issue facing life-extension efforts for current reactors is radiation induced degradation of materials. One of the most important issues facing further extension of reactor lifetimes is IASCC, where exposure to neutron irradiation increases the susceptibility of in-core structural stainless steels to stress corrosion cracking. IASCC is EPRI's first priority. IASCC is a complex phenomenon that involves simultaneous actions of irradiation, stress, and corrosion that, despite five decades of research, is not well understood. In recent years, as nuclear power plants have aged and irradiation dose increases, IASCC has become an increasingly important issue. Gaining a better understanding of IASCC in reactor materials is a high priority for the Electric Power Research Institute (representing nuclear industry research), the Nuclear Regulatory Commission, and DOE's LWR Sustainability Program. From an applied (i.e., industry) perspective, it is essential to measure and understand changes in crack growth rates and fracture toughness as a function of radiation fluence; therefore, when cracks are identified during outage inspections, quantitative decisions can be made as needed for component replacement.

The current capability at MFC is unique in the world in that it is used to make these measurements on materials with gamma dose rates up to 40,000 R. The current cell is fully subscribed through FY-18. The design of the second cell will be nearly identical to the first.

Status: IASCC cell #1 is currently in service in FASB and fully subscribed through FY-18.

ROM cost estimate: $8,500K
Project start: FY-21
Project completion: FY-22

24. Replacement of the Thermal Ionization Mass Spectrometer (TIMS)

Facility: Analytical Laboratory

Description and Benefits

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.

The replacement of the TIMS unit will allow for better, more 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: $2,000K
Project Start: FY-20
Project completion: FY-21

Appendix C

Detailed Descriptions of TREAT Instrument Capability Activities

Appendix C

Detailed Descriptions of TREAT Instrument Capability Activities

1. Transient Testing Experiment Preparation and Handling

Facility: TREAT Warehouse

Description and Benefit

TREAT experiment vehicles are complex systems that require dedicated equipment to support assembly and checkout as well as disassembly and preliminary examination prior to shipment to INL PIE facilities. Modifications to the former TREAT warehouse are being considered to provide a co-located facility ideal for cross-cutting TREAT experiment support.

Many TREAT experiments will be conducted on low activity samples (fresh fuel or small samples) that will require minimal shielding during post-transient handling. A specialized test train assembly facility supporting TREAT will allow for rapid assembly, modification, and repair of test rigs prior to installation in the reactor. The assembly area will require 2-5,000 sq ft of high bay space to contain experiment handling and assembly fixtures, light machining capability, and the ability to handle radiological materials. Co-location of this area is essential to optimal support of experiments and integration of system design and performance testing with TREAT operations staff.

Small separate effects experiments will also be conducted on pre-irradiated fuel samples. These tests are typically highly instrumented and require delicate assembly activities that are poorly suited to large hot cell facilities. Interim work will be conducted in the IMCL Shielded Sample Prep Area (SSPA) until a similar system (tailored to the TREAT experiments needs) is installed closer to TREAT. Preliminary PIE can also be performed during disassembly or reconfiguration of tests following irradiation in TREAT.

Present MFC facility availability for assembly and disassembly of experiments is limited. TREAT will require additional assembly/disassembly capability to support the envisioned testing schedule. Installation of a suspect ventilation system in the TREAT warehouse will provide the required environmental control for an experiment support system (ESS) to meet these needs. The ESS would initially include a glovebox for disassembly of contact handled tests and workspace for assembly of non-irradiated test assemblies.

Future installation of additional gloveboxes will provide higher activity sample disassembly and inert assembly/disassembly capabilities. Initial rough order estimates are $2M for design and installation of the suspect ventilation system, $1.5M for the experiment disassembly glovebox. Co-location will simplify shipping of samples for PIE and provide expanded MFC capacity for support of experiment preparation and handling.

Currently, a shielded handling stand is being developed for the TREAT reactor building that will enable extraction and/or reloading of the test specimens from the TREAT irradiation vehicle and subsequent transport.

Status: Design of the shielded handling stand for the TREAT reactor building will be completed in FY18. Facility ventilation and glovebox upgrades were assessed previously and cost estimates are available.

ROM cost estimate: $3,500K
Project start: FY-17
Project completion: FY-19

2. HFEF Capsule Experiment Handling Capability

Facility: HFEF

Description and Benefit

Irradiated experiments were historically assembled and disassembled on tables located at windows 5D and 4D in the HFEF decontamination cell. This capability was re-established following execution of the planned HFEF activities to clean out legacy equipment in FY-15. However, an existing mission activity may need to be moved from the area to allow TREAT experiment manipulations in the future. Further facility readiness activities are required to support TREAT experiments including;

A hot cell system to <u>disassemble</u> experiments that became significantly radioactive during irradiation at TREAT. A general purpose system will be developed that is the foundational interface for design of future drop-in TREAT capsules.

A hot cell system to <u>assemble</u> experiments that are already significantly radioactive prior to irradiation in TREAT. A general purpose system will be developed that is the foundational interface for design of future *drop-in* TREAT capsules. This system will provide provisions for operational checks on the test device prior to transport to TREAT.

Status: Facility assessment and cost estimates were completed in FY-17 and are documented in TEV-3093.

ROM cost estimate: $3,000K
Project start: FY-18
Project completion: FY-19

3. HFEF TREAT Loop Handling Capability

Facility: HFEF

Description and Benefit

Re-establishing TREAT loop testing capability will require an assembly and checkout station to support both 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. This station will support full operational testing of the loop prior to shipment to TREAT for transient testing. Some of the infrastructure to support the sodium loop is still installed at HFEF but must be assessed and refurbished.

Status: Facility assessment and cost estimates were completed in FY-17 and documented in TEV-3093.

ROM cost estimate: $3,000K
Project start: FY-20
Project completion: FY-21

4. TREAT Hodoscope

Facility: TREAT

Description and Benefit

A key nondestructive examination system at TREAT is the Fuel Motion Monitoring System, also called the Hodoscope. The Hodoscope is a fast-neutron imaging system mounted at the reactor's north beam port that provides real-time information about the location, deformation, and relocation of experimental fuels held within test devices during high-power transient events. The system incorporates hundreds of channels of data operated in parallel and is capable of recording movement at sub-millisecond timescales over a large field of view. It is capable of simultaneously imaging an entire advanced-reactor fuel assembly. However, individual image pixels within the hodoscope are coarse and are not optimized for studies of small-scale effects in single fuel pins, such as the quantification of minor axial fuel swelling or fuel-clad bowing. New investments are needed to design and develop a new FMMS optimized for the measurement and analysis of smaller-scale phenomena in single pins, with higher image-plane spatial resolution, higher signal rates, and better signal-to-noise performance than the current hodoscope.

Effective use of TREAT requires continuous development of fast neutron hodoscope to support evolving experimenter objectives. This development requires three phases of capability recovery outlined below;

Limited-View Hodoscope – Prior to being placed in standby, the TREAT hodoscope was capable of accommodating a large field of view (1.2 m × 0.66 m) using 2 complementary sets of 360 individual 'pixel' sensor channels. However, early TREAT experiments are not expected to utilize this full field of view. As such, a sub-set of 100 proton scintillators ('hornyak buttons') where fully refurbished and coupled to a modern data acquisition system to enable performance testing and technique development during early reactor operations. Testing and qualification of the hodoscope is currently being performed using this system.

Full-View Hodoscope – Use of the hodoscope for full-size experiments requires that all imaging slots be activated. Detectors will be refurbished (or procured) and qualified to support all 360 (×2) hodoscope detectors. This will likely include reactivation of the remaining Hornyak buttons, refurbishment of existing methane proportional counters, and design/fabrication/installation of the next generation detectors. The data acquisition system required to support the full device will also be designed and installed. This work will commence immediately following completion of the limited-view system.

Next Generation Hodoscope – To further support real-time monitoring of fuel behavior during transient operation, a next generation hodoscope with improved spatial resolution is required. Concept development, detailed design, and deployment of such a device are a long-term undertaking that will require sustained attention for approximately 10 years to fully implement.

Like other specialized nuclear science instruments, the TREAT fuel motion monitoring system will require the long term support of an instrument scientist.

Status: Reactivation of the limited view hodoscope was achieved in FY-17 just prior to TREAT restart. Coupled performance assessment the hodoscope and TREAT is currently underway.

ROM cost estimate: $5,800K
Project start: FY-18
Project completion: FY-22

5. Remanufacturing Bench for Irradiated Fuel Pins

Facility: HFEF

Description and Benefit

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. As 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. In addition, capability to install advanced instrumentation is a crucial element of the remanufacturing bench/process to access valuable data streams from irradiated fuel. 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 required to enable this process.

A first device is required that simply allows for rod sectioning, extraction of excess fuel pellets, installation of new end plugs, and re-pressurization of the pin.

A second device that allows for the installation of instrumentation will be required for further scientific and qualification studies.

Status: Preliminary work has been performed in collaboration with ORNL to prepare samples for re-irradiation in ATR.

ROM cost estimate: $3,700K
Project start: FY-18
Project completion: FY-21

6. Transient Science Modular Irradiation Vehicle (MARCH System)

Facility: TREAT

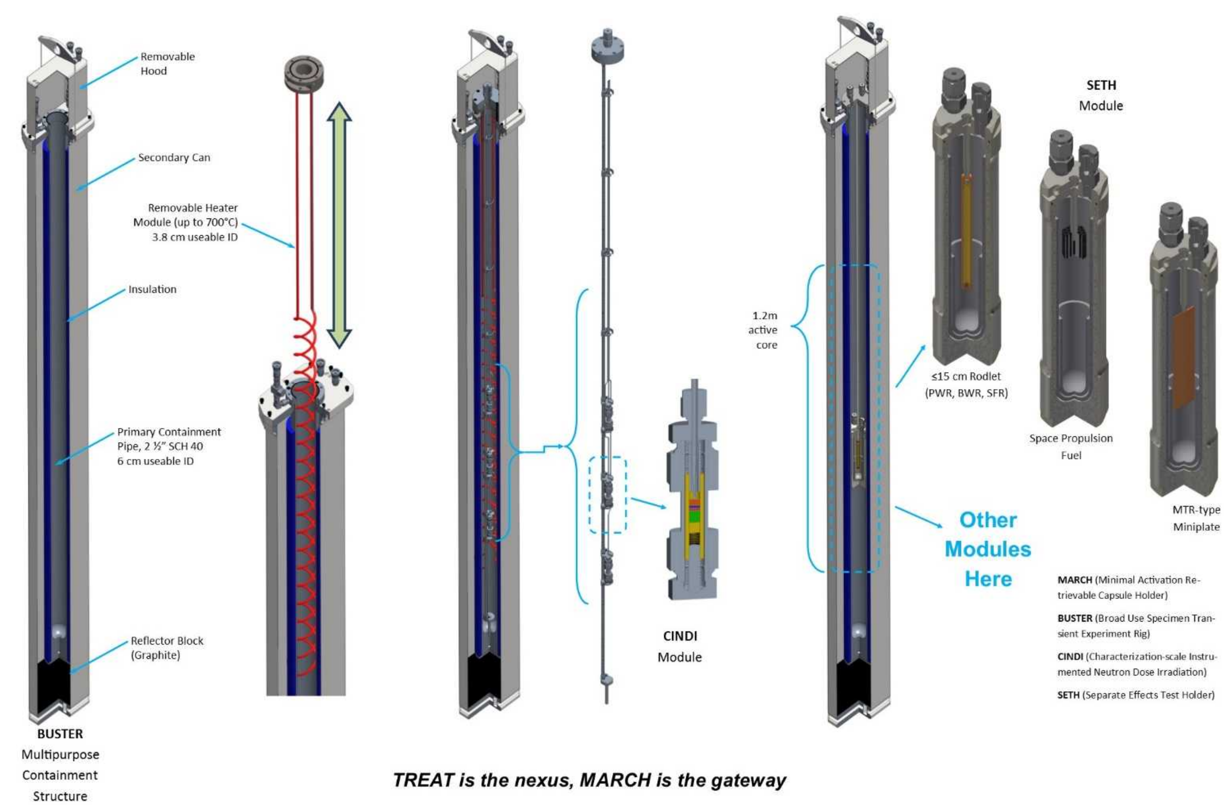
Description and Benefit

The Minimal Activation Retrievable Capsule Holder (MARCH) is a modular irradiation vehicle system designed to enable cost effective and high throughput irradiations in TREAT. By using simplified boundary conditions in small capsule layouts, the MARCH system is ideal for separate effects and phenomena identification tests to progress fundamental transient science, development of advanced fuel performance models, and rapid screening of advanced fuel concepts. When used with small, fresh fuel samples, low activation structural materials and typically-brief TREAT irradiations combine to enable PIE within weeks of irradiation. Electric preheat modules enable irradiations at conditions representing current-fleet and advanced reactor concepts.

Status: The foundational structure and baseline test modules, originally developed under LDRD and later adopted by the NTRD program for early-phase ATF testing, are planned for deployment in FY-18. With this initial investment complete, future efforts will develop other enhanced transient science capabilities via new irradiation modules. Future module design and deployment will enable static sodium heat sink tests, transient water boiling investigations, and advanced in-situ optical instruments all to support a variety of nuclear fuel technologies including rodlets, plates, compacts, and molten uranium salts.

ROM cost estimate: 2,000K
Project start: FY-19
Project completion: FY-20

The MARCH System



TREAT is the nexus, MARCH is the gateway

7. Recirculating Sodium Transient Irradiation Loop (Mk-IV Sodium Loop)

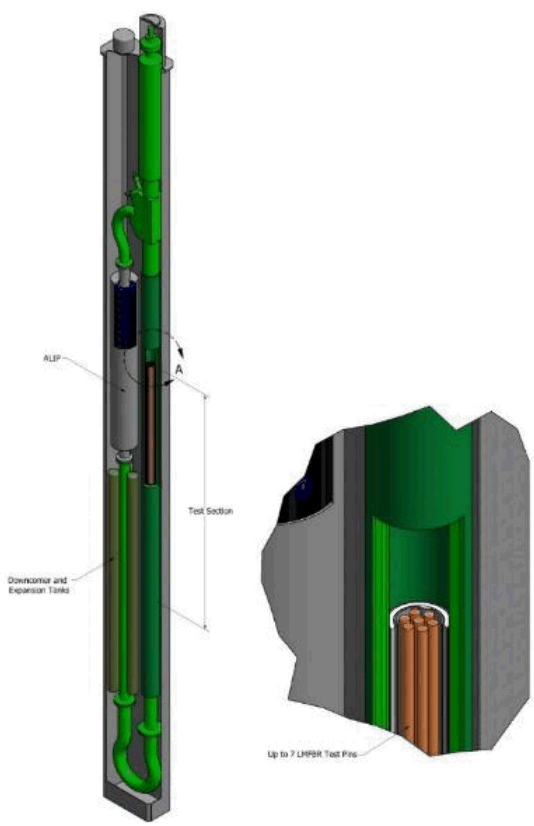
Facility: TREAT

Description and Benefit

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. This recirculating sodium device, which allows for irradiation under prototypic liquid metal reactor thermal hydraulic conditions, 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.

Status: 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.

ROM cost estimate: $8,000K
Project start: FY-18
Project completion: FY-20



8. Large-Capsule PWR Transient Irradiation Vehicle (Super-SERTTA)

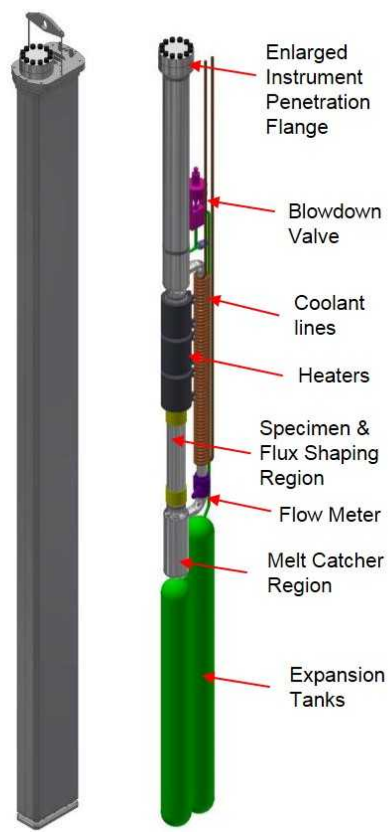
Facility: TREAT

Description and Benefit

Super-SERTTA is a scaled up version of Multi-SERTTA that will allow for single rodlet up to 1.2m in active fuel length. More importantly, this geometric layout greatly facilitates insertion of pre-irradiated fuel rods via hot cell operations while providing greater access for in-situ instrumentation. While certainly capable of fresh fuel tests, the Super-SERTTA capability is needed to access enhanced data opportunities for high-value pre-irradiated specimens. This enlarged layout and modular test train layouts enable Super-SERTTA to accommodate TREAT-based simulation of pulse type reactivity initiated transients with very narrow pulse widths or to blowdown from pressurized water to steam conditions representing loss of coolant accidents. An enhanced natural convection layout enables increased capabilities for establishing more prototype temperature distributions and stored fuel energy to simulate accidents which are postulated to initiate from full power operations in nuclear plants. This same natural convection layout also 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.

Status: The Super-SERTTA is planned to proceed through conceptual design (i.e. 30% complete) by the end of FY-18.

ROM cost estimate: $6,000K
Project start: FY-18
Project completion: FY-20



9. Recirculating PWR Transient Irradiation Loop (TWERL)

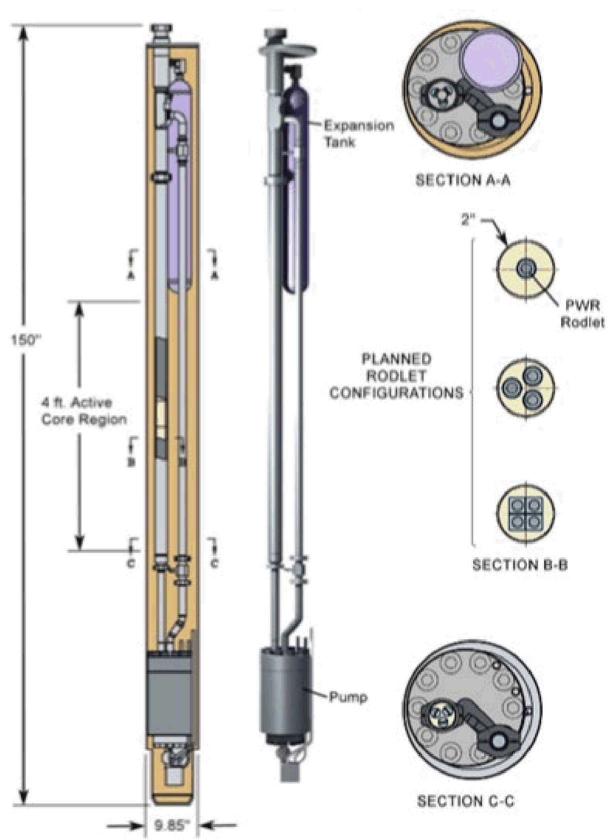
Facility: TREAT

Description and Benefit

The TREAT Water Environment Recirculating Loop (TWERL) will take all of the capabilities of the preceding Super-SERTTA device, but will add two crucial capabilities including: 1) A pump for full forced convection and 2) the ability to accommodate small fuel rod bundles. The TWERL will be needed for the most faithful representation of water-cooled reactor plant conditions for evaluating 'post-failure' phenomena, including fission product release and fuel relocation. These types of tests, based on systems used in the Power Burst Facility, are essential in completing the qualification and licensing case for new fuel designs. The presence of a pump will necessitate that the TWERL be cylindrical in form and require modification of a few facility interfaces including new shaped core graphite fillers, enlargement of the rotating shield plug opening, and modification to the HFEF-15 upper shield ring.

Status: Conceptual design (30%) of the TWERL system was completed in FY-15, but no further work has been performed since that time.

ROM cost estimate: $8,000
Project start: FY-20
Project completion: FY-22



10. Enhanced Reactivity Clipping System (HENRI)

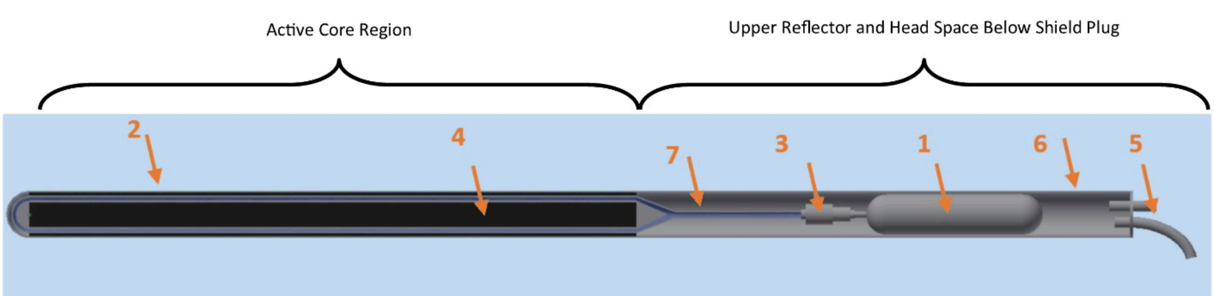
Facility: TREAT

Description and Benefit

Very-brief power bursts meant to simulate postulated Reactivity-Initiated Accidents (RIA) in light water reactors are of great interest for addressing data gaps in current gen fuels as well as development of advanced nuclear fuels. TREAT is innately capable of performing RIA-type pulse transient excursions. However, the duration (or width) of these excursions is longer than desired. Pulse width has a significant rate effects on thermo-mechanical interaction between fission-heated fuel pellets and cladding. Pulse width can make the difference between rod failure and survival, especially in pre-irradiated fuel specimens. TREAT's graphitic core produces an innate pulse width that is at least two times longer than postulated RIAs. A device which injects helium-3 neutron poison gas into evacuated in-core chambers can more rapidly terminate a transient power excursion for abbreviated pulse widths. This system has been termed the Helium-3 Enhanced Negative Reactivity Insertion (HENRI) system. Currently, the Full-Width at Half Maximum (FWHM) duration of a TREAT pulse is approximately 90ms. To achieve a desired pulse width in the range of ~40-50 ms, the HENRI system will be fabricated and installed into TREAT. The HENRI system will be needed to accompany deployment of the Super-SERTTA capability in order to provide faithful simulation of pellet cladding mechanical interaction for pre-irradiated specimens.

Status: The HENRI system design began in FY-17 under LDRD funding. The completed system design, along with a deployment strategy plan, are planned for completion under the LDRD by end of FY-19. Fabrication, installation, and implementation of the system will be undertaken by other funding sources starting as soon as FY-20.

ROM cost estimate: 5,000K
Project start: FY-20
Project completion: FY-22



Labels:
1) Driver Tank
2) Receiver Chamber
3) Fast opening device valve or burst disc.
4) Graphite filler
5) Feedthroughs for control lines and re-charging line
6) Containment vessel
7) Connector Tube

11. Advanced In-Reactor Instrumentation for TREAT

Facility: Transient Reactor Test Facility

Description and Benefits

State-of-the-art and cutting-edge transient testing capability at the TREAT facility requires a well-coordinated and innovative instrumentation development and qualification program to support near-term and future objectives. Advanced instrumentation is key to unraveling the complex multiphysics involved during transient irradiation experiments including development and validation of modern modeling and simulation tools. In addition to state-of-the-art, next-generation sensors require development for obtaining critical data including neutron flux (energy deposition), temperature, mechanical behaviors such as fuel deformation and coolant behaviors, fission product transport, and advanced materials characterization for properties, microstructure, and chemistry.

Integration of these devices into fundamental TREAT experiment vehicles and in-reactor testing is a critical and demanding component of the required R&D to establish these technologies. The fuel safety research requires R&D and qualification of several advanced instrument technologies to meet near-term experiment programmatic goals while establishing the base measurement capabilities (state-of-the-art) for next-generation experimentation. State-of-the-art instrumentation capabilities includes devices to measure neutron flux (energy deposition), temperature, and dimensional changes (assuming bulk fuel movement and relocation is measured by the TREAT hodoscope) for LWR and SFR fuels and environments. Fission product transport and other advanced materials characterization technologies represent strategic areas of development measurement categories.

Status: Advanced instrumentation development is currently being supported in an ad-hoc manner through competitive awards from NSUF, NEET, and NEUP.

ROM cost estimate: $7,000K
Project Start: FY-18
Project completion: FY-22

12. Advanced Radiography Examination Station for TREAT

Facility: Transient Reactor Test Facility

Description and Benefits

Advanced Radiography Examination Station (ARES): An important experimental resource needed to support advanced transient testing research and development at TREAT is an instrument station for performing gamma-ray spectrometry, single-photon emission computed tomography (SPECT) imaging, and high-energy x-ray radiography and tomography imaging of fuel held within transient test devices. Gamma-ray spectrometry scanning will provide valuable 1-dimensional (1-D) information concerning the spatially-dependent power coupling factor (PCF) within test devices. SPECT imaging, based on passive gamma-ray spectrometry, will provide 2-D spatially-dependent PCF information within test devices and important information concerning volatile fission product diffusion and condensation. High-energy x-ray radiography, enabled using bremsstrahlung from a multi-MeV electron accelerator, will enable critical pre-transient inspections to verify test device integrity upon receipt from MFC and equally important post-transient inspections to quantify fuel deformation (e.g., elongation, swelling, fragmentation) and fuel relocation. The high-energy x-ray radiography capability will also support generation of 3-D tomographic images, providing quantitative, high-resolution, spatially-resolved images of intact fuel, failed fuel, failed cladding, and other structural materials in single-element and multi-element fuel assemblies.

Status: Collaborative discussions with IRSN and Halden have been held to prepare for conceptual design.

ROM cost estimate: $4,000K
Project Start: FY-19
Project completion: FY-22