

**SECTION A. Project Title:** NASA Sirius Experiments (Gaseous Hydrogen Supply and Exhaust System for Experiments in TREAT), Rev 6

**SECTION B. Project Description and Purpose:**

### **Revision 6:**

The scope of this revision is based on the work being stopped in the last stages of Final Design of SIRIUS-4 due to a change in NASA's direction and a new NASA collaboration with Defense Advanced Research Projects Agency (DARPA). Since that time, NASA has worked with the INL to start working on SIRIUS-5. The most impactful design changes from SIRIUS-4 to SIRIUS-5 are: radial flow (SIRIUS-4 - axial flow), the use of cylindrical/conical frits (or other porous material) to allow for radial flow, and location of the fuel (between the cylindrical/conical frits). Hydrogen heating is still the primary goal. The hydrogen delivery/exhaust systems are described in Revision 4 of the ECP – no updates to that design, currently. The SIRIUS-5 irradiation test is expected to include the following activities:

1. Finalize and issue EEP
2. Perform concept design
3. Perform preliminary design
4. Perform final design
5. Fabricate SIRIUS-5 irradiation test capsule
6. Perform SIRIUS-5 transient irradiation calibration tests
7. Fabricate SIRIUS-5 fuel specimens
8. Assemble SIRIUS-5 irradiation test
9. Conduct SIRIUS-5 transient tests
10. Develop SIRIUS-5 transient test data reports
11. Perform SIRIUS-5 neutron radiography examinations
12. Perform SIRIUS-5 post-irradiation specimen examinations
13. Develop SIRIUS-5 examination reports
14. Develop and execute SIRIUS-5 test specimen disposal plan.

Fuel fabrication will be completed by a NASA industrial contractor.

### **Revision 5:**

In complement to the other activities described in the scope below, BWXT has fabricated TRISO fuel particles as a candidate fuel for the nuclear thermal propulsion (NTP) system. BWXT has performed a "shuttle" irradiation of several TRISO fuel particles in collaboration with the Massachusetts Institute of Technology Reactor (MITR) and now wishes to perform detailed characterization of both the irradiated TRISO particles from MITR, and sister unirradiated particles from the fabrication lot. This scope includes shipping the irradiated TRISO particles from MITR, and archive unirradiated particles from BWXT to MFC's IMCL facility where sample preparation, electron microscopy, x-ray computed tomography characterization activities will take place. Additional characterization activities may be performed as needed.

The NRC completed the Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for License Renewal for BWX Technologies, INC., Lynchburg, VA in 2006 for renewing Materials License SNM-42 (NRC Agency-wide Documents Access Management System (ADAMS) ML053410253). Materials License SNM-42 authorizes BWXT to possess nuclear materials, manufacture nuclear fuel components, fabricate research and university reactor components, fabricate compact reactor fuel elements, perform research on spent fuel performance, and handle the resultant waste streams, including recovery of scrap uranium. It also analyzes the transportation of materials from BWXT to the likely or representative destinations for use. The term of the license is 20 years.

Packaging, repackaging, transportation, receiving, and storing used nuclear fuel and R&D for used nuclear fuel management is covered by DOE's Programmatic Spent Nuclear Fuel (SNF) Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (EIS) and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). The analyses include those impacts related to transportation to, storage of, and research and development related to used nuclear fuel at the INL (see Tables 3.1 of the SNF Record of Decision (May 30, 1995) and Table 1.1 of the Amended Record of Decision [February 1996]).

#### **Revision 4:**

This revision encompasses additional scope and corrections to revision 2. In revision 2, for reviewing and analyzing low enriched uranium (LEU) engine component development activities, ATR is not a location where this activity was performed. The activity is performed at TREAT.

**Purpose and Need:** This project concerns the design, construction, installation and operation of a gaseous hydrogen supply and exhaust system for experiments in TREAT as part of a NASA program. NASA's Space Nuclear Power (SNP) program is in the process a multi-year effort to investigate nuclear thermal propulsion (NTP) systems with a proposed demonstration flight in 2026 in the short term, and a mission to Mars in the long term. The Sirius 2 irradiations in TREAT are part of the overall program, and the Sirius 3, 4 and 5 irradiations are in the planning stage. Each experiment is a stepping stone to the final design of a reactor for NTP. Fundamentally, the SIRIUS tests will determine whether startup and operating conditions under irradiation will lead to detrimental conditions such as cladding ballooning, fuel fragmentation and cracking for a given fuel geometry and material system. An essential part of the Sirius 4 experiment is to provide a flowing, gaseous, hydrogen environment to investigate interactions of irradiated candidate materials and hydrogen, such as hydride formation. Sirius 5 will build upon these results and is intended to contain a representative unit cell of a reactor for NTP. There is currently no reactor with a flowing hydrogen capability to perform these tests, and there are many open questions about material behavior during irradiation while exposed to flowing hydrogen. INL and NASA's Marshall Space Flight Center (MSFC) are working together to design and build such a system. INL has expertise relating to nuclear power and irradiation experiments, while NASA has expertise in hydrogen systems. The gaseous hydrogen supply and exhaust system is often referred to as the "Loop".

**Schedule:** The conceptual design phase was completed in September of 2020, and an informal conceptual design review was held on Oct. 6, 2020. The preliminary design is schedule to be completed by the end of January 2021. The irradiation of Sirius 4 was scheduled for May 2022, prior to the shutdowns caused by COVID-19. The H2 Loop must be installed and tested and ready for use prior to that irradiation. To meet a May 2022 irradiation date, the current schedule is to build and test the gas control system at MSFC by the end of Sept. 2021, and ship the system to TREAT at INL in November 2021. Work at TREAT could start as early as September 2021, but is more likely to be scheduled closer to the irradiation date for Sirius 4. All dates are likely to be delayed due to the constraints at both INL and MSFC facilities caused by the COVID-19 pandemic, so these are the earliest possible completion dates. The irradiation of Sirius 5 will be approximately 1 year after the irradiation of Sirius 4.

**What and Where:** This project concerns the design, construction, installation and operation of the Loop. The Loop is a gaseous hydrogen supply and exhaust system for experiments in TREAT. Argon will also be supplied to purge the gas lines before and after the experiment is irradiated. The Loop is a flow through system. Exhaust gases will include H<sub>2</sub>, Ar and any fission products from the experiment (during and after irradiation). Irradiated materials will include enriched uranium, molybdenum, tungsten, and other as yet unspecified materials, along with the standard Sirius and Buster capsule materials.

Figure 1 is the proposed layout of the Loop at TREAT. As shown, a mobile skid containing a 12 pack of hydrogen storage bottles and a gas supply control panel will be located outside the south wall of the TREAT building. Another skid with a 12 pack of argon bottles, or possibly a tube trailer, will be located next to the H<sub>2</sub> skid. Construction work will be done to pour a concrete pad for the skids which will allow for safe operation and forklift access. A drainage ditch lined with rocks is currently in that location. A vent line (not pictured) will leave the supply skids, go over the top of the building, and join with the experiment exhaust line (shown in green). The exhaust line from the Loop is currently not intended to join with the exhaust stack from TREAT, but it will use the exhaust stack as a support. A gas control panel will be mounted near the outside gas supply area and a second gas control panel will be mounted on the 2nd mezzanine inside the TREAT building. Wherever possible, tubing will be welded. Mechanical connections will be needed, as a minimum, at the gas control panels and at the top of the experiment above the TREAT reactor. Hydrogen detection and fire suppression is needed for those mechanical connections.

There are several design elements that will not be determined in the conceptual design phase:

- The exact specimen composition will not be known for several months in the case of Sirius 4 and a few years for future experiments. The specimen composition will affect the exhaust composition. The material used for the main portion of the specimen (the fuel material) is the same as one used for Sirius 2. Some scoping or bounding calculations of the source term can be performed based on the existing completed, approved calculations for Sirius 2.
- Design changes to the current ventilation system in the TREAT building have not yet been determined, nor have they been ruled out.
- The requirements of systems for hydrogen detection and fire suppression are under discussion.
- No exhaust processing or capture is planned at this time, but that is dependent upon analysis of the exhaust source term from a given experiment and the results of the NEPA process.
- Seismic requirements at TREAT will be determined by INL when the final layout is determined.
- The Loop is being designed to provide anywhere from 10 g/s to 200 g/s of H<sub>2</sub> flow during the TREAT transients, which is adequate for all experiment scenarios being considered by NASA. A 12 pack of T-bottles containing H<sub>2</sub> will be more than adequate for a set of transients. The supply volume for Ar will be larger, but the exact amount will vary based on the operating requirements for purge duration from TREAT. Therefore, the supply of AR may be provided by a 12 pack of T-bottles, 2 12 packs of T-bottles, or a tube trailer, depending on the volume needed.

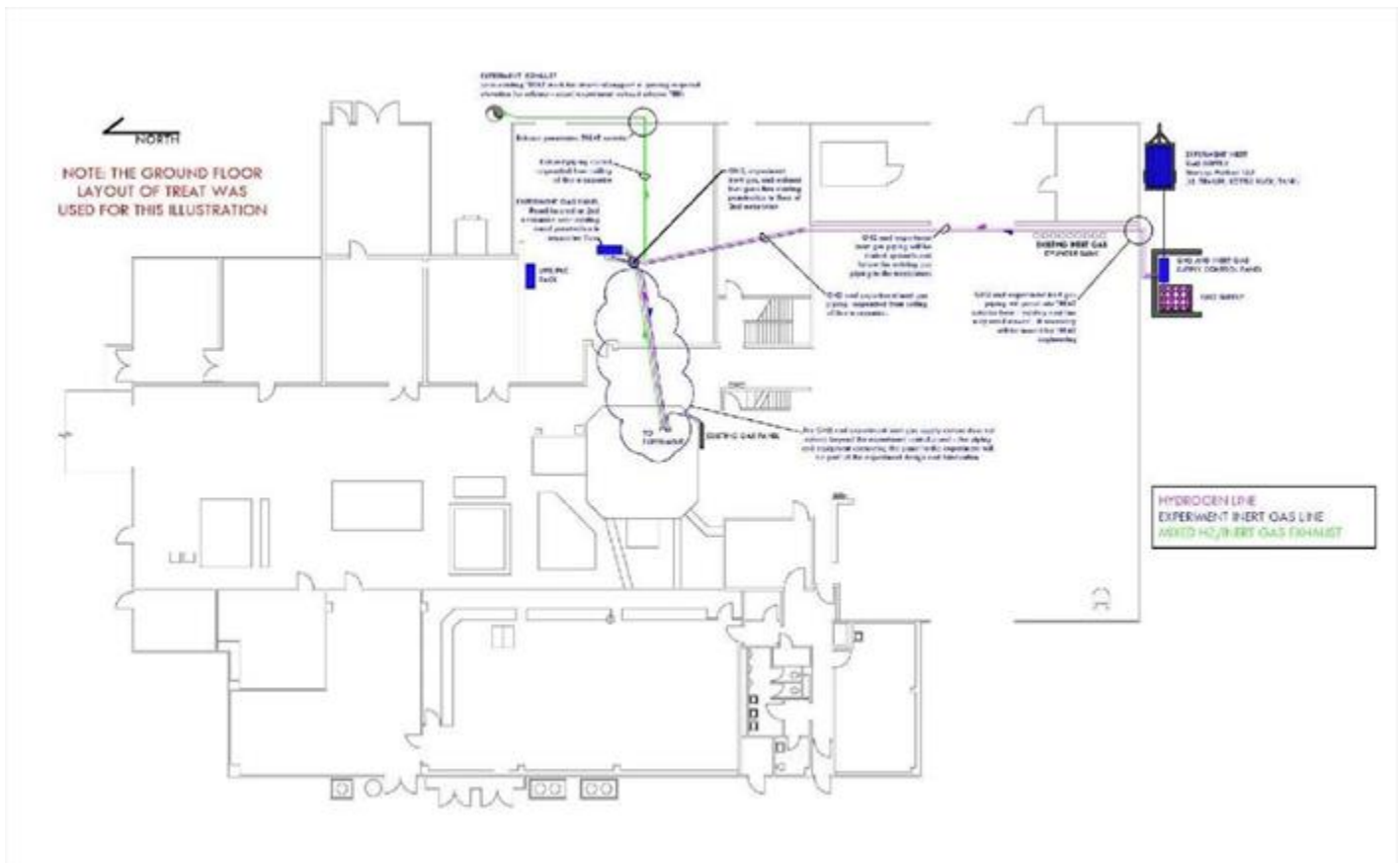
The SIRIUS-3 experiment will expand upon the SIRIUS-2 experiment and has the same goals and objectives regarding the NASA NTP development. Where SIRIUS-2 irradiated a single, approximately 0.5-inch-tall specimen, SIRIUS-3 will irradiate a stackup of 16 of those specimens to make an 8 inch long specimen. The flow holes in the specimen will be lined with Molybdenum tubes. Like SIRIUS-2, the SIRIUS-3 test specimen will be irradiated in a static safe gas environment.

The SIRIUS-3 irradiation test is expected to include the following activities:

1. Finalize and issue EEP
2. Perform preliminary design
3. Perform final design
4. Fabricate SIRIUS-3 irradiation test capsule
5. Perform SIRIUS-3 transient irradiation calibration tests
6. Fabricate SIRIUS-3 fuel specimens
7. Assemble SIRIUS-3 irradiation test
8. Conduct SIRIUS-3 transient tests
9. Develop SIRIUS-3 transient test data reports
10. Perform SIRIUS-3 neutron radiography examinations
11. Perform SIRIUS-3 post-irradiation specimen examinations
12. Develop SIRIUS-3 examination reports
13. Develop and execute SIRIUS-3 test specimen disposal plan.

Budget: NASA is funding the costs for work at NASA facilities directly so that portion of the cost is not listed. Costs for work at INL are unofficially estimated at \$2.3M for FY20-22. NASA has approved FY20 funding for this project (\$591K) and work has been approved beyond FY20. The FY21 budget (\$1.4M for INL) is not approved, but is currently under consideration by NASA. An official Class 5 estimate is being finalized. The cost is below the unofficial estimates given above.

Figure 1: Proposed layout loop at TREAT.



**Revision 3:**

The purpose of this revision is to capture additional project details. Activities defined in Phase II continue into FY 2020. The project supports the National Aeronautics and Space Administration's (NASA's) Nuclear Thermal Propulsion (NTP) program and develops apparatus and methodology for transient testing--thermal cycle testing on candidate nuclear fuels at Idaho National Laboratory's (INL's) Transient Reactor Test (TREAT) Facility. Testing furnishes fuel performance data to support operation of an NTP test reactor or prototype engine. The initial phase develops a first experiment (SIRIUS-1) to test NTP fuel specimens at peak design operating temperatures when subjected to a prototypical temperature ramp rate, or an average rate of 95 K/s. The SIRIUS-1 test subjects fuel specimens to 5 thermal cycles emulating proposed NTP system operational cycles. Post Irradiation Examination (PIE) examines specimen integrity, fission products released to the irradiation capsule, hydrogen reaction with the specimen, and incipient stress detection on fuel and coolant interaction (FCI). Phase III completes experiment design, fabricates and assembles the test, and executes the initial SIRIUS-1 test. Later testing in flowing hydrogen and from space cold temperatures are planned in future Phases of the project.

In addition, various aspects of the testing, fabrication, and assembly in support of NTP development require working within an inert atmosphere environment to prevent sample oxygen contamination. In order to provide adequate working space and atmosphere control, an inert atmosphere glovebox will be installed within MFC-784.

Phase II: Design SIRIUS-1 Static Capsule Test During Phase II, INL performs the following tasks:

- Test planning and management
- Develop SIRIUS-1 transient test functional and operational requirements (F&OR)
- Complete SIRIUS-1 irradiation test mechanical integration conceptual design
- Complete physics, thermal & structural conceptual design
- Develop Experiment Execution Plan (EEP)
- Develop PIE plan
- Fabricate and assemble prototype experiment capsule with mock-up test specimens.

Phase III: Develop Phase III Statement of Work

Contractor and Participant will jointly develop a Statement of Work (SOW) and Experiment Execution Plan for subsequent Phase II tasks that the Parties intend to use for designing, fabricating, irradiating, and performing post-irradiation examination of the SIRIUS-1 experiment. This effort will yield an overall cost estimate and time-phased budget for each Phase III task that will be incorporated within the to-be-developed SOW. Upon agreement through a suitable Phase III SOW, the Parties anticipate modifying the contract and then performing the SIRIUS-1 experiment in accordance with the Phase III SOW and Experiment Execution Plan.

INL anticipates performing the following activities in Phase III:

1. Develop pre-conceptual design
2. Finalize and issue EEP
3. Perform preliminary design
4. Perform final design
5. Fabricate SIRIUS-1 irradiation test capsule
6. Fabricate SIRIUS-1 transient irradiation calibration test specimens
7. Perform SIRIUS-1 transient irradiation calibration tests
8. Fabricate SIRIUS-1 fuel specimens
9. Assemble SIRIUS-1 irradiation test
10. Conduct SIRIUS-1 transient tests
11. Develop SIRIUS-1 transient test data reports
12. Perform SIRIUS-1 neutron radiography examinations
13. Perform SIRIUS-1 PIE
14. Develop SIRIUS-1 PIE reports
15. Develop and execute SIRIUS-1 test specimen disposal plan.

In addition to developing a Phase III SOW and Experiment Execution Plan to be implemented by Modification of this statement of work, the Parties further anticipate, in the same Modification of this statement of work, to address Participant contributions that may be available at that time to support the experimental work to be performed under the Phase III SOW.

**Revision 2:**

The National Aeronautics and Space Administration (NASA) and the US Department of Energy (DOE) are evaluating Nuclear Thermal Propulsion (NTP) for advanced space exploration missions. Ongoing tasks include: reactor core studies, architectural and feasibility studies for engine sizing, fuel element manufacturing studies and demonstrations, assessment of fuels and regulatory issues associated with low-enriched uranium, technology infusion studies, a ground test demonstration, cost and schedule estimation, NTP vehicle studies, and ground test planning support by NASA Stennis Space Center (SSC). Marshall Space Flight Center (MSFC) is responsible for project management.

The proposed project builds on related efforts by NASA, DOE, industry, and the Nuclear Engine for Rocket Vehicle Application (NERVA) engine development that ended in 1972. Program activities at Idaho National Laboratory (INL) were initially reviewed in environmental checklist (EC) INL-17-072 and INL-17-072 R1 "NASA/INL Transient and Irradiation Testing for Nuclear Thermal Propulsion Fuels Development and Qualification." This revision addresses Fiscal Year (FY) 2019 activities associated with the NTP.

Baselined fuel systems for NASA's NTP program are hexagonal-prismatic in geometry and feature multiple internal flow channels that serve as integral heat exchange surfaces, through which hydrogen gas is passed and heated. NASA is evaluating ceramic-metallic (Cermet) fuels. These fuels have a variety of compositions and are fabricated in a variety of ways. NASA's current NTP designs require the fuel peak operating temperature to be held at approximately 2,850 K to heat the H<sub>2</sub> propellant to approximately 2,700 K. The peak volumetric power density is on the order of 5 MW/L. The total thermal power generation of NASA/DOE's current NTP reactor design is nominally 500 MW. Initial systems are anticipated to require a minimum 100 minute operating lifetime and a minimum of four system starts. Startup temperature ramps of approximately 95 K/s have been attractive for space mission design purposes, allowing the reactor to be at full power within 30 seconds of startup.

Operation of NTP systems requires that fuel systems must maintain their geometric integrity, and hence core coolable geometry, and retain the fissile constituents of the fuel at these very high temperatures and power densities for the mission life duration. Since NTP reactor systems will be started following a period in long-lived earth orbit, during which system readiness checkout can be performed, the initial temperature of the fuel will be cold. At these temperatures, many of the candidate fuel systems are below their material ductile-to-brittle transition temperatures. This material attribute compounds the challenge of thermally driven stresses within the fuel matrix, and if the ramp rate to full operating temperature and/or power is too great, these attributes could result in stress-cracking of the fuel matrix and/or claddings. Thus, candidate NTP fuels must be tested under prototypical fission heating conditions to demonstrate that they can meet all of the rigors implied by the fuel design specifications. Similarly, the power/temperature ramp-rate derived failure thresholds attributed to incipient cracking, fissile material loss and fuel-coolant interactions (FCI) with the propellant (e.g., hydride formation) must be understood in order to bound operational performance margins and hence

inform NASA's mission design activities.

BWXT Inc., headquartered in Lynchburg, Virginia, is responsible for the NTP engine design.

INL investigates risks in the design, development, manufacture, and test/qualification of an LEU engine and determines technical requirements, approaches, and program risks that drive uncertainty in NTP program cost and schedule estimates. The FY 2019 scope of work includes technical, cost, and schedule assessments of each phase of the NTP design, demonstration, testing, and evaluation program, with emphasis on preparation for an early-stage NTP ground test demonstration project.

Technical Project Oversight Under this task, INL reviews and analyzes low enriched uranium (LEU) engine component development activities including the following:

- Coordinate activities performed at DOE facilities that support development of the LEU engine
- Review technical information related to nuclear component design and analysis
- Complete technical analyses and quality assurance activities related to LEU engine design, fabrication, and testing
- Complete development, testing, and examination of nuclear components in INL facilities such as the Transient Reactor Test Facility (TREAT), the Advanced Test Reactor (ATR), the Hot Fuel Examination Facility (HFEF), and other INL nuclear and non-nuclear facilities.
- Coordinate DOE preparations and support for an early-stage ground test demonstration.

#### Ground Test Trade Study Support

For this task, INL explores engine testing options and post-test fuel examination at INL facilities, the Nevada National Security Site (NNSS), or other suitable DOE site. INL also evaluates the technical feasibility of performing testing at the identified location and develops rough order of magnitude (ROM) cost and schedule estimates for needed infrastructure, performing the testing, and supporting post-test cleanup or remediation. The results of the evaluation will be used to update the Ground Test Trade Study developed by NASA.

#### TREAT Precursor Testing/Planning

INL will prepare for and perform NTP fuel irradiation testing at the Transient Reactor Test (TREAT) facility. Test preparation in 2019 includes technical analyses to define the test conditions, development of required reactor operations and safety evaluations, and development of test equipment designs. Testing includes fabrication of test equipment, placement and irradiation of the test equipment in the TREAT reactor, completion of post-irradiation examinations, and development of reports and data packages for test results. Once test conditions and equipment design has developed, additional NEPA review will be performed.

#### Reactor Conceptual Design

BWXT designs the NTP core, including fuel form, fuel element (FE) design, moderator element (ME) design, and core parameters. This task includes variable sensitivity analyses for the design. BWXT also interfaces with the MSFC engine systems design cycle for requirements from the NTP Engine Requirements Document. Other BWXT activities under this task include modeling and developing requirements documentation.

#### Fabrication Technology and Fuel Tests

BWXT will develop core fabrication methods. Initial fuel tests will be performed at the Compact Fuel Element Environmental Tester (CFEET) / Nuclear Thermal Rocket Element Environmental Simulator (NTREES) and includes the following:

- Pre-analysis of test articles
- Test planning/preparations
- Fabricate cold end FE test article
- Test cold end FE testing (CFEET/NTREES)
- Fabricate hot end FE test article
- Test hot end FE
- Complete post-test analyses
- Complete report(s) summarizing each cold and hot end testing activity

Fabrication Development includes development of weld activities, advanced materials manufacturing (AMM), machining, assembling, and fuel loading. Report(s) and/or memo(s) summarizing engine integration support activities will be developed.

BWXT will also develop Uranium Nitride (UN) Fuel Physical Vapor Deposition (PVD) and/or Chemical Vapor Deposition (CVD) Coating and integrate MSFC support efforts, develop a Sol-Gel UN fuel fabrication process, produce lab quantities of UN fuel with natural uranium or depleted uranium (DU), and verify UN stabilizer requirements.

The scope of work from previous iterations of this EC remain valid and is included below:

**Revision 1:**

The purpose of this revision is to clarify and address additional project scope.

Under the authority of the Atomic Energy Act of 1954, the Department of Energy's (DOE's) mission includes meeting the nuclear material needs of other federal agencies. DOE has supplied materials for radioisotope power systems as the source of electric power and heat for the National Aeronautics and Space Administration (NASA) and national security missions for over 50 years. DOE's role in these missions reflects established ongoing cooperation between DOE and NASA to ensure that radioisotope power system production capabilities are maintained and coordinated to meet NASA mission requirements.

The National Aeronautics and Space Administration (NASA) Space Technologies Mission Directorate has been authorized by Congress to continue to develop Nuclear Thermal Propulsion (NTP) systems for the peaceful exploration of the solar system and beyond by both manned and unmanned missions. NTP systems rely on a very high temperature once-through / open gas-cooled fission reactor to provide thermal energy and hence excite the coolant (H<sub>2</sub>) that also serves as the propellant. This heated propellant is exhausted through a converging-diverging nozzle to provide propulsive thrust. The fuel systems adopted by NASA's NTP program are hexagonal-prismatic in geometry and feature multiple internal flow channels that serve as integral heat exchange surfaces, through which the hydrogen gas is passed and heated. NASA is currently examining a number of candidate nuclear fuel compositions including ceramic-metallic (cermet), and (U, Zr) C-graphitic composite fuels that may be able to be operated at the required temperatures of interest.

Operation of NTP systems require that fuel systems maintain their geometric integrity and core coolable geometry and retain the fissile constituents of the fuel at very high temperatures and power densities for mission life duration. Since NTP reactor systems will be started following a period in long-lived earth orbit, during which system readiness checkout can be performed, the initial temperature of the fuel will be at cryogenic, space cold temperatures. At these temperatures, many of the candidate fuel systems are below their material ductile-to-brittle transition temperatures (DBTT). This material attribute compounds the challenge of thermally driven stresses within the fuel matrix, and if the ramp rate to full operating temperature and/or power is too great, these attributes could result in stress-cracking of the fuel matrix and/or claddings. Therefore, candidate NTP fuels must be tested under prototypical fission heating conditions to demonstrate they can meet the rigors implied by the fuel design specifications. Similarly, the power/temperature ramp-rate failure thresholds attributed to incipient cracking, fissile material loss and Fuel-Coolant Interactions (FCI) with the propellant (e.g., hydride formation) must be understood in order to bound operational performance margins and inform NASA's mission design activities.

The purpose of Phase I of the proposed action is to determine the feasibility of developing a simplified first test (SIRIUS-1) to study NASA NTP fuel specimens at peak design operating temperatures when subjected to a prototypical start up ramp rate. To determine experiment feasibility, Idaho National Laboratory (INL) will perform conceptual design for an irradiation test vehicle and experiment life-cycle planning. Phase I activities will be performed at INL's Engineering Research Office Building (EROB), the Materials and Fuels Complex (MFC), subcontracted fabrication facilities if necessary, and NASA facilities in Huntsville, AL and Washington, D.C.

Additional phases of the proposed action are contingent upon the feasibility of developing the SIRIUS-1 experiment. If the determination is made to proceed with the SIRIUS-1 experiment following Phase I, additional analysis under the National Environmental Policy Act (NEPA) will be conducted. It is anticipated Phase II would address preliminary and final design of the SIRIUS-1 experiment, fabrication of an irradiation test capsule and transient irradiation calibration test specimens, performance of transient irradiation calibration tests, fabrication of fuel specimens, assembling irradiation test experiment, performing transient testing at the Transient Reactor Test Facility (TREAT), developing data reports, conducting neutron radiography examination and post-irradiation examinations (PIE), developing examination reports, and developing and executing a test specimen disposal plan.

The following tasks comprise Phase I of the proposed action:

**TASK 0: TREAT Capabilities Scoping Study** Capabilities and NTP test scoping study will be executed and documented in a report. The study will examine the range of tests that could be executed at TREAT and identify the post irradiation examination and testing activities that are applicable to NTP fuels. The study will consider the NTP fuel materials of importance to NASA and DOE that could be tested to make preliminary calculations of ramp rates, hold time and temperatures that could be achieved in both static capsule and flowing loop testing.

The following task comprise Phase II of the proposed action:

**Task 1: SIRIUS-1 Static Capsule Test Conceptual Design and Design and Issue Functional and Operational Requirements (F&OR)** INL will develop and issue Functional and Operational Requirements (F&OR) based on notional test conditions and fuel specimen composition and specifications provided by NASA. INL will create sketches of potential irradiation test specimens and test specimen fixtures as positioned in SIRIUS-1 test capsule. The sketches will be used to develop computer models for performing neutronic, thermal, and structural calculations. The developed models will then be used to perform neutronic, thermal, and structural analyses to determine if the SIRIUS-1 experiment meets the desired test response. Design options for the SIRIUS-1 experiment will be evaluated as modeling results become available to determine preferred design. After evaluation, a decision will be made whether or not to proceed with the experiment. If the experiment is determined to be feasible, issuance of the F&OR completes Phase I.

**Task 2: Develop SIRIUS-1 Post-Irradiation Examination (PIE) Plan**

A PIE plan for the SIRIUS-1 experiment will be developed.

**Task 3: SIRIUS-1 Capsule Prototype Fabrication and Assembly with Mock-Up Test Specimens**

INL or an INL subcontractor will fabricate the prototype components to assemble into a completed mock-up assembly of the SIRIUS-1 capsule. The capsule prototype will include all necessary thermal protection materials and mock-up test specimens. This activity will facilitate design assembly concurrence.

Task 4: Develop Phase II Experiment Execution Plan

An Experiment Execution Plan (EEP) will be developed for subsequent Phase II tasks for designing, fabricating, irradiating, and performing PIE on the SIRIUS-1 experiment. The following experiment life-cycle activities will be addressed by Phase II:

1. Finalize and issue EEP
2. Perform preliminary design
3. Perform final design
4. Fabricate SIRIUS-1 irradiation test capsule
5. Fabricate SIRIUS-1 transient irradiation calibration test specimens
6. Perform SIRIUS-1 transient irradiation calibration tests
7. Fabricate SIRIUS-1 fuel specimens
8. Assemble SIRIUS-1 irradiation test
9. Conduct SIRIUS-1 transient tests
10. Develop SIRIUS-1 transient test data reports
11. Perform SIRIUS-1 neutron radiography examinations
12. Perform SIRIUS-1 post-irradiation specimen examinations
13. Develop SIRIUS-1 examination reports
14. Develop and execute SIRIUS-1 test specimen disposal plan.

Following Phase II, studies on cryogenically cooled specimen tests in flowing H<sub>2</sub> may be pursued. Phase III (SIRIUS-2) activities are anticipated to include the following:

1. Finalize and issue EEP
2. Perform preliminary design
3. Perform final design
4. Fabricate SIRIUS-2 irradiation test loop
5. Fabricate SIRIUS-2 transient irradiation calibration test specimens
6. Perform SIRIUS-2 transient irradiation calibration tests
7. Fabricate SIRIUS-2 fuel specimens
8. Assemble SIRIUS-2 irradiation test
9. Conduct SIRIUS-2 transient tests
10. Develop SIRIUS-2 transient test data reports
11. Perform SIRIUS-2 neutron radiography examinations
12. Perform SIRIUS-2 post-irradiation specimen examinations
13. Develop SIRIUS-2 examination reports
14. Develop and execute SIRIUS-2 test specimen disposal plan.

**Original ECP:**



This environmental checklist analyzes the environmental impacts and aspects, and project work activities for Phase I specifically related to static capsule test conceptual design, development of functional and operating requirements, development of a PIE plan, and prototype fabrication and assembly with mock-up test specimens to facilitate design concurrence. Subsequent Phases (II and III) require additional NEPA analysis as specific activities are defined (e.g. waste profile and volume, air emissions, etc.).

If Phases II and III of the project are implemented, irradiated sample segments and PIE remnants would be stored after PIE with other similar DOE-owned irradiated materials and experiments at MFC, most likely in the HFEF or the Radioactive Scrap and Waste Facility (RSWF). Ultimate disposal of the irradiated sample segments and PIE remnants would occur along with similar DOE-owned irradiated materials and experiments currently at MFC which are generated from other research and development activities. Categorizing the material as waste is supported under DOE Order (O) 435.1, Att. 1, Item 44, which states "...Test specimens of fissionable material irradiated for research and development purposes only...may be classified as waste and managed in accordance with this Order..."

The HFEF hot cell contains both defense and nondefense related materials and contamination. Project materials will come into contact with defense related materials. It is impractical to clean out defense related contamination, and therefore, waste associated with project activities is eligible for disposal at the Waste Isolation Pilot Plant (WIPP). National Environmental Policy Act (NEPA) coverage for the transportation and disposal of waste to WIPP are found in Final Waste Management Programmatic Environmental Impact Statement [WM PEIS] (DOE/Environmental Impact Statement [EIS]-0200-F, May 1997) and Waste Isolation Plant Disposal Phase Supplemental EIS (SEIS-II) (DOE/EIS-0026-S-2, Sept. 1997), respectively. The 1990 Record of Decision (ROD) also stated that a more detailed analysis of the impacts of processing and handling transuranic (TRU) waste at the generator-storage facilities would be conducted. The Department has analyzed TRU waste management activities in the Final Waste Management Programmatic Environmental Impact Statement (WM PEIS) (DOE/EIS-200-F, May 1997). The WM PEIS analyzes environmental impacts at the potential locations of treatment and storage sites for TRU waste; SEIS-II addresses impacts associated with alternative treatment methods, the disposal of TRU waste at WIPP and alternatives to that disposal, and the transportation to WIPP.

### **SECTION C. Environmental Aspects or Potential Sources of Impact:**

#### **Air Emissions**

The proposed action, the Hydrogen Loop at TREAT will be a flow through system and exhaust gases will include H<sub>2</sub>, H<sub>3</sub>, Ar and a potential for gaseous fission products from the experiment (during and after irradiation). The proposed action has the potential to generate radiological and chemical emissions from destructive and non-destructive post irradiation examination (PIE) at the Hot Fuels Examination Facility (HFEF), Analytical Laboratory (AL), and Irradiated Materials Characterization Laboratory (IMCL) at MFC. Air emissions are anticipated to be minor, and concentrations would not exceed the existing monitored air emissions from these facilities. All radionuclide release data associated with the PIE portion of this experiment will be recorded as part of the continuous stack monitoring program at MFC. The PIE examination in these facilities would not be considered a modification in accordance with Idaho Administrative Procedures Act (IDAPA) 58.01.01.201 and 40 Code of Federal Regulation (CFR) 61 Subpart H. In 2019, the effective dose equivalent to the offsite MEI from all operations at the INL Site was calculated as 5.59 E-02 mrem/yr, which is 0.56% of the 10-mrem/yr federal standard and was calculated using all sources that emitted radionuclides to the environment from the INL site. The additional increment in emissions from the proposed action would not significantly change the total site-wide MEI dose.

#### **Discharging to Surface-, Storm-, or Ground Water**

NA

#### **Disturbing Cultural or Biological Resources**

Cultural: Pursuant to the 2023 Programmatic Agreement, the proposed action does not meet the threshold of a federal undertaking and there is no effect to historic properties.

#### **Generating and Managing Waste**

Project activities have the potential to generate radioactive waste (LLW and TRU waste), industrial waste, and hazardous waste. Total project waste volume from the research and development performed on the used fuel material is projected to be less than 1 m<sup>3</sup>. INL Waste Management

Program and MFC Waste Generator Services (WGS) staff would be consulted for characterization and disposition pathways determination for the generated wastes. Operations also have the potential to generate MLLW. MLLW, if generated, is accumulated and stored in accordance with Federal and state regulations, treated if required, and disposed at an off-site permitted/licensed facility.

#### Releasing Contaminants

When chemicals are used during the project there is the potential for spills that could impact the environment (air, water, soil).

#### Using, Reusing, and Conserving Natural Resources

NA

#### Environmental Justice

According to the CEQ Climate and Economic Justice Screening Tool, the INL site as well as the Research and Education Campus in Idaho Falls, ID are located in U.S. Census tracts that are identified as disadvantaged communities. Census tracts identified as disadvantaged meet or exceed socioeconomic, environmental, health, or demographic thresholds identified by CEQ. Given that activities analyzed in this document will happen within the boundaries of existing DOE/INL land and/or facilities where there are no permanent residents, any impacts to Environmental Justice in surrounding communities are anticipated to be negligible.

Activities taking place offsite must follow all applicable requirements. Assuming these requirements are followed, any impacts to environmental justice offsite are anticipated to be negligible.

**SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification:** Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not "connected" to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

**References:** B3.6 "Small-scale research and development, laboratory operations, and pilot projects"

Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS0203-SA-02) and the Amended Record of Decision (1996).

Final Environmental Impact Statement for the Waste Isolation Pilot Plant (DOE/EIS-0026, October 1980) and Final Supplement Environmental Impact Statement for the Waste Isolation Pilot Plant (SEIS-I) (DOE/EIS-0026-FS, January 1990).

Final Waste Management Programmatic Environmental Impact Statement [WM PEIS] (DOE/EIS-0200-F, May 1997) and Waste Isolation Plant Disposal Phase Supplemental EIS (SEIS-II) (DOE/EIS-0026-S-2, Sept. 1997).

Final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the Resumption of Transient Testing of Nuclear Fuels and Materials (DOE/EA-1954, February 2014).

NRC Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for License Renewal for BWX Technologies, INC., Lynchburg, VA (2006) for renewing Materials License SNM-42 (NRC Agency-wide Documents Access Management System (ADAMS) ML053410253).

**Justification:** Based on the purpose and need and description of the proposed action and potential environmental impacts, the proposed action fits within the class of actions that is listed in Appendix B CX B3.6. There are no extraordinary circumstances related to the proposed action that may affect the significance of the environmental effects of the proposal. The proposed action has not been segmented to meet the definition of a categorical exclusion. This proposal is not connected to other actions with potentially significant impacts (40 CFR 1508.25(a)(1)), is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1508.27(b)(7)) and is not precluded by 40 CFR 1506.1 or 10 CFR 1021.211 concerning limitations on actions during preparation of an environmental impact statement.

Authorizing the proposed action will not (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environment, safety, and health, including DOE and/or Executive orders; (2) require siting of new facilities or expansion of existing facilities; (3) disturb hazardous substances, pollutants, or contaminants; (4) adversely affect environmentally sensitive resources; or (5) involve genetically engineered organisms, synthetic biology, governmentally designated noxious weeds, or invasive species.

**DOE-ID NEPA CX DETERMINATION**  
**Idaho National Laboratory**

The impacts of transporting and disposing of waste resulting from defense activities that was placed in retrievable storage pursuant to a 1970 Atomic Energy Commission policy (see Section 1.2) and TRU waste that was reasonably expected to be generated by ongoing activities and programs was analyzed in DOE/EIS-0026 (October 1980) and the Final Supplement Environmental Impact Statement for the Waste Isolation Pilot Plant (SEIS-I) (DOE/EIS-0026-FS, January 1990).

NEPA coverage for the transportation and disposal of waste to WIPP are found in DOE/EIS-0200-F (May 1997) and Waste Isolation Plant Disposal Phase Supplemental EIS (SEIS-II) (DOE/EIS-0026-S-2, Sept. 1997), respectively. The 1990 ROD also stated that a more detailed analysis of the impacts of processing and handling TRU waste at the generator-storage facilities would be conducted. DOE has analyzed TRU waste management activities in DOE /EIS-200-F (May 1997). The WM PEIS analyzes environmental impacts at the potential locations of treatment and storage sites for TRU waste; SEIS-II addresses impacts associated with alternative treatment methods, the disposal of TRU waste at WIPP and alternatives to that disposal, and the transportation to WIPP. (SEIS-II also includes potential transportation between generator sites.)

DOE evaluated the environmental impacts of transient irradiations in the TREAT reactor, including 1) transporting experiment materials between MFC and TREAT, 2) pre- and post-irradiation radiography, 3) PIE of test components at HFEF or other MFC facilities, and 4) waste generation and disposal in the Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the Resumption of Transient Testing of Nuclear Fuels and Materials (DOE/EA-1954, February 2014).

The NRC completed the Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for License Renewal for BWX Technologies, INC., Lynchburg, VA in 2006 for renewing Materials License SNM-42 (NRC Agency-wide Documents Access Management System (ADAMS) ML053410253). Materials License SNM-42 authorizes BWXT to possess nuclear materials, manufacture nuclear fuel components, fabricate research and university reactor components, fabricate compact reactor fuel elements, perform research on spent fuel performance, and handle the resultant waste streams, including recovery of scrap uranium. It also analyzes the transportation of materials from BWXT to the likely or representative destinations for use. The term of the license is 20 years.

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act)     Yes     No

Approved by Robert Douglas Herzog, DOE-ID NEPA Compliance Officer on: 8/15/2024