

DOE-ID NEPA CX DETERMINATION

Idaho National Laboratory

SECTION A. Project Title: Nuclear Thermal Propulsion Development

SECTION B. Project Description and Purpose:

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 (Cermets) 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 H₂ 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.

DOE-ID NEPA CX DETERMINATION

Idaho National Laboratory

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:

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_2) 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.

DOE-ID NEPA CX DETERMINATION

Idaho National Laboratory

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 H₂ 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

DOE-ID NEPA CX DETERMINATION

Idaho National Laboratory

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.

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 has the potential to generate radiological and chemical emissions from irradiation in ATR and TREAT and the 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.

Experiment irradiation will be performed at the ATR and TREAT. The irradiation activities in the ATR and TREAT are not modifications in accordance with Idaho Administrative Procedures Act (IDAPA) 58.01.01.201 and 40 Code of Federal Regulation (CFR) 61 Subpart H. ATR and TREAT radionuclide emissions are sampled and reported in accordance with Laboratory Wide Procedure (LWP)-8000 and 40 CFR 61 Subpart H. All experiments will be evaluated by Environmental Support and Services staff. All radionuclide release data (isotope specific in curies) directly associated with this proposal will be calculated and provided to the Environmental Support organization.

The irradiated specimens will be delivered to the MFC HFEF for disassembly and then undergo routine PIE. All radionuclide release data associated with the PIE portion of this experiment will be recorded as part of the HFEF continuous stack monitor. The PIE examination in HFEF is not 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 2017, the effective dose equivalent to the offsite MEI from all operations at the INL Site was calculated as 8.02 E-03 mrem/yr (8.02 E-08 Sievert/yr), which is 0.08% 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. Therefore, the emissions are bounded by the analysis in the 1995 EIS, which estimated the annual cumulative doses to the maximally exposed worker, offsite maximally exposed individual (MEI), and the collective population from DOE's decision to implement the preferred alternative (DOE 1995a, Volume 2, Table 5.7-4). The potential air emissions and human health impacts associated with the proposed action would be smaller than and are bounded by the impacts presented in the 1995 PEIS.

Generating and Managing Waste

No LLW or TRU waste is anticipated to be generated from FY 2019 work scope.

DOE-ID NEPA CX DETERMINATION

Idaho National Laboratory

At the end of Phase I identified in the original EC and Revision 1, the test activities for Phases II and III will be identified. The activities will determine what waste streams may be generated.

All waste must be managed in accordance with guidance from Waste Generator Services (WGS).

Releasing Contaminants

As described in the air emissions section above, radioactive air emissions are anticipated as a result of irradiation activities associated with Task 3. Those emissions will be evaluated once scope has been defined.

Using, Reusing, and Conserving Natural Resources

All material would be reused and/or recycled where economically practicable. All applicable waste would be diverted from disposal in the landfill when possible. Project personnel would use every opportunity to recycle, reuse, and recover materials and divert waste from the landfill when possible. The project would practice sustainable acquisition, as appropriate and practicable, by procuring construction materials that are energy efficient, water efficient, are bio-based in content, environmentally preferable, non-ozone depleting, have recycled content, and are non-toxic or less-toxic alternatives. New equipment will meet either the Energy Star or Significant New Alternatives Policy (SNAP) requirements as appropriate (see <https://sftool.gov/greenprocurement>).

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: 10 CFR 1021, Appendix B, 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/EIS-0203-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)

Justification: Project activities are consistent with 10 CFR 1021, Appendix B, B3.6, "Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); and small-scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions provided that construction or modification would be within or contiguous to a previously disturbed or developed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment."

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

DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

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.)

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

Approved by Jason Sturm, DOE-ID NEPA Compliance Officer on: 8/21/2018