U.S. Department of
ENERGY

Start-up Plan for Plutonium-238 Production for Radioisotope Power Systems

Report to Congress
June 2010

United States Department of Energy
Washington, DC 20585

Message from the Assistant Secretary for Nuclear Energy

The Conference Report accompanying the Energy and Water Development Appropriations Bill for Fiscal Year 2010 specifies that the Department of Energy submit a start-up plan for plutonium-238 production to include the role and contribution of major users of plutonium-238 with the fiscal year 2011 budget submission. The report, entitled *Start-up Plan for Plutonium-238 Production*, is enclosed. I apologize for the late delivery of this report. The delay allowed the Department of Energy, the National Aeronautics and Space Administration and other agencies to verify demand and evaluate potential supply options. This report presents an agreed strategy with the National Aeronautics and Space Administration, a principal user agency for this material, on funding and agency roles.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

- **The Honorable** Daniel K. Inouye
  Chairman, Committee on Appropriations

- **The Honorable** Thad Cochran
  Ranking Member, Committee on Appropriations

- **The Honorable** David R. Obey
  Chairman, Committee on Appropriations

- **The Honorable** Jerry Lewis
  Ranking Member, Committee on Appropriations

- **The Honorable** Byron L. Dorgan
  Chairman, Subcommittee on Energy and Water Development

- **The Honorable** Robert F. Bennett
  Ranking Member, Subcommittee on Energy and Water Development

- **The Honorable** Peter J. Visclosky
  Chairman, Subcommittee on Energy and Water Development

- **The Honorable** Rodney P. Frelinghuysen
  Ranking Member, Subcommittee on Energy and Water Development

If you have any questions, please contact me at (202) 586-2240, Ms. Betty Nolan, Acting Assistant Secretary for Congressional and Intergovernmental Affairs, at (202) 586-5450, or Ms. Kristy Hartman, Office of External Coordination, at (202) 586-4246.

Sincerely,

Warren F. Miller, Jr.
Assistant Secretary
for Nuclear Energy

Executive Summary

The Administration has requested the restart of plutonium-238 (Pu-238) production in fiscal year (FY) 2011. The following joint start-up plan, consistent with the President's request, has been developed collaboratively between the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA), and defines the roles and contributions of major users of Pu-238 in response to Congressional request.

DOE has examined current national needs for Pu-238 and received significant input from NASA regarding its specific mission needs. Both agencies agree that an adequate national supply of Pu-238 can be maintained if an average production rate of 1.5 kilograms per year is in place by 2015. Using existing facilities with some modifications, DOE expects to produce up to two kilograms of Pu-238 per year and to accommodate an average annual production rate of 1.5 kilograms on a sustained basis.

START-UP PLAN FOR PLUTONIUM-238 PRODUCTION FOR RADIOISOTOPE POWER SYSTEMS

Table of Contents

I. Legislative Language

This plan responds to the request in the Conference Report to Accompany H.R. 3183, Energy and Water Development and Related Agencies Appropriations Act, 2010, Report 111-278 on page 16, to provide:

> *… "a start-up plan which shall include the role and contribution of major users of Pu-238, such as the National Aeronautics and Space Administration…"*

II. Introduction

DOE is responsible for maintaining the national capability to support the development, production and safety of radioisotope power systems for national security and space exploration missions as required. DOE and its predecessor agencies have been producing radioisotope power systems for nearly fifty years. Radioisotope power systems uniquely enable missions that require a long-term, unattended source of electrical power and/or heat in harsh and remote environments. These systems are reliable, maintenance free, and capable of producing heat and electricity for decades. The Pu-238 in these units serves as the source for generating heat and electricity.

The Pu-238 production process consists of the fabrication of neptunium-237 (Np-237) targets, irradiation of the targets in a nuclear reactor, and recovery of Pu-238 from the irradiated targets through chemical extraction. In the past, Pu-238 was produced at DOE's Savannah River Site in South Carolina, using reactors that have since been shut down. The last Pu-238 production in these reactors occurred in 1988. After DOE stopped producing Pu-238, DOE's inventory was drawn down to continue to supply power systems to user agencies. Beginning in 1992, this inventory was augmented by Pu-238 purchased from Russia to fuel power systems that provide heat and electricity for NASA missions. By agreement, Pu-238 purchased from Russia cannot be used for national security applications. In September 2009, the Russian government informed DOE that it did not intend to deliver an existing order under the existing government-to-government agreement nor accept any future orders without a new government-to-government agreement being negotiated in the future. Although DOE is pursuing a new agreement under new terms with Russia for this material, this process could delay a next delivery of material by three to four years and such an arrangement will always be a risk to NASA missions.

The power source for the next budgeted NASA mission that requires Pu-238, Mars Science Laboratory, is already fueled with the material and ready for launch in 2011. However, the

existing Pu-238 inventory reserved for NASA missions will not fully support the next four envisioned NASA missions expected within the next decade. While no future national security needs for Pu-238 have been identified, national security applications have required Pu-238 in the past.

Because of the long lead-time associated with reestablishing a domestic production capability, newly produced Pu-238 will not be available until later this decade. Meeting NASA's expected needs requires that the restart project begin now. DOE has been working in coordination with agencies that historically have used Pu-238 to identify their projected Pu-238 requirements so as to reestablish production at a rate sufficient to support both future NASA missions and potential national security applications. DOE plans to use known technology and modifications to existing facilities to reestablish the capability to produce and separate Pu-238.

III. Mission Need

Pu-238 has provided power for 26 different missions that NASA has flown over the years, missions that have been enabled or significantly enhanced with radioisotope power systems that require this particular fuel. For example Cassini is currently orbiting Saturn, revolutionizing our understanding of the solar system from a distance at which solar energy is not sufficient to maintain the many scientific instruments and the spacecraft subsystems which return fantastic new images every day. NASA's mission to explore the solar system necessitates its ability to construct and operate similar missions in the future.

A recent National Research Council study (Radioisotope Power Systems: An Imperative for Maintaining U.S. Leadership in Space Exploration) found the lack of a U.S. production capability is already having an effect on the plans made by the scientists and engineers who develop future missions. In concrete terms, without a new production capability for Pu-238, the United States will no longer have the means to explore the majority of the solar system, including significant portions of the Moon and Mars, by the end of this decade.

The production rate and timing for startup is governed by projected user demands and the projected depletion of existing supplies of Pu-238. Based on the latest formal NASA evaluation of projected mission requirements, the current inventory reserved for space missions is insufficient to support the next four envisioned NASA missions that could be significantly enhanced or enabled by the use of radioisotope power systems. A table of the missions NASA is currently envisioning over the next two decades, and their related power and Pu-238 requirements, is contained in Table 1. Realization of these missions is beyond FY 2011 budget horizons and dependent on future policy decisions and budget constraints.

Table 1. NASA's Projected Mission Requirements for Pu-238

	Power Requirement (We)	Pu-238 Usage (kg)
Missions scheduled for launch in 2010-2014		
Mars Science Laboratory	100	3.5†
Missions envisioned for launch in 2015-2019		
Discovery 12	280	1.8
*Lunar Precursor	280	1.8
Mars (radioisotope power systems and heater units)	280	1.8
Missions envisioned for launch in 2020-2024		
Major Outer Planets Mission	612	21.3†
Discovery 14	280	1.8
New Frontiers 4	280	1.8
Missions envisioned for launch in 2025-2030		
New Frontiers 5	280	1.8
Discovery 16	280	1.8

Notes:

† Mars Science Laboratory is designed to use the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) technology and the Major Outer Planets Mission is currently expected to use MMRTGs. The rest of these missions assume the use of Advanced Stirling Radioisotope Generator technology, reducing the quantity of Pu-238 required by a factor of four to meet these power requirements.

* Exploration systems will require a small quantity of Pu-238 starting with the Lunar precursor mission requiring up to two Advanced Stirling Radioisotope Generators. The combined exploration and science system requirements will not exceed an average production rate of 1.5 kg per year once DOE has established production capability for Pu-238.

NASA's projected mission requirements can be met with an average production rate of 1.5 kilograms of Pu-238 per year. This estimated annual production rate is less than previous estimates of up to five kilograms per year, the rate that had been examined by prior DOE project evaluations and that aligned with the historic average demand for NASA and national security users. Factors contributing to the reduction in the estimated annual requirement are: (1) planned use of new Advanced Stirling Radioisotope Generator technology for future missions which would reduce quantities of required Pu-238 by as much as a factor of four for the same power levels; (2) projected quantities of Pu-238 needed for exploration missions are expected to be small compared to that needed for science missions; and (3) projected power requirements for some future missions have been reduced due to updated understanding of mission-specific requirements.

The urgency to restart domestic production of Pu-238 remains extremely high. As noted by the National Research Council, NASA's ability to plan for future missions has already been adversely affected by the uncertainty surrounding long-term supplies of Pu-238. NASA requires at least six to eight years advance notice of adequate Pu-238 supplies to properly plan for future planetary missions that are enabled or enhanced by radioisotope power systems. The amount of power available to a spacecraft and its science instruments is a fundamental design consideration and must be resolved early in the mission planning process in order to avoid costly overruns and to ensure the scientific return of these proposed missions.

Pu-238 has also historically been used in certain national security applications. National security users have not identified a known need for the rest of this decade. For the foreseeable future, national security needs will be met with existing inventory. However, demand in this area has generally been less predictable than NASA's and it is possible that additional national security applications could emerge.

To meet the full scope of projected user needs, DOE plans to establish a production capacity of up to two kilograms per year, with a predicted average annual production rate of 1.5 kilograms. It will take approximately five to six years to reach this rate of production, and no new material will become available before the 2015 timeframe. This production rate will satisfy NASA's current projected mission requirements and allow some flexibility in addressing any new priorities for space exploration missions and potential national security applications.

DOE will proceed with efforts to obtain the remaining amount of Pu-238 available for purchase from Russia; however, the ability to obtain this material is not certain and will likely be delayed by three to four years due to the need to renegotiate the terms of the agreement with Russia. Obtaining this material will not alter the need for or timing of reestablishing a domestic production capability; however, it would reduce risks associated with meeting near-term NASA mission needs.

IV. Planning for Restart

The three basic steps that are required to produce new Pu-238 are target fabrication, target irradiation and target processing to recover Pu-238. Target irradiation can be accomplished in existing reactors. Target fabrication and target processing are the two functions that need to be reestablished. This plan presents the agreed strategy to use existing facilities, modified as needed to specifically produce Pu-238. This approach is viewed as the most cost effective and timely means of reestablishing production at a rate that meets projected user needs.

A production rate of up to two kilograms per year can be accomplished in existing facilities modified as needed for upgrades to equipment and support services. Target fabrication and

irradiated target processing would be established in a phased approach to allow the early introduction of targets into a reactor while the post-irradiation processing facilities are brought online. Both target fabrication and irradiated target processing are well-understood processes and do not require research. Some development is required to optimize and finalize target designs and plutonium separations processes in order to maximize recovery of Pu-238 and minimize wastes.

Neptunium-237 (Np-237), used in preparation of targets as feed material for the production of Pu-238, is currently stored at Idaho National Laboratory. Np-237 will be fabricated into targets that will produce Pu-238 when inserted into a reactor. Targets will be irradiated in existing DOE research reactors, the High Flux Isotope Reactor in Oak Ridge National Laboratory and the Advanced Test Reactor at Idaho National Laboratory. Irradiation time of targets in the reactor is approximately three to twelve months, depending on the target location in the reactor and the amount of Np-237 loaded in the specific target. After targets are irradiated, additional cooling time is required before they are processed to allow impurities introduced in the irradiation process to decay. Irradiated targets will be processed to extract Pu-238. From this step, newly produced Pu-238 is available for fabricating heat sources and power systems in existing operating infrastructure that is not part of the scope of the restart project. Those steps involve shipping Pu-238 to Los Alamos National Laboratory for storage until it is used to fabricate heat sources for NASA and potential national security applications. Sealed heat sources are shipped to Idaho National Laboratory for power system assembly and testing and delivery to the customer.

This project will require modifications to existing facilities, such as installation of necessary processing equipment, upgrades to ventilation systems and removal of any obsolescent equipment. The target fabrication capability can be accommodated in existing facilities and will require the installation of new glove boxes and equipment. Target processing operations will require shielded structures for remote operations, called hot cells, in order to separate Pu-238 from irradiated targets. Irradiated target processing will be conducted in an existing hot cell facility, with some modifications as needed for Pu-238 production.

DOE's preliminary cost range estimate to implement this Pu-238 production scheme is $75 – 90 million. This preliminary cost range estimate assumes use of existing, operating isotope production facilities at Oak Ridge National Laboratory. The Pu-238 restart project will be executed in accordance with DOE's formal process for evaluating and implementing capital acquisition projects, which includes a formal evaluation of alternatives and the establishment of updated cost and schedule estimates to support project decisions. This process is outlined in DOE Order 413.3A Change 1 (11-17-08), or its successors, and can be downloaded from: http://management.energy.gov/policy_guidance/project_management.htm.

V. Funding Requirements

As outlined in the FY 2011 President's Budget, DOE and NASA will share in equal amounts the full project cost of reestablishing a production capability. Although NASA is expected to be a primary user of Pu-238 produced in the near future, this capability will also be available to support future national security applications, if such needs emerge. This proposed funding allocation properly acknowledges the Department's mission to maintain a national capability for a range of Federal users and its responsibility to manage efforts related to the safe and secure production of special nuclear material. Considering DOE's role in this project, the fact that the production capability will be entirely DOE owned, the uncertainty in future user needs, and other factors, the Administration believes the proposed cost sharing arrangement between DOE and NASA is the most appropriate scenario.

NASA recommends that Congress provide specific direction in FY 2011 appropriations that both authorizes and directs NASA to transfer its portion of the production infrastructure funding to DOE. NASA included in its budget request proposed legislative language that would accomplish this objective. This Congressional direction would most clearly resolve potential fiscal law issues and streamline the National Environmental Policy Act (NEPA) review process.

Formal arrangements will be established under an existing DOE-NASA memorandum of understanding (MOU) to execute this cost sharing arrangement.

VI. Activities in FY 2011

Since the 2011 Budget was transmitted, DOE and NASA obtained additional data that impacted the planned activities. As such this plan reflects updated information and project activities.

Assuming sufficient funding, priorities for FY 2011 are: 1) conduct and complete appropriate NEPA review and analysis; 2) complete conceptual design and initiate engineering design of necessary facility modifications; and 3) initiate target development efforts. Another major objective is to accelerate target production so that irradiation of targets may proceed while the target processing facility is being completed. To achieve this objective, early target development effort is necessary.

Based on these priorities, the following FY 2011 work is planned:

Conceptual Design and NEPA Support • As necessary, update and complete NEPA review and analysis to support the program mission. • Complete conceptual design of Np-237 target fabrication and irradiated target processing facilities • Prepare documentation for approval of alternative selection and cost range estimate	$10,500,000
Engineering Design/Performance Baseline • Initiate engineering design of Np-237 target production and irradiated target processing facilities, including project management and technical support. • Approve Performance Baseline. Initiate equipment procurement.	7,000,000
Target Production and Separations Development and Reactor Optimization • Fabricate development targets to evaluate pellet production methods with respect to target assembly operations and target irradiation. • Perform irradiation tests for performance verification and technology maturity assessments and value engineering studies to guide design decisions. Evaluate Advanced Test Reactor and High Flux Isotope Reactor internal core configurations for optimal neutronics to produce Pu-238	12,500,000
Total	$30,000,000

VII. Agency Roles and Responsibilities

DOE and NASA coordination for startup of Pu-238 production will be executed under the existing MOU established in 1991 for development, production and delivery of radioisotope power systems for space missions.

- Supplements to the DOE-NASA MOU will establish funding contributions for DOE and NASA for the purpose of budget planning and execution of appropriations for full restart project costs.

NASA will:

- Define its requirements for Pu-238 consistent with its projected mission requirements.
- Update DOE on an annual basis of its projected Pu-238 requirements.
- Participate in partnership with DOE to establish annual funding requirements.

- Review progress of the Pu-238 restart project to help ensure the project is well managed and remains on schedule and within budget.

DOE will:

- Manage the Pu-238 production restart project in accordance with applicable DOE capital acquisition orders, including siting decisions, technology decisions and nuclear safeguards and security considerations.
- Conduct appropriate NEPA review and analysis.
- Consult with NASA on key project decisions relevant to NASA's interests.
- Provide NASA regular reporting to assure full accountability to NASA in the expenditure of NASA funds.

A joint senior management review group will be established to provide oversight and governance of performance and schedule requirements, management provisions and funding arrangements.