

**RECORD OF DECISION  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
ADVANCED RADIOISOTOPE POWER SYSTEM DEVELOPMENT**

**A. Background (Purpose and Need for the Proposed Action)**

The purpose of the development of advanced Radioisotope Power Systems (RPSs) is to develop and qualify for flight the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) and the Stirling Radioisotope Generator (SRG) to provide modular power systems for use in the environments encountered in space and on the surfaces of solar system bodies that have an atmosphere. NASA is also pursuing longer-term research and development activities directed at alternative RPS designs and improvements in power converter technologies for potential future NASA missions, including improvements that could: improve RPS operation under an expanded set of mission conditions and environments; further increase power conversion efficiency (thereby reducing the quantity of plutonium-238 required per unit power); reduce mass; increase specific power (power per unit mass); increase reliability, lifetime, and operability; enhance the ability to operate in harsh environments; and increase mission power system flexibility.

NASA's future scientific exploration of the solar system is planned to include missions throughout the solar system and to the surfaces of solar system bodies. To accomplish these missions, NASA has identified a need for a variety of long-lived, reliable electric power sources that would be capable of functioning in space as well as on the surface of solar system bodies that have an atmosphere. Current non-nuclear energy production and storage technologies available to NASA, such as batteries, solar arrays, and fuel cells are unable to deliver the reliable electric power needed for some types of missions (e.g., a long-lived mission to orbit an outer planet). In addition, the existing General Purpose Heat Source Radioisotope Thermoelectric Generator (GPHS-RTG) used on previous orbital missions has limited applicability on solar system bodies that have an atmosphere. The performance of the GPHS-RTG, which is designed to operate un-sealed in space vacuum, degrades in most atmospheres and does not provide the long-term operating capabilities desired for surface missions. In addition, the GPHS-RTG provides power in the range of 250 to 300 watts of electricity ( $W_e$ ). NASA envisions the need for lower levels of electric power (approximately 100  $W_e$ ), and physically smaller power systems, enabling NASA to more efficiently fly smaller missions that require less power than that provided by the GPHS-RTG. The MMRTG and SRG RPS designs are considered modular units. Thus one or more of these devices could be fitted to a spacecraft to provide the required level of electric power.

The MMRTG and SRG would enable NASA, in the near future, to attempt solar system exploration missions with substantial longevity, flexibility, and greater scientific exploration capability. The power converter technology research efforts could ultimately result in RPS designs with characteristics enabling more diverse solar system exploration missions with an even greater scientific exploration capability. The fundamental goal of these potential missions is to understand how our solar system and planetary systems in general became habitable – and how they maintain their ability to nurture life. The goal would be achieved by answering two fundamental questions. The first is related to

habitability in planetary environments, "How have specific planetary environments evolved with time, when and in what way were they habitable, and does life exist there now?" The second is associated with the planetary system architecture, "What determines the arrangement of planetary systems, what roles do the position and masses of giant planets play in the formation of habitable planets and moons?" Some possible missions would include:

- Comprehensive and detailed planetary investigations creating comparative data sets of the outer planets - Jupiter, Saturn, Uranus, Neptune and Pluto and their moons. NASA has identified potential missions to Europa, Titan, and Triton, which are moons of Jupiter, Saturn, and Neptune, respectively, to address habitability in planetary environments and planetary architecture. An advanced RPS could enable such missions that would otherwise be infeasible due to a combination of factors, which include long distance from the Sun, long mission duration, and, in the case of Europa, a high radiation environment.
- Exploration of Venus (a very high pressure and temperature environment) to answer the questions of habitability from the point of view of planetary architecture (How wide is the long-term habitable zone?) and habitable worlds (By what process did Venus lose its early habitability?).
- Comprehensive exploration of the surfaces and interiors of comets, possibly including samples returned to Earth to better understand the building blocks of our solar system and ingredients contributing to the origin of life.
- Expanded capabilities for surface and on-orbit exploration, and potential sample return missions to Mars and other planetary bodies to greatly improve our understanding of planetary processes, particularly those affecting the potential for life.

## B. The Environmental Impact Statement

On April 22, 2004, NASA published a Notice of Intent (NOI) to prepare a Programmatic Environmental Impact Statement (PEIS) and conduct scoping for the development of advanced RPSs in the *Federal Register* (69 FR 21867). The scoping period originally was to close on June 4, 2004, but was extended until July 30, 2004 (69 FR 43629). One hundred eighty-two scoping comments were received from private organizations and individuals. Primary issues raised in the scoping comments included concerns about: (1) The use of radiological material for the spacecraft electrical power source; (2) Impacts to workers at the U.S. Department of Energy's (DOE's) Los Alamos National Laboratory (LANL) due to heat source preparation; (3) Impacts to the groundwater at LANL due to plutonium fuel and heat source preparations; (4) The lack of methods to properly dispose of nuclear waste; (5) Launch-area accidents when using RPSs; and (6) Possible military applications of the advanced RPS technology. Comments were also received that suggested the use of alternative (non-plutonium-radiological and non-radiological) sources for electrical power. DOE served as a cooperating agency in the development of the PEIS.

NASA published a Notice of Availability (NOA) of the *Draft Programmatic Environmental Impact Statement for the Development of Advanced Radioisotope Power Systems* on January 5, 2006 (71 FR 625) and mailed copies to Federal, State, and local agencies, and interested organizations and individuals. The U.S. Environmental Protection Agency (EPA) published its NOA for the Draft PEIS on January 6, 2006 (71 FR 928). The public review and comment period closed on February 21, 2006. NASA received a total of fifty-five comment submissions (letters and e-mails) from Federal, State, and local agencies; private organizations; and individuals.

These comment submissions included concerns regarding: (1) The use of radiological material for the spacecraft electrical power sources; (2) The impacts to workers, the public, and the environment at DOE facilities; (3) The proper disposal of nuclear waste (including proper material safeguards); (4) Launch-area accidents when using an RPS; and (5) Possible military applications of the advanced RPS technology. Additionally, several comment submissions recommended alternative actions, including: (1) The development and use of alternative (non-radiological) sources for electrical power; and (2) Using advanced RPS development funds on other societal issues (e.g., health, education).

These comments were considered in the development of the Final PEIS.

The EPA published a finding of no objection (i.e. LO – Lack of Objection) to the Proposed Action regarding NASA's Draft PEIS on March 10, 2006 (71 FR 12355).

NASA published its NOA for the Final PEIS on September 26, 2006 (71 FR 56181) and mailed copies to Federal, State, and local agencies, and interested organizations and individuals. In addition, NASA made the Final PEIS available in electronic format on its web site. The EPA published its NOA on October 6, 2006 (71 FR 59105), initiating the 30-day waiting period, which ended on November 5, 2006. The Florida Department of Environmental Protection issued a finding of No Objection to the Proposed Action regarding NASA's Final PEIS on October 11, 2006. The EPA issued a finding of no objection to the Proposed Action regarding NASA's Final PEIS on November 3, 2006. No additional comments were received by NASA during this period.

## C. Alternatives Considered

### C.1 Alternatives Evaluated in Detail

The Alternatives addressed in the PEIS were:

- The Proposed Action which has two basic elements. (1) NASA proposes to develop and qualify for flight for use in space two types of advanced Radioisotope Power Systems (RPS), the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) and the Stirling Radioisotope Generator (SRG), to enable a wide range of future space exploration missions. These advanced RPSs would be capable of functioning in the environments encountered in space and on the surfaces of solar system bodies that have an atmosphere. These modular power systems would be

based upon an enhanced version of the General Purpose Heat Source (GPHS) fueled by plutonium dioxide (consisting mostly of plutonium-238). The GPHS was originally developed by DOE and used in Radioisotope Thermoelectric Generators (RTGs) on previous NASA missions. (2) The Proposed Action also includes continued research and development (R&D) of alternative radioisotope power systems and power converter technologies.

The No Action Alternative in which NASA would (1) discontinue efforts for the development of the MMRTG and SRG. NASA would continue to consider the use of available RPSs, such as the GPHS-RTG, for future solar system exploration missions. While well suited to use in space, the GPHS-RTG would have substantially limited application on missions to the surface of solar system bodies where an atmosphere is present. In addition, DOE's GPHS-RTG production line is no longer operative, including the Silicon/Germanium (SiGe) thermocouple manufacturing operations. It may be possible to construct a limited number (one, two, or possibly three) of GPHS-RTGs from existing parts inventories, but longer term reliance on this technology would require the reactivation of the production capabilities, including re-establishing vendors for GPHS-RTG components, which could involve a substantial financial investment. (2) As with the Proposed Action, NASA would continue to pursue R&D of alternative radioisotope power systems and power converter technologies.

## C.2 Alternatives Considered but not Evaluated Further

In addition to the two alternatives evaluated, several alternatives were considered but not evaluated further. These alternatives include the consideration of the development of alternative radioisotope power converter technologies for the approximately 100 W<sub>e</sub> advanced RPS, the development of alternative converter technologies that would not make use of a radioisotope heat source, and modifying the GPHS-RTG for surface missions where an atmosphere is present.

### Alternative Advanced RPS Concepts

NASA considered developing a single power system concept rather than both the MMRTG and SRG systems. NASA also considered developing power systems using alternative power conversion technologies (*i.e.*, other than free piston Stirling and flight-qualified thermoelectrics) for use on near-term missions.

Both the MMRTG and SRG designs were judged most able to meet the schedule demands of near-term NASA mission plans. The MMRTG represents a "high confidence" solution in that it uses existing GPHS and flight-qualified converter technologies. The SRG represents a class of advanced converter technologies offering significantly higher heat-to-electric-power conversion efficiency. The Stirling-free piston engine was made a part of the Proposed Action as it was the only advanced power conversion technology considered sufficiently mature to be made flight ready within a reasonable time-frame. The Proposed Action to pursue development of both designs, rather than one or the other, is based on the combination of a high confidence design (with the MMRTG), potential increases in advanced RPS efficiency (with the SRG) and creation of enhanced flexibility in power system options for future missions.

Alternative power conversion technologies considered included the Alkali Metal Thermal to Electric Converter (AMTEC), Thermo-photovoltaic (TPV), and segmented thermoelectric technologies. All of these alternative converter technologies show promise for higher power conversion efficiencies than those available with the previous state-of-the-art flight-qualified thermoelectric converters. The technological issues associated with the development of these RPSs technologies suggested that they could not be developed in time to support NASA's near term exploration goals. NASA and DOE attempted to develop an AMTEC device for space applications and determined that this technology could not be made ready within given parameters. To achieve a reasonable efficiency, the TPV devices would require a large radiator system to maintain the relatively low temperatures required for efficient TPV cell operation. The size of the radiator, degradation of the TPV cell (a lifetime issue), compatibility with the GPHS module, and space qualified TPV cell materials need further development. A key issue associated with developing the combination of materials to be used in a segmented thermoelectric converter, is to select materials that can be mated together with little electrical resistance while retaining structural integrity of the device.

### **Modified GPHS-RTG**

A modified GPHS-RTG design was an option when considering thermoelectric designs for the advanced RPS. The GPHS-RTG used on previous orbital and flyby missions (*i.e.*, in the absence of an atmosphere) could be modified for use on surface missions where an atmosphere is present. Potential modifications to the GPHS-RTG would focus on preventing atmospheric contact with internal components susceptible to degradation (such as the multi-foil insulation or thermocouples) or replacing or coating components with materials that would not readily degrade in the atmosphere. While both of these approaches have merit, a number of engineering concerns (including mass and material compatibility) and the need to reinstate manufacturing capabilities, including restarting currently closed production lines, would have to be considered. In addition, a modified GPHS-RTG (producing between 250 and 300 W<sub>e</sub>) would not meet NASA's goal of enhanced flexibility in powering missions.

### **Non-Radioisotope Power Systems**

Solar energy has been used for most U.S. space applications, and it is usually the preferred choice of mission planners because solar power converters (solar arrays) are typically readily available and easier to incorporate into a mission than RPS-powered devices. However, for many solar system exploration missions the current state of solar power technology is not adequate. For example, for the deep-space Cassini mission, the weight of the solar array would have made launch impossible with existing launch vehicles; and control of the massive solar panels untenable if launch hurdles could have been overcome. Similar technical barriers faced planners for the New Horizons mission to Pluto and the Kuiper Belt, and the use of solar power was determined not to be feasible.

Research continues on a host of advanced solar power technologies, including; high efficiency solar cells, solar concentrators, low-intensity low-temperature solar cells,

solar-driven Stirling or Brayton converters, and solar collector technology. These technologies are intended to address the limitations identified by NASA for solar power use during extended Mars surface exploration and for missions to the outer planets.

For missions to the outer planets these limitations include:

- Decreased effectiveness as distance from the sun increases (need for large solar arrays for missions to outer planets),
- Large structures impact the ability of spacecraft to perform mission
  - obstruction of view
  - difficulty in orienting the spacecraft,
- Need to orient solar array toward sun most of the time, and
- Degradation in high radiation environments.

When considering solar power for an extended Mars surface mission, NASA identified the following limitations:

- Intermittent operation,
- Limited lifetime due to system degradation from dust,
- Battery cycle life,
- Seasonal variations in solar incidence,
- Interruption of power production by dust storms,
- System inoperability at certain locations (e.g., in crater or canyon shadows).

#### **D. Key Environmental Issues Evaluated**

The key environmental issues associated with implementing the Proposed Action were the radiological impacts associated with the fabrication of plutonium fuel and the fabrication and testing of the advanced RPS qualification units (MMRTG and SRG test units fueled with the plutonium dioxide fuel) at DOE facilities. The impacts considered in detail in the PEIS for the development of advanced RPS included impacts from normal operations and from accidents on both public health and worker health.

In addition, environmental considerations associated with radiological risks arising from the potential end use of an advanced RPS on future NASA missions, in the event the Proposed Action is implemented, were qualitatively assessed.

#### **E. Environmental Consequences of the Alternatives**

Under the Proposed Action, plutonium would be needed for the Qualification Units for both the MMRTG and the SRG. Impacts associated with DOE's plutonium operations have been analyzed in previous DOE NEPA documentation. This documentation addresses the importation of plutonium from Russia, the fabrication of plutonium fuel pellets at Los Alamos National Laboratory (LANL) and the assembly and testing of RPS units at Idaho National Laboratory (INL). Results from those analyses were incorporated

into the analysis performed for the *PEIS for the Development of Advanced Radioisotope Power Systems*.

Activities and impacts associated with transporting plutonium-238 to the U.S. from Russia are evaluated in two DOE NEPA documents: *Environmental Assessment of the Import of Russian Plutonium-238 (Russian Plutonium-238 EA)*, and *Finding of No Significant Impact for Import of Russian Plutonium-238 Fuel*. The proposed action addressed in the Russian Plutonium-238 EA was to import up to 40 kilograms (kg) (88 pounds (lb)) of plutonium-238 fuel (isotopic mass) in powdered dioxide form from Russia to supplement the current U.S. inventory. DOE would need to import less than 10 kg (22 lb) to fuel the Qualification Units in support of MMRTG and SRG development. Therefore, the impacts associated with importation of plutonium-238 for the Proposed Action would be within the envelope of activity and impacts analyzed in DOE's Russian Plutonium-238 Environmental Assessment (EA). The dose to transportation workers associated with importing 40 kg (88 lb) of plutonium-238 to LANL was reported to be 2.6 person-rem; the dose to the public was reported to be 4.5 person-rem. Accordingly, incident-free transportation of plutonium-238 would result in 0.0011 latent cancer fatality among transportation workers and 0.0023 latent cancer fatality in the total affected population over the duration of the transportation activities discussed in the Russian Plutonium-238 EA.

The reported transportation accident risks under this option in the Russian Plutonium-238 EA for the importation of 40 kg (88 lb) of plutonium dioxide are as follows: a radiological dose to the population of 0.2 person-rem, resulting in  $1.0 \times 10^{-4}$  latent cancer fatality; and traffic accidents resulting in 0.0032 traffic fatality. These estimates include the risk to the crew, handlers, and the public during both ocean and highway transportation.

The *Draft Environmental Impact Statement for the Proposed Consolidation of Nuclear Operations Related to the Production of Radioisotope Power Systems* (Draft Consolidation EIS) has most recently analyzed the impacts associated with plutonium operations at DOE facilities. This EIS addressed, among others, the impacts of activities associated with domestic production of plutonium-238 (from target fabrication through target irradiation in a nuclear reactor to the extraction of plutonium-238 from the targets), purification, conversion to an oxide, and encapsulation of the plutonium into fueled clads; and the assembly and testing of RPS units.

The Draft Consolidation EIS reported that the impacts of continued national security and space related plutonium-238 fuel pellet fabrication operations at LANL would result in very, very small releases (on the order of  $1 \times 10^{-8}$  curies per year) with an estimated  $1.8 \times 10^{-5}$  person-rem/yr (or  $3.8 \times 10^{-7}$  Latent Cancer Fatalities over the 35 year operating life) and a dose to the maximally exposed member of the public of  $1 \times 10^{-9}$  rem/yr. The radiological impacts to the public from normal RPS-related operations at the LANL facilities are well below any regulatory limit applicable to the DOE and are expected to be a very small fraction of the public health impact from site-wide operations. Worker exposures from continued operations were estimated as 19 person-rem/yr with an average

worker dose of 0.24 rem/yr. These exposure estimates are within the limits set for occupational exposure and are not significantly different from worker exposures from other site plutonium glovebox activities.

The Draft Consolidation EIS also reported that the radiological accident risks of continued national security and space related plutonium-238 fuel pellet fabrication operations at LANL would be very small (with a maximum annual cancer risk of 0.00025 for the surrounding population). Radiological risks to the public associated with potential accidental releases from RPS related activities also are a small contributor to the overall risks associated with operations at the site. Exposures from some accidents could be in excess of occupational dose limits for some site workers.

Continued national security and space related plutonium-238 fuel pellet fabrication operations at LANL were estimated in the Draft Consolidation EIS to result in generation of about 13 cubic meters ( $m^3$ ) of transuranic waste and 150  $m^3$  of low-level radioactive wastes yearly.

The Draft Consolidation EIS reported that continued national security and space related plutonium-238 operations at INL would result in very, very small releases (estimated  $1.7 \times 10^{-6}$  person-rem/yr or  $3.5 \times 10^{-8}$  Latent Cancer Fatalities over the 35 year operating life and the maximally exposed member of the public dose of  $1.4 \times 10^{-10}$  rem/yr). The facilities at INL where such operations would occur would handle only fully encapsulated radioactive material and therefore these operations would result in no expected releases and off-site radiological consequences. There would be no other types of radiological releases from RPS nuclear production operations. The radiological impacts to the public from normal RPS-related operations at the INL facilities are well below any regulatory limit applicable to the DOE and are expected to be a very small fraction of the public health impact from sitewide operations. Worker exposures from continued operations were estimated as 1.2 person-rem/yr with an average worker dose of 0.017 rem/yr. These exposure estimates are well below the limits set for occupational exposure.

The Draft Consolidation EIS also reported that the radiological accident risks of continued national security and space related RPS assembly operations at INL would be very small (with a maximum annual cancer risk of 0.0026 for the surrounding population). Radiological risks to workers and the public associated with accidental releases from RPS related activities also are a small contributor to the overall risks associated with operations at the site.

Continued national security and space related RPS assembly operations at INL were estimated in the Draft Consolidation EIS to result in generation of a minimal amount of transuranic waste and 1  $m^3$  of low-level radioactive wastes per year.

Additional impacts addressed for the Proposed Action include the minor environmental impacts associated with development of the MMRTG and the SRG converters and the research and development of advanced converter technologies. These impacts are expected to be within the permitted quantities of airborne emissions, waterborne

effluents, and waste disposal at each of the involved facilities; and subsequently both the short-term and long-term environmental impacts are expected to be within the limits of all applicable environmental laws, permits, and licenses. Specifically:

- Any increases in air emissions as a result of MMRTG development would be expected to be minimal or non-existent and within existing permits.
- No direct adverse effects would be anticipated on either aquatic or terrestrial ecosystems as a result of MMRTG development as no major construction activities are anticipated.
- Impacts on water quality as a result of MMRTG development would be minimal and would be expected to be within the scope of referenced documents.

Implementation of the development effort should result in no substantial change in the employment levels at the facilities and therefore, have little or no incremental socioeconomic impacts to the local communities.

Under the No Action Alternative, NASA would not develop the MMRTG nor the SRG. The impacts associated with plutonium operations needed to fuel the MMRTG and SRG Qualification Units would not be incurred. Only those impacts identified above for the research and development of advanced converter designs would be associated with the No Action Alternative.

#### **F. Assessment of the Analysis**

The advanced RPS fuel production and test activities associated with the Proposed Action would occur at DOE sites, such as LANL and INL, within existing DOE facilities that: 1) already support the NASA's RPS needs as well as other government agencies, and 2) are subject to existing DOE NEPA documentation which address production levels sufficient to include the production of plutonium-238 dioxide fuel for NASA. The proposed advanced RPS development actions that would be performed at DOE facilities are the same as ongoing RPS activities; activities that would be expected to continue whether or not the development of the advanced RPS designs continue.

Impacts associated with the MMRTG and SRG converter development and the research and development of advanced converters are expected to be minimal and within the levels allowed by existing permits and licenses for the research facilities.

#### **G. Choice of Alternatives**

Given the relatively small environmental impact and potential substantial benefits associated with the development of the MMRTG and the SRG, I have decided to choose the Proposed Action, based on the following:

When evaluating the consequences of the actions associated with the Proposed Action and the No Action Alternative, the No Action Alternative is the environmentally

preferred alternative. The No Action Alternative has none of the radiological impacts at DOE facilities associated with the development of the MMRTG and the SRG. The impacts associated with the converter technology efforts at commercial and government facilities would be essentially the same for both alternatives.

However, when the impacts of reasonably foreseeable actions that could result from the selection of either alternative are considered, there could be very little difference in the impacts from either of the two alternatives. Under both alternatives, NASA would be able to consider an RPS for use on future missions; the MMRTG and SRG under the Proposed Action and the GPHS-RTG under the No Action Alternative. Therefore, under both alternatives, DOE could continue to fabricate plutonium fuel and manufacture RPSs in support of NASA. (NASA is not the only client agency for which DOE develops and fabricates RPSs. RPS related operations at DOE are expected to continue in support of these other clients regardless of the demand for RPSs by NASA.) At this time it is not possible to determine the number of RPSs and the amount of plutonium fuel that could potentially be needed for future NASA missions under either alternative. The decision to use an RPS is a mission specific decision, made while the mission requirements and goals are being developed (and subject to additional NEPA evaluation).

Several factors will determine the quantity of plutonium to be fabricated into RPS fuel and correspondingly the potential impacts associated with fuel fabrication. The amount of fuel used in an MMRTG or SRG (developed under the Proposed Action) is less than that used in a GPHS-RTG (the only RPS available for use under the No Action Alternative), although the power produced by the MMRTG and RPS is less than half that produced by the GPHS-RTG. The types and number of missions that could ultimately select an RPS for use would be different under the two alternatives. Under the Proposed Action, NASA would be able to consider the use of an MMRTG or SRG on long term missions to the surface of certain solar system bodies and on orbital and fly-by missions. Under the No Action Alternative, the missions to certain planetary surfaces that would require an RPS that functions effectively in planetary atmospheres would not be possible. Without modification, the GPHS-RTG is not suited for use on many planetary surfaces and could be used for orbital or fly-by missions only.

Selection of the Proposed Action enables solar system exploration missions with substantial longevity, flexibility, and greater scientific exploration capability. The fundamental goal of these potential missions is to understand how our solar system became, and planetary systems in general became, habitable – and how they maintain their ability to nurture life. The goal would be achieved by answering two fundamental questions. The first is related to habitability in planetary environments, “How have specific planetary environments evolved with time, when and in what way were they habitable, and does life exist there now?” The second is associated with the planetary system architecture, “What determines the arrangement of planetary systems, what roles do the position and masses of giant planets play in the formation of habitable planets and moons?”

## H. Additional Information

There were no other environmental requirements (for example, Endangered Species Act consultations or assessments and consultations under the National Historic Preservation Act) that needed to be addressed in this PEIS. No additional comments were received by NASA during the mandatory 30-day waiting period prior to the rendering of this Record of Decision.

Use of an MMRTG and SRG, under the Proposed Action, or GPHS-RTG, under the No Action Alternative, on future missions was considered to be a reasonably foreseeable action. Environmental impacts associated with the end use of any of these RPSs were qualitatively discussed in the PEIS. Each mission that proposes to carry an advanced RPS or a GPHS-RTG would be the subject of both a NEPA process and a separate and independent nuclear safety launch approval process. The NEPA process for each mission utilizes a mission-specific nuclear risk assessment to evaluate the potential radiological impacts of launch accidents. This risk assessment would consider mission specific factors such as the type of advanced RPS selected, the launch vehicle configuration and reliability, launch-site meteorological conditions, and demographic data (launch area and worldwide) that could influence the risk estimates for a specific mission. No mission-specific risk assessment addressing the use of either advanced RPS has been developed to date.

Mission specific factors that affect the calculated risk include: (1) the protective features of the launch vehicle and the devices containing the radioactive material, (2) the probability of an accident which could threaten the radioactive material, (3) the accident environments, and (4) the amount and type of radioactive material used in a mission. For missions that would use an advanced RPS, many of these factors would be similar to those factors considered in the analyses for missions that used the GPHS-RTG.

## I. Mitigation

RPS production for NASA is only a part of the DOE mission with regards to RPS production. Therefore, the types of impacts at DOE sites associated with RPS production would be incurred regardless of NASA's decision to pursue development of advanced RPS designs. Therefore, it is anticipated that the existing conditions, potential environmental impacts, and mitigation activities at the respective sites would mostly remain unchanged.

The only expected or immediate environmental impacts of launching individual missions incorporating an Advanced RPS as an electrical power supply are in kind with the impacts of missions that have used previous RPS designs, such as the GPHS-RTG, and mitigation will accordingly be the same. Regarding such possible radiological impacts, the development of a mission-specific risk assessment provides the opportunity to generate

feedback into the mission design to possibly reduce the impact of these factors. NASA will continue to use this process to assess and manage potential radiological risks associated with any RPS mission. Each mission risk assessment would build upon the information and insights developed in earlier assessments of all types of launches and tailor the assessment to the specific mission parameters. It is reasonable to expect that risk and safety assessments performed for future RPS-powered missions may result in mission modifications intended to address mission-specific risk factors.

Furthermore, NASA, with expert technical assistance from DOE, the EPA, the U.S. Department of Homeland Security, the U.S. Department of Defense, and other Federal agencies, and in cooperation with State and local authorities, would develop a federal radiological contingency response plan for each RPS-powered mission. Key elements of monitoring and data analysis equipment would be pre-deployed to enable rapid response in the event of a launch accident. The plan for each such mission, to be documented elsewhere, would define the roles of the agencies involved and would address short-term monitoring and mitigation activities associated with each launch. Post-accident mitigation activities, if required, would be based upon detailed monitoring information and assessment.

#### Decision

Based upon all of the foregoing, it is my decision to pursue development of Advanced RPSs, specifically the MMRTG and SRG, and to continue research and development of alternative radioisotope power systems and power converter technologies, as defined in the Proposed Action.



Mary L. Cleave  
Associate Administrator  
Science Mission Directorate

1/06/2006  
Date



National Aeronautics and Space Administration

# Routing Slip

Mail Suite	Name	Action	
		Approval	
1 I&A/EMD	Mr. Leatherwood <i>11/13/06</i>	Call me	
		Concurrence	
		File	
2 OGC	Mr. Stewart <i>11-14-06</i>	Information	
		Investigate and Advise	
3 I&A	Ms. Dominguez <i>10/10/06</i>	Note and Forward	
		Note and Return	
4 SMD	Mr. Lavery <i>11-27-06</i>	Per Request	
		Per Phone Conversation	
5 SMD	Mr. Green <i>11/13/06</i>	Recommendation	
		See me <i>12/1/06</i>	
6 SMD <i>SMD</i>	Dr. Hartman <i>11/13/06</i> Mr. <i>11/13/06</i>	Signature	x
7 SMD	Dr. Cleave <i>11/13/06</i>	Circulate and Destroy	

RE: Record of Decision (ROD) for the Development of Advanced Radioisotope Power Systems (ARPS)

The ROD found herein represents the final step in the National Environmental Policy Act process for the Development of ARPS. The proposed decision would authorize NASA to continue development of the MMRTG and SRG. The Final Programmatic Environmental Impact Statement (PEIS) for the Development of ARPS is a primary source document for the ROD as written.

No public comments were received on the Final PEIS during the 30-day required waiting period before a ROD can be issued. The U.S. Environmental Protection Agency published a Lack of Objection (LO) finding for NASA's Proposed Action (i.e., continue development of the MMRTG and SRG) as described in the PEIS.

This ROD has been fully coordinated among Science Mission Directorate, HQ Environmental Management Division, Office of the General Counsel, and Jet Propulsion Laboratory staffs. Concurrences and signature are recommended.

Name <i>Kenneth M. Kumor</i> Kenneth M. Kumor	Tel. No. (or suite) & Ext. 358.1112
Suite (or other designation) I&A/EMD	Date November 9, 2006

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