DISCOVERY AO
RADIOISOTOPE HEATER UNIT (RHU) INFORMATION SUMMARY
April 2004

All Radioisotope Heater Units (RHUs) used in missions proposed for this AO, including the services associated with their provisioning on space missions (e.g., National Environmental Policy Act (NEPA) Compliance, Nuclear Safety Launch Approval, Emergency Preparedness and Planning), will be provided by NASA and the Department of Energy (DOE) as Government Furnished Equipment (GFE) and Services (GFS). Funding for these units and services will be provided directly by the Discovery Program, and budgeted within the cost cap for each selected mission.

This document describes the RHUs that would be made available to proposed missions, provides additional links and contact information as resources for developing proposals, and contains general information concerning special considerations that have to be taken when proposing to use RHUs and their associated costs. During Phase A study of the selected mission concepts, the teams that have proposed use of RHUs in their missions will be provided a NASA Point of Contact (POC) who will support them in developing more refined approaches and cost estimates for accommodation of RHUs.

1.0 Introduction

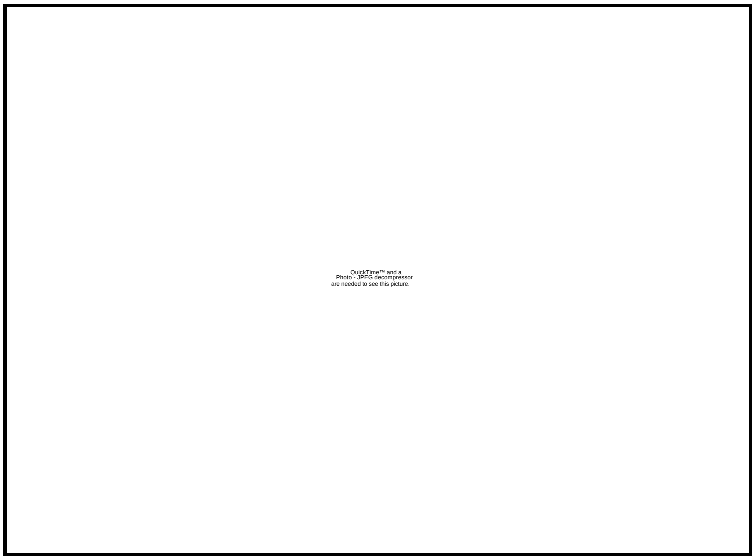
Most spacecraft can use solar energy to provide heat to keep their structure, systems, and instruments warm enough to operate effectively. However, when solar or other heat source technologies are not feasible, an alternate heat source is required for the spacecraft. By using RHUs, the spacecraft designer can allocate scarce spacecraft electrical power to operate the spacecraft systems and instruments. RHUs also provide the added benefit of reducing the potential for electromagnetic interference generated by electrical heating systems.

Characteristics of RHUs include:

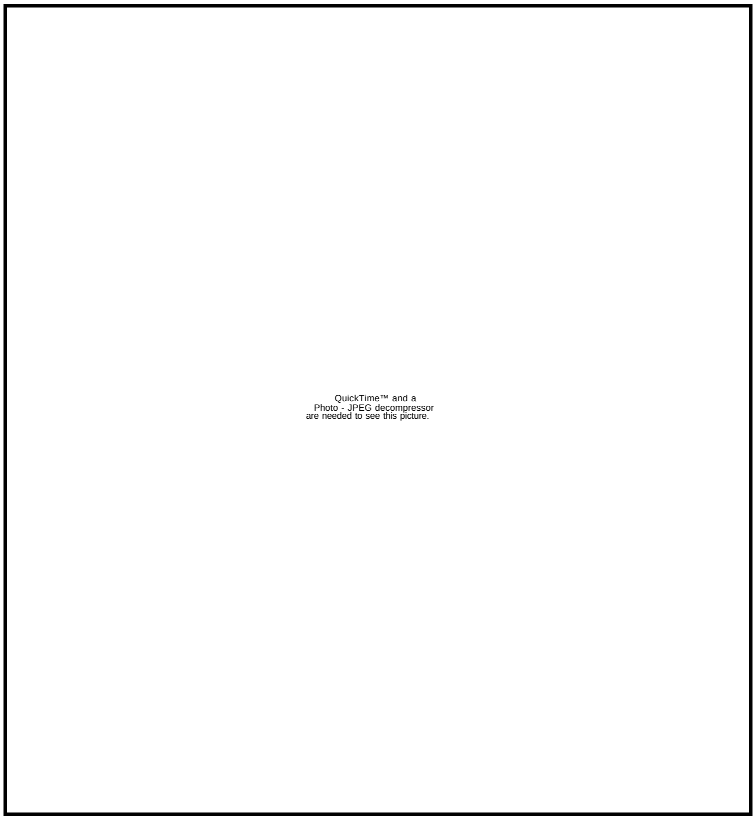
- Highly reliable, continuous, and predictable output of heat.
- No moving parts.
- Compact structure.
- Resistance to radiation and meteorite damage.
- Heat produced is independent of distance from the sun.

RHUs provide proven and reliable continuous heat to sensitive spacecraft instruments and scientific experiments enabling their successful operation throughout the mission.

RHUs generate heat from the natural radioactive decay of a small pellet of plutonium dioxide (mostly plutonium-238). This heat is transferred to spacecraft structures, systems, and instruments directly without moving parts or intervening electronic components. RHUs are very compact, 3.2 centimeters (1.3 inches) long and 2.6 centimeters (1 inch) in diameter. The fuel pellet is about the size and shape of a pencil eraser weighing approximately 2.7 grams (0.1 ounces). All together each RHU weighs about 40 grams (1.4 ounces).



RHUs have a very rugged containment system to prevent or minimize the release of plutonium dioxide fuel even when subjected to severe accident conditions. Containment is achieved through multiple layers that are resistant to the heat and impact that might be encountered during a spacecraft accident. An external graphite aeroshell (a reentry shield) and a graphite insulator protect the fuel from impacts, fires, and atmospheric reentry conditions. Internally, the fuel is encapsulated in a high-strength, platinum-rhodium metal shell (or "clad") that further contains and protects the fuel during any potential accident.



In addition to this containment, the plutonium dioxide fuel is used in a ceramic form of the material that tends to break into large pieces rather than dispersing as fine particles. This minimizes interaction of the fuel with the environment and the potential for human exposure in the extreme unlikely event the multiple fuel containment barriers are breached. Since each RHU fuel pellet is individually encapsulated in its own aeroshell and fuel clad, the potential for a single event to affect more than one pellet is reduced.

The following sections provide more information relevant to the provisioning of RHUs for the Discovery AO. Section 2.0 provides links and contact information for additional information about RHUs. Section 3.0 summarizes all of the activities, processes and costs that AO respondents should assume in proposing a mission potentially utilizing RHUs.

2.0 Additional Information

Historical information and general information concerning the use of radioisotopes in space can be found at: http://www.ne.doe.gov/. General questions concerning RHUs and their use should be directed to the Discovery and New Frontiers Program Director Andrew Dantzler at 202-358-1024. General questions concerning RHU technical details (e.g., technical specifications, spacecraft integration) should be directed to the Department of Energy's Office of Space & Defense Power Systems, Tim Frazier at 301-903-9420.

3.0 Provisioning of RHUs for Discovery Missions

Potential use of RHUs in space requires many special considerations that must be accounted for in the budgeting and scheduling of a space mission. Most of these elements, such as National Environmental Policy Act (NEPA) Compliance and Nuclear Safety Launch Approval (NSLA), are well-defined, multi-year processes involving development of specific documentation and coordination among several government agencies.

Many of these elements are delineated in NASA guidelines available through links in the Discovery Program Library, while some have evolved as accepted practices over the years. For the Discovery AO, the special considerations for use of RHUs have been divided into the six elements described below.

3.1 NEPA Compliance

NEPA requires federal agencies to consider, before an action is taken, environmental values in the planning of activities that may have a significant impact on the quality of the human environment. NEPA accomplishes this by directing agencies to evaluate alternative courses of action that may mitigate the potential environmental impact of a planned activity, such as use of radioactive material on a space mission. NASA's implementing regulations for NEPA can be found at 14 CFR 1216.1 and 1216.3. These regulations specify actions that can be expected to have a significant effect on the quality of the human environment. Such actions, which include the development and operation of nuclear systems, require preparation of an EIS.

Development of the EIS commences as early as possible in the development program, with a target for completion by Critical Design Review (CDR) or earlier. NASA Headquarters is responsible for preparation of the EIS and has enlisted subcontractors to assist in its development. When missions plan to use RHUs development of the EIS also requires development of a nuclear risk assessment by the Department of Energy (DOE), and participation by NASA Kennedy Space Center (KSC) and the Jet Propulsion Laboratory (JPL), NASA's launch nuclear approval engineering technical representative.

3.2 Nuclear Safety Launch Approval (NSLA)

For any U.S. space mission involving use of nuclear energy for heating or electrical power, launch approval must be obtained from the Office of the President per Presidential Directive/National Security Council Memorandum #25 (PD/NSC-25) paragraph 9. The approval decision is based on an established and proven review process that includes an independent evaluation by an ad hoc Interagency Nuclear Safety Review Panel (INSRP). The NSLA begins with development of a launch vehicle databook (i.e., a compendium of information describing the mission, launch system, and potential accident scenarios). DOE uses the databook to prepare a preliminary safety analysis report (PSAR) for the space mission. In all, three safety analysis reports (SAR's) are typically produced and submitted to the INSRP – the PSAR, an updated

SAR (USAR) and a final SAR (FSAR). The DOE project office responsible for providing the nuclear power system develops these documents.

The ad hoc INSRP conducts its nuclear safety/risk evaluation in three sequential steps following the PSAR, USAR and FSAR. The results of the INSRP evaluation are documented in a nuclear Safety Evaluation Report (SER). The SER contains an independent evaluation of the mission radiological risk. The DOE uses the SER as its basis for accepting the SAR. If the DOE Secretary formally accepts the SAR-SER package, he/she forwards the package to the NASA Administrator for use in the launch approval process.

NASA distributes the SAR and SER to other cognizant government agencies, such as DOD and EPA, and solicits their assessment of the documents. After receiving responses from these agencies, NASA conducts internal management reviews to address the SAR and SER and any other nuclear safety information pertinent to the launch. If the NASA Administrator recommends proceeding with the launch, then a request for nuclear safety launch approval is sent to the Office of Science and Technology Policy (OSTP) within the Office of the President.

From a historical perspective, DOE has requested completion of a mission's launch vehicle databook at least three years prior to launch. Although this schedule has emerged as a convention, it is not a requirement. In fact, there are incentives to begin the databook preparation process earlier and complete it sooner, if possible.

NASA Headquarters is responsible for implementing the NSLA process for NASA missions. It has traditionally enlisted JPL to assist in this activity. DOE supports the process by analyzing the response of RPS hardware to the different accident scenarios identified in the databook, and prepares a probabilistic risk assessment of the potential radiological consequences and risks to the public and the environment for the mission. NASA KSC is responsible for overseeing development of databooks, and traditionally uses JPL to characterize accident environments. KSC subcontractors are also under contract to provide information relevant to launch vehicle accident probability analysis, and other contractors assist in performing impact assessments and analyses. The development team ultimately selected for this Discovery mission would be responsible for providing payload descriptions, describing how the nuclear hardware integrates into the spacecraft, describing the mission, and supporting NASA KSC and JPL in their development of the databooks for the EIS and NSLA processes.

3.3 Emergency Preparedness and Planning

Any launch involving significant amounts of radioisotope materials (e.g., RHUs, Radioisotope Power Systems) requires special accommodations at the launch site to ensure mitigation of associated hazards arising from an unlikely launch anomaly. This activity involves deployment of emergency response team assets at the launch site and preparations to respond to any launch anomaly with radioisotope materials onboard. It also includes the detailed planning that must be conducted prior to deployment of these assets, including formulation of procedures for handling different accident scenarios. The deployed assets range in capability and size – from a small contingent (from one of DOE's Radiological Assistance Program (RAP) Regions) to larger resources (which could form the basis of a Federal Radiological Monitoring and Assessment Center (FRMAC)). The radiological emergency preparedness and planning requirements are tailored for each launch based on the understood risk (documented in the FSAR) and experience/lessons learned from previous missions using radioisotope materials.

As the Lead Federal Agency (LFA), per the Federal Radiological Emergency Response Plan (FRERP), NASA has responsibility for overall emergency preparedness and planning. As part of that effort, DOE supports the LFA planning and preparedness functions, both on and off-site, associated with any response to launch anomalies possibly involving the release of radiological materials. DOE would provide the initial radiological response team, including command and control, for resources off-site under provisions of the FRERP. The funding for these activities would be provided to DOE directly by NASA as part of the overall project cost.

3.4 RHU/Spacecraft Accommodations, Processing and Integration

Use of RHUs requires special provisions for accommodations and processing at the launch site. There are also unique aspects that have to be accounted for when integrating the unit(s) with the launch vehicle. RHUs also require special security to protect the units and the radioisotope fuel. This element begins early in the design process and culminates in activities directly supporting processing and integration at the launch site.

3.5 Risk Communication

The unique issues associated with using nuclear materials on missions require extra measures to ensure communication of risk throughout all activities in the program. The design of spacecraft utilizing radioisotopes depends on how technical decisions impact safety and development risk of the entire system. Most importantly, these impacts dictate how risks to the populace and environment are communicated to the public and key stakeholders. This activity ultimately supports all other nuclear-unique activities, such as NEPA Compliance, NSLA, and Emergency Preparedness, in addition to the activities usually conducted for any space science mission, such as education and public outreach.

3.6 Delivered Hardware

DOE provides RHUs for NASA missions per a 1991 interagency Memorandum of Understanding (MOU). Details relevant to specific flight missions and development programs are detailed in Supplements to the MOU. The provision and delivery of RHUs for this Discovery mission will be covered in a new MOU Supplement that will reflect the budget allocation for RHUs in the eventual development contract. Flight unit delivery costs are expressed on a per RHU basis, and include the purchase and processing of Pu-238, fabrication and integration of the RHUs assembly, delivery, and acceptance tests.

3.7 Costs

Launch approval engineering for a mission involving RHUs would roughly cost between $5–10 million depending on the selection of launch vehicle, the mission's complexity, the existence of potential cost-sharing opportunities with other NASA programs, and interagency negotiations concerning RHU safety analysis and radiological contingency planning costs. In general, costs would tend towards the lower range if: a databook already existed for the proposed launch vehicle, another NASA program was already funding development of the same or similar launch vehicle configuration, the mission does not require a solid motor upper stage, and the mission uses a standard (e.g., direct) trajectory.

Other costs associated with the use of RHUs include the actual costs of the RHUs [TBD by NASA – past estimate was $30K (h/w) + $3.6K (Pu-238 cost) = ~$35K/RHU], modifying standard launch vehicle integration activities to account for radiation safety procedures, and augmented security measures at KSC while the RHUs are on-site. The latter two costs typically add about $1–3M for the mission.