Space Radioisotope Power Systems
Safety
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The U.S. Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA) place the highest priority on assuring the safe use of radioisotope power systems for space missions. Prior to each mission, the agencies jointly conduct extensive safety reviews supported by safety testing and analysis. Further, an independent safety evaluation of the mission is performed as part of the launch approval process by an *ad hoc* Interagency Nuclear Safety Review Panel (INSRP) supported by experts from government, industry and academia. Safety is of utmost importance and is reflected in the overall design of radioisotope power systems, their applications, the choice of radioisotope, and the extensive testing, analysis and review that each system undergoes.

Plutonium-238 Dioxide as a Heat Source and Radioisotope Power System Fuel Module Design

The Plutonium-238 isotope used in radioisotope power systems (RPSs) and lightweight radioisotope heater units (LWRHUs) produces heat through natural decay by giving off alpha particles - helium nuclei - which travel only about three inches in air. Clothing, skin, or even a sheet of paper stops external alpha radiation.

The ceramic form of plutonium-238 dioxide that is used in RPSs and LWRHUs is designed specifically for safety. The ceramic form of plutonium-238 dioxide is heat-resistant and limits the rate of vaporization in fire or reentry conditions. The material also has low solubility in water. This material does not disperse or move easily through the environment, and primarily fractures upon impact into large particles and chunks that cannot be inhaled as dust. This is important because plutonium-238 dioxide particles would have to be of a sufficiently small size to be inhaled and deposited in lung tissue, where they could lead to an increased lifelong chance of incurring cancer. Other plutonium-238 dioxide exposure pathways, such as ingestion, contribute far less to the potential development of cancer.

The plutonium in radioisotope power systems is not weapons-grade plutonium and its ceramic form has a low chemical reactivity (i.e., does not react with other chemicals). The radioisotope is enclosed in small, independent modular units, each with its own heat shield and impact shell. This modularity reduces the likelihood that significant amounts of the radioisotope could be released in launch accidents.

More than 35 years have been invested in the engineering and testing of RPS systems. Multiple layers of protective materials, including iridium capsules (or platinum-rhodium capsules for radioisotope heater units) and high-strength, heat-resistant graphite blocks are used to protect the radioisotope and prevent its release. Iridium is a metal that is strong, corrosion-resistant, and chemically compatible with plutonium dioxide. These characteristics make iridium ideal for protecting and containing each radioisotope pellet. Graphite is used because it is lightweight and highly heat-resistant.

Safety Testing

Radioisotope power systems are designed to contain their plutonium dioxide in a wide range of potential accidents. Rigorous testing is conducted to demonstrate the radioisotope power system's plutonium dioxide containment capabilities in severe launch vehicle accidents. The battery of tests that the modular units have undergone include solid and liquid propellant fires, blasts due to launch vehicle propellant and motor explosions, re-entry ablation and thermal environments, Earth impacts, impacts by shrapnel and large launch vehicle fragments, and immersion in water. The multi-layer containment concept employed for the systems is designed to contain the radioisotope, but even if the containment is breached, the ceramic radioisotope pellet has been designed to limit dispersal of the material into the environment.

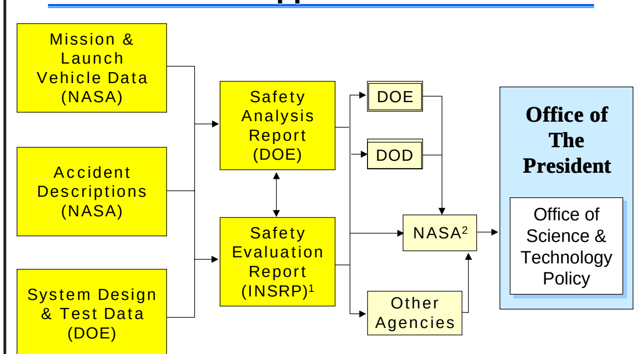
Risk Assessment and Launch Approval

A mission that uses radioisotope heaters or power sources undergoes a safety analysis carried out by DOE. In that process, DOE prepares a safety analysis report that provides a comprehensive assessment of the potential consequences of a broad range of launch accident scenarios described by NASA. The potential consequences are based upon a detailed understanding of the potential accident environment, characterization of the radioisotope power system responses based upon testing and analyses, modeling of how any potential releases might be transported, and in turn, estimates of potential public exposure and the consequences of those exposures. In addition to internal agency reviews for missions that involve radioisotope power or heater systems, an *ad hoc* Interagency Nuclear Safety Review Panel (INSRP) is established as part of a Presidential nuclear safety launch approval process to evaluate the safety analysis report prepared by DOE. Based upon recommendations by DOE and other agencies and the INSRP evaluation, NASA may then submit a request for nuclear safety launch approval to the White House Office of Science and Technology Policy (OSTP). The OSTP Director (i.e., the President's science advisor) may make the decision or refer the matter to the President. In either case, the normal process for launch cannot proceed until nuclear safety launch approval has been granted.

Public Safety and Risk

Radioisotope power systems are not a new part of the U.S. space program. In fact, they have enabled NASA's safe exploration of the Solar System for many years. The Apollo missions to the Moon as well as the later Viking, Pioneer, Voyager, Ulysses, Galileo, Cassini, Pluto New Horizons missions all used radioisotope thermoelectric generators (RTGs). The RTGs for the Pioneer 10 spacecraft have operated reliably for three decades and continue to power the spacecraft as it travels beyond Pluto. Over the last three decades, the United States has launched 26 missions involving 45 RTGs. While RTGs have never been the cause of a spacecraft accident, they have been on board three space missions that did fail for other reasons. In all three cases, the RTGs performed as designed.

Nuclear Safety Review and Launch Approval Process



[1] Interagency Nuclear Safety Review Panel
[2] Responsible mission agency makes launch recommendation

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