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COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE
Scientific and Technical Subcommittee
Forty-third session
Vienna, 20 February - 3 March 2006
**Agenda item 9**
**Use of Nuclear Power Sources in Outer Space**

# JOINT UNITED NATIONS/INTERNATIONAL ATOMIC ENERGY AGENCY TECHNICAL WORKSHOP ON THE OBJECTIVES, SCOPE AND GENERAL ATTRIBUTES OF A POTENTIAL TECHNICAL SAFETY STANDARD FOR NUCLEAR POWER SOURCES IN OUTER SPACE (VIENNA, 20-22 FEBRUARY 2006)

## Session 3. PRESENTATIONS PERTINENT TO OBJECTIVE I.A.

## Presentation on "Design Safety Considerations for Space Radioisotope Power System (RPS). Launch, Normal Operations and Contingencies"

## Note by the Secretariat

1. In accordance with paragraph 16 of General Assembly resolution 60/99 of 8 December 2005, the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space will organize, jointly with the International Atomic Energy Agency, a technical workshop on the objectives, scope and general attributes of a potential technical safety standard for nuclear power sources in outer space, to be held in Vienna from 20 to 22 February 2006.

2. The presentation contained in the present conference room paper was prepared for the joint technical workshop in accordance with the indicative schedule of work for the workshop, as agreed by the Working Group on the Use of Nuclear Power Sources in Outer Space during the intersessional meeting held in Vienna from 13 to 15 June 2005 (A/AC.105/L.260).

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# Design Safety Considerations for Space Radioisotope Power System (RPS) Launch, Normal Operations, and Contingencies

February 2006

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## United States Approach to RPS Safety

- Design for safety
  - RPS design: Layered protection against credible accidents employing materials selected for abilities to withstand extremely high temperatures, impacts and other challenges
  - Mission planning: Enhanced safety through spacecraft design, launch system modifications, and selection of mission parameters
- Extensive safety testing, modeling, and analysis
  - Materials are tested for physical and chemical properties
  - Heat sources and generators are tested at the component, subsystem, and system levels for a wide variety of challenges
  - Results from tests are used to calibrate computer models used to verify performance and extend the safety envelope
- Risk analysis for each application
  - Performed on a mission-by-mission basis
  - Launch system, spacecraft configuration, and flight profile assessed
- Independent safety review for each mission

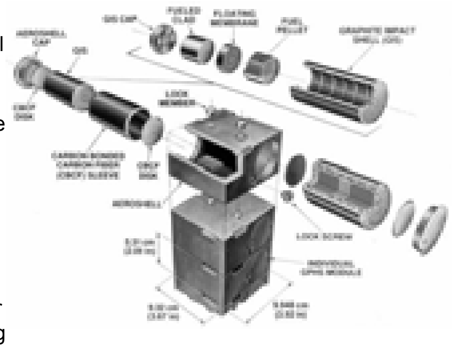


## Space RPS Safety Design Challenges

- The primary safety objective is containment of the radioisotope fuel to avoid radiological exposure of the public at large and the earth's biosphere
- The safety program must address all credible accident situations
  - Mechanical loading due to blast overpressure, dynamic pressure, fragment impact, or ground impact, particularly in the event of launch vehicle failure on or near the launch pad
  - High temperature environments due to propellant fires on the launch pad
  - Aerodynamic heating and stresses on reentry
  - Ground impact following reentry
- Minimization of the exposure hazard in the event of loss of containment (second layer of defense)

## RPS Design for Safety

- Components and safety functions
  - Ceramic plutonium-238 oxide fuel pellet for low-level alpha radiation, insolubility in water, long-life chemical stability, and low generation of small particles upon impact
  - Iridium cladding contains radioisotope fuel during normal operation and in high-temperature and high-load accident environments
  - 3-D carbon-carbon graphite impact shell protects fueled clad by absorbing impact energy
  - Carbon-bonded carbon fiber insulator prevents overheating of iridium during reentry
  - 3-D carbon-carbon aeroshell protects fueled clad during reentry and launch vehicle explosions



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## Mission Planning to Enhance Safety

- Safety is further enhanced through spacecraft design, launch system modifications, and selection of mission parameters that mitigate threats to fuel containment.
- Appropriate steps depend on the details of each mission.
- Examples include:
  - Incorporating destruct mechanisms on launch vehicle propellant tanks and stages to:
    - Disassemble launch vehicle hardware that could pose mechanical loading (i.e., crushing) threats to the spacecraft and it's space NPS
    - Disperse launch vehicle propellant that could pose fire threats to the space NPS
  - Selecting mission trajectories that reduce risk (for example, implementing flight paths biased away from the Earth when executing an Earth swingby)
  - Locating the RPS on the spacecraft to reduce fragment hazards in the event of a launch accident

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## Safety Testing and Analysis

- Extensive testing of materials, components and systems has continued over the 40+ year history of the U.S. space RPS development
- Simulated accident environments include:
  - Fire: direct exposure to liquid and solid propellant fires
  - Blast: pressure waves simulated with explosives
  - Shrapnel: aluminum and titanium bullets to simulate small fragments from launch vehicle failures
  - Large fragments: steel plates fired at simulated RTGs to simulate solid rocket booster casing fragments from launch vehicle failures
  - Reentry: exposure of aeroshell materials in arc-jet tunnel tests simulating reentry environments
  - Earth impact: high-speed impact of heat source modules and bare fuel clads on sand, water, soil, rock, and concrete
  - Water immersion: long-term exposure to sea water
- Test data used to validate analytical models of accident environments and hardware response to exposure to those environments



## Safety Design for Release Minimization and Localization

- Goal is to minimize and localize any releases in event of containment breach of iridium clad
- Properties of ceramic fuel form minimizes potential release
  - Extremely difficult to vaporize
  - Tends to break into chunks and large particles
  - Radiation hazard is posed by inhalation of small particles; fuel is designed to avoid such “respirable fines” generation
- Layered containment
  - Iridium clad tends to form small cracks due to impacts
  - Any fuel that may exit the clad must also traverse multiple layers of graphite to reach the Earth’s biosphere

## Summary

- The primary safety objective is containment of the radioisotope fuel.
- RPS must be designed to minimize exposure in the event of a variety of accident scenarios.
  - Fires and shrapnel due to launch vehicle explosions
  - Inadvertent reentry
  - Earth impact
- RPS design employs multiple layers of defense.
  - Ceramic Pu-238 fuel form
  - High ductility iridium clad
  - High-temperature 3-dimensional graphites
- Design is demonstrated by extensive analysis and testing.
  - Tests used to verify responses to accidents and validate analytical and numerical models
- Safety is further enhanced on a mission-by-mission basis through spacecraft design, launch vehicle modifications, and selection of mission parameters.

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