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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 2. BACKGROUND (CONTINUED)

## Presentation on "United States Perspective on Space Radioisotope Power System (RPS) Design and Safety Consideration"

## 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).

V.06-51232 (E)

# United States Perspectives on Space Radioisotope Power System (RPS) Design and Safety Considerations

February 2006

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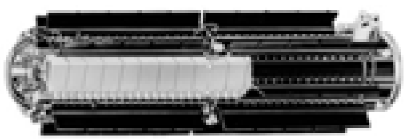
## Agenda

- Applications of space radioisotope power systems (RPS)
- United States space RPS history of success and safety
- United States approach to space RPS safety
- Designing for safety and performance
- Early history of United States considerations for RPS performance and safety
- Evolution of safety processes and designs for United States Space RPS
- Continuing Evolution of Space RPS Technology and Safety Design
- Current and Future Perspectives in United States Space RPS design



## Applications of Space Radioisotope Systems

- Provide reliable, long-lived electric power for spacecraft for missions where solar power or energy storage can not fulfill mission needs
  – RPS systems function in dark, cold, and high-radiation environments and on long-duration missions where non-nuclear power systems are not practical
  – Convert the heat from decay of radioisotopes to electricity
  – Radioisotope power systems (RPSs) typically provide up to several hundred watts of electrical power
  – All radioisotope systems flown to date use direct conversion of heat to electricity (Radioisotope Thermoelectric Generators or RTGs)
  – No RTG has ever failed in flight



**General-Purpose Heat Source Radioisotope Thermoelectric Generator (GPHS-RTG)**

***Cutaway view***

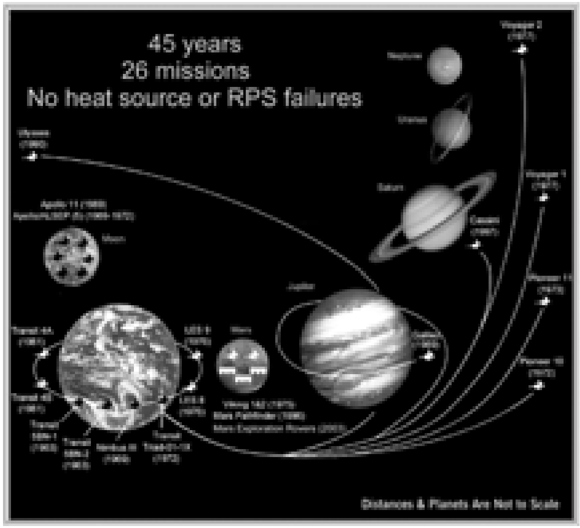
## Applications of Space Radioisotope Systems (continued)

- Provide heat for thermal management of spacecraft


  - Must maintain structures, electronics, and sensors in given temperature range
  - Radioisotope heaters provide long-lasting, steady (typically about 1 watt) heat
  - Allows spacecraft designers to avoid extremely low temperatures in deep space, or manage temperature swings between night and day (Moon, Mars, etc.)
  - Radioisotope Heater Units (RHUs) are small, completely reliable, and afford great flexibility in spacecraft design



## United States Space Radioisotope Systems: A History of Success and Safety



## 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



## Early History of United States Considerations for RPS Performance and Safety

- Fuel selection and safety features
  - Earliest RPS systems designed for atmospheric dispersal on reentry
    - Containment: Sealed capsule for containment in event of launch accidents
    - Fuel form: Plutonium-238 (in metal form) selected for useful half-life
    - Shielding: no need for heavy shielding (alpha emitter only)
    - Reentry: heat source designed to burn up completely and disperse fuel at high altitude, diluting the radioactive material far below levels of concern
  - Dispersal approach demonstrated with 1964 launch failure navigational satellite – RPS (SNAP-9A) disintegrated and fuel dispersed as designed
- Institutional features
  - United States Atomic Energy Commission (AEC) and National Aeronautics and Space Administration (NASA) cooperated in risk analysis, safety procedures, and launch preparation
  - These and other organizations prepared safety analyses prior to launch

## Evolution of Safety Processes and Designs for United States Space RPS

Significant changes in institutional and technological approaches to space RPS safety beginning in the mid-1960s

- Safety review processes and products formalized
  - Interagency Nuclear Safety Review Panel (INSRP) constituted for each RPS mission, chartered with reviewing safety analysis
- Concern over SNAP-9A dispersion and higher plutonium fuel loading for newer RPS designs led to change in reentry philosophy from dispersion to containment and recovery
  - Heat sources designed to survive reentry, with individual fuel capsules landing intact after impact on various surfaces
- Design changes further enhanced radioisotope heat source safety
  - Fuel made in ceramic oxide form ($PuO_2$) – designed to break up into chunks with little respirable material generated in any scenario
  - Vented fuel capsules allowing long-term power generation without buildup of internal helium pressure while providing fuel containment
- Containment demonstrated with 1968 launch failure and intact reentry of RPS from weather satellite and 1970 RPS return on Apollo 13 lunar lander



## Continuing Evolution of Space RPS Technology and Safety Design

- Mission requirements: longer lives, higher power levels, change from Earth-orbit applications to deep-space and planetary missions
- Fuel forms: all plutonium oxide since SNAP-19 in late 1960s, usually in ceramic pressed pellet form
- Fuel capsule: Evolution in materials and containment geometries
  - Development of high temperature iridium alloys supported higher operating temperatures for deep-space missions; later supporting safety design for high speed reentries
- Reentry protection: different graphite forms and aeroshells used
  - High-temperature, high-strength carbon composite used for two decades
  - General Purpose Heat Source (GPHS) with design improvements to enhance safety

## Current and Future Perspectives in United States Space RPS design

- Ongoing improvement in safety design
  - General Purpose Heat Source enhanced for very high-speed reentries (although Earth flyby assists rarely planned)
  - Investigation of new materials and graphite forms for enhancement of heat source performance and protection
  - Increased sophistication of modelling tools coupled with enormous increase in computing power can enhance safety analysis capabilities
- Ongoing investigation into higher-efficiency power conversion technologies
  - Reduces amount of radioisotope fuel necessary for a given electrical power level
- United States launch safety approval process continues to ensure a thorough review of safety analyses