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COMMITTEE ON THE PEACEFUL USES OF
OUTER SPACE
Scientific and Technical Subcommittee
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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 "Unique Design Considerations for Nuclear Power Sources (NPS) Applications in Outer Space"

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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Unique Design Considerations for Nuclear Power Source (NPS) Applications in Outer Space

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Space NPS Designs Relative to Terrestrial

- Low mass designs
- Environment
- Radiative heat rejection
- Autonomous control
- End of mission life
- Safety
- Planetary Protection

Note that Nuclear Power Systems include both reactor and radioisotope systems

Low Mass Designs

- Mass is a critical hardware design factor in all space missions
- Mass is not available to implement simplistic solutions to design problems
- Mass limitation can lead to other constraints
- Configuration mass to implement required radiation shielding and heat rejection radiator
  - Substantial issue for reactor systems
  - Much less significant for RPS systems

Launch and Space Environment

- Environment includes both conditions the power system must survive (operating or not) and conditions the power system must tolerate operationally
- Conditions that are primarily survival issues
  - Launch driven dynamic issues
    - Several g's linear acceleration
    - Launch vibration loads (~20 g's)
    - Launch vehicle failure scenarios
  - Landing loads are not usually a driving issue
- Conditions that are primarily operational issues
  - Operation is often in vacuum
  - Severe natural radiation on some missions
  - Micrometeoroid protection is required

Radiative Heat Rejection

- Heat rejection is primarily by radiation
- Heat rejection radiator typically dominates nuclear electric propulsion (NEP) spacecraft design
  - Area is large and must be protected from micrometeoroids and shielded from reactor radiation
  - Constraining area drives reactor to temperature technology limit
  - Radiator accommodation is typically the power level constraint
- RPS heat rejection well understood
  - Relatively small configurational consequences unless spacecraft encapsulates RPS
  - Encapsulation implementation worked for specific design

Autonomous Control Required

- Round trip light time typically makes real time monitored control impossible
  - Autonomous control issues for reactor and dynamic RPS
  - Not an issue for RTG
  - Manned missions cannot practically dedicate personnel time for adequate monitoring without autonomous control
- Reactor
  - Failures during operations threaten mission success and/or planetary protection, not personnel
  - Requires good implementation yet to be fully detailed, but no apparent show stoppers
  - Re-start after SCRAM is impractical for outer planet missions; SCRAM can be made recoverable in the inner solar system
- Dynamic RPS
  - Issues are reliability (not adequately demonstrated at this time) and fault protection (probably not a driver)

NPS End of Mission Life Considerations

- Dynamic RPS can be shut down, RTG cannot
  - Passive radiation decay in either case
  - Shutdown desirability is mission dependent
- Typical end of reactor mission is shutdown in place
  - Straightforward on the surface of a large body or in stable orbit
  - Issues if the mission orbit is not long term stable
- Unstable science orbits will usually impact the body being orbited if not maintained
  - Deliberate constrained location impact is an option
  - Impact can be a Planetary Protection issue, but not a hazard
- The satisfactory resolution of all spacecraft failure issues (which must be done) essentially encompasses NPS end of mission issues
  - Unplanned loss of control always presents more difficulty than planned activity
  - Environmental issues (e.g., micrometeoroid damage) must be resolved for a satisfactory mission

Safety Considerations

- Existing terrestrial standards apply to space NPS during ground processing
- After Earth departure safety considerations are generally limited to personnel or Earth environment (e.g., human missions and/or Earth flybys)
- Nuclear safety includes design of overall spacecraft, launch system, and mission during all project stages
  - All credible launch accident scenarios must be dealt with

Planetary Protection

- The term Planetary Protection refers to avoiding biological cross contamination and is not related to radiation or radioactive materials
- Planetary Protection requirements usually force actions to reduce bio-burden on spacecraft elements for missions having life detection or organic measurement requirements
  - NPS radiation does not generally result in sterilization adequate for planetary protection requirements
  - Biologically based residue is an issue for life detection
- NPS Planetary Protection issues can be related to the consequences of the activities to reduce bio-burden that complicate NPS design, manufacture, and test
  - Heat or other sterilization can affect allowable materials and processes
  - Maintaining the reduced bio-burden constrains handling options
- NPS waste heat can affect microbial survival in some planetary environments

Summary

- **Mass is a critical issue and a system driver**
- **Large range of Environments operating and non-operating (much more extreme than terrestrial systems)**
- **Systems must be long life; generally unattended and without hands on maintenance**
- **System design can benefit from terrestrial experience, but is far from a simple and direct derivative**