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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 "Space Reactor Safety From a US Perspective"

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.06-51231 (E)

Space Reactor Safety From a U.S. Perspective

February 2006

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Managed and Operated by Lockheed Martin for the U.S. Department of Energy

Agenda

1. **Introduction**
2. **Safety Considerations**
3. **Evolution of Safety Practices**
4. **Current Approach**
5. **Summary and Conclusions**

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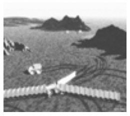
Types of Space Reactor Applications

- In-space Electrical Power
  - Deployed and operated in space (1965)



- Surface Electrical/Thermal Power
  - Robotic
  - Human

- Nuclear Electric Power and Propulsion
  - Very High Efficiency, Relatively Low Thrust

- Nuclear Thermal Propulsion/Power
  - Higher Thrust, High Efficiency

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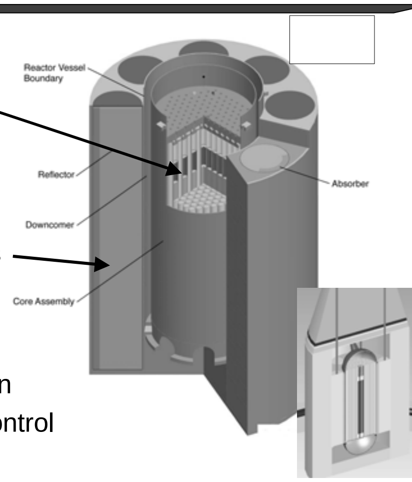
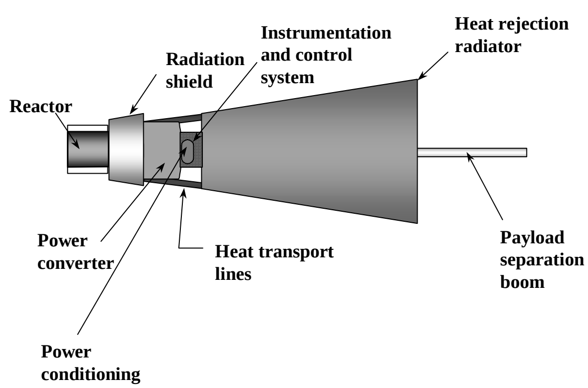
Example Space Power Reactor

- Small core
  - U^{235} fuel elements
  - Cooling channels
  - with or w/o moderator
- Reflector/Control
  - Reflector/poison drums
  - Other designs
- Fission power
  - Controlled chain reaction
  - Remote/Autonomous control



Example Space Reactor Power System



Space Reactors: Unique Safety Considerations and Approaches

- Considerations differ from Radioisotope Sources
  - "Radiologically cold" at launch
  - Focus is on preventing accidental criticality
- Considerations differ from Commercial Reactors
  - Do not operate in Earth's biosphere
  - Much lower power levels
  - Must be small and low mass
  - Threats: propellant fires, impact, etc.
  - Broad range of design environments

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Postulated Launch and Deployment Accident Scenarios

- **Propellant Explosions and Fires**
- **Launch Failures, Impact**

Safety Considerations

- **Fresh Fuel Dispersal**
  - ~Fresh fuel, low activity
  - Low hazard
- **Inadvertent Criticality**

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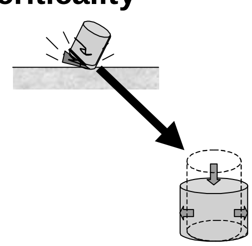
Postulated Fire, Explosion, Impact Criticality Accidents

Potential accident scenarios that need to be evaluated for inadvertent criticality

- Loss of shutdown device
- Fuel slumping
- Fuel ejection
- Core compaction
- Core reshaping



Reconfiguration

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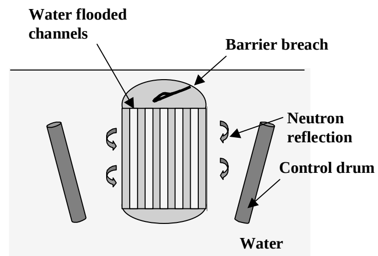
Postulated Impact/Immersion Criticality Accident Scenarios

- **Flooding Scenarios**
  - Submersion
  - Impact, barrier failure
  - Flooding of core voids
  - Increased moderation
- **Reflection Scenarios**
  - Impact
  - Lose reflector/shutdown
  - Submersion in water or sand
  - Enhanced reflection



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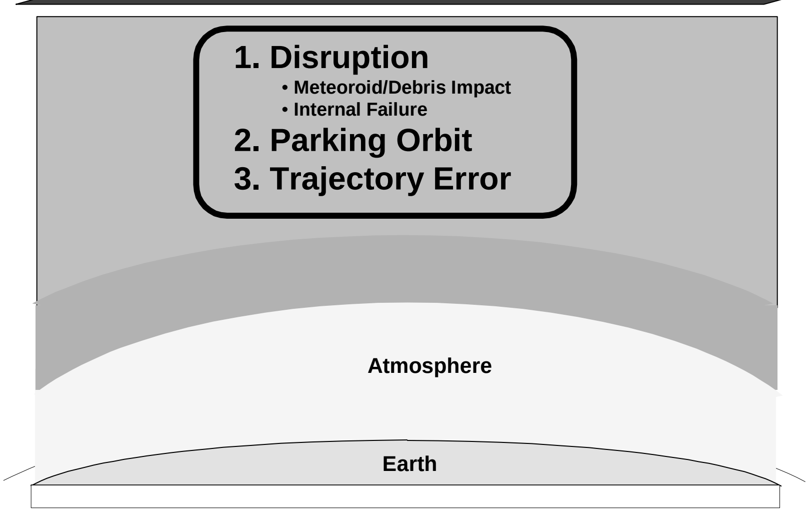
Safety Considerations for Operation and Retirement Phases



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1st Space Reactor Safety Approach

- 1965 SNAP-10A launched
  - First/Only U.S. reactor space-deployed
- For reflection criticality accident concluded:
  - Prompt disassembly likely
  - Subcriticality not required, no safety rods
- Dispersed reentry design

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Other Pre-1980 Space Reactor Safety

- NERVA (nuclear rocket)
  - Developed and tested, never deployed
  - Flooded-subcriticality design (safety wires)
- Other space reactor programs:
  - Never fully developed
  - Generally favored flooded subcriticality

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SP-100 Space Reactor Safety

- SP-100 ~1980s, 100 kWe
  - Major development, broad mission scope
  - Flooded subcriticality, intact reentry
  - Borrowed terrestrial safety concepts
- Designed for broad range of missions
  - Terrestrial safety approaches had limited applicability
  - Optimization possible if focused on a particular application

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Important Lessons Learned

- **Terrestrial ? Space Reactor Safety**
  - Earth/Space conditions very different
  - Focus is primarily on launch safety for space reactors
  - Issues and approaches differ
- **Distinguish Space Nuclear Safety from:**
  - Mission Assurance
  - Safeguards
  - Space Environment Protection
  - Debris Mitigation

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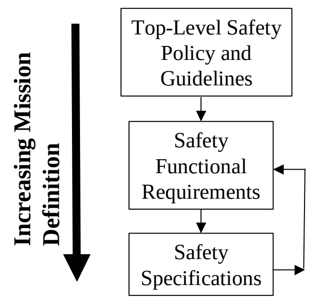
Establish Safety Guidelines at Appropriate Levels

- **Mission affects safety requirements/approach**
- **Premature prescriptive safety: costly, counterproductive**



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Safety Approaches for More Recent Space Reactor Efforts

- **Reactors launched**
  - Shutdown
  - Radiologically cold
- **Prevent sustained criticality for credible accidents**
  - Use inherent safety features
  - Use safety devices
- **Assure stable configuration prior to start-up**
- **Intact reentry approach**
  - Reentry shield

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Summary and Conclusions

- Space safety approaches differ from terrestrial
- Pre-launch/Launch focus is on preventing inadvertent criticality
- Operation/Retirement focus is preventing reentry
- Specific requirements depend on the mission application and basic reactor design concept
- High level safety guidance should emphasize functional safety

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