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Discussion about Safety Issues of Space Nuclear Reactor Power System Ground Test

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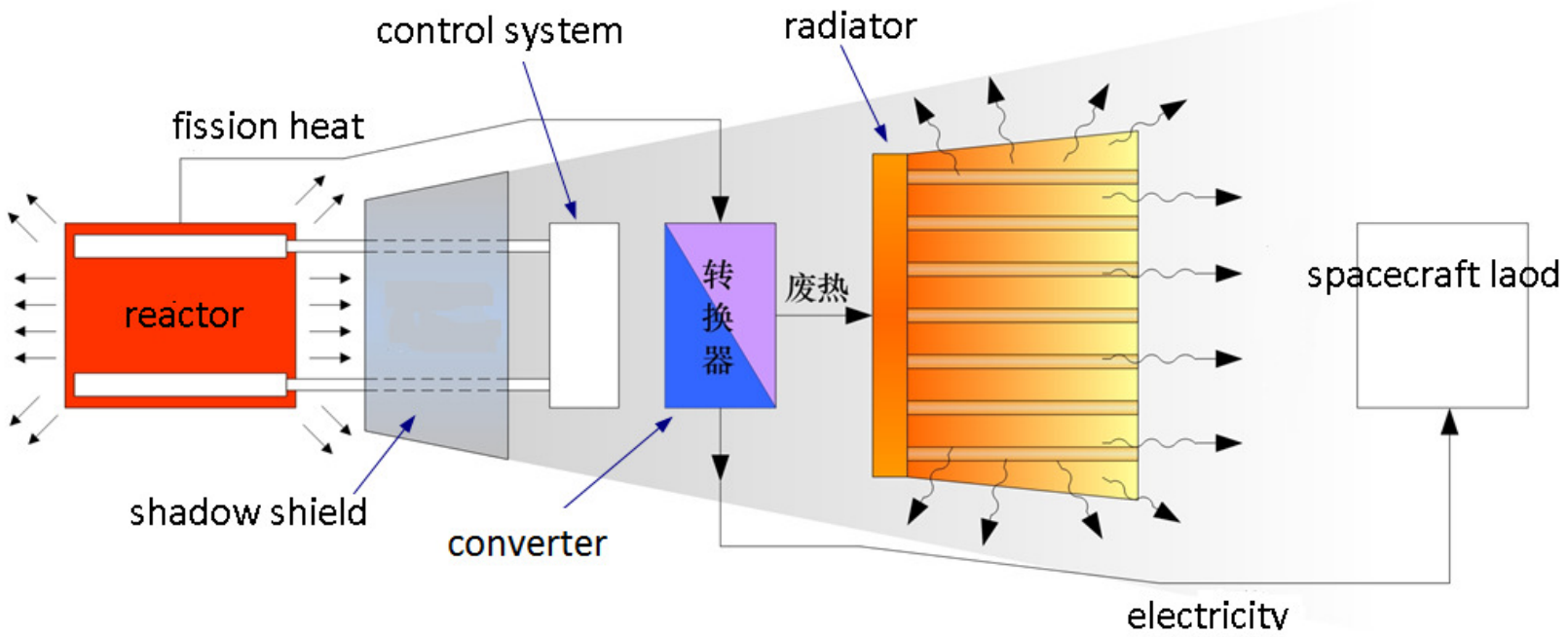
Introduction

- What is space nuclear reactor power system (SNRPS)?
  - It converts fission heat into electricity using for spacecraft.



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Introduction

- What is the use of SNRPS?
  - For deep space exploration, especially the mission with high power requirement.
- What is the different between SNRPS and ground reactor?
  - SNRPS works in space, and has many restrictions on volume and weight.
  - Redundancy and diversity could not be applied in many subsystems design.

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Introduction

- Ground test for electricity production should be taken in the development of SNRPS.
- In the stage of ground test, SNRPS is similar to research reactors. So it should follow the regulations and standards which establish requirements for research reactors.
- Because of the difference between SNRPS and research reactor, the prototype of SNRPS for ground test has many characteristics, and the safety issues involved deserve discussion.

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Regulations and standards

- National law.
- Administrative laws
- Department rules
- Nuclear safety guides
- Technical documents
- They cover all the contents of IAEA safety standards for research reactors, and could be used for SNRPS ground test.

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Reactivity

- Solid moderator is a better option for SNRPS in which thermal reactor is used as heat source.
- But the moderator temperature coefficient of reactivity will be positive. One example is TOPAZ-Ⅱ.

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Reactivity

- Impact of positive temperature coefficient of reactivity:
  - Not good for steady operation;
  - Small excess reactivity, good for prevent the critical safety accident happening which is caused by carrier rocket failure and falling to the earth in launching stage.
  - Every reactivity control system could be as independent shutdown system.

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Reactivity

- Inherent safety characteristics:
  - It is required in regulations and standards.
  - One example is prompt negative coefficient of reactivity.
  - For SNRPS, solid uranium is used for fuel, so fuel temperature coefficient of reactivity could be negative and prompt.

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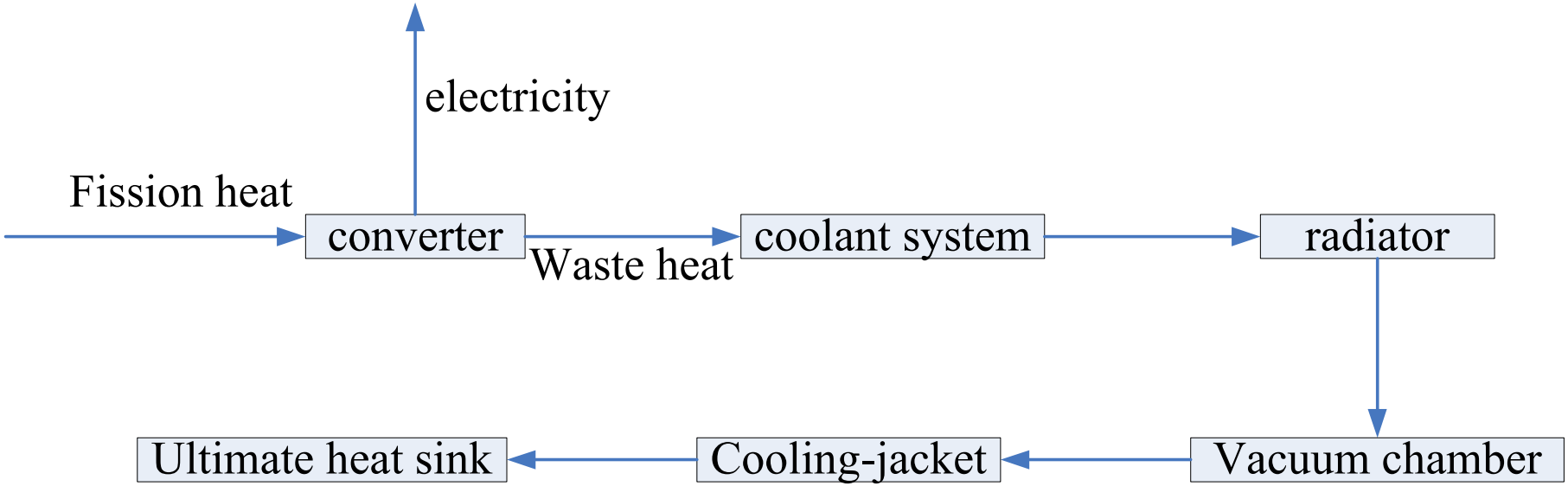
Reactivity control system

- In the stage of ground test, two reactivity control systems is used for SNRPS:
  - Self control system
  - Test bed control system with higher authority
- In the initial stage of ground test, SNRPS's operation is controlled by test bed control system. When operational progress is fully mastered, the reactor could operate under self reactivity control system to simulate the real work condition. At this time, test bed control system is in standby state.
- Different set points could be established for self protection system and test bed protection system.

Core cooling

- Heat transfer



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Core cooling

- SNRPS does not have the ability of natural circulation, and its heat capacity is very small.
- But in the event of a loss of coolant accident, reactor core could radiate residual heat to prevent core temperature from exceeding safety limits, because of its small thermal power.
- Helium could be inject into vacuum chamber to increase heat transfer from core to vacuum chamber.
- When cooling-jacket loses coolant or flow, vacuum chamber could be sprayed with water to remove heat.

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Contain radioactive material

- For research reactors, radioactive material is contained by fuel matrix, fuel cladding, the primary heat transport system, the pool and reactor building.
- For TOPAZ-Ⅱ, fuel cladding and the primary heat transport system can not contain radioactive material.
- Fission gas is collected by sealed container, and then discharged into ventilation system with filtration.
- If sealed container breaks, fission gas will enter vacuum chamber, then discharged into ventilation system with filtration by vacuum pump.

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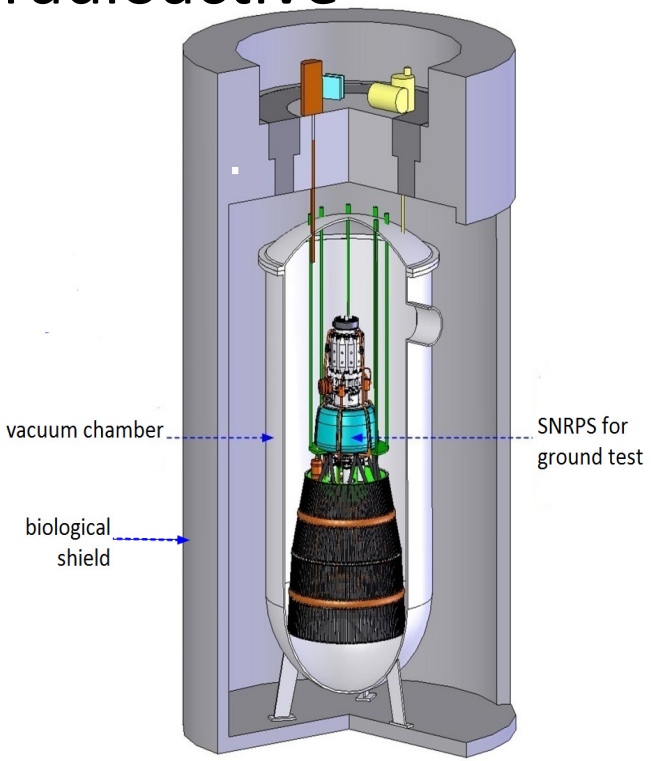
Contain radioactive material

- Vacuum chamber and biological shield could confine radioactive material in the accident of fuel melt.
- Building in which vacuum chamber is put should be subject to special design requirements, and it is the last barrier for the confinement of radioactive material.



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Conclusion

- In the stage of SNRPS ground test, requirements in current regulations and standards could be met by adding special systems.
- Dedicated regulations and standards should be established for SNRPS.
- Research and cooperation should be strengthened in development of SNRPS to improve the level of safety technologies.

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Thank you for your attention!