NASA SBIR 2005 Phase I Solicitation

X10.04  Heat Rejection Technologies for Nuclear Systems

Lead Center: GRC

Participating Center(s): GSFC, JPL, MSFC

NASA is interested in the development of advanced heat rejection subsystems for use with high-power, fission-based power and propulsion systems for a variety of future robotic and manned exploration missions to the Moon, Mars, and beyond. Anticipated electric power levels for these high-power, space nuclear systems could range from 30 to 100s of kilowatts for the nearer-term and possibly up to multi-megawatts (2-20 MWe) for the far-term. Potential applications include in-space transfer vehicles and planetary orbiters, and surface bases with global site capability on the lunar and Mars surface. The heat rejection sub-systems for any of the possible high power space nuclear power plant choices would need to be matched with the thermodynamic cycles of the power plants in a manner that will maximize space nuclear power system performance while keeping heat rejection subsystem and overall power system specific mass (kg/kW) to a minimum. The levels of heat rejection could be from about 100 kilowatts to many megawatts, and the task could be even more challenging by the long life requirements imposed by deep space missions, the extreme radiation environments possibly encountered, and the unique challenges imposed by surface missions including the effect of an atmosphere, elevated sink temperature, and particle contamination. The radiator operating temperature range can vary greatly depending on the mission, but temperatures as low as 400K and in excess of 1000K are possible.

Typical heat rejection systems usually include a) a heat transport loop carrying heat to radiator surfaces for rejection to space, and b) a space radiator, which accomplishes the final heat rejection to space by thermal radiation. If the cycle working fluid is different from the radiator heat transport fluid, a "heat sink" heat exchanger and a fluid-circulating pump also need to be included in the design.

Proposals are sought in the following critical technologies areas:

- Low areal density heat rejection radiators (2);
- Innovative heat transfer approaches between heat transport loop and radiating surfaces;
- Development of light weight, radiation tolerant, thermally stable, high-performance components and pump loop systems including heat pipes and pumps in the low to intermediate temperature ranges (300K to
500K), intermediate temperature ranges (450K to 650K), and intermediate to high temperature ranges (700K to 1000K and higher);

- Pumped loops that take advantage of the abundance of waste heat and transport some of it to the spacecraft and payload components for thermal management. Waste heat source to spacecraft radiator distances will likely be too large for passive technologies, and pumped loops may offer a possible solution. Since rejection of megawatts of waste heat could require large radiating surfaces, loop heat pipes may provide a lightweight solution to distributing this heat over long distances. Specific areas of interest for this area include:
  - Long term material/working fluid compatibility, lightweight material integration, and working fluid performance for the various temperature ranges; and
  - High temperature, long-life pump technology, single- and two-phase systems, and thermal bus concepts involving multi-evaporators and condensers.

- High temperature, lightweight heat rejection system materials. Such materials may include those to enable lightweight radiators and heat pipes. Work in this area should address harsh radiation environments, launch/landing loads, and long life issues;
- Durable low-absorptivity/high-emissivity and variable emissivity coatings for radiating surfaces;
- Novel and efficient deployment systems/mechanisms for radiators in zero gravity and/or non-zero gravity fields to minimize mass, complexity, and stowed area/volume;
- Systems and technologies to mitigate adverse effects of planetary surface operating environments, such as cosmic and fission process induced radiation, dust accumulation, wind loading, planetary atmospheric effects due to CO₂, and variable sink temperatures;
- Design considerations for heat rejection subsystems should include long service life (>10 years) and autonomous operation;
- Development of advanced, high temperature heat pump technologies based upon conventional vapor compression cycles, absorption/adsorption cycles, and advanced thermoelectric and/or thermo-acoustic technologies;
- Advanced eutectic working fluids capable of extended duration use that would mitigate design issues related to the freezing and subsequent reuse of thermal management coolants; and
- Alternate cooling technologies for the rejection of waste heat from large capacity planetary or surface nuclear power systems. Such systems may include, but are not limited to, deployable cooling towers and/or optimized radiators.

In addition to reducing overall system mass, volume, radiator area, and cost, increased safety and reliability are of prime importance. Technologies are desired that readily scale in heat rejection capability for various power plant outputs, and thus can be used in a range of applications.