All spacecraft and extraterrestrial bases require thermal management systems. The long duration lunar bases that are foreseen in 15 years will present several challenges to the design and operation of active thermal control systems. Even though system design may be easier for the reduced gravity of the Moon than it is for the microgravity case of a spacecraft, the large variations in thermal environment and the risk of contamination by lunar dust will complicate system design. Innovative thermal systems and components are needed for this next phase of human space exploration.

**Subtopics**

**X11.01 Thermal Control for Lunar Surface Systems**

**Lead Center:** JSC  
**Participating Center(s):** GRC, GSFC, JPL

The lunar environment presents several challenges to the design and operation of active thermal control systems. During the Apollo program, landings were located and timed to occur at lunar twilight, resulting in a benign thermal environment. The long duration lunar bases that are foreseen in 15 years will see large variations in their thermal environment during the Moon's day/night cycle. Long stays remote from low-Earth orbit will require lightweight, but robust and reliable systems.

Innovative thermal management components and systems are needed to accomplish the rejection of heat from lunar bases. Advances are sought in the general areas of radiators, thermal control loops and equipment, heat pumps, and thermal storage devices.

For radiators on the Moon, lightweight deployable radiators are required that will operate at temperatures between 150 and 300K. Shading devices and strategies would allow them to reject more heat in the hot lunar environment. In addition, variable emissivity coatings would prevent freezing during the long, cold, lunar night. Also, the dusty environment of an active lunar base will require dust mitigation and removal techniques to maintain radiator performance over the long term.
Heat pumps (especially high lift) may be required for heat rejection in the lunar environment.

The lunar base active thermal control system will include high efficiency, long life mechanical pumps. Lightweight, high-performance thermal switches plus thermal energy storage and rejection devices could be used to accommodate the extremes of the available heat rejection. Part of the thermal control system in the lunar base is likely to be a condensing heat exchanger, which should be designed to preclude microbial growth.

Thermal management of the lunar habitat, landers, and rovers may require mechanically pumped two-phase fluid loops. Innovative design of the loops and components is needed.

A scaling methodology is needed to allow long term 1-g testing of two-phase systems (including pumped two-phase loops, heat pumps, and condensing heat exchangers) representative of the 1/6th Earth-normal gravity of the Moon.

Lightweight, low volume, robust Extravehicular Activity (EVA) systems are needed that maximize human productivity and improve the capability to perform useful work tasks on the lunar surface. Low-venting or non-venting regenerable support subsystem(s) are needed for crewmember cooling, heat rejection, and removal of expired water vapor. Lightweight and freezable radiators will be needed for thermal control. Innovative direct crewmember thermal control garments are sought, i.e., variable conductivity flexible suit layups that can function as a heat sink for high metabolic loads and as an insulator during period of low physical activity.