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Space Exploration Applications for Development of High Capacity Reverse Turbo-Brayton Cycle Cryocoolers

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Long term storage of cryogens is necessary to enable NASAs long duration crewed missions to both the lunar and Martian surfaces. Such missions require in-space transport systems such as Nuclear Thermal Propulsion (NTP), and descent/ascent vehicles for transportation to and from the lunar and Martian surfaces. NTP systems and Lunar/Martian landers utilize cryogenic fluids to minimize architectural volume and mass. To further enhance the capability of these cryogenic systems, the Agency is putting emphasis on reusability, which requires the NTP and ascent/descent elements be replenished on-orbit via tankers or propellant depots, or on the lunar or Martian surface using liquefied in-situ produced propellants. NTP is one of the leading propulsion option for human Mars missions and requires liquid hydrogen to be stored on-orbit for over four years. For such a long duration mission, near "Zero Boil-Off" (ZBO) must be achieved which requires an optimized suite of passive Cryogenic Fluid Management technologies and active cooling (cryocoolers). Tens of Watts of 20K cooling is required to achieve ZBO conditions for NTP, however two-stage cooling using both 20K and 90K systems can lead to a significant reduction in both active cooling mass and power. The use of in-situ resources for lunar and Martian missions will require 150 Watts of 90K cooling for oxygen liquefaction and 300 Watts of 20K cooling for hydrogen liquefaction (lunar only). Descent/Ascent vehicles, propellant depots, and tankers will also require the use of cryocoolers to achieve ZBO conditions. To support these programs, NASA is developing high capacity 20K and 90K reverse turbo-Brayton cycle cryocoolers which offer a scalable, high efficiency, low vibration solution.