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Efficiency Improvements for Turbo-Brayton Cryocoolers for Space

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The thermodynamic performance of turbo-Brayton cryocoolers is predicted to first order by the efficiency of the compression and expansion processes, and the thermal effectiveness of the recuperation between the high and low pressure streams. Other performance factors such as recovery of expansion work (a benefit); pressure losses in tubing, fittings and components; thermal parasitics from the environment; real-gas effects; and thermal performance of heat rejection and load interface heat exchangers can have negligible impact on cryocooler performance through proper design. The key then for optimization of turbo-Brayton cryocooler performance is to optimize the performance of the compressor, turbine and recuperator. Recuperator optimization involves maximizing the heat transfer per unit volume while maintaining low axial conduction and ability to withstand launch loads. Optimization of turbines and compressors is similar and involves optimization of the aerodynamic design of the rotating and stationary flow elements while minimizing overhead losses associated with viscous drag and electromagnetic losses and not compromising reliability and lifetime. This paper presents the advances in analysis, design and fabrication techniques for the turbomachines, in particular, that have led to milestone advances in turbo-Brayton cryocooler performance.