Space Micro Pulse Tube Cooler

T. Nguyen, M. Petach, M. Michaelian, J. Raab, E. Tward

Northrop Grumman Aerospace Systems
Redondo Beach, CA, 90278

ABSTRACT

The Northrop Grumman space micro pulse tube cooler (micro) is a split configuration cooler incorporating a coaxial cold head connected via a transfer line to a vibrationally balanced back to back linear compressor. The micro compressor is scaled from the flight proven high efficiency cooler (HEC) compressor and contains non-wearing pistons suspended on flexure bearings. Designed for > 10 year operation with no performance change, the 800 gram mechanical cooler can cool sensors and optics to temperatures <50K while rejecting heat to radiators over a wide range of reject temperatures. The very small, low vibration, high frequency cooler is designed to be readily integrated into space payloads. The coaxial cold head can also be integrated with custom focal planes into an integrated detector cooler assembly (IDCA) similar to those used with the shorter lived tactical coolers. This paper reports on the performance of this cooler

INTRODUCTION

The engineering model space micro pulse tube cooler (micro) that was tested is shown in Figure 1A without its integrated inertance line and reservoir tank. As shown in Figure 1B it is a split configuration cooler incorporating a coaxial pulse tube cold head connected via a transfer line to a vibrationally balanced back to back linear compressor. A description of the design and performance of the earlier prototype versions of the micro was reported previously[1,2]. The micro compressor is scaled from the flight proven high efficiency cooler (HEC) compressor and contains non-wearing pistons suspended on flexure bearings. The HEC compressor has been scaled both to larger and in this case to smaller sizes over a 2 order of magnitude capacity range[3,4]. As shown in Figure 1 the flight micro cooler has been implemented with an all welded compressor and in the flight configuration shown has an estimated mass of 900g. The cold head is designed to interface with infrared focal planes either through a thermal strap as is typical of space cryocoolers or into an integrated detector cooler assembly (IDCA) as is typical of tactical cryocoolers. The integrated reservoir tank/inertance line assembly shown in Figure 1A is designed to be integrated with the cold head or alternatively to be located elsewhere if required by instrument packaging constraints. The transfer line can also be lengthened or re-oriented as required by payload packaging constraints. The chief hardware difference between the em cooler

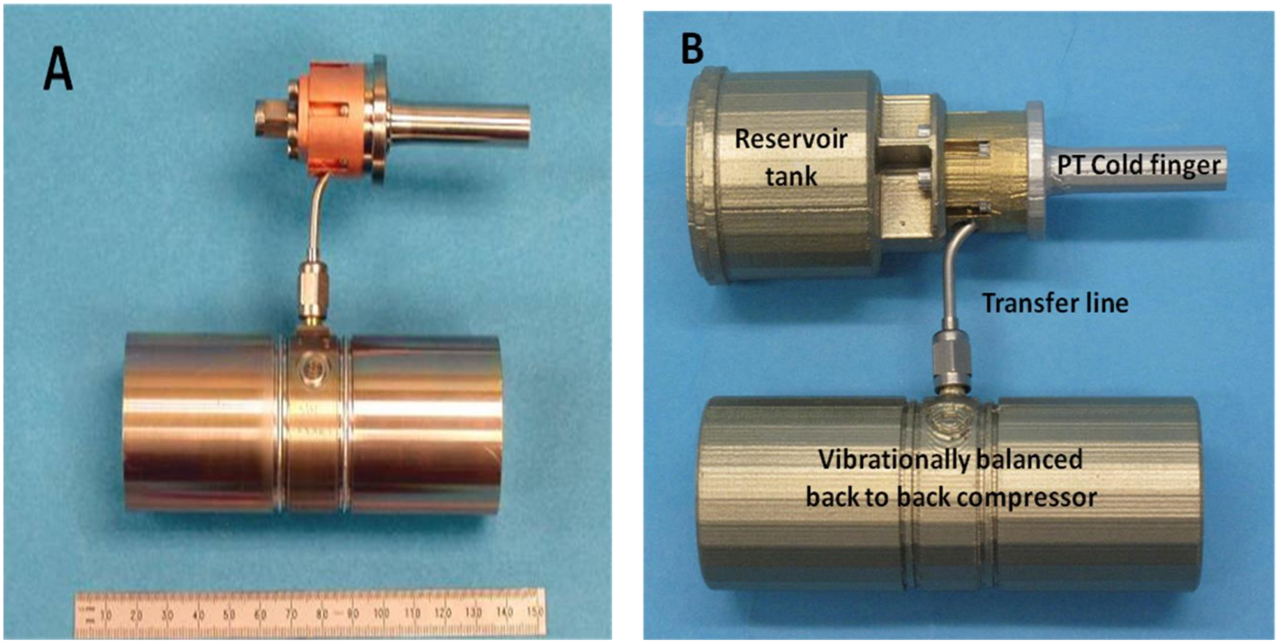

Figure 1. Flight design PT microcooler and its flight configuration with attached reservoir tank

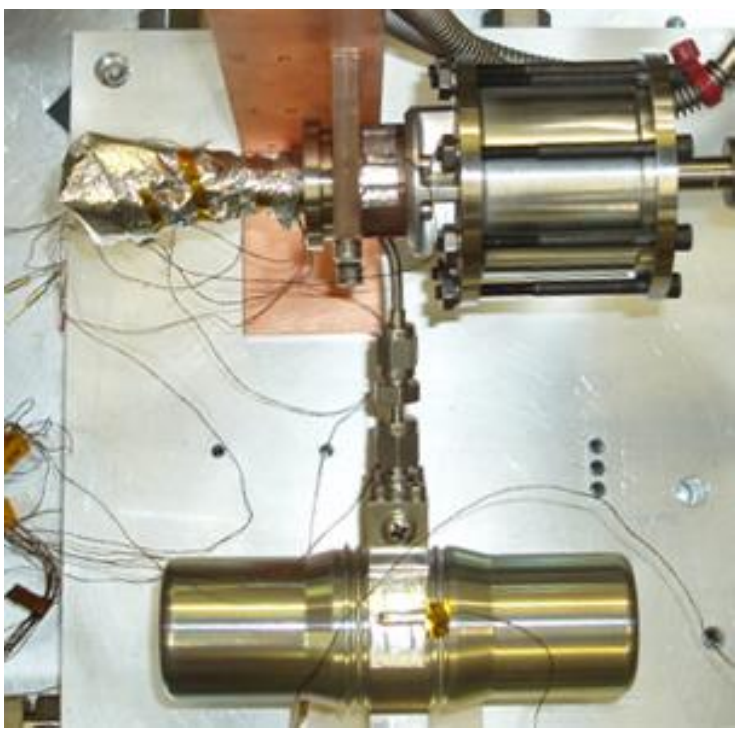

Figure 2. Micro cooler test configuration

that was tested in this report and that previously reported is the flight design cold head. The cylindrical flight compressor is 43 mm in diameter and 120 mm long. The coaxial pulse tube cold head assembly that is connected to the compressor in a split configuration including the cold head, the tuning network and the reservoir are packaged in a cylindrical envelope of 5 cm in diameter by 12.7 cm long.

This paper presents the characterization test data for the microcooler over a wide range of input powers and heat rejection temperatures.

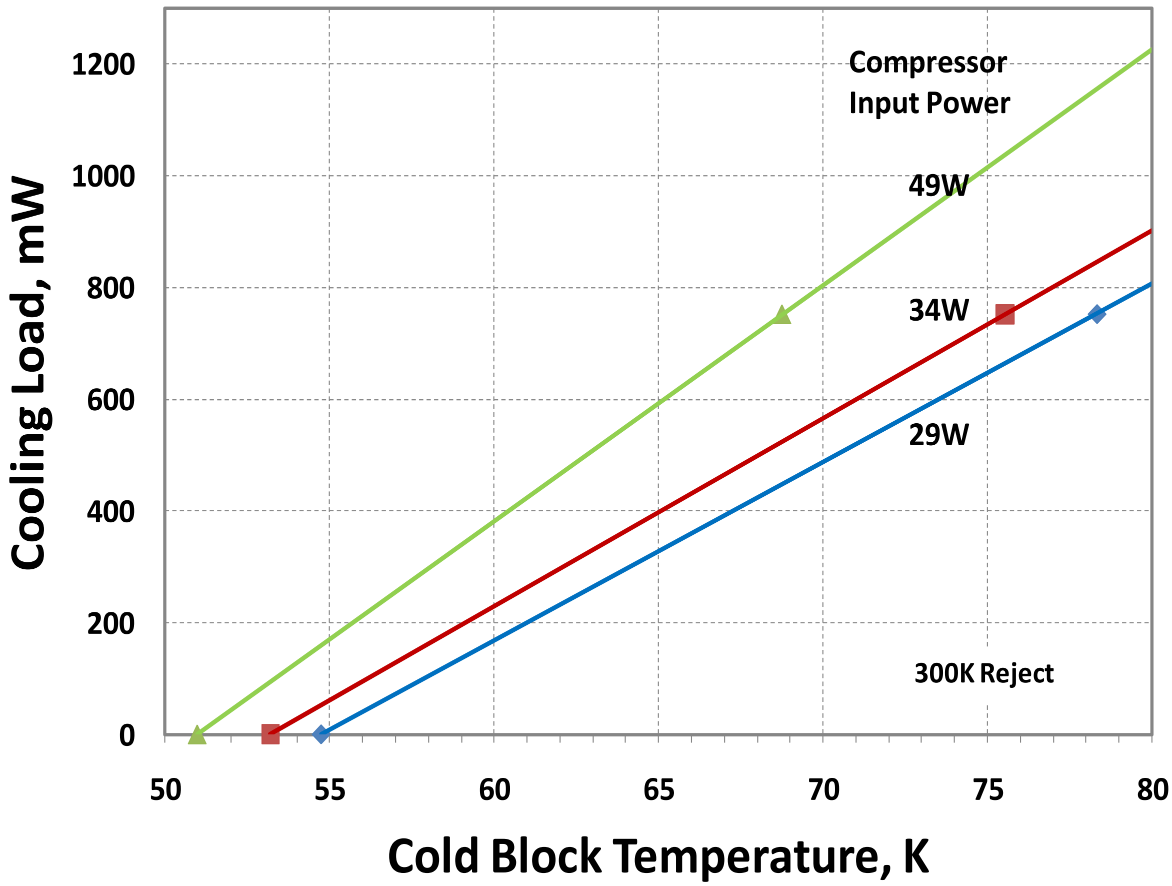

Figure 3. Microcooler load lines at 300K reject temperature

CRYOCOOLER TESTS

Figure 2 is a photo of the microcooler in its test configuration. The tested cooler is identical to the flight configuration shown in Figure 1B except that the reservoir tank end cap is sealed with a bolted flange rather than being welded. The tests were conducted in a thermal vacuum chamber with varying input powers and reject temperatures. Figure 3 shows some measured load lines of the cooler at different input powers. At 300K reject temperature the microcooler has a cooling capacity >1.2 W at 80K. Measurements were taken over a range of input powers shown by the data points of Figure 4. Figure 4 also shows the detailed performance map including lines of constant power measured between 10W and 49W and interpolated lines of constant cooling temperature overlaid over lines of constant specific power (input power/cooling power). The microcooler cooling capacity at 150K ranges from 1W to 4.5W as the compressor input power changes from 10W to 49W. The effect of the heat rejection temperature on the cooler performance is shown in Figure 5. Comparing the isotherms to the specific power lines demonstrates that at this operating frequency the cooler is tuned so that the cooler efficiency is higher at a lower reject temperature as expected. The test data also show that at this frequency the cooling capacity at temperatures of 85K and below is reduced at the higher reject temperature even at the full input power level.

The exported vibration signature of the micro cooler without active vibration control has also been characterized with the cooler being driven by both the tactical Sensitron electronics with its simple PWM output amplifier and using laboratory electronics containing an output linear drive amplifier[5]. The exported vibration along the three axes for the first 5 harmonics of the 95Hz fundamental frequency to 500Hz are shown in Figure 6 as a function of compressor input power for the linear drive amplifier case. Note that at all powers the exported vibration is <80mN for all harmonics in the compressor drive direction.

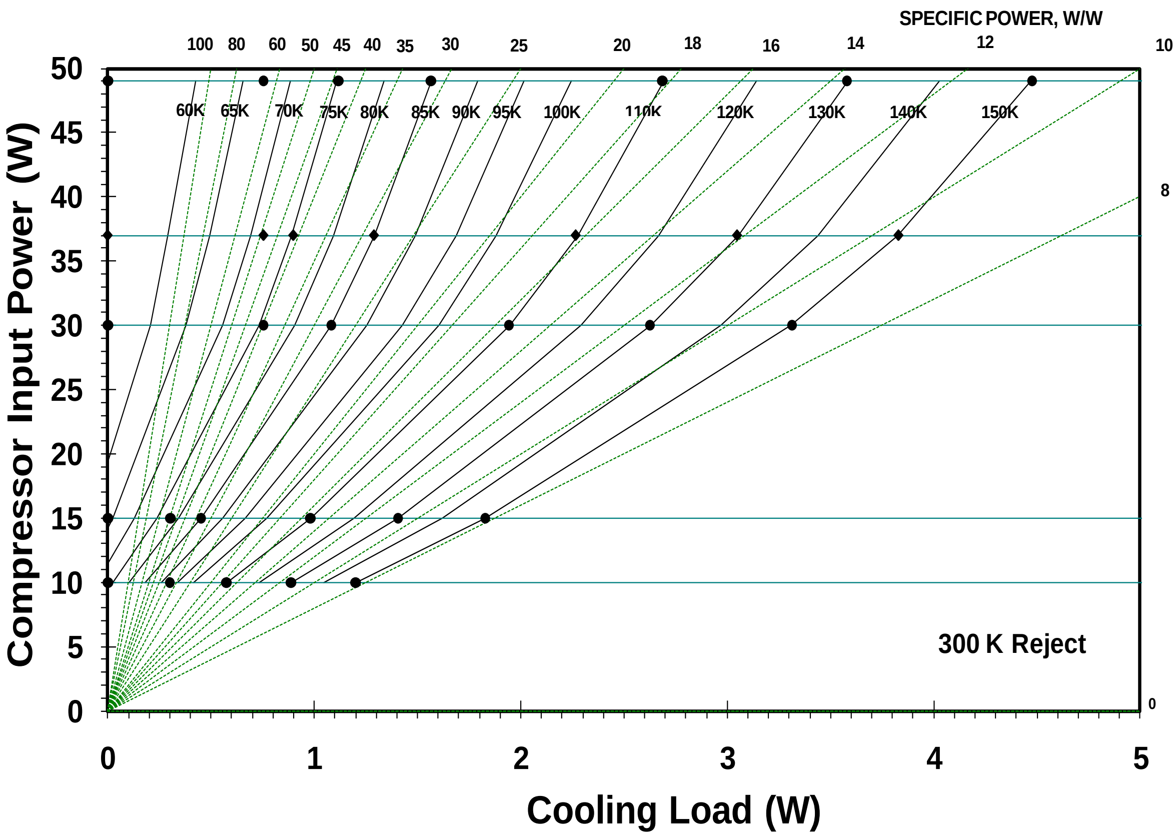

Figure 4. Microcooler performance map at 300K reject

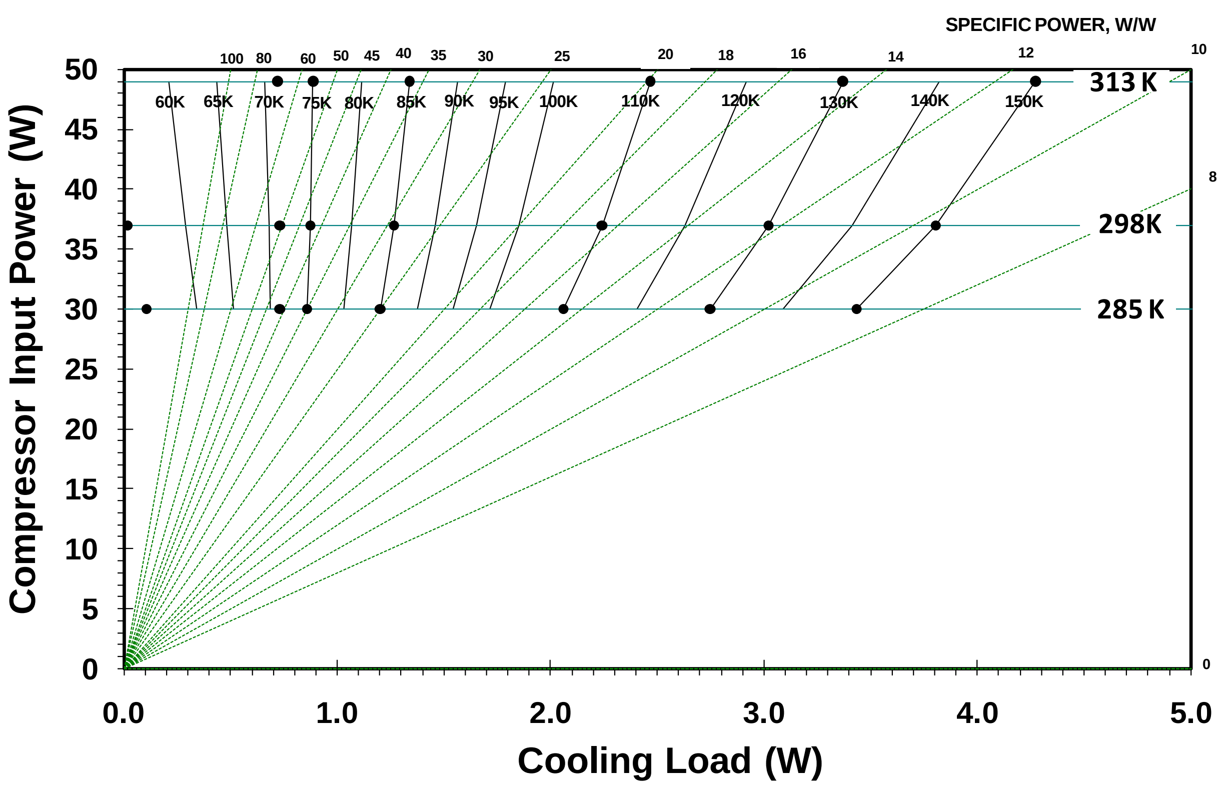

Figure 5. Microcooler performance map as function of reject temperature

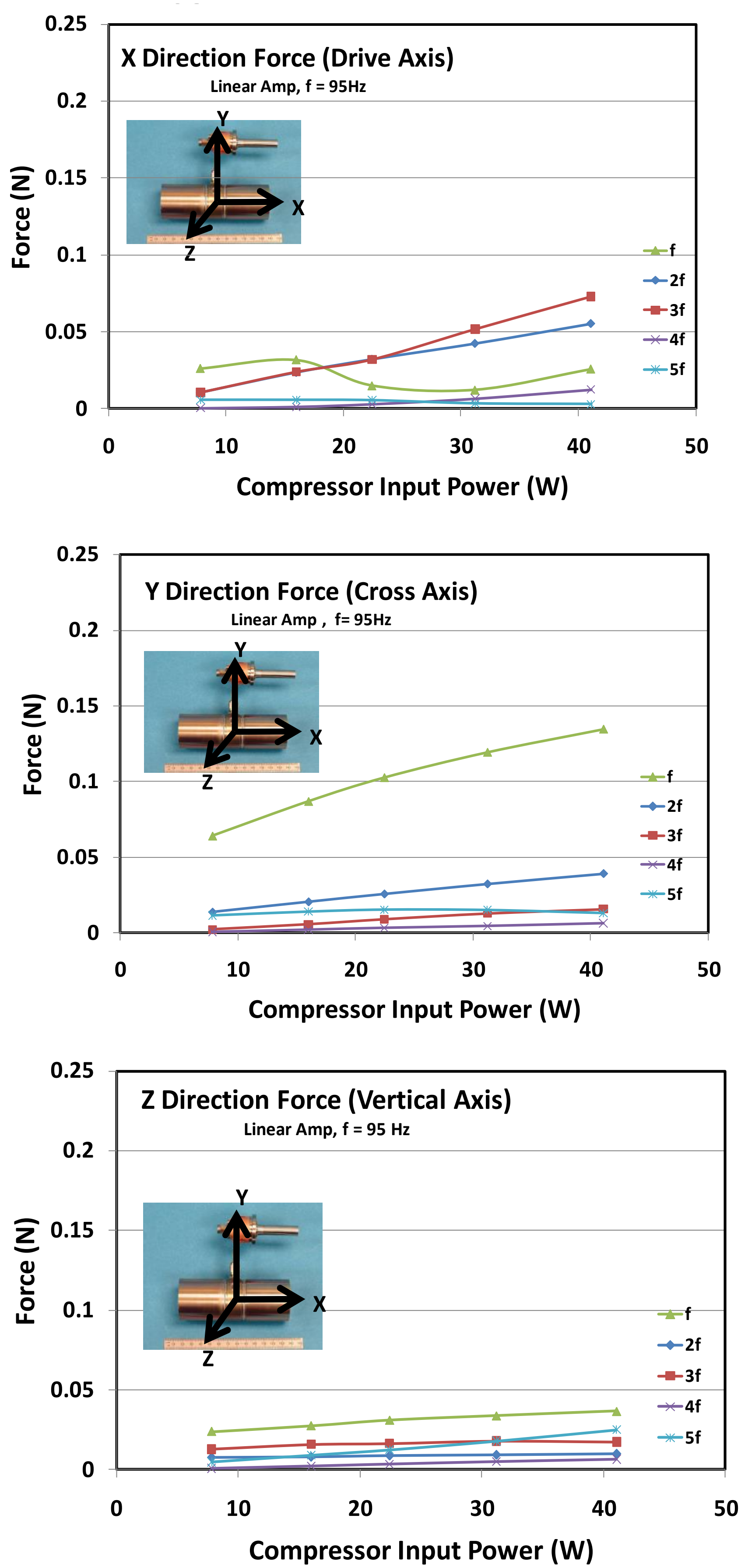

Figure 6. Microcooler exported vibration in 3 axes without active vibration control

CONCLUSION

The microcooler has been characterized for its thermal performance and exported vibration Its high cooling capacity in its small envelope with its low mass and very long life makes it attractive as a focal plane, filters or cold optics cooler and as a replacement for cold radiators.

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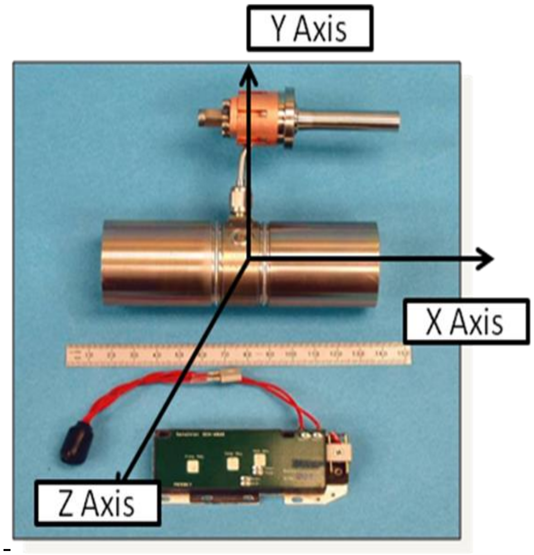
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