

# Development of Low Magnetic Field ADR for Transition Edge Sensors

**T. Nast, D. Martinez-Galarce, S. Deiker, J. R. Olson, E. Roth and J. Mix**

Lockheed Martin Advanced Technology Center Palo Alto, CA USA

## ABSTRACT

Trends in remote sensing space-based photon detectors are to operate at temperatures  $< 100$  mK. One of the leading techniques for achieving these temperatures is with the Adiabatic Demagnetization Refrigerator (ADR). We are developing an ADR system leveraging on earlier work done by the University of Wisconsin. Our design is compatible with the next generation microcalorimeter sensors (i.e. transition edge sensors operating at  $< 100$  mK) which require very low magnetic fields. The system is compatible with sounding rocket flight loads with a liquid helium guard tank. There was a focused effort to reduce the magnetic field to allowable values ( $< 50$  mGauss at full magnet current of 8.5 A) and several shielding approaches were considered before the final selection. In addition, extensions of this technology utilizing a Lockheed Martin 4-5 K pulse tube cryocooler as the guard for long life missions is under study.

This paper will present data on the operation of the system and results of magnetic field measurements and attenuation from the superconducting magnet.

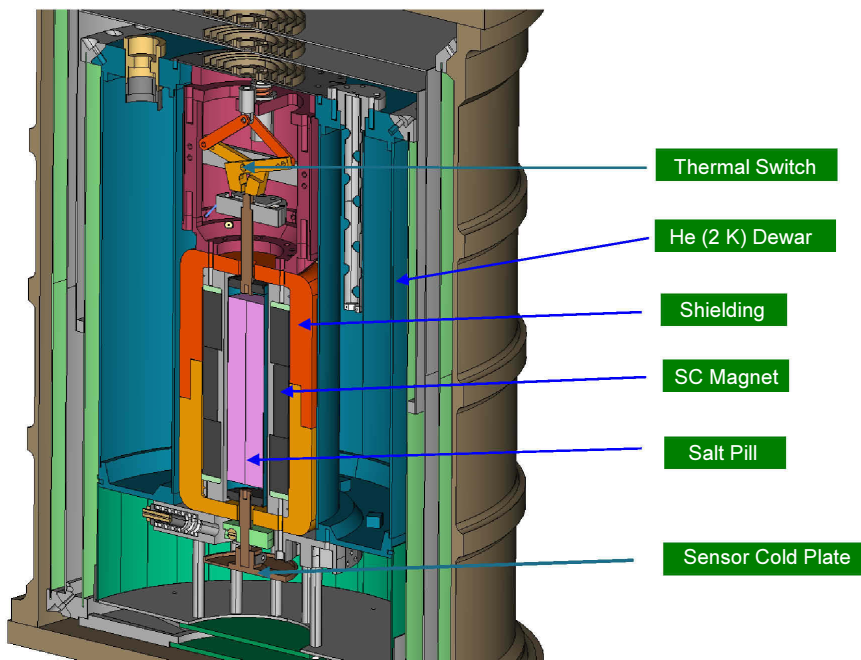
## INTRODUCTION

The Lockheed Martin Advanced Technology Center (LMATC) has been developing ADR technology for initial use on rocket borne missions with long term goals of operating on longer life satellite missions. We have leveraged from work done at University of Wisconsin which has successfully flown rocket mission.<sup>1</sup> Substantial efforts were devoted to reducing the magnetic field at the sensor location for compatibility with some of the newer sensors, such as the transition edge sensors (TES). This effort is a collaborative effort between LM Thermo Physics and Solar Astrophysics departments. The Solar Astrophysics group has active collaborations on low temperature detectors (LTD) with Stanford University, NIST and MIT, as well as CRAD activities with NASA and the US Air Force for LTD developments.

LM has advanced the pulse tube technology to produce four stage cryocoolers which have cooled to as low as 3 K.<sup>2</sup> This cryocooler technology provides a guard boundary to replace the previously utilized liquid helium Dewar guards for both rocket flight and space applications.

## DESCRIPTION OF OVERALL DESIGN AND LAYOUT

Figure 1 presents the design layout of the system. The layout shows the “ADR insert” packaged in a rocket flight configuration which employs a super fluid helium Dewar, at 2 K. The ADR insert which contains the salt pill, thermal switch, superconducting magnet and magnetic shielding is surrounded by the 2 K helium guard. This salt pill utilizes a ferric ammonium alum paramagnetic



**Figure 1.** Design layout of ADR configured for rocket flight

salt to provide the required entropy variation with magnetic field. The salt pill along with the sensor cold plate is supported from a network of Kevlar fibers, to limit the heat leak. These fibers are required to be spring loaded since the Kevlar strands lengthen on cooling, unlike most other materials. A superconducting magnet provides a magnetic field of approximately 4 Tesla to the salt pill. A Vanadium Permendur shield surrounds the superconducting magnet, and in combination with an additional local shield around the sensor limits the magnetic field to  $< 50$  mGauss to the sensor. The thermal switch is a mechanical clamping type and is mechanically activated by a Kevlar strand. A complete stress analysis has been conducted on the system utilizing the rocket loads, including the critical landing loads. At this point in the development the ADR insert has been designed and tests are in progress.

## MAGNETIC SHIELDING ANALYSIS AND SELECTION

Extensive modeling was performed for various magnetic field shield approaches and optimizations. Fig. 2 shows the field at full 8.5 amp current.

The field in the salt pill is between 3.5 T and 4.1 T throughout its entire volume. The field in the mu metal shield around the detector is 400 gauss at full field.

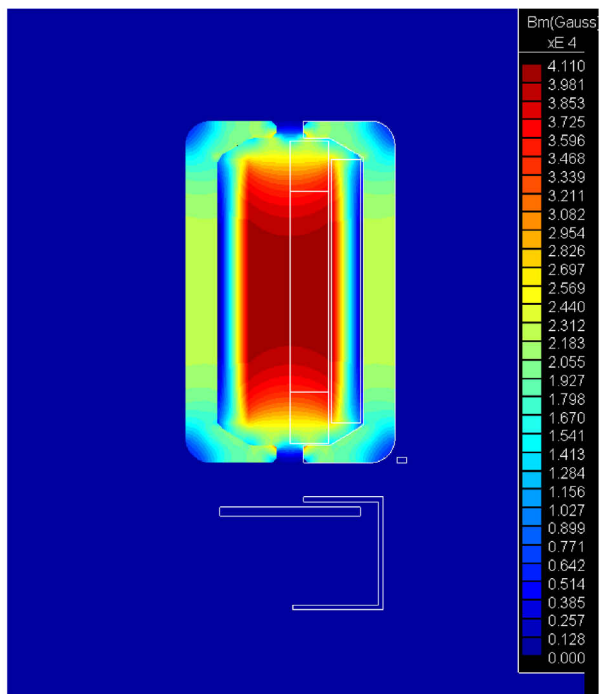
Figure 3 shows the field around the detector at the nominal operating conditions (0.15 amperes) for the selected design.

It appears that a bucking coil will not be necessary to limit the magnetic field to the sensor below 0.05 Gauss with the present design.

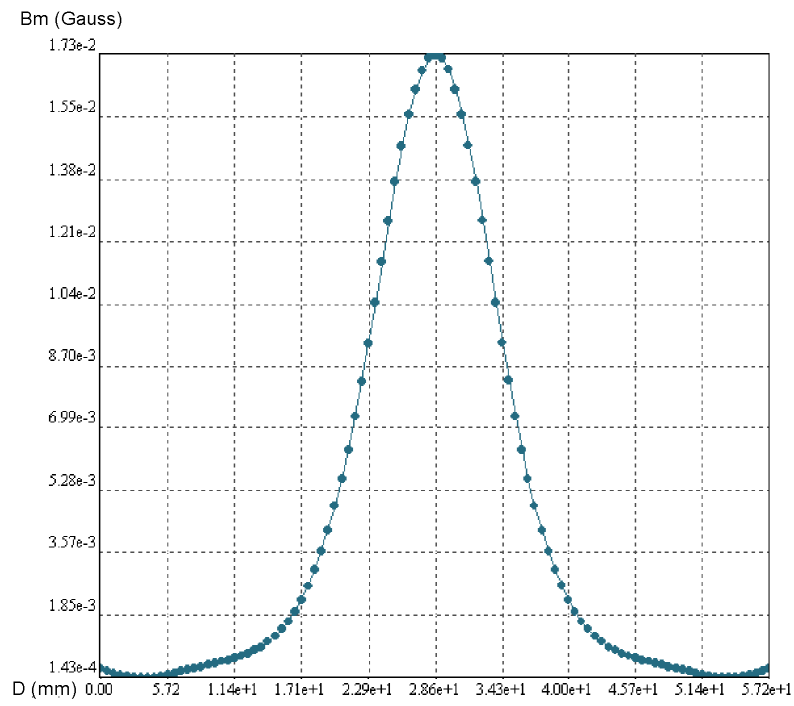
## HARDWARE DEVELOPMENT

The major sub assemblies of the system are shown in Figure 4.

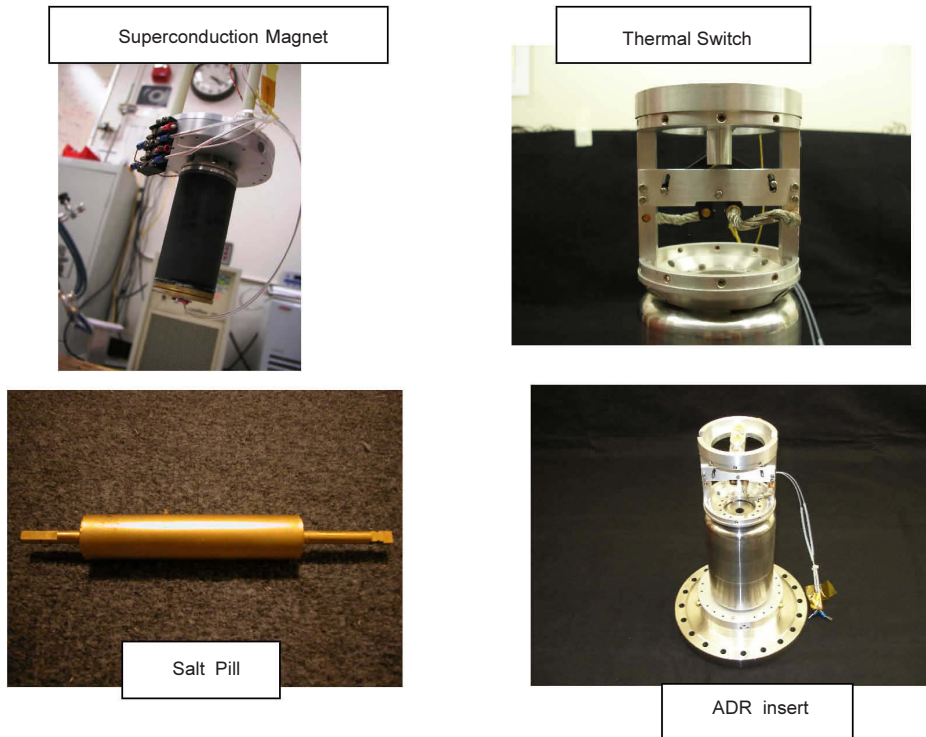
The salt pill was subcontracted for and utilizes ferric ammonium alum. The assembly includes end support rods with interlocking ends for the mount assembly which is supported by the Kevlar filaments. It is a copper and stainless steel construction which includes gold wires inside the salt growth for heat conduction from the salt to the area of the thermal switch.



**Figure 2.** Magnetic field distribution at 8.5 A maximum current.



**Figure 3.** Magnetic field at the detector plane, with no bucking coil, at 0.15 ampere nominal operating current.



**Figure 4.** Major Sub Assemblies of ADR Insert

The thermal switch is constructed from aluminum and is a mechanical scissors device which is closed by load on the filament from an actuator and opened when the load is released by springs.

The superconducting magnet was vendor supplied and provides 4.5 Tesla field with a current of 8.5 amperes.

The magnetic shield is made from Vanadium Permendur and surrounds the SC magnet with only small clearance holes for the support rods of the salt pill. The superconducting magnet and the shield were assembled, immersed in LHe to measure the field inside the magnet with good agreement with predictions.

The completed assembly of the ADR insert is shown on the figure, and provides for thermal grounding to the helium bath at the bottom flange in the test configuration.

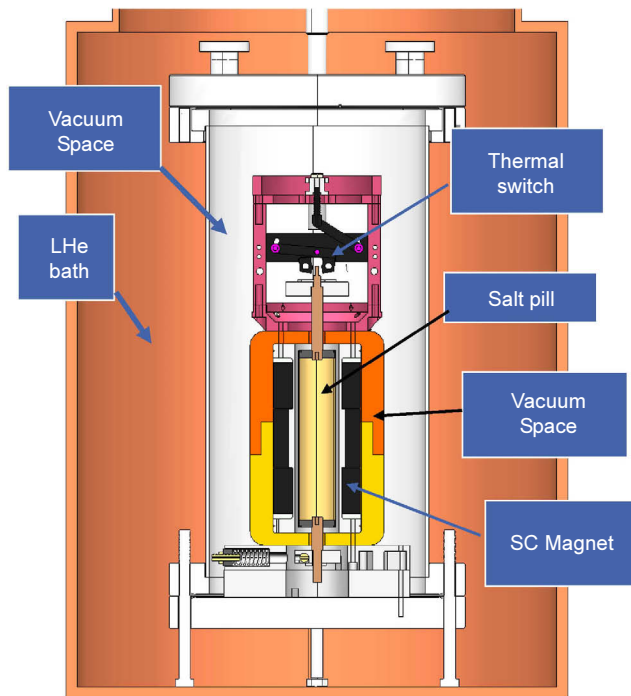
## THERMAL PERFORMANCE

We developed a test apparatus which would simulate the conditions of the liquid helium guard Dewar or alternatively could utilize a cryocooler as a guard to validate the operation of the ADR insert. The configuration of the test apparatus is shown in Figure. 5.

This apparatus places the ADR insert in a vacuum container, which is immersed in liquid helium, simulating the operation in the rocket flight with a liquid helium Dewar.

Initial testing was conducted on the ADR insert with 4.2 K LHe. We tested the system up to a current of 6 amperes. Above that current we had some quenching occurrences of the magnet, which we believe is due to incomplete thermal grounding of the current leads. The apparatus will be modified and tested to full current.

To date, we have achieved 139 mK, which is above our goal of 50 to 100 mK at the limited current and 4.2 K helium. The initial temperature of the salt pill at the time of the ramp down of the current was 4.7 K.



**Figure 5.** Test configuration for ADR insert

## FUTURE WORK AND PLANS

Future testing will include improved grounding of the current lead wires and complete characterization of the ADR insert at various conditions, primarily at various guard temperatures, currents and ramp rates. Present plans are to do the design and fabrication of the super fluid helium Dewar for the rocket flight in 2009.

## SUMMARY

The design and construction of an ADR system has been completed and initial testing shows good agreement with expected operation at the reduced currents. Structural design and magnetic shielding tests have been conducted with good results and final characterization testing will be conducted at full current.

## ACKNOWLEDGMENT

This work was supported under Lockheed Martin internal funding.

## REFERENCES

1. D. McCamman, et. al., "A High Spectral Resolution Observation of the Soft X-Ray Diffuse Background With Thermal Detectors," *The Astrophysical Journal*, Vol. 576, September 1 2002, pp. 188-203.
2. Olson, J.R., Moore, M., Champagne, P., Roth, E., Evtimov, B., Jensen, J., Collaco, A., and Nast, T., "Development of a Space-Type 4 Stage Pulse Tube Cryocooler For Very Low Temperature," *Adv. in Cryogenic Engineering*, Vol. 51, Amer. Institute of Physics, Melville, NY (2006), pp 1885-1892.