Improvement on the magnetic shielding for the XRISM/Resolve Adiabatic Demagnetization Refrigerator

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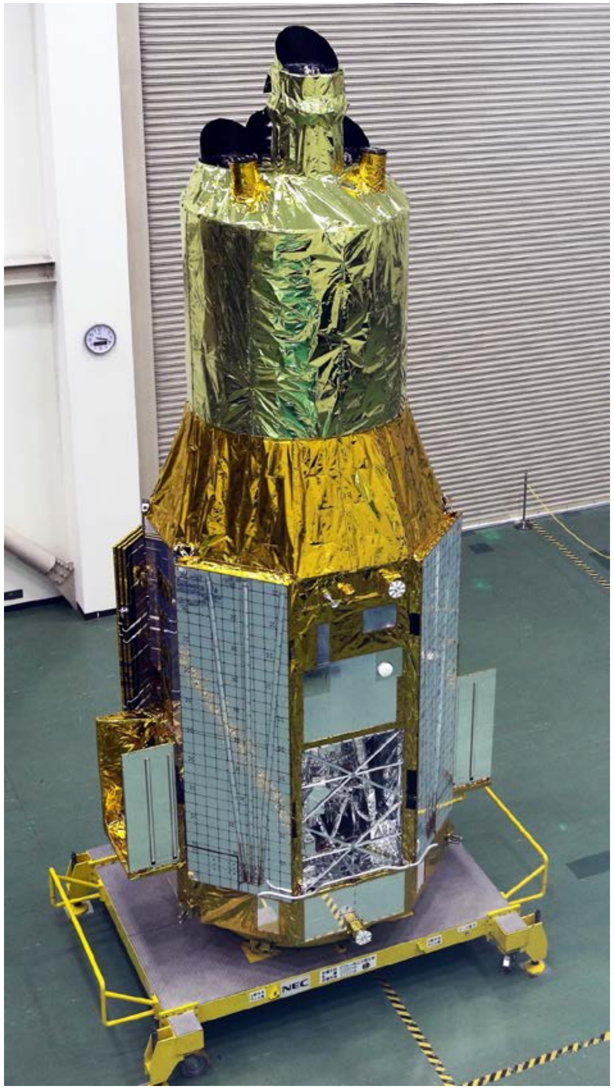
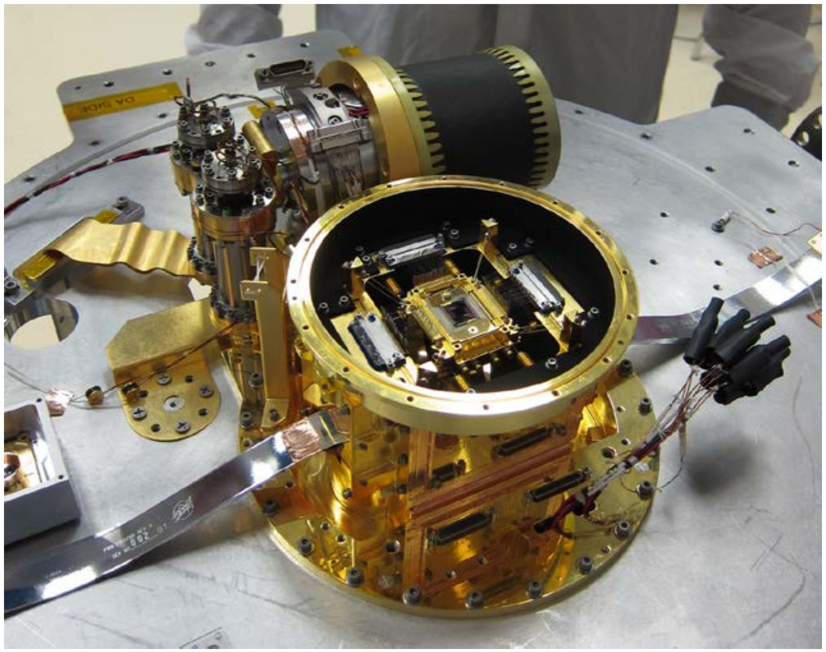
Overview of the System



For Hitomi (Astro-H), a three-stage adiabatic demagnetization refrigerator (ADR) was built to hold an array of microcalorimeters at 0.050 K during science operations

- When the ADR is combined with the 36-pixel microcalorimeter (the Soft X-ray Spectrometer or SXS), this forms what is known as the Cryogenic Spectrometer Insert (CSI)
- The CSI is mounted to a well in the liquid helium tank aboard the Astro-H cryogenic Dewar
- The Dewar is housed on the Astro-H satellite inline with the Soft X-ray Telescope (SXT-s) and puts the plane defined by the X-ray absorbers at the focal plane of the SXT-s
- System design duplicated for XRISM/Resolve

Overview of the Problem

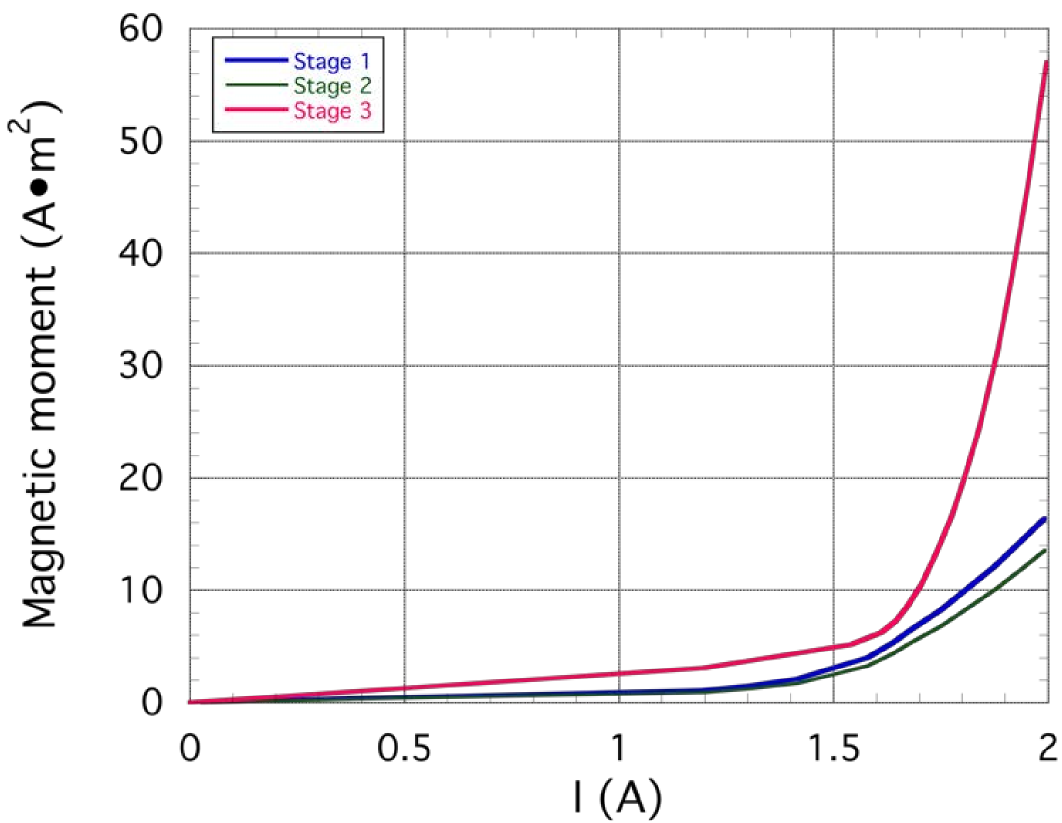


A three-stage adiabatic demagnetization refrigerator was built to hold an array of microcalorimeters at 0.050 K during science operations

- Hold time > 40 hours in cryogen mode [CM] (1.2 K liquid helium heat sink, Stages 1 and 2 only)
- ~ 16 hours in cryogen-free mode [CFM] (4.5 K JT cooler as the heat sink, All three stages needed)
  - In cryogen-free mode, an interference with the temperature reported by the sensors in the detector array [DA] occurred when the current in the Stage 3 superconducting magnet (used only in cryogen-free mode) was greater than 1.7 A.
  - This limited the cooling performance of that stage therefore limiting the lowest temperature achievable at the helium tank when liquid helium is depleted
  - Higher heat loads on the lower temperature stages shortened their hold time

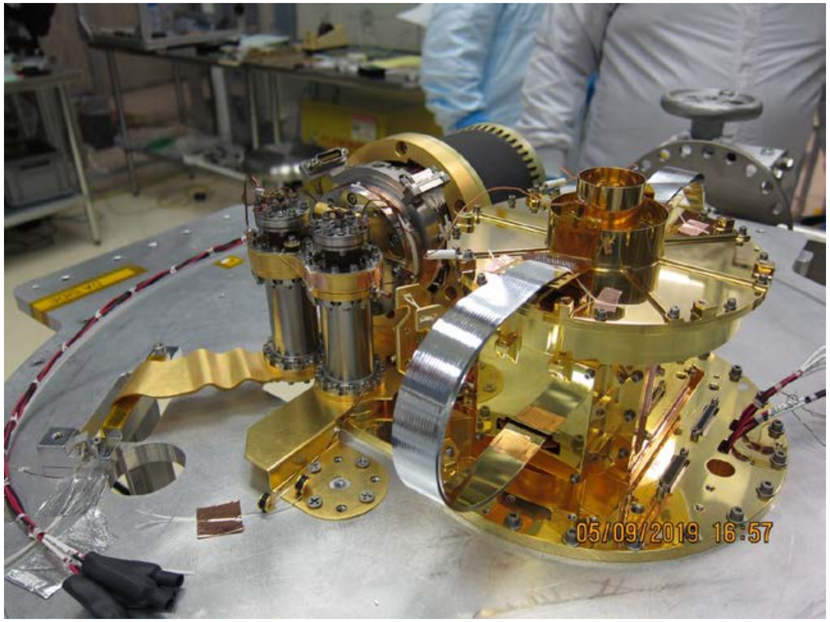
Overview of the Problem

- Measurements at GSFC appeared to confirm compliance with requirements
  - Requirement states the magnetic moment must be ≤30 $A \cdot m^2$ for any combination of magnets at full current
  - Electrical noise in the test Dewar masked the detector interference
- The first definitive measurements of fringing fields were made at the Flight-Model level using magnetometers aboard the spacecraft



- With Stage 3 at ≤1.75 A, ADR meets magnetic moment requirement
- Stage 3 uses full current only when recycling Stage 1 in CFM (allowed based on waiver)
- *Interference with the DA is the real problem that needs to be solved*

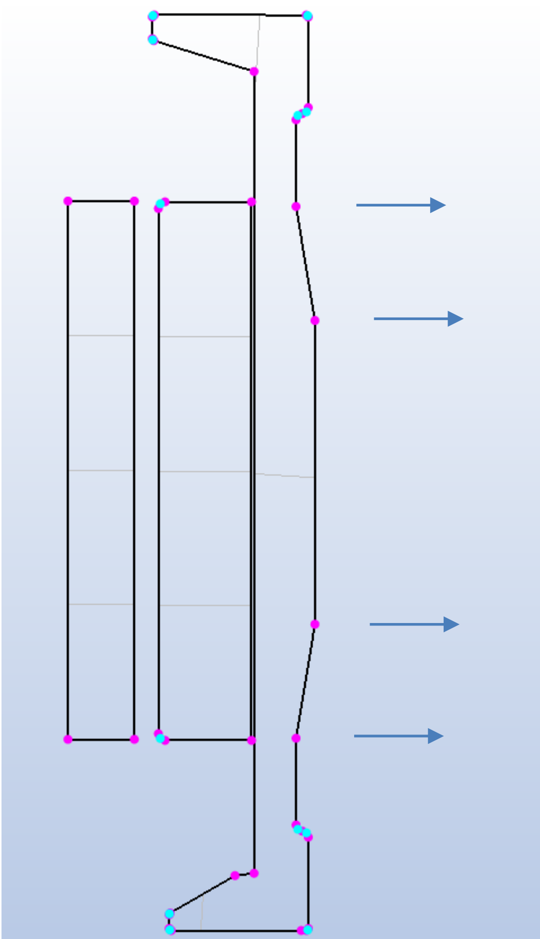
The System



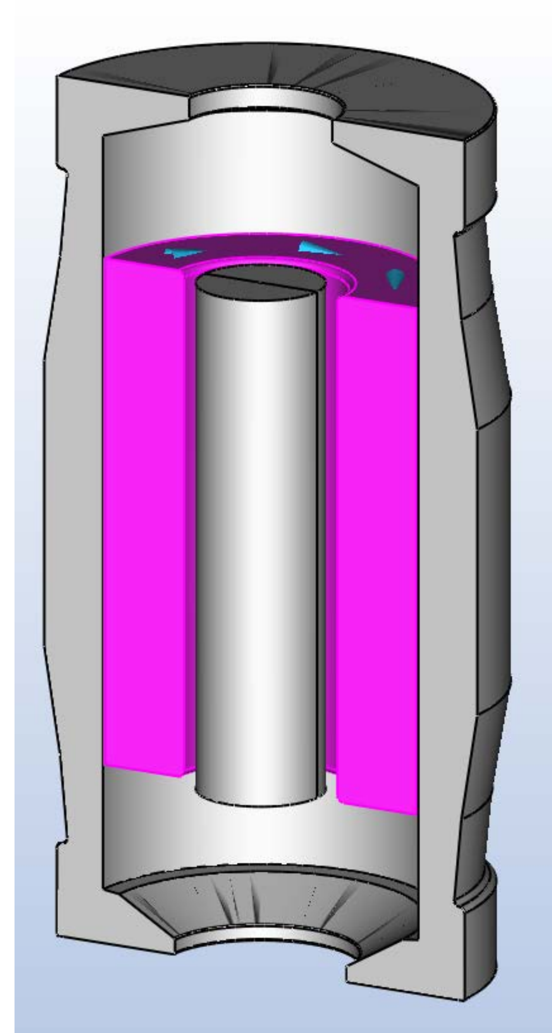
Stage 3 is closest to the detector assembly (DA) and away from the other stages

- Proximity to DA makes it more critical to return most field through the shielding
- Shielding material is Hiperco-50A (aka vanadium permendur)
    - Highest saturation point of typical ferromagnetic materials used as shielding

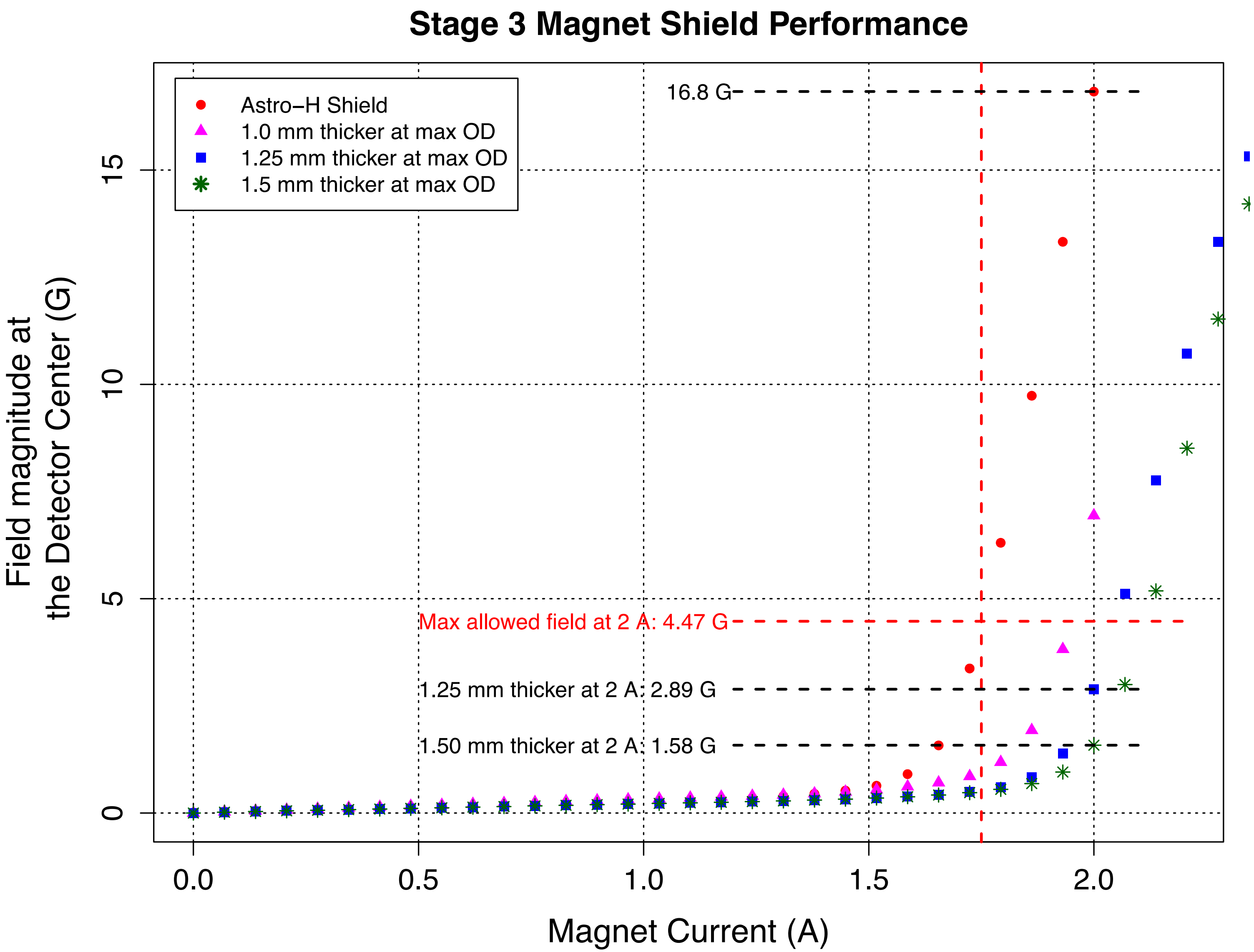
Model the Problem



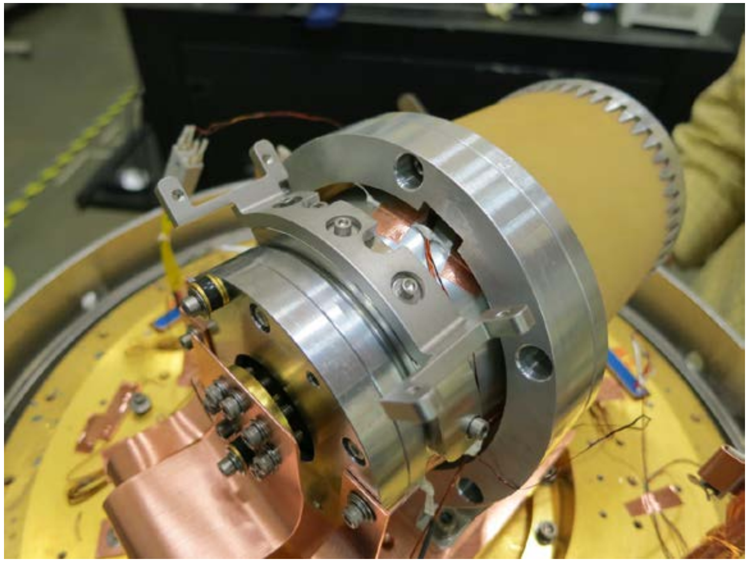
1. Move 4 Points
2. Re-sweep model to become half-model
3. Assign Volume Current
4. Assign Paramagnetic Material
5. Assign Shield Material
6. Copy rotate all pieces to become full model
7. Run model at full current adding nodes until field converges to some value at a given point
8. Run parametric study of field as function of magnet current; pick off field points at desired locations
9. Repeat if needed



Results from Modeling



Measure the Field in Flight Configuration



- Mounted a magnet wound for this particular stage into a shield fabricated to meet the requirements determined via the field modelling
- Mounted the entire stage in the experimental space of a liquid helium Dewar
- Position an array of flux-gate magnetometers at a known distance from the center of magnet's bore (both radially and axially)
- Ramp current in magnet from 0 to 2 back to 0 A (range of current in operation in orbit) while measuring the field generated on the four magnetometers
- Rotate Dewar ten degrees and repeat measurement.

The magnetometers are so sensitive that we witnessed cars moving in the parking lot outside and chairs rotating within the lab.

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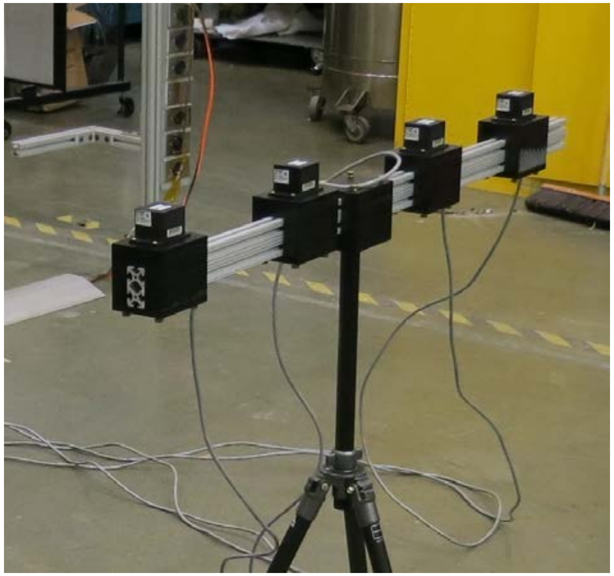

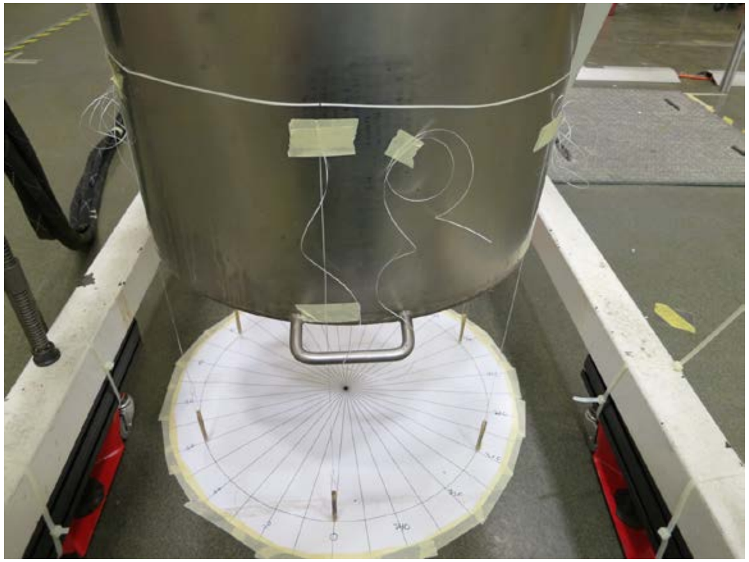

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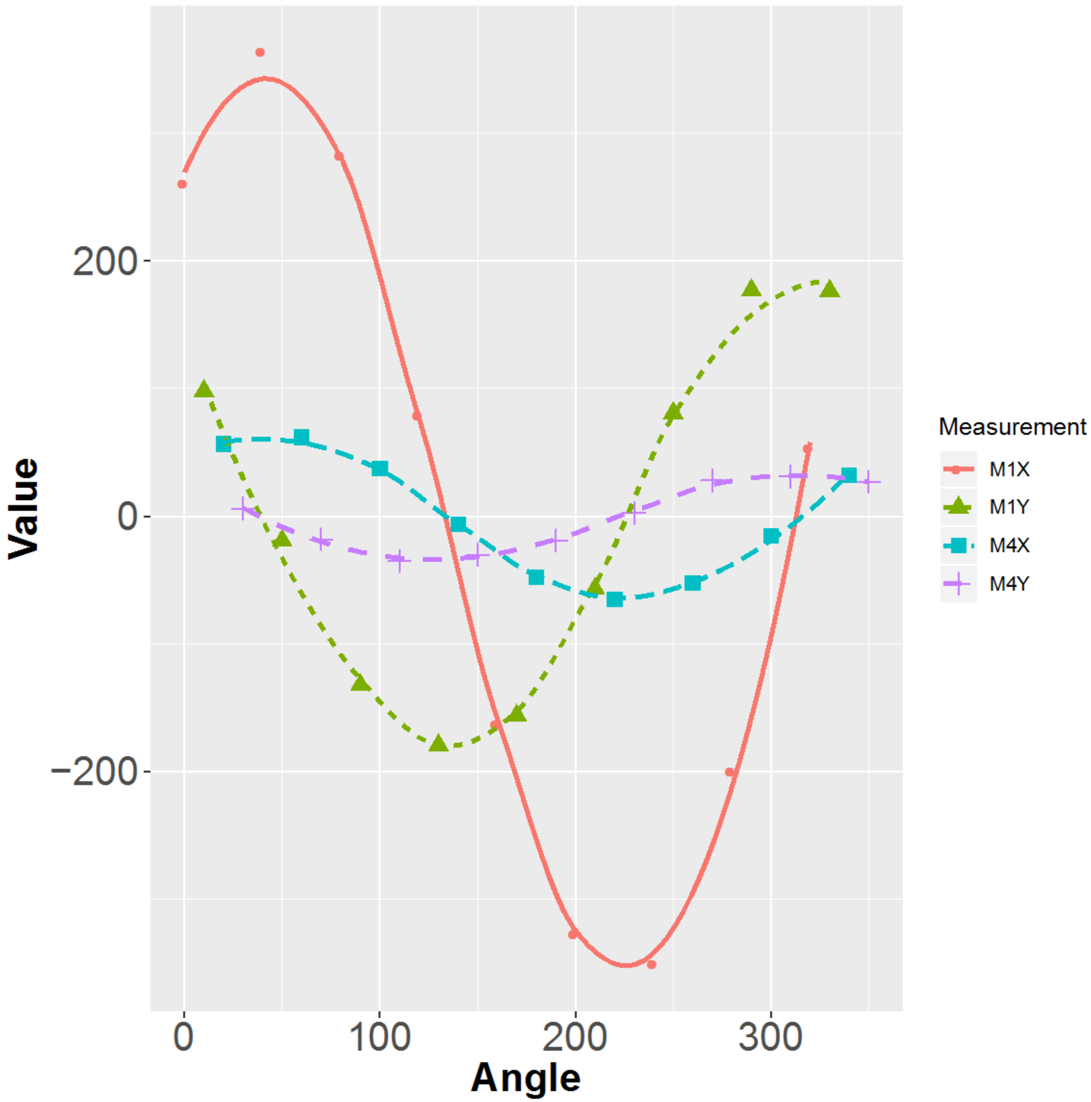

Variable	Value (A·m²)
x	-0.21
y	-1.54
z	-0.05
Total Magnitude	1.56

- Nearly sinusoidal function of X and Y components from all four magnetometers with Dewar rotation gives confidence in the measurement (two shown here)
- The results from fitting data from all four magnetometers as function of distance from the Dewar and the angle of rotation produces the numbers shown above
- The total magnitude is the vector addition of all three components
- The total magnitude is well below the new requirement of 20 $A \cdot m^2$

Conclusion

- Modeling of shielding material that surrounds Stage 3 of the XRISM/Resolve ADR shows a modest 1.5 mm increase in the thickest portion of the shielding solves two problems:
  - Dipole moment requirement satisfied and will not require a waiver like Astro-H
  - Interference between Stage 3 at full current and the Detector Array demonstrated to be eliminated in ground testing