ADR Design and Operation for the X-Ray Imaging and Spectrometer Mission (XRISM)

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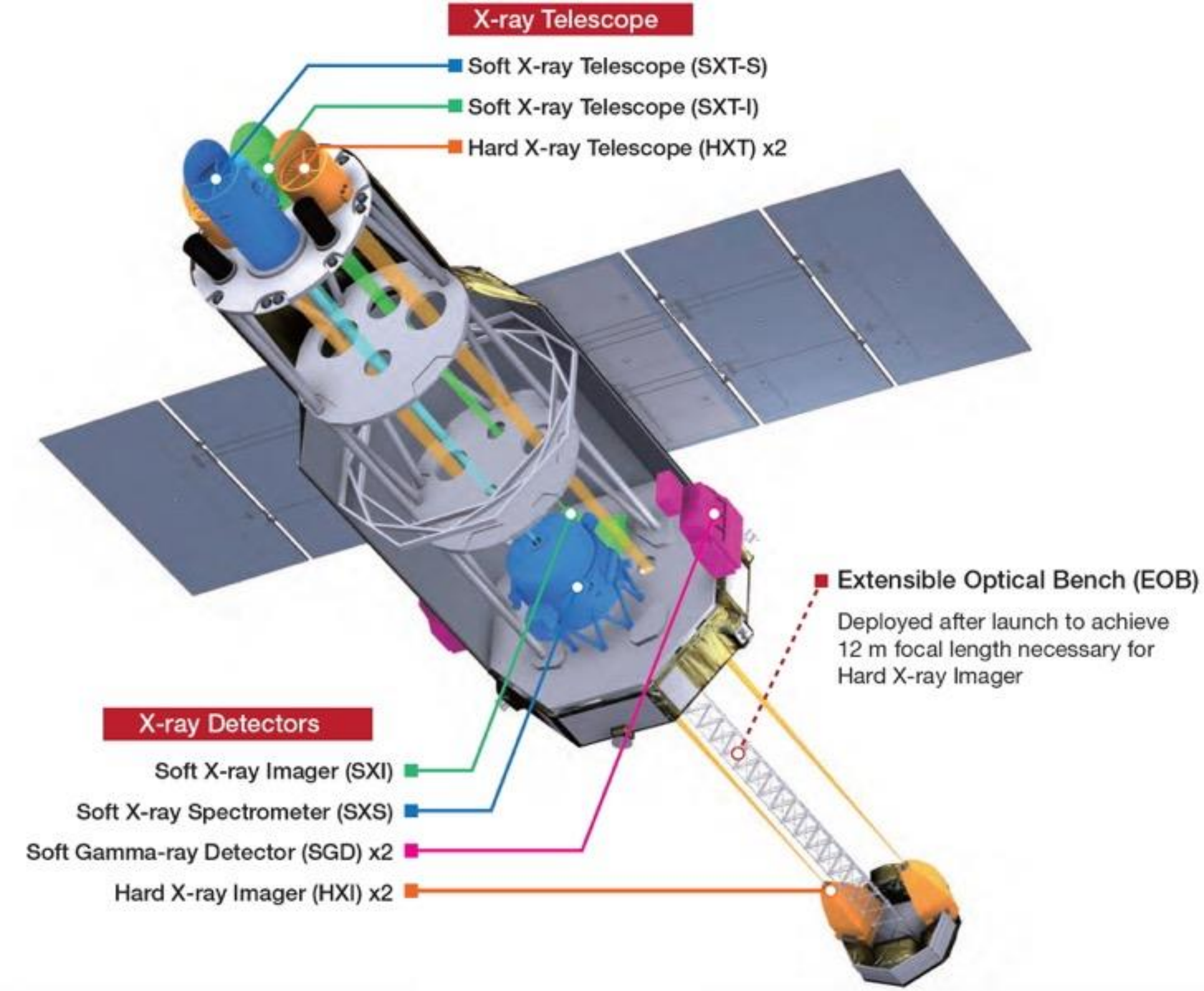
Launch: February 17, 2016

Hitomi (formerly Astro-H)



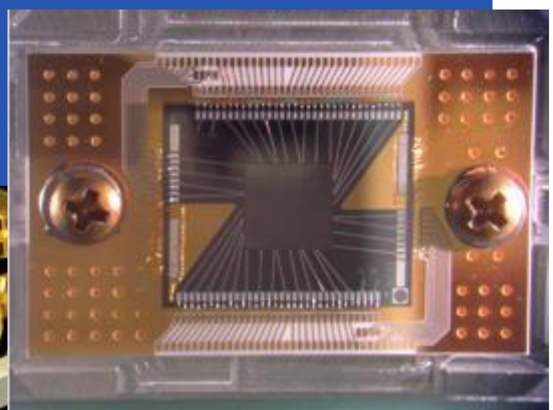
Study structure and evolution of the Universe

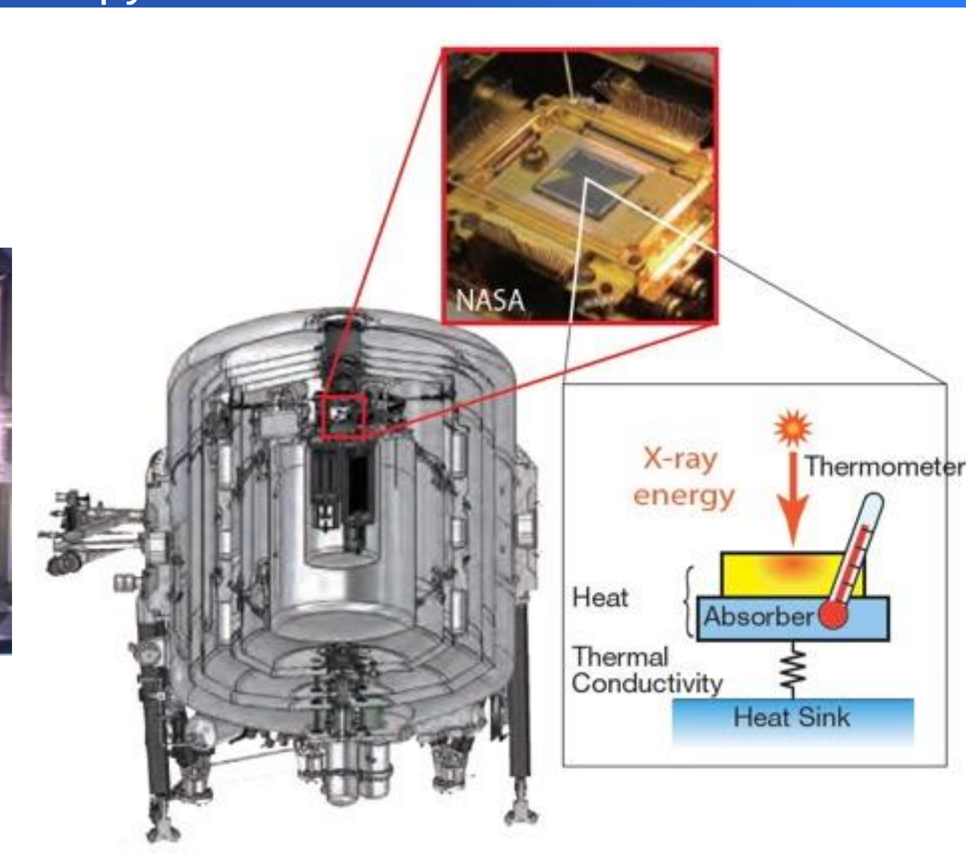
Study matter in extreme environments

- Black holes
- Galaxies
- Heavy elements
- Cosmic rays

The Resolve X-ray Spectrometer

- 6x6 array of silicon microcalorimeters
  - High resolution imaging and spectroscopy of x-rays in the 0.2-13 keV band
- ADR for detector cooling
  - 50 mK operation



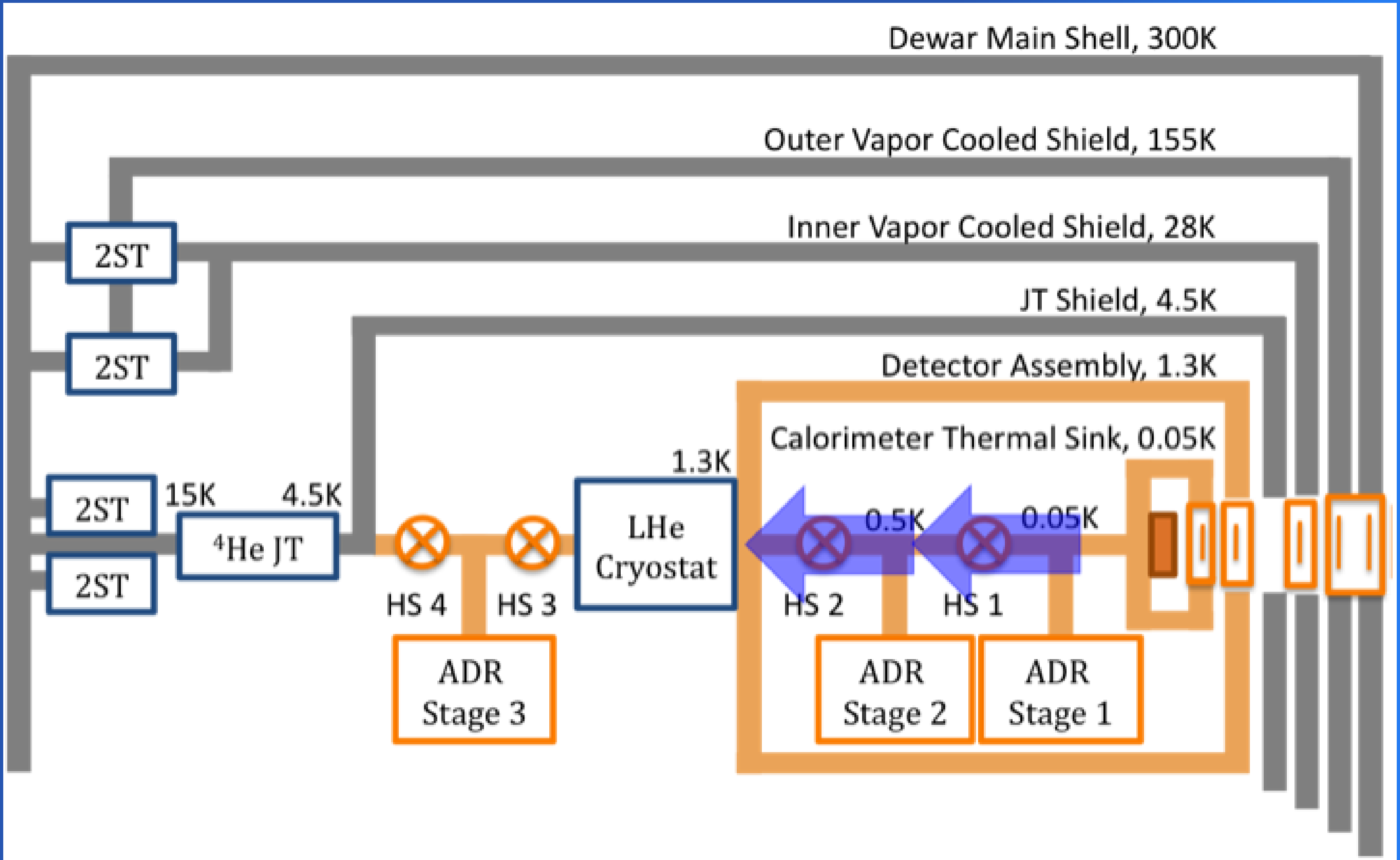


Low temperature ⇔ low heat capacity

$\Delta E \sim$ 4-5 eV for 0.2-13 keV x-rays

Resolve Cryogenic System

2-stage ADR uses liquid helium as a heat sink

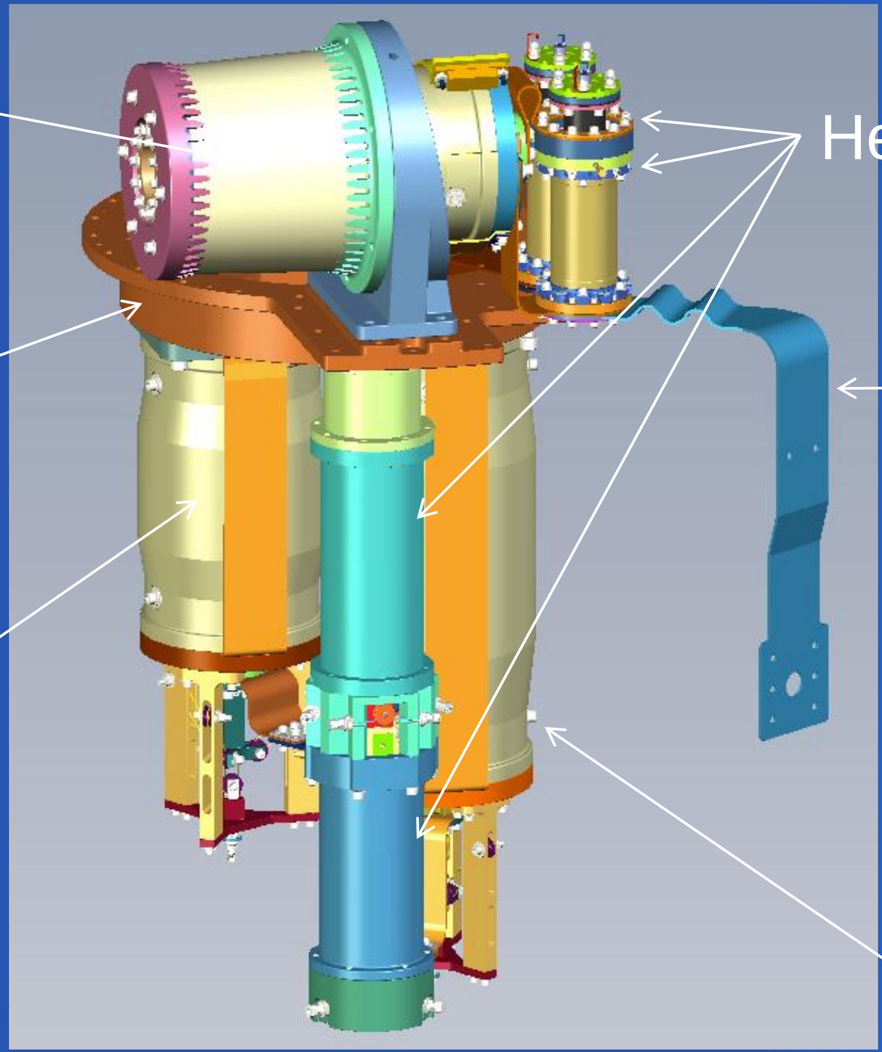


SXS ADR Layout

Stage 3

Mounting plate – mechanical and thermal I/F to He Tank

Stage 2



Heat switches (4x)

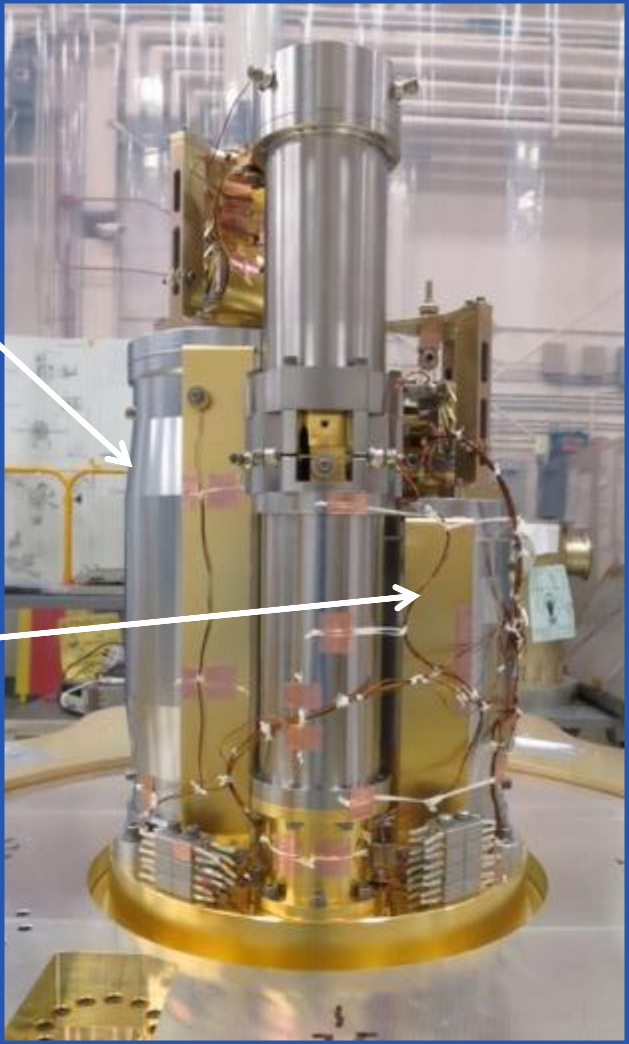
Thermal strap To JT cooler

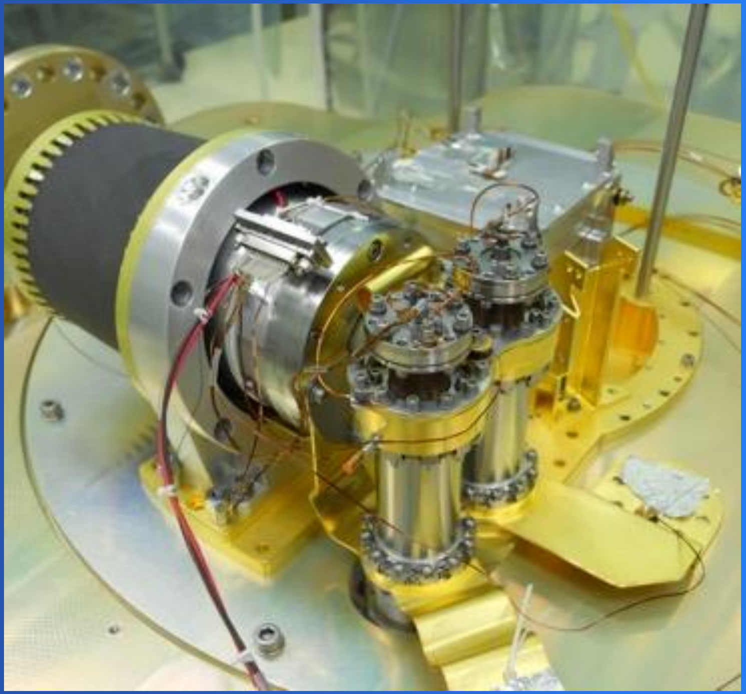
Stage 1

ADR Assemblies

Stage 1:
- 270 g CPA
- 2 T, 2 amp magnet

Stage 2:
- 150 g GLF
- 3 T, 2 amp magnet

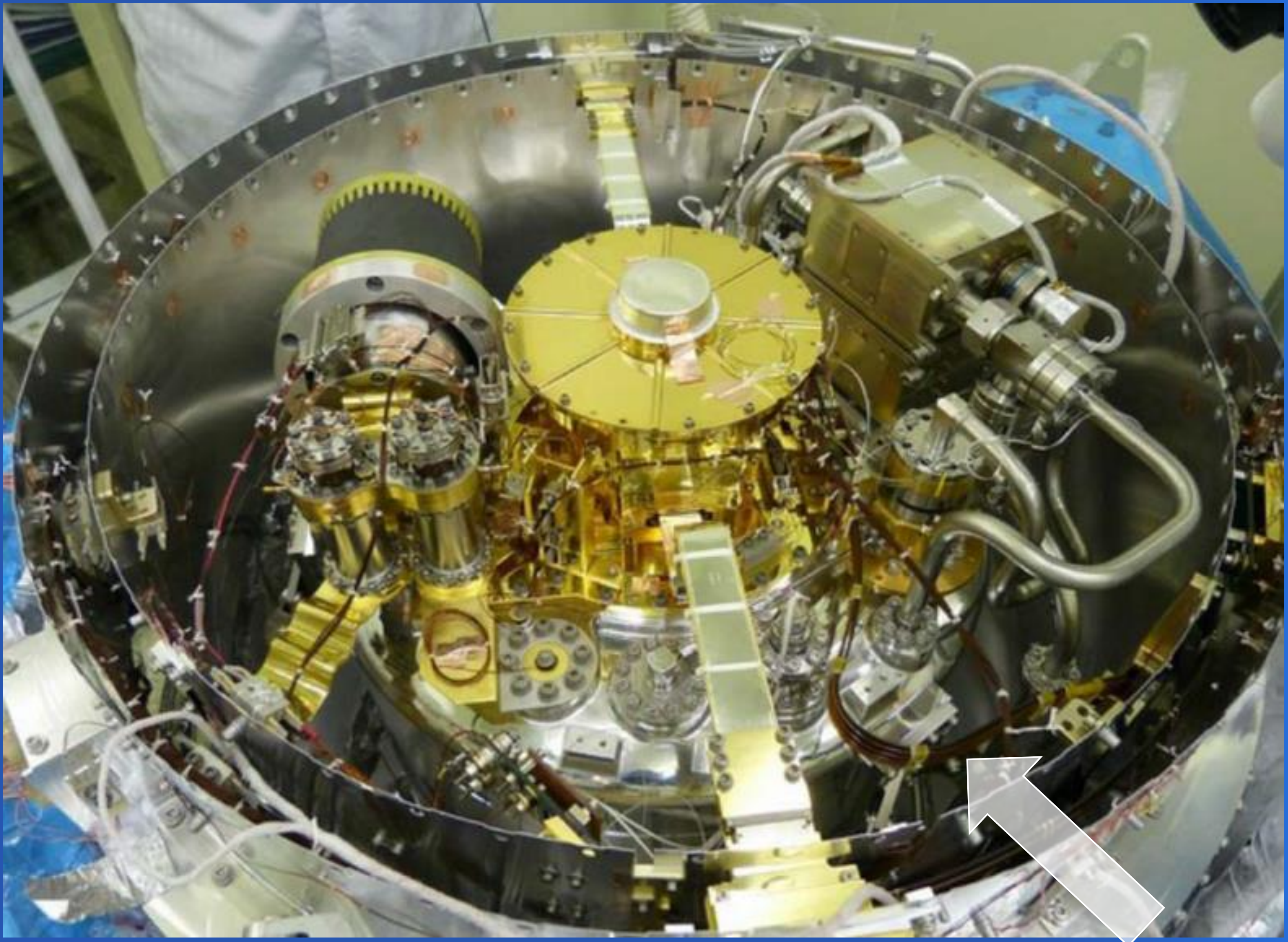




Stage 3:
- 150 g GLF
- 3 T, 2 amp magnet

Heat switches are active gas-gap

Flight ADR, Detector and Dewar (April '14)



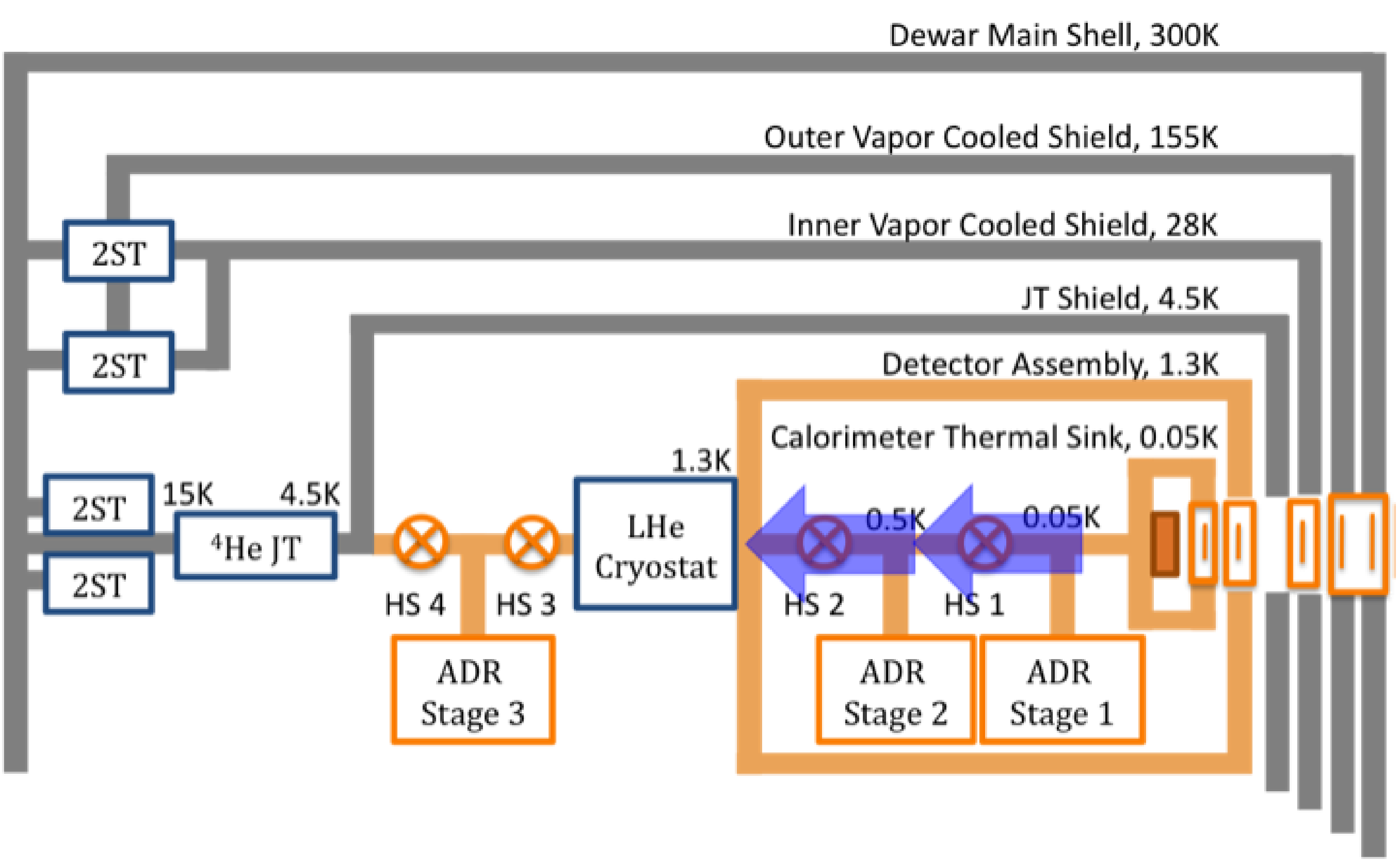
HTS leads:

YBCO tape

Supported by carbon fiber composite carrier

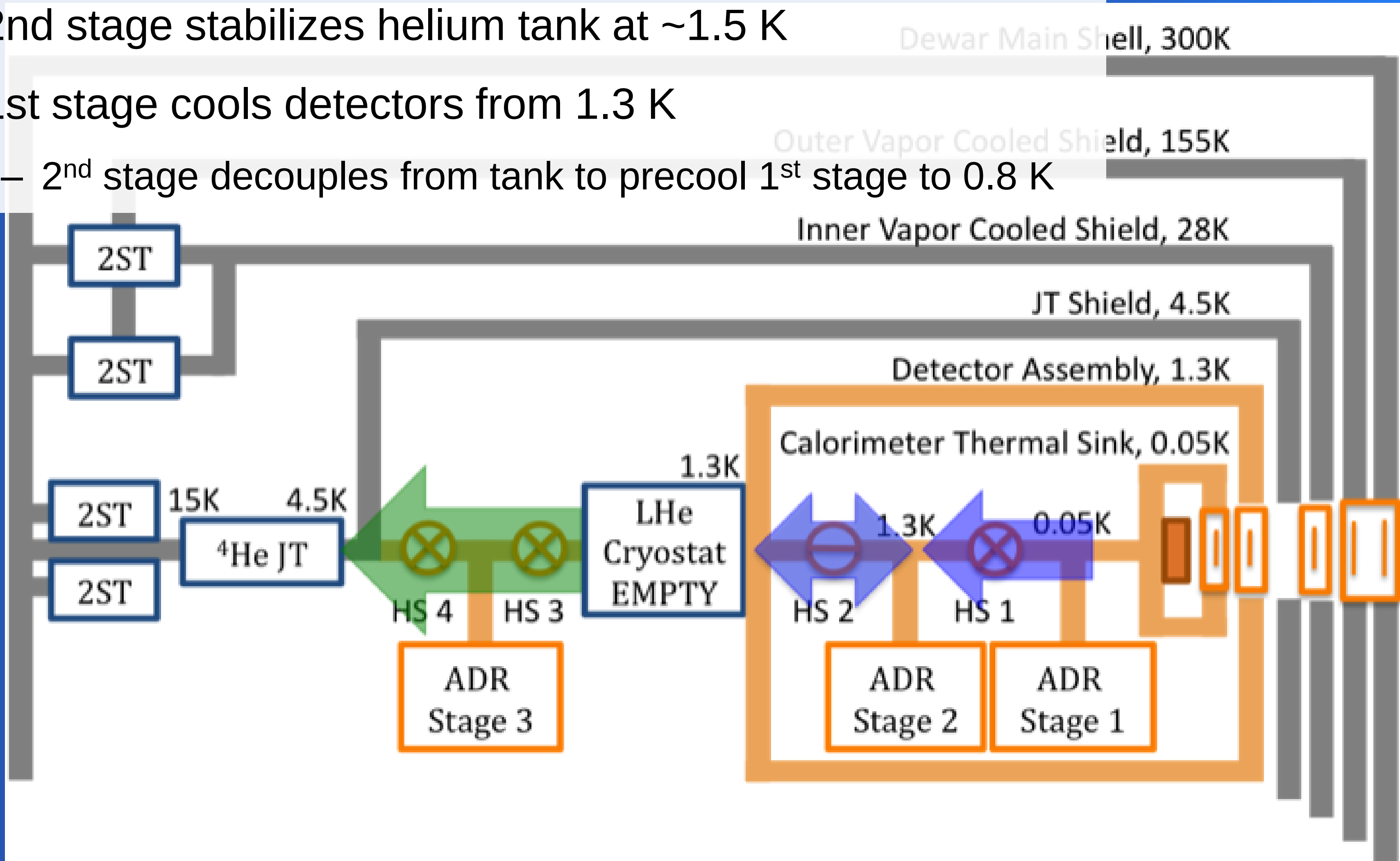
ADR Operation with Liquid Helium

2-stage ADR uses liquid helium as a heat sink



ADR Operation in Cryogen-Free Mode

- 3rd stage transfers heat from tank to JT cooler
- 2nd stage stabilizes helium tank at ~1.5 K
- 1st stage cools detectors from 1.3 K
  - 2[nd] stage decouples from tank to precool 1[st] stage to 0.8 K

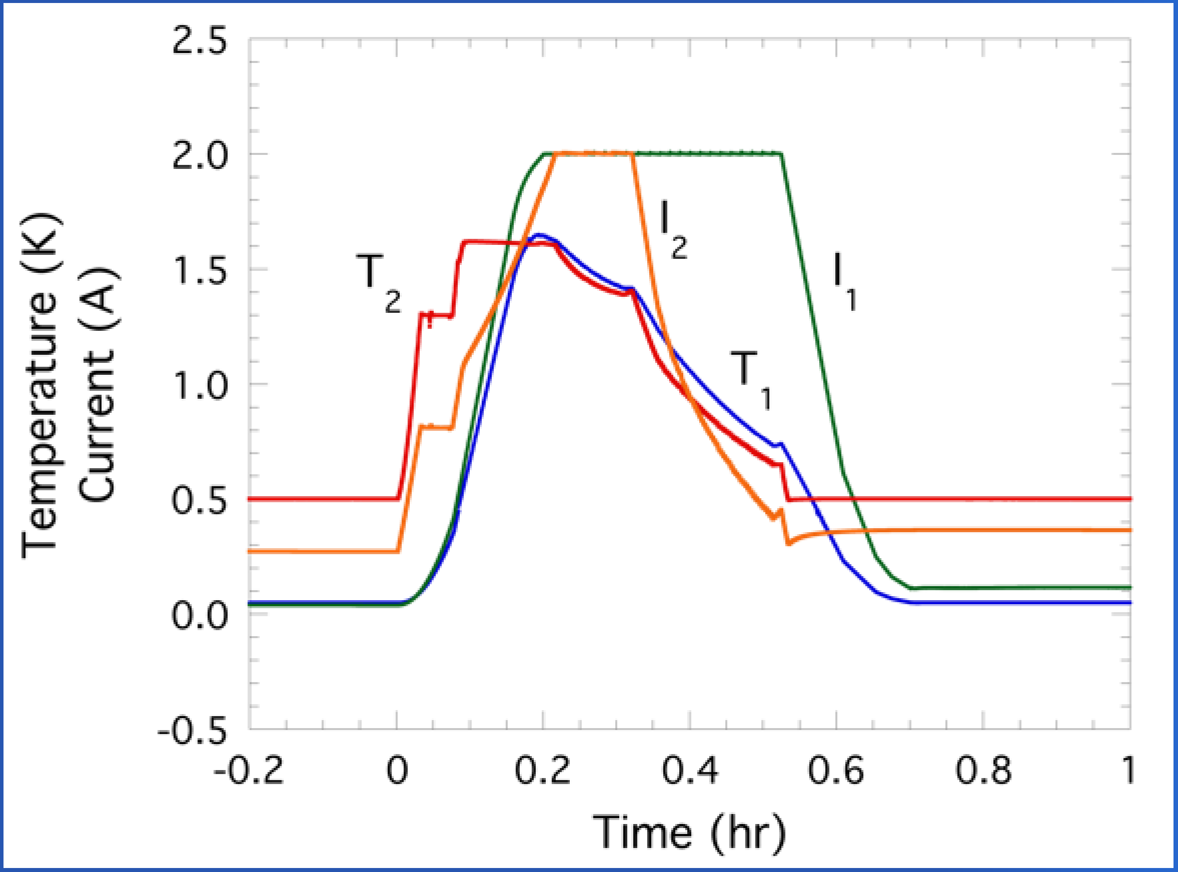


SXS/Resolve Design and Operating Strategy

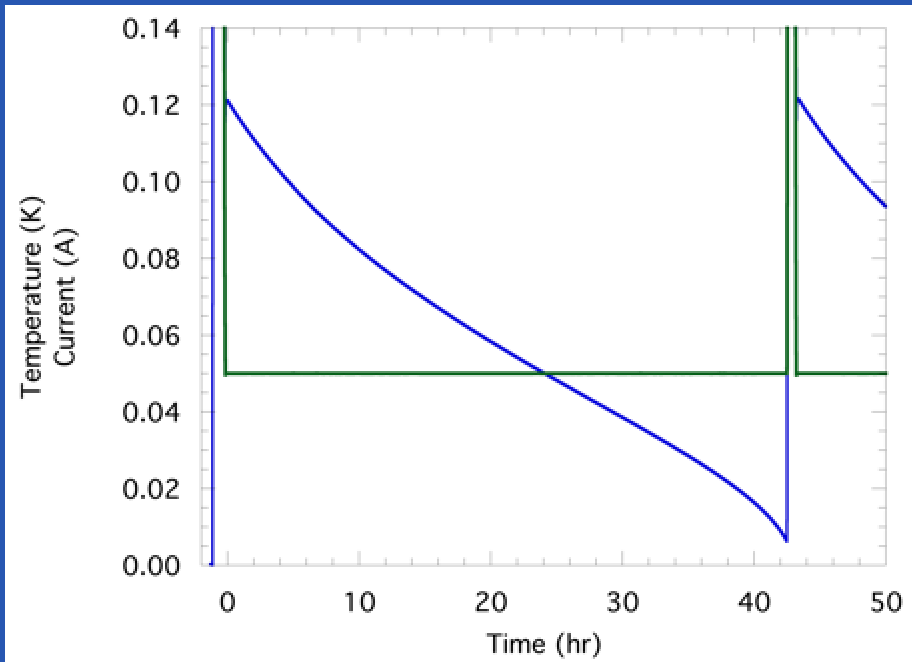
- Launch with minimum of 33 L of liquid helium (<1.3 K)
  - Cryocoolers act as guards to intercept parasitic heat loads
  - Nominal lifetime >3 years
- 2-stage ADR single-shot cools the detectors, rejecting heat to the liquid helium
- When helium is depleted, ADR operation changes to 3-stage operation

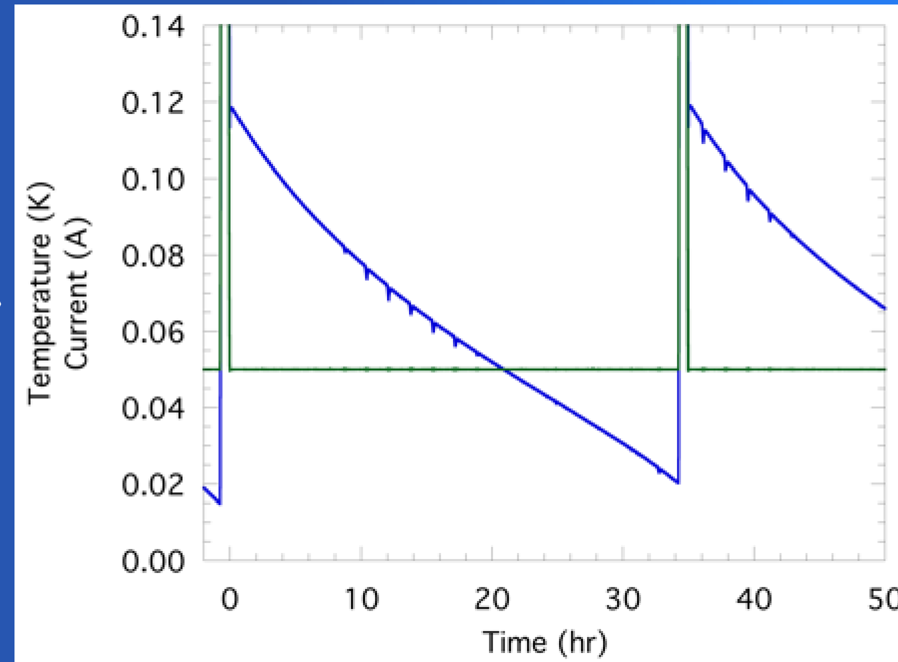
ADR Recycling

- Recycling sequence was structured to minimize recycle time and to minimize I^2R heating of the IVCS
  - JFET amplifiers are thermally coupled to IVCS



Stage 1 – Ground vs On Orbit

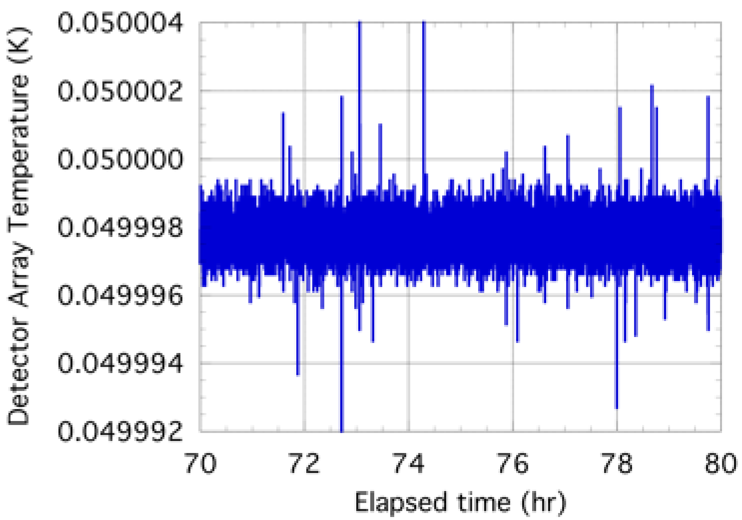




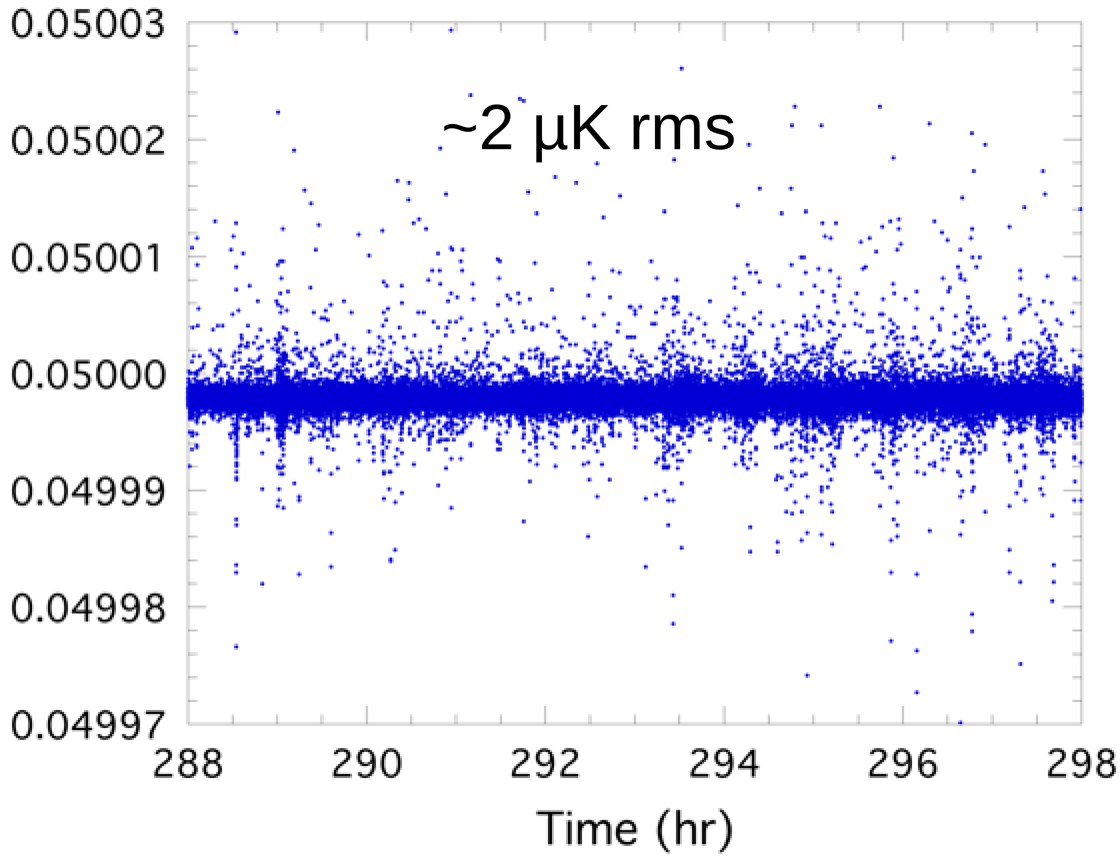
Recycle time	~45 minutes	~45 minutes
Heat load	0.80 μW	0.86 μW
Hold time*	~42 hours	~39 hours

* Dependent on tank temperature; values are for ~1.20 K

Temperature Stability



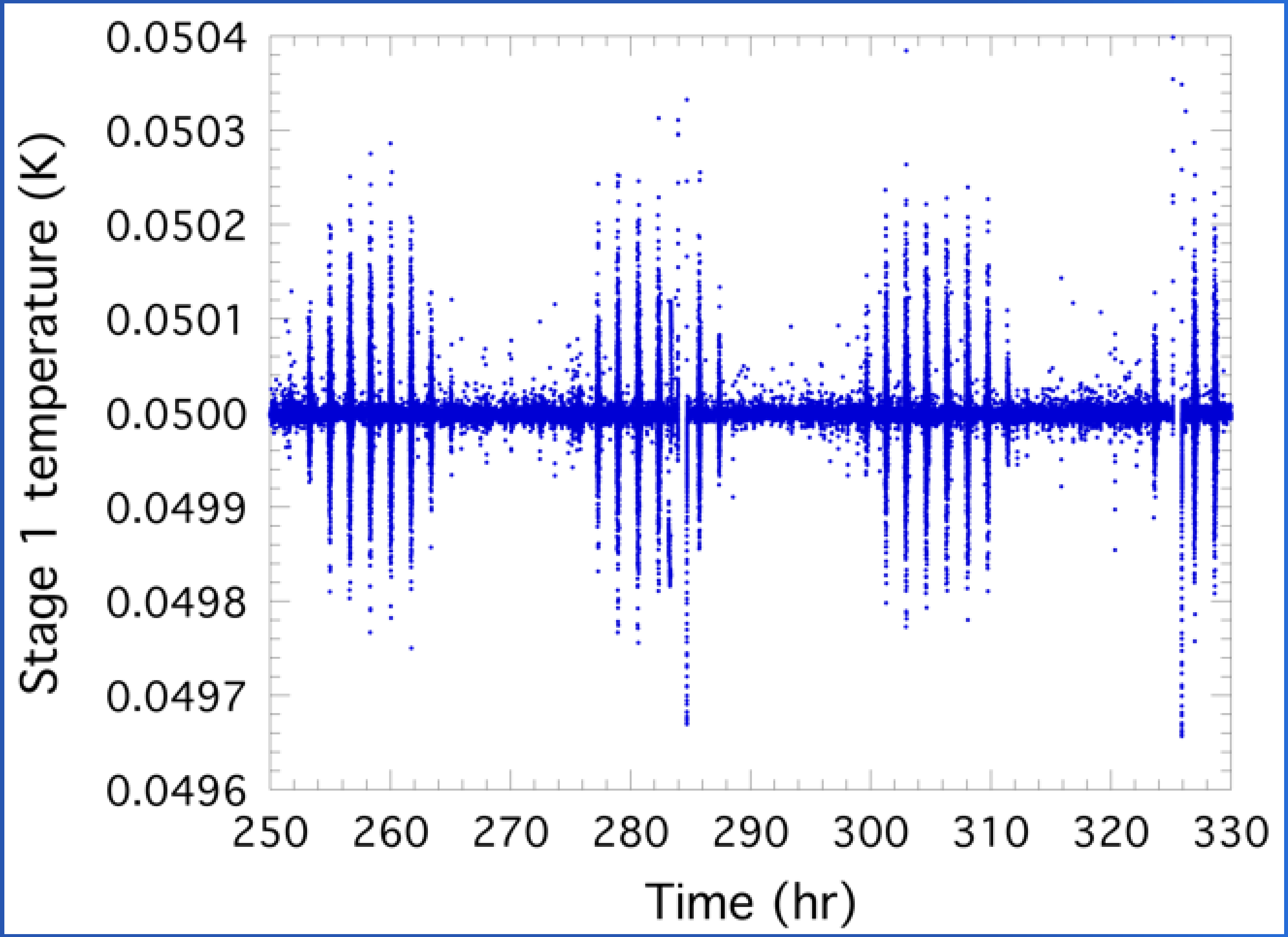
Ground tests: ~0.4 µK rms



On orbit: ~2 µK rms

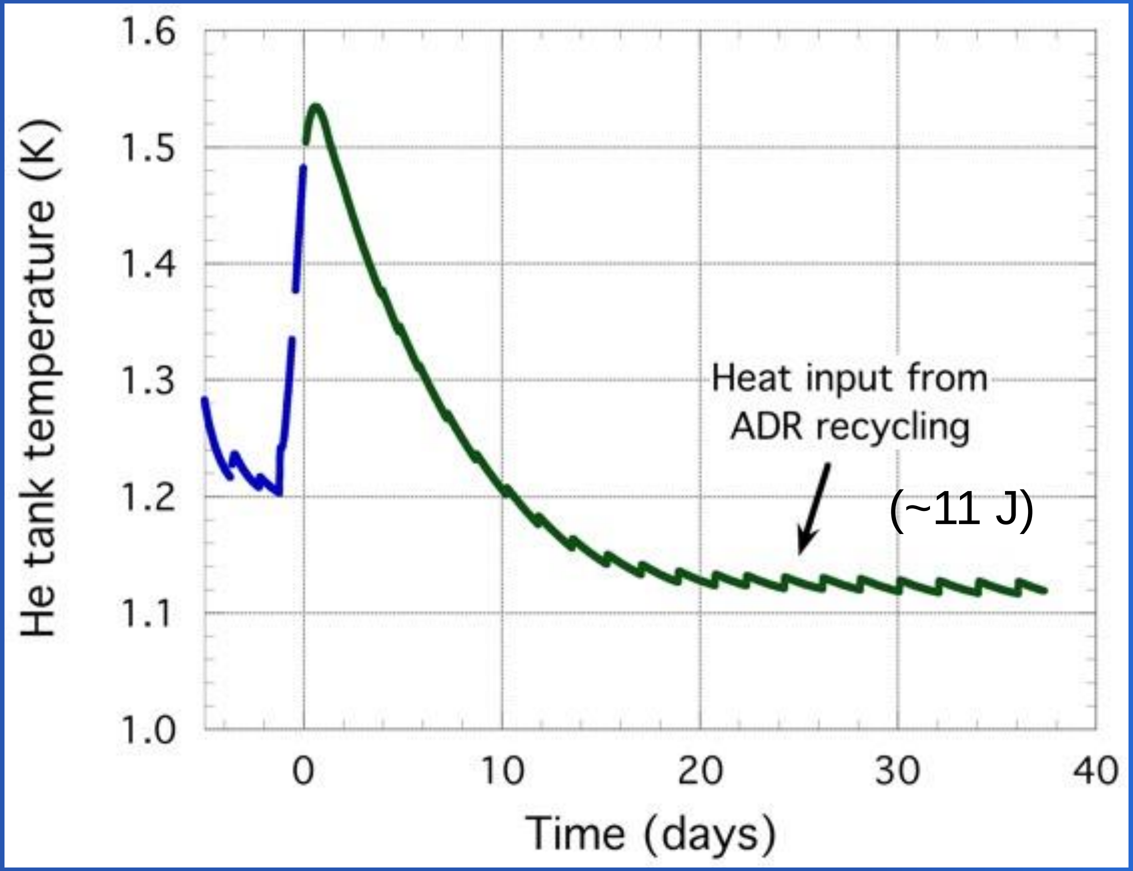
Effect of High Energy Particles

- Effect concentrated in SAA
- Response appears to be primarily within thermometers



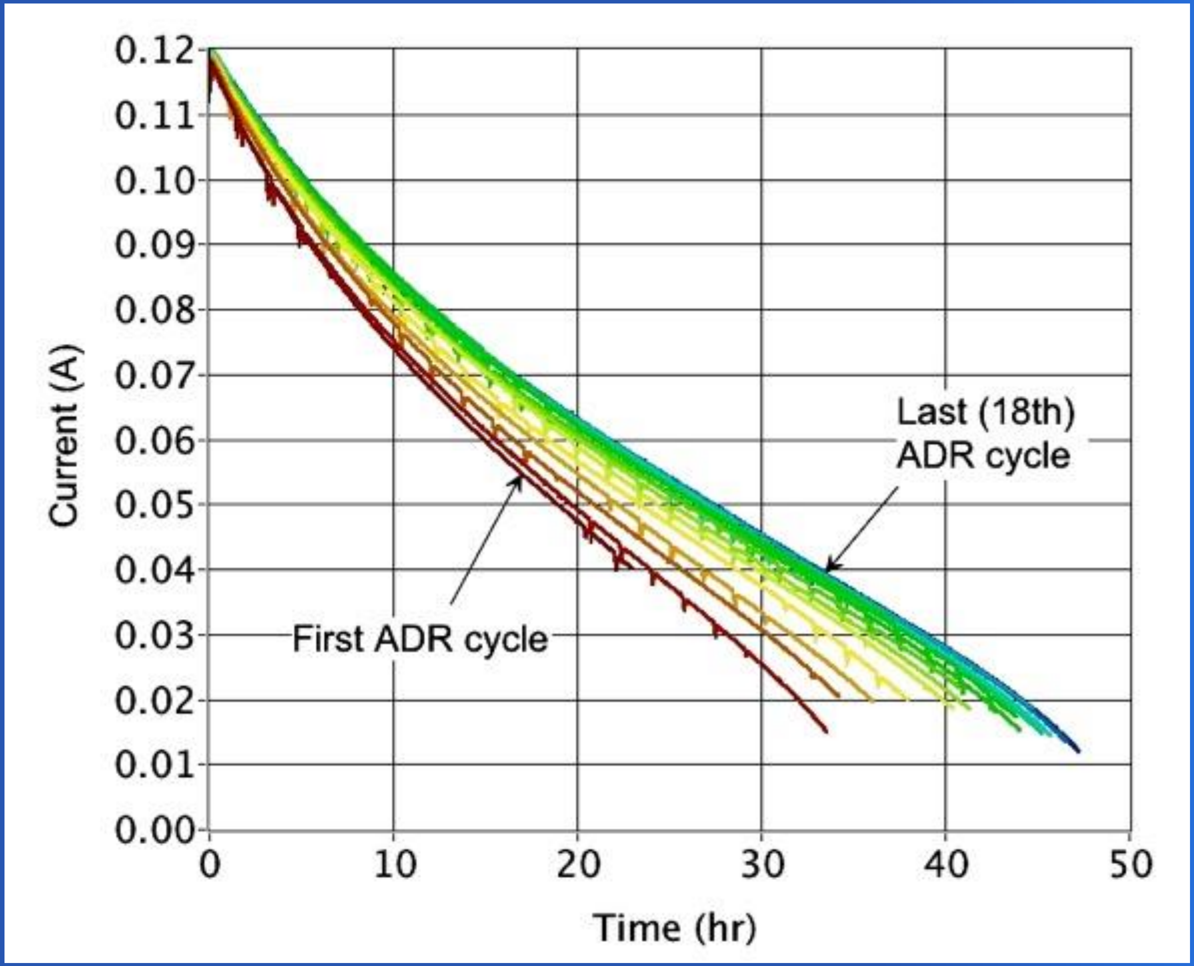
He Tank Temperature

- Cooling rate is consistent with ground tests of porous plug phase separator
- Steady-state temperature was ~1.12 K



ADR Performance

- ADR hold time steadily increased as He tank cooled
- At 1.12 K, hold time was ~48 hours



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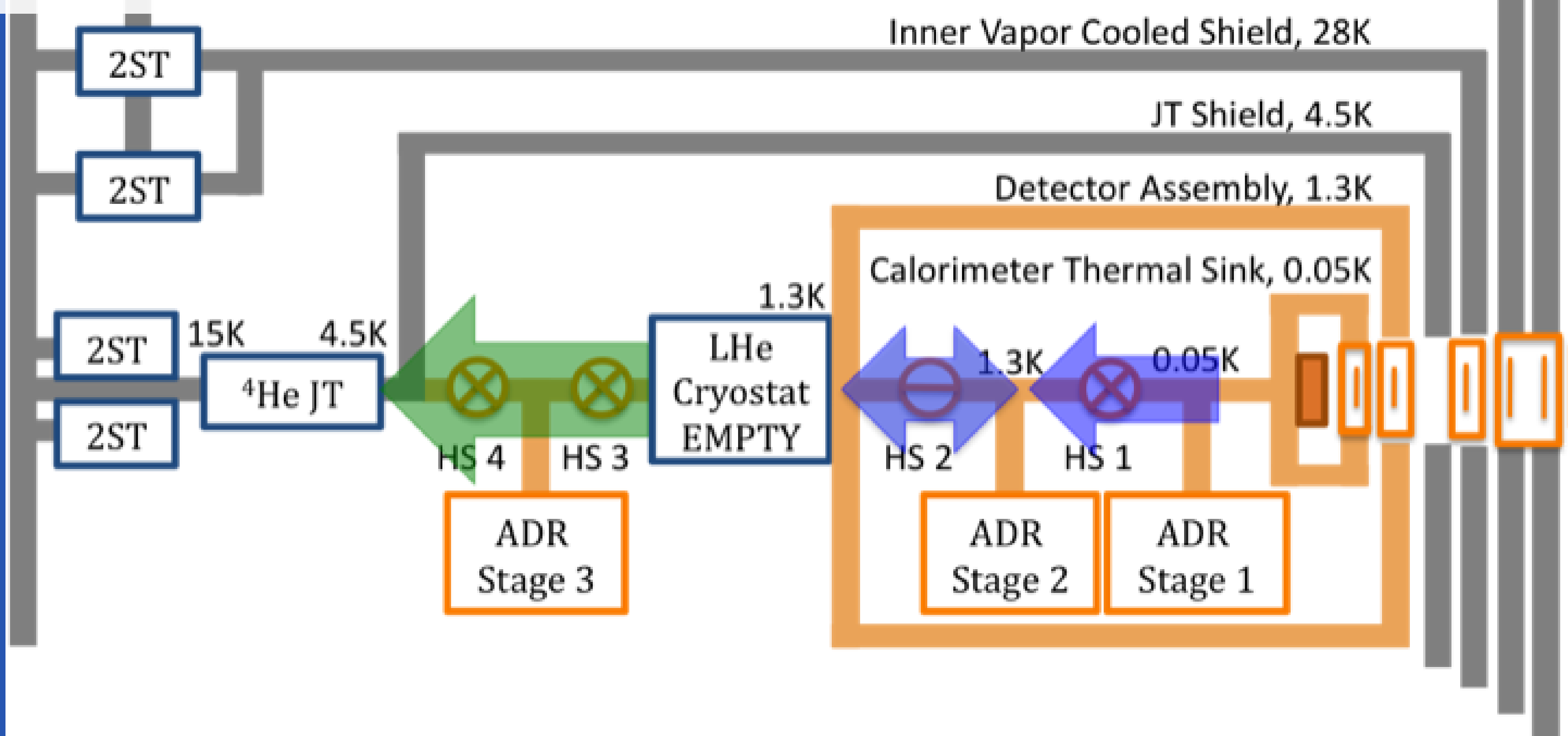
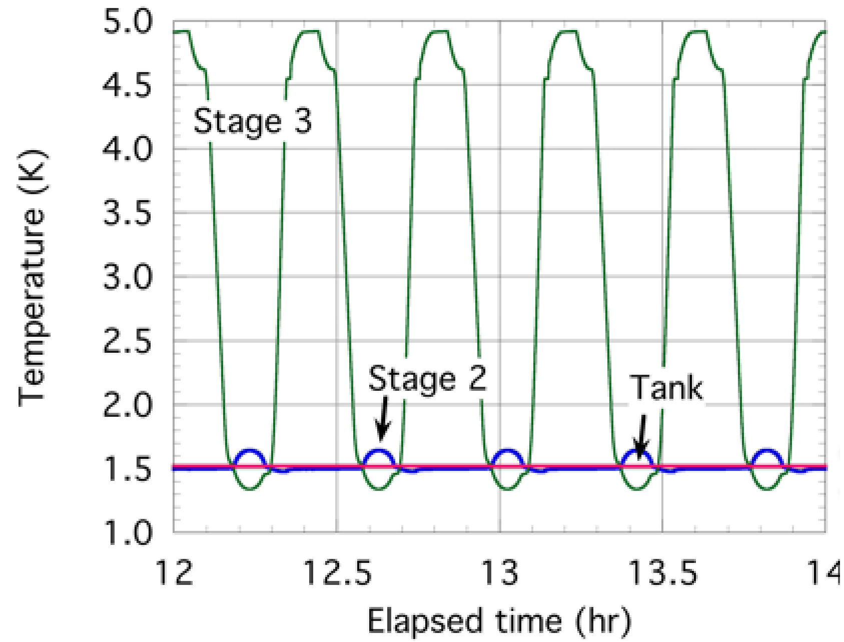
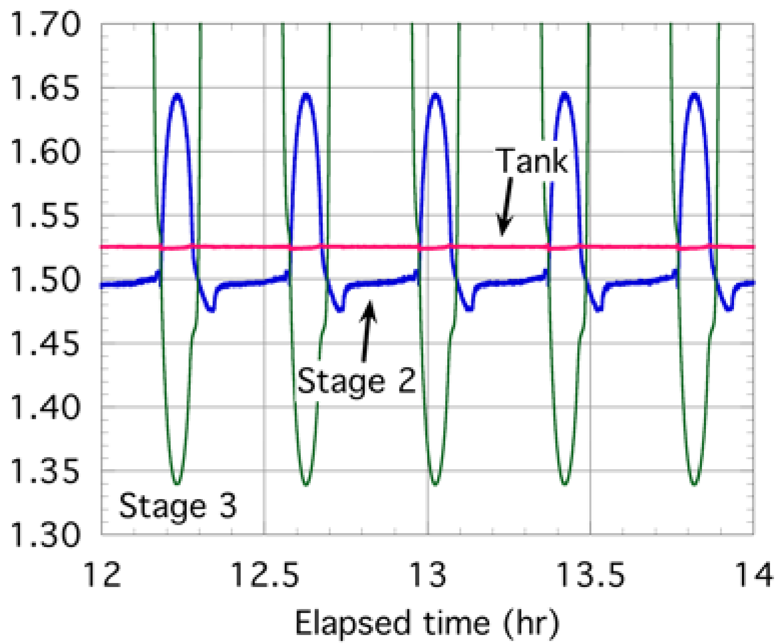


Continuous ADR Cooling

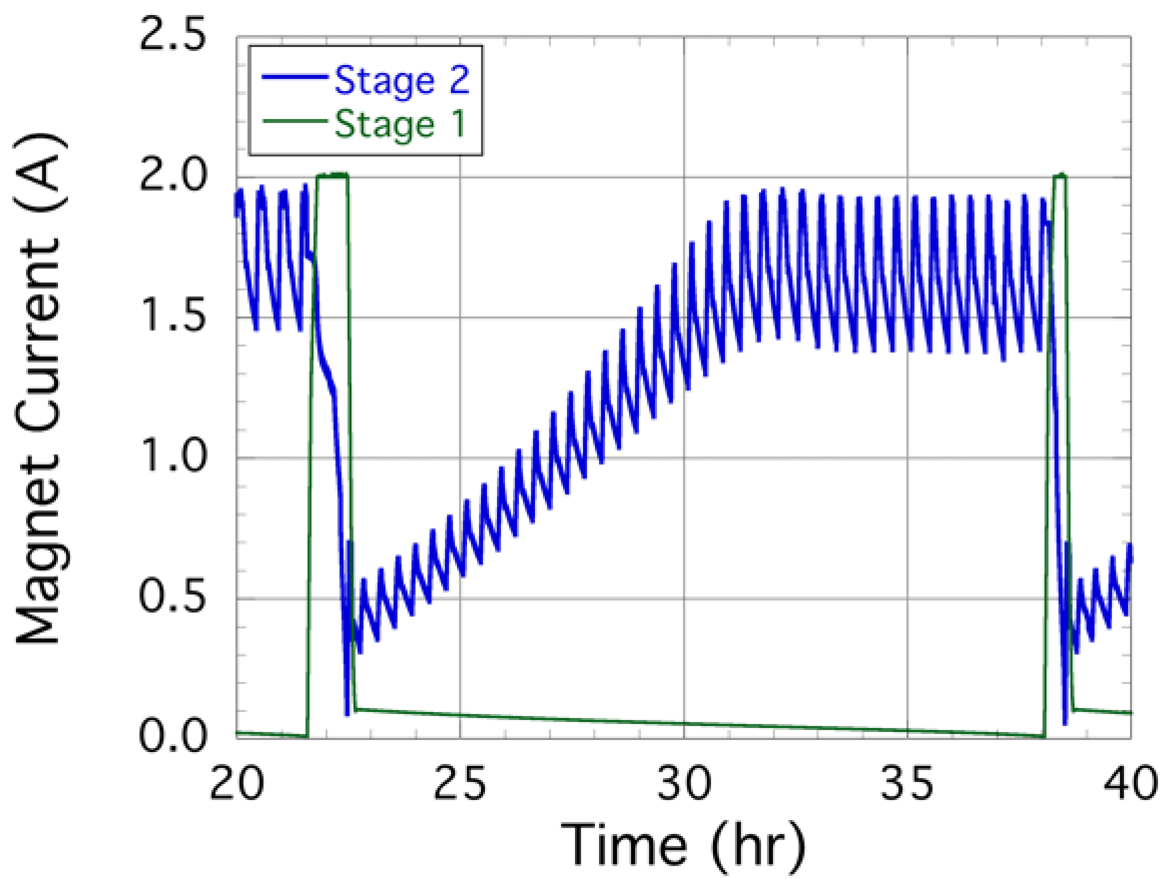
- Stages 2 and 3 operate together as a continuous ADR to cool the helium tank





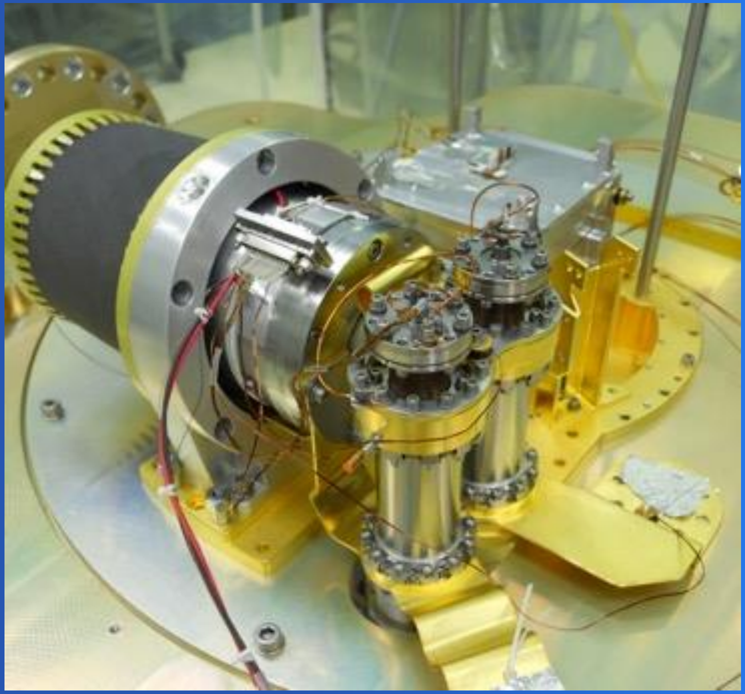
Full Cycle with He tank at 1.525 K

- S1 is automatically recycled when current falls below 10 mA
- 45 minute recycle
- 15.0 hour hold
- >94% observing efficiency



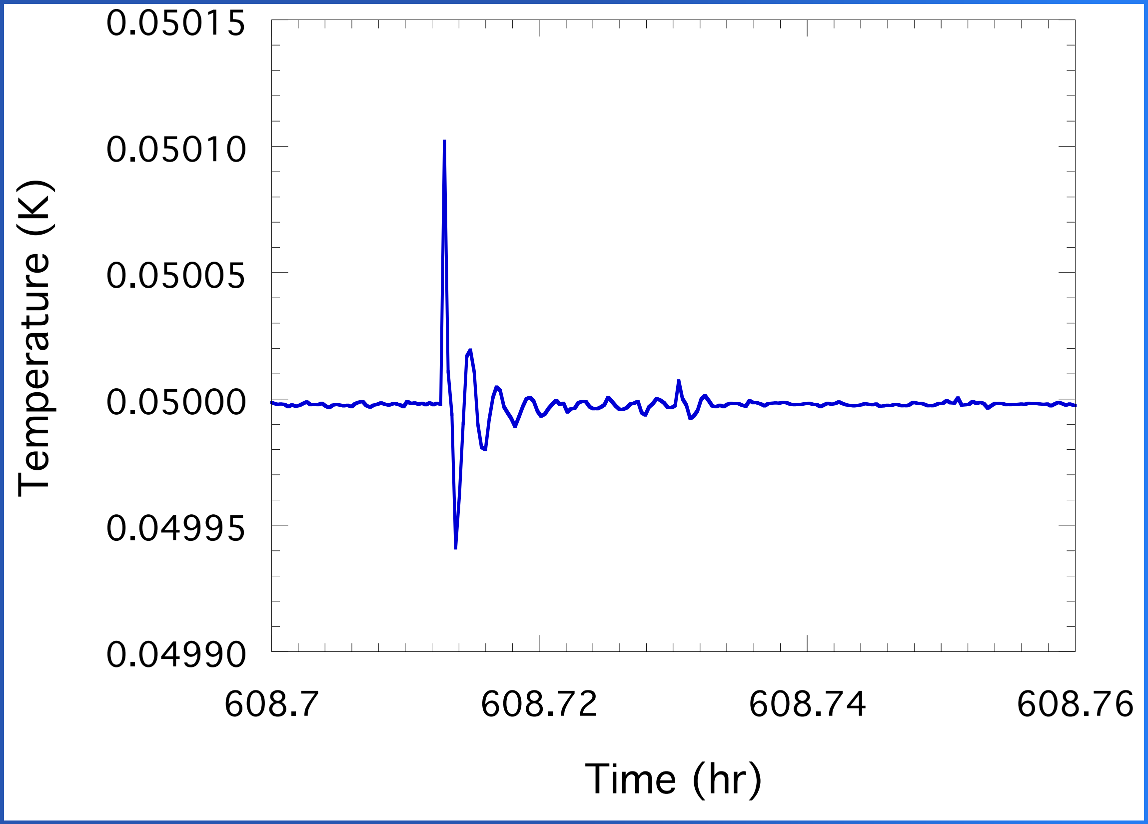
Changes for Resolve

- Increase magnetic shielding of ADR Stage 3
  - Interactions between the detector array and the stage required limiting its current to 1.75 A, which reduced the ADR's cooling power
  - 1.5 mm increase in magnetic shield thickness (~200 grams) reduced fringing fields by an order of magnitude
  - Cryogen-free operation is (hopefully) improved by maintaining the helium tank at lower temperature



Changes for Resolve

- Reduce ADR controller response to cosmic ray events
  - Suppress response to a reading outside a narrow band at 50 mK



Summary

- XRISM received final approval for funding by JAXA in mid-2018
  - Launch is currently scheduled for early 2022
- The Resolve instrument is essentially a built-to-print copy of SXS
  - Limited number of changes based on experience with ground and on-orbit performance
  - Challenge: SXS was not fully demonstrated on orbit
    - Gate valve was not opened to expose the detectors to full energy range of x-rays
    - Long-term performance (cryocoolers, progressively smaller LHe volume)
    - Environmental effects: micrometeoroid damage, residual helium