# First Engineering Results from the Maiden Flight of the Micro-X Sounding Rocket

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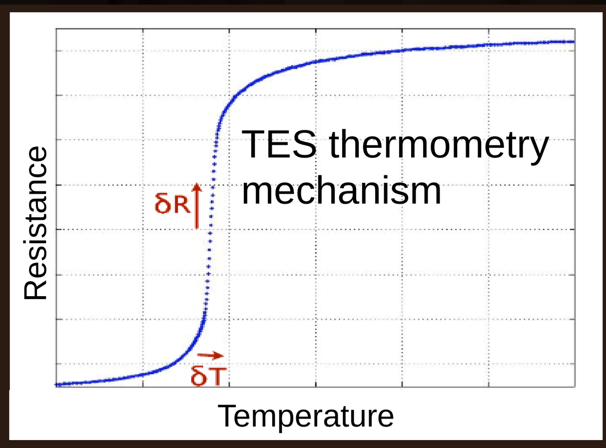
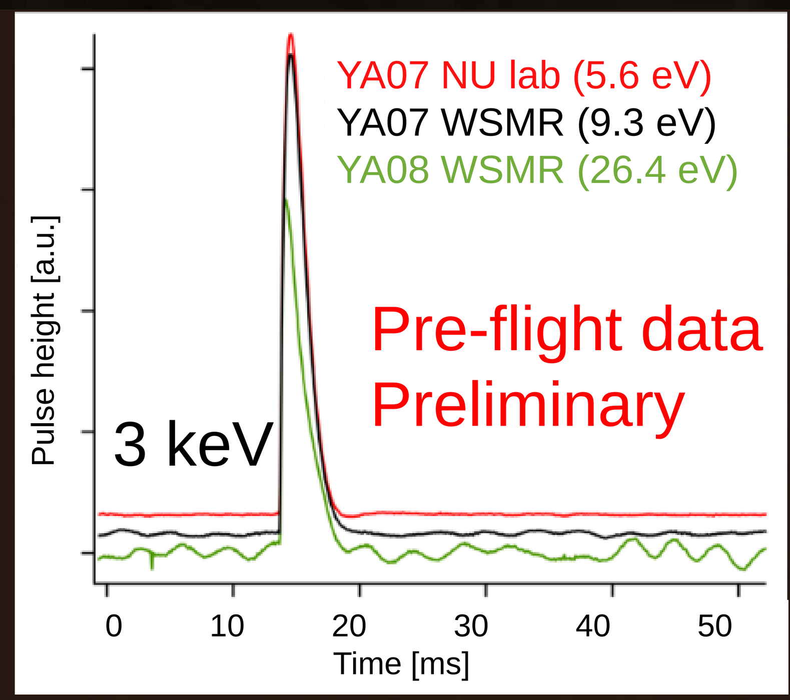
## 1st space flight of TES detectors

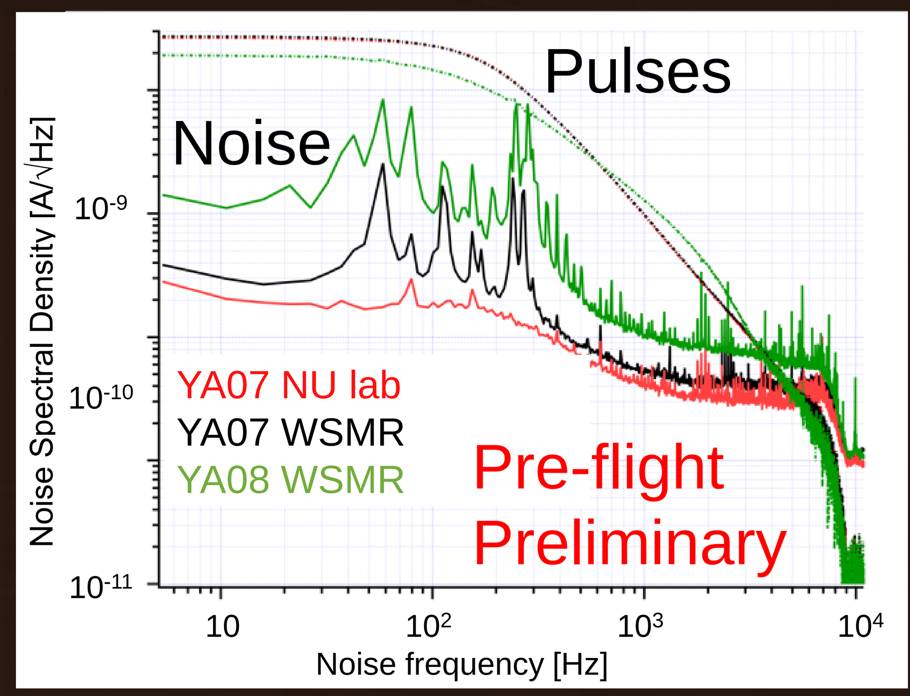
Micro-X launched on July 22, 2018 from the White Sands Missile Range (WSMR) in New Mexico. This was the first space flight of Transition-Edge Sensors (TES) and their Superconducting Quantum Interference Device (SQUID) multiplexer readouts.




TESs are the thermometer component of the larger microcalorimeter detectors; incident X-rays heat up an absorber whose temperature is read out by the TES. They achieve excellent energy resolution by maintaining a superconductor in its superconducting transition, where a small change in temperature yields a large changes in resistance. State-of-the-art TESs can resolve a 6 keV X-ray to down to 2 eV resolution, compared to ~100 eV in CCDs.

## Detector Performance

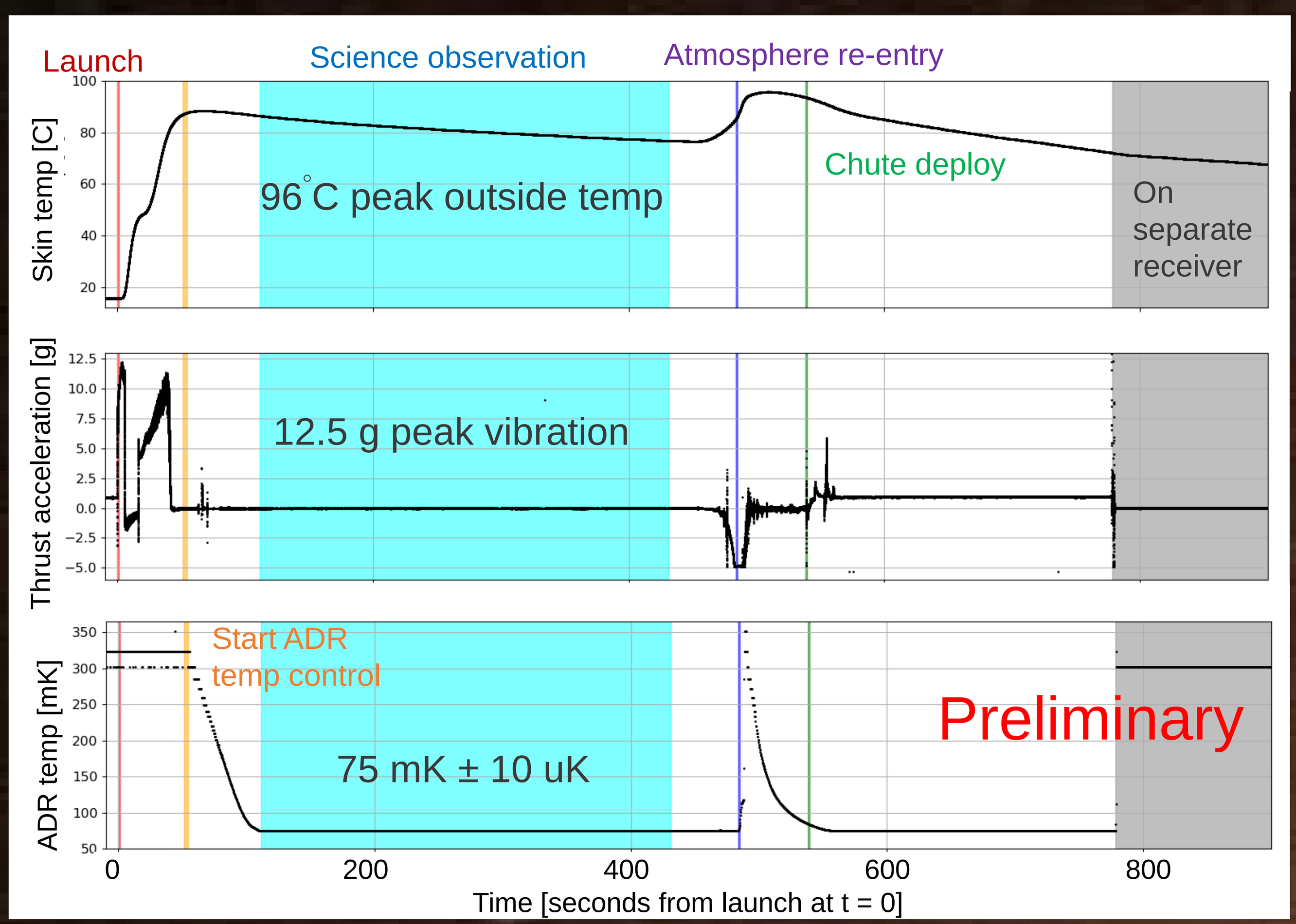


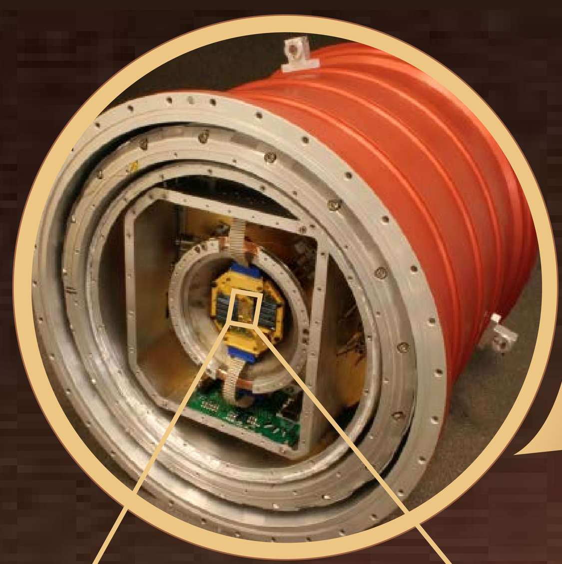



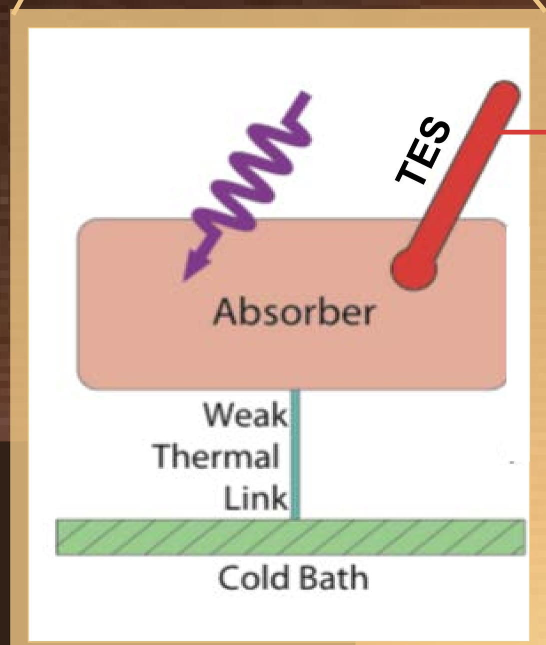

Micro-X has a 128-pixel TES array, with each pixel spanning 600 um x 600 um. The array uses Au/Bi absorbers with Mo/Au TESs and is sensitive to the 0.2 – 3 keV region of interest. Of the 128 pixels, 117 were operational at launch. Over 90% of pixels achieved an integrated NEP (resolution metric) less than 10 eV at 3 keV in individual lab testing with flight electronics. Integrating into the rocket introduced noise that varies in amplitude across pixels but is largely correlated between them. This led to degraded resolution between lab and pre-flight calibration measurements at WSMR on a number of pixels; mitigating this effect is an ongoing effort.

## Cold Cryogenics on a Hot Rocket

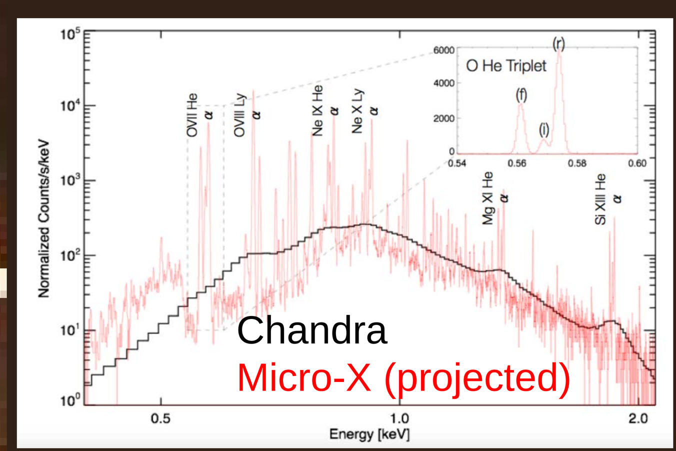
TESs require a stable, cryogenic operating temperature, which presents an engineering challenge on a sounding rocket. Micro-X uses an Adiabatic Demagnetization Refrigerator (ADR) to maintain temperature; it is vibration-isolated to minimize heating during the large launch vibrations. After passing through these vibrations, the on-board ADR controller keeps the detectors at a stable 75 mK +/- 10 uK during the science observation.






## Micro-X Science




Micro-X has established TESs as a viable type of flight detector for X-ray astrophysics. Micro-X has a unique combination of energy resolution and imaging to map extended X-ray sources.

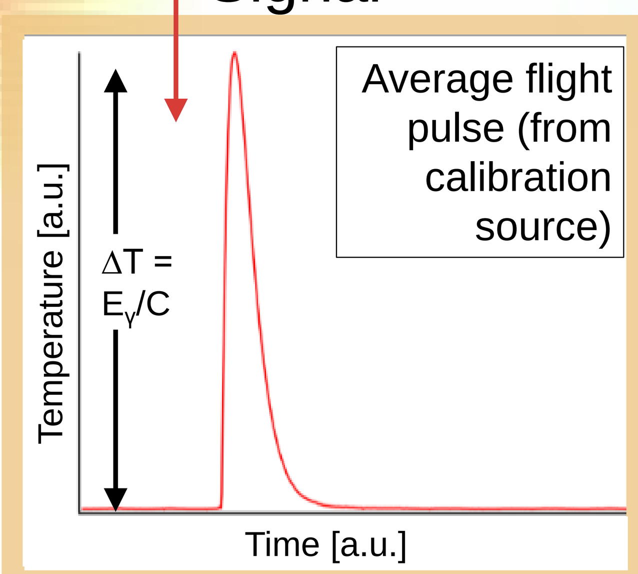
A rocket pointing error led to minimal time on target, but the instrument behaved as designed, and data from this flight will be used for background flux limits and as calibration data in preparation for future flights. Reflights will be proposed to observe Supernova Remnants (SNR) and BSM interactions, like those proposed from keV-scale sterile neutrinos. The SNR flight will map emission lines and study plasma diagnostics, dynamics, and nucleosynthesis models.

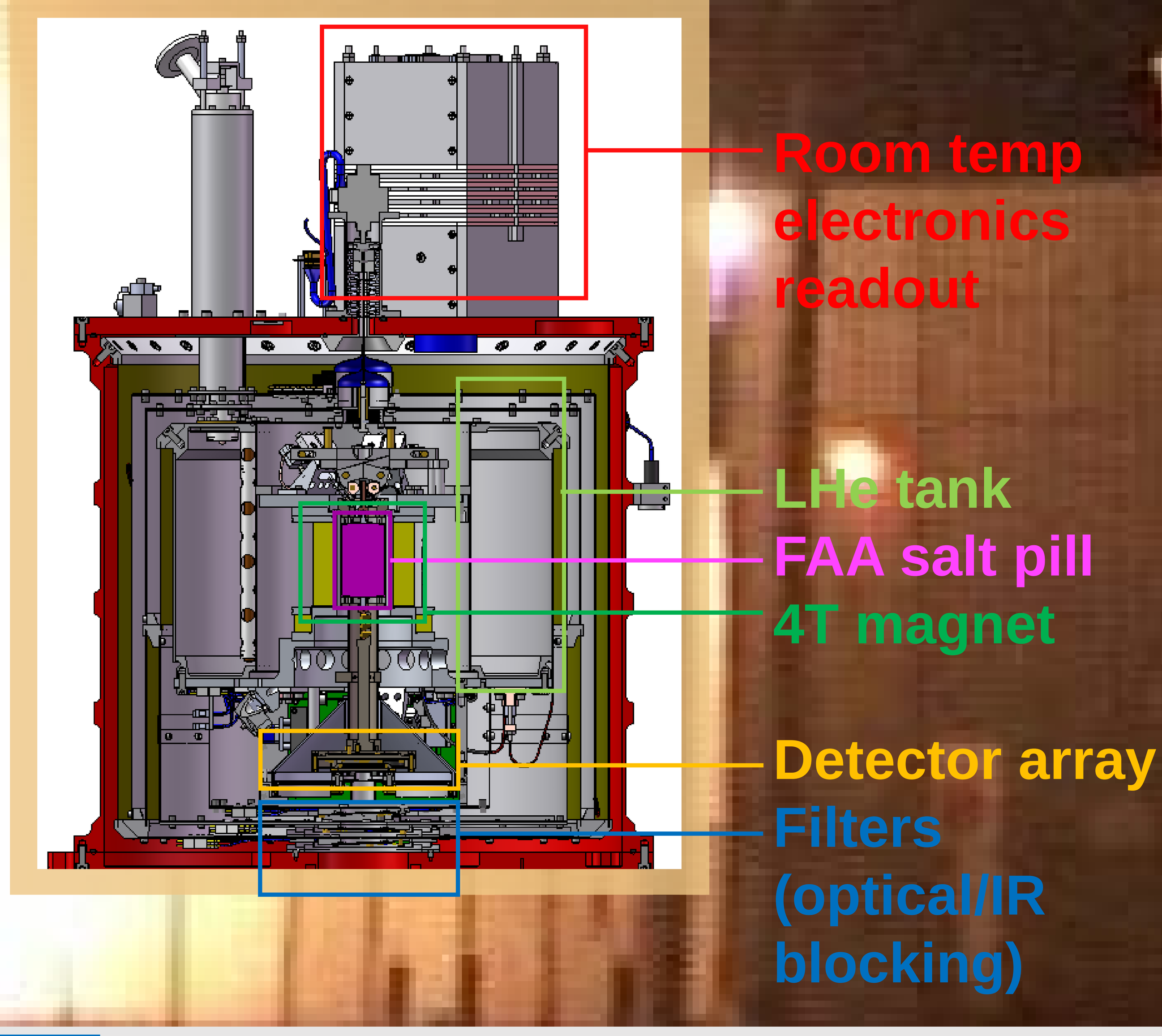
## Following an X-ray in Micro-X

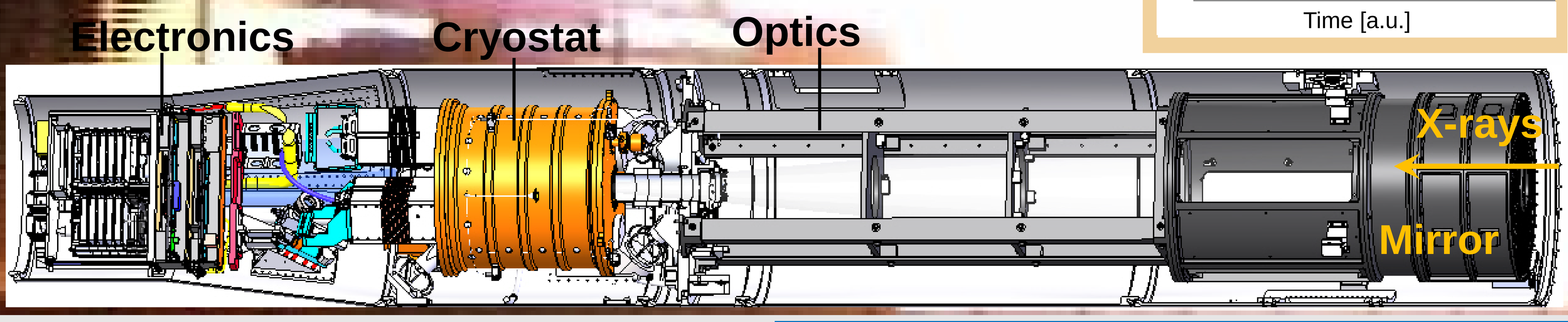
Incident X-rays are focused by an X-ray mirror (11' FOV, 2.5' HPD, 2.5 m focal length) onto the detector array. Magnetic brooms reject charged particles while thin filters reject optical and infrared photons. An on-board calibration source (KCl fluoresced by $^{55}$Fe) tracks the detector gain in flight, and timers open and close valves to protect the instrument during launch before allowing X-rays in.

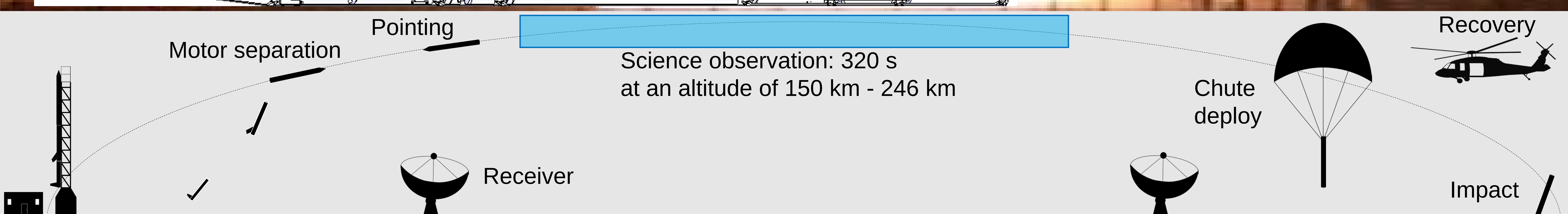
Micro-X flew a time-division multiplexing SQUID readout for the first time in space. The SQUID chain amplifies the TES signal and transmits it to room-temperature electronics while minimizing thermal noise to the cryogenic stages. The room temperature electronics set the SQUID parameters and package the data. All data is recorded on-board, and a subset (30%) is transmitted in real time in case the payload is destroyed. On-board data was recovered, and the full dataset is being analyzed.

Signal

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