TES Bolometer Development for SAFARI

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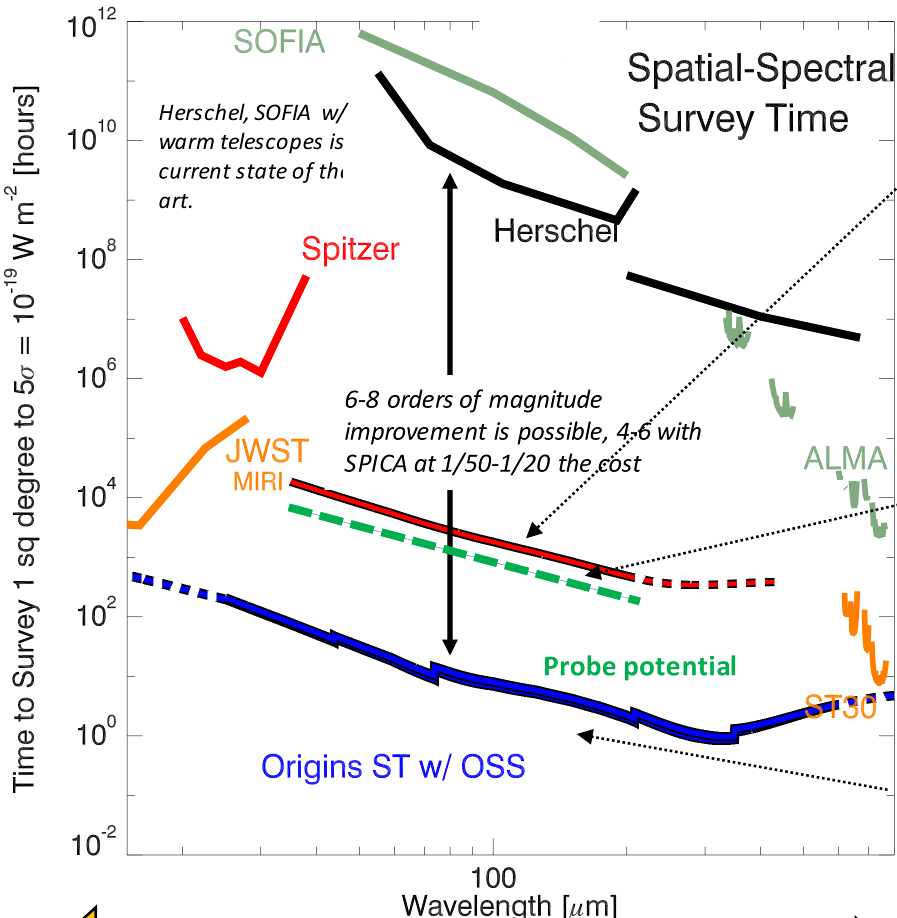
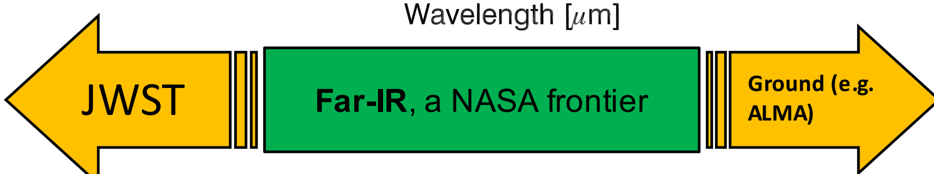
Far-IR astrophysics is a final frontier in the electromagnetic spectrum, but requires ultrasensitive direct detectors.

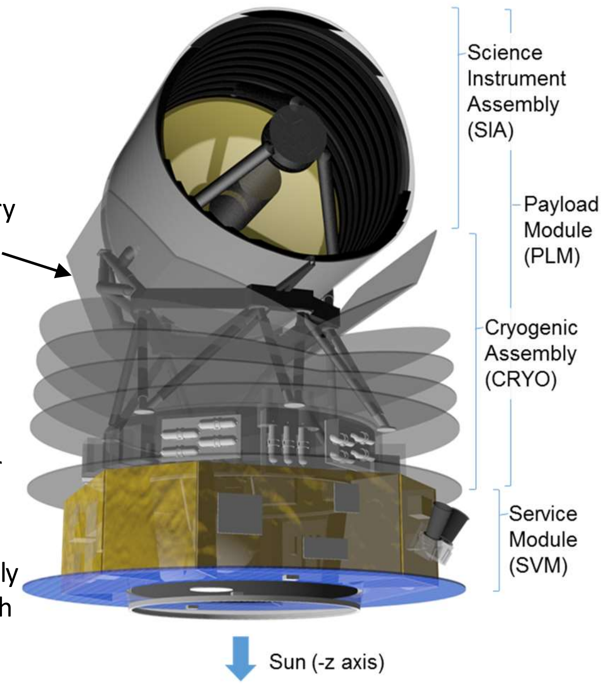
Time required for new spectroscopic discoveries in the far-IR (lower is faster)





- # SPICA

Now in phase-A at ESA – a candidate for Cosmic Visions M5. 2.5m cooled observatory w/ potential JPL provision of far-IR detectors. Launch in 2030.



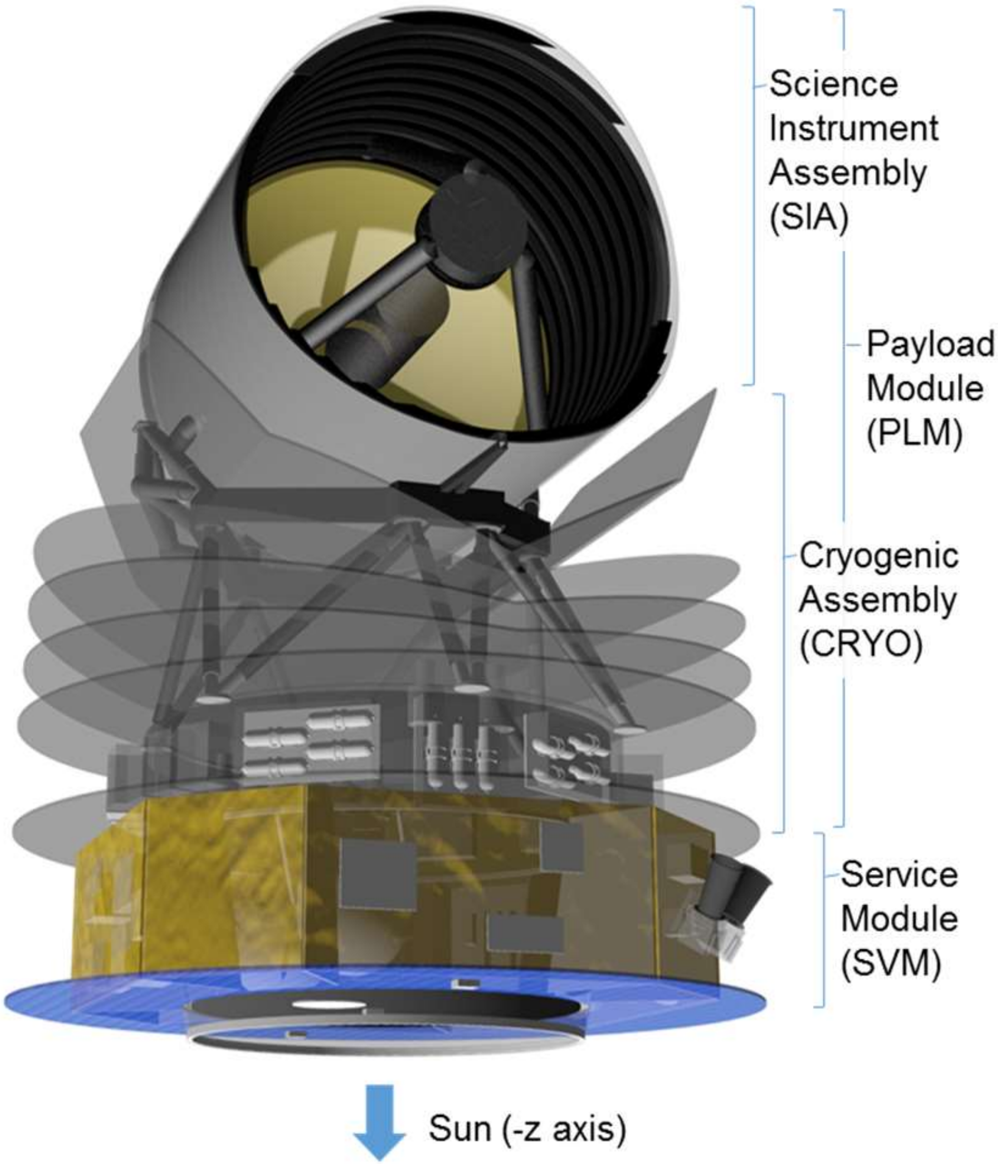
- # GEP

Galaxy Evolution Probe. Under study @ JPL for submission to Decadal. 2.0 m telescope. Similar to SPICA, but potentially more capable for mapping with long-slit spectrometers

- # Origins

Origins Space Telescope -- Far-IR flagship under study for NASA submission to 2020 Decadal. Key tall pole is detectors. JPL technology and science experience positions us for instrument and/or mission leadership. Start 2020s, launch 2030s.

SPICA



- ESA / JAXA collaboration, 2032 launch.
  - In phase-A study at ESA now.
  - JAXA commitment in place.
- 2.5 meter telescope actively cooled to below 8 K
  - Sumitomo closed cycle 4.5K, 1.7K coolers
  - Planck-like thermal design.
- **European-led SAFARI multi-purpose far-IR spectrometer with US contribution.**
- Wide-field mid-IR instrument which complements JWST (JAXA).

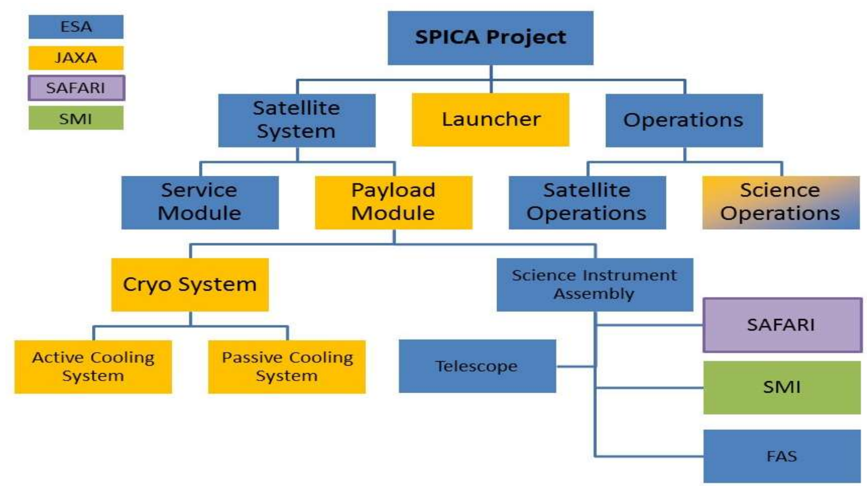
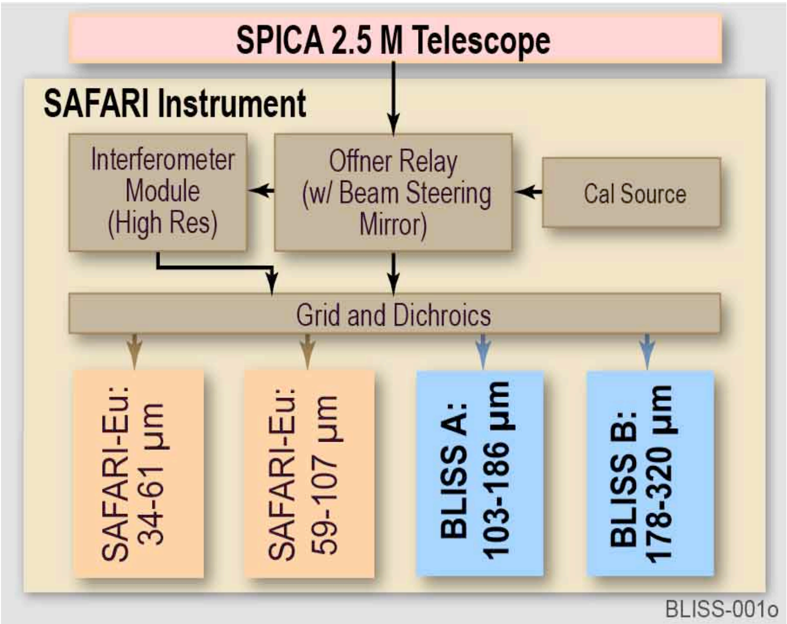
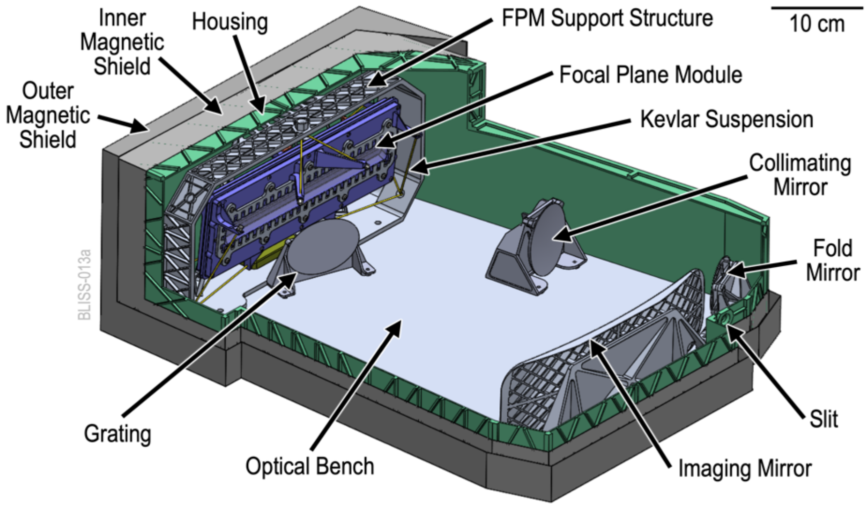


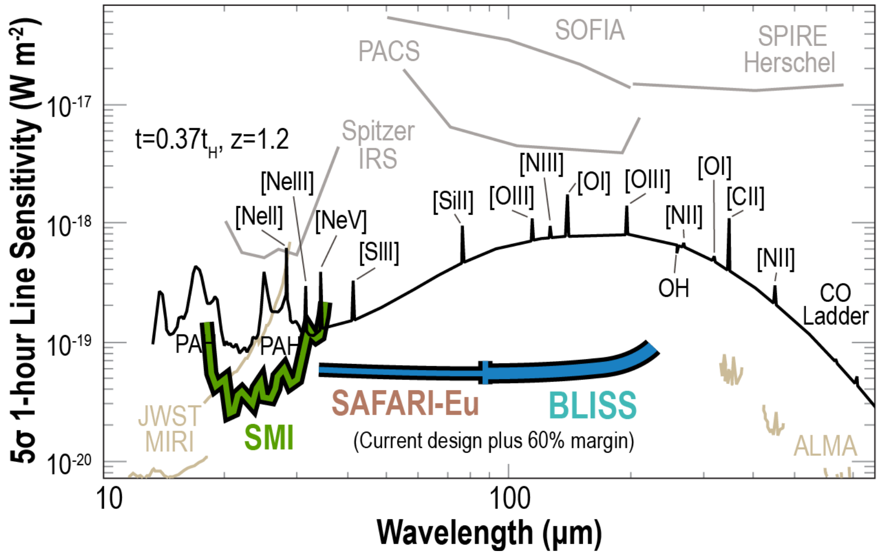
Figure 5-1 Baseline plan for the distribution of responsibilities over the major project partners

US Contribution 'BLISS' =
Two Grating Detector Modules for SAFARI/SPEC

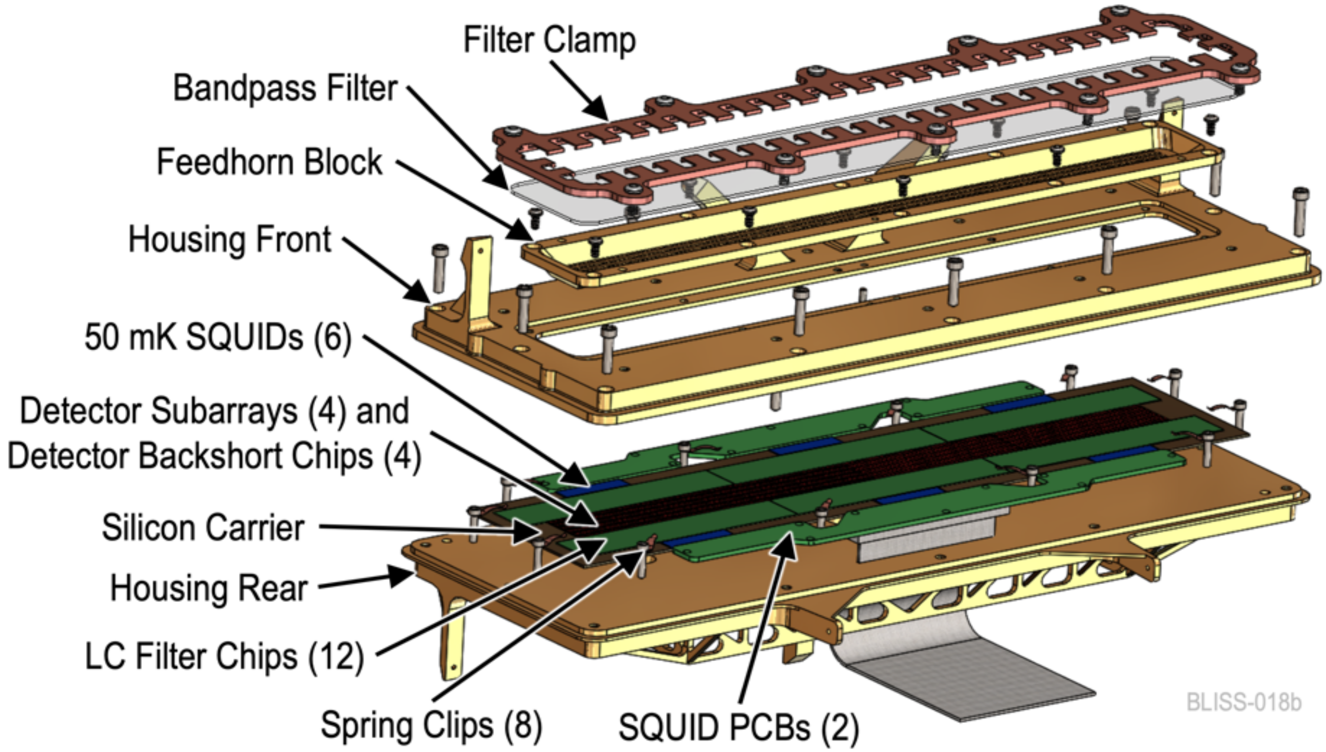


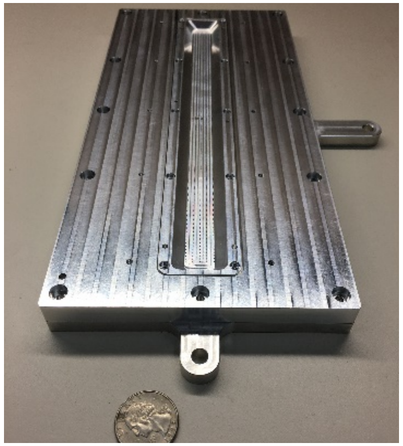


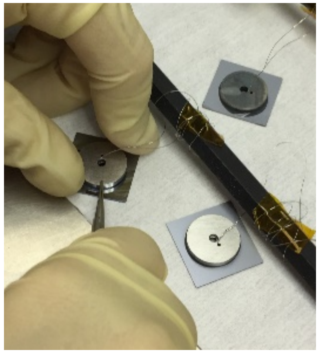
- SAFARI/SPEC is a suite of four grating spectrometer modules which combine to cover the full wavelength range instantaneously.
- US builds two of the four wideband grating modules, including TES detector arrays.
  - SRON supplies (passive) cold multiplexer elements.



BLISS FPA Concept

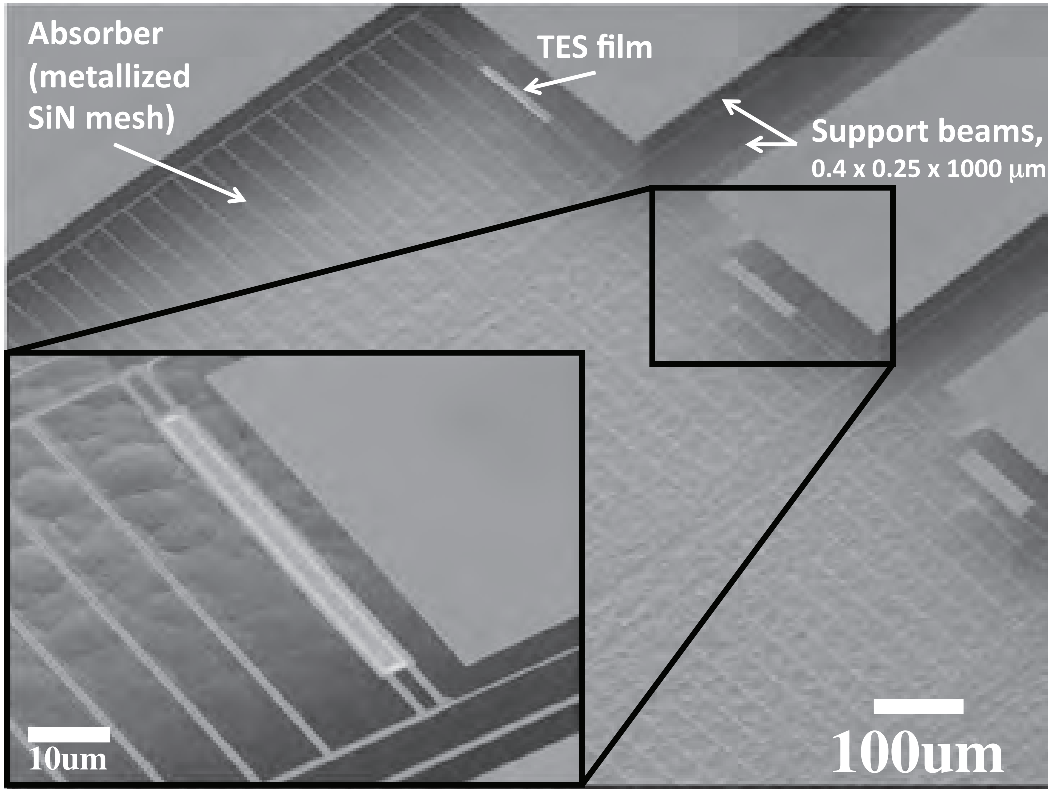


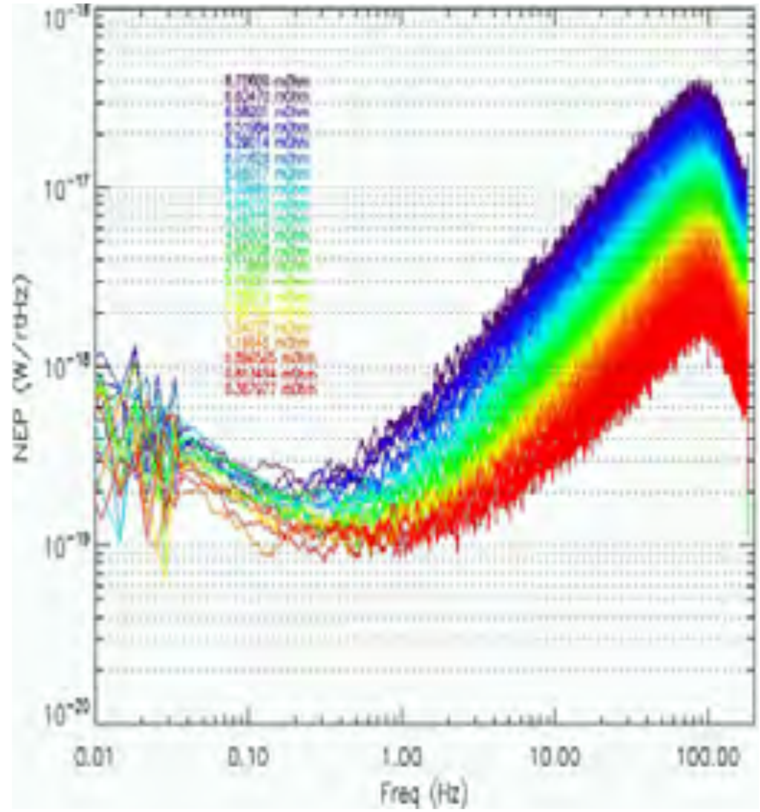




Silicon detector subarrays are bonded to silicon backshort chips, which are then bonded to a silicon carrier wafer to which the silicon LC chips and silicon 50 mK SQUID amplifiers (components of the multiplexing system) are also mounted. The entire silicon assembly is then epoxied to the aluminum FPM housing backplate with a molybdenum plug. Two additional Mo plugs on the backside of the wafer assembly fit into slots in the backplate to provide a rotational constraint while allowing for thermal expansion mismatch between Si and Al. Beryllium-copper spring clips around the periphery of the silicon assembly hold down its edges to prevent motion under launch loads. A pair of printed circuit boards (PCBs) containing the bias resistors, RF filtering, and connectors is also attached to the housing backplate and wirebonded to the wafer assembly.

Historical JPL low-NEP measurements

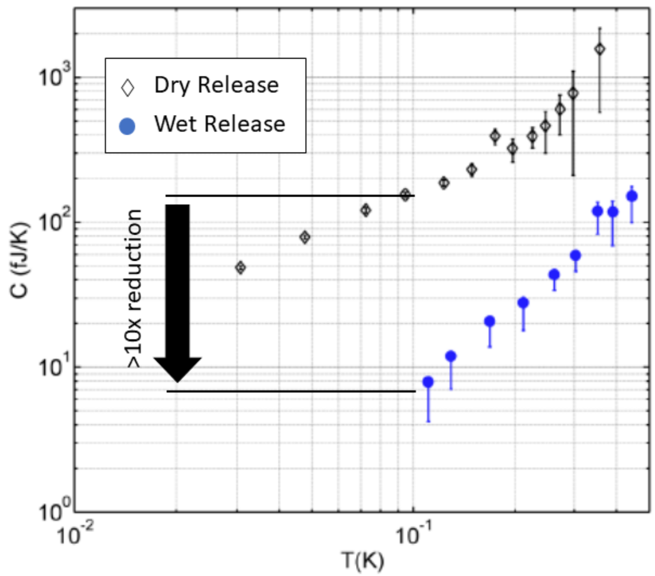


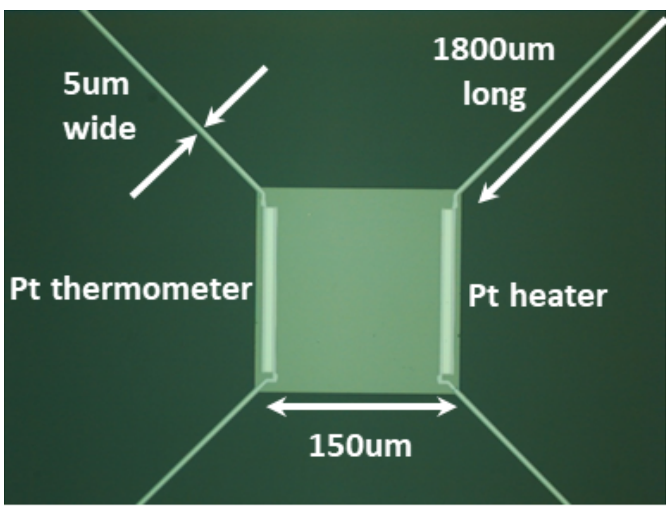


- SiN micromesh structure with 1 mm legs (Beyer el at, 2011)
- MoCu Thermistor
- NIST TDM SQUID MUX
- Measured NEP below 1 x 10^{-19} W/$\sqrt{Hz}$, but device is slow – we believe due to XeF2 etch creating excess surface states.

A. Beyer

Heat capacity Improvement with Wet release

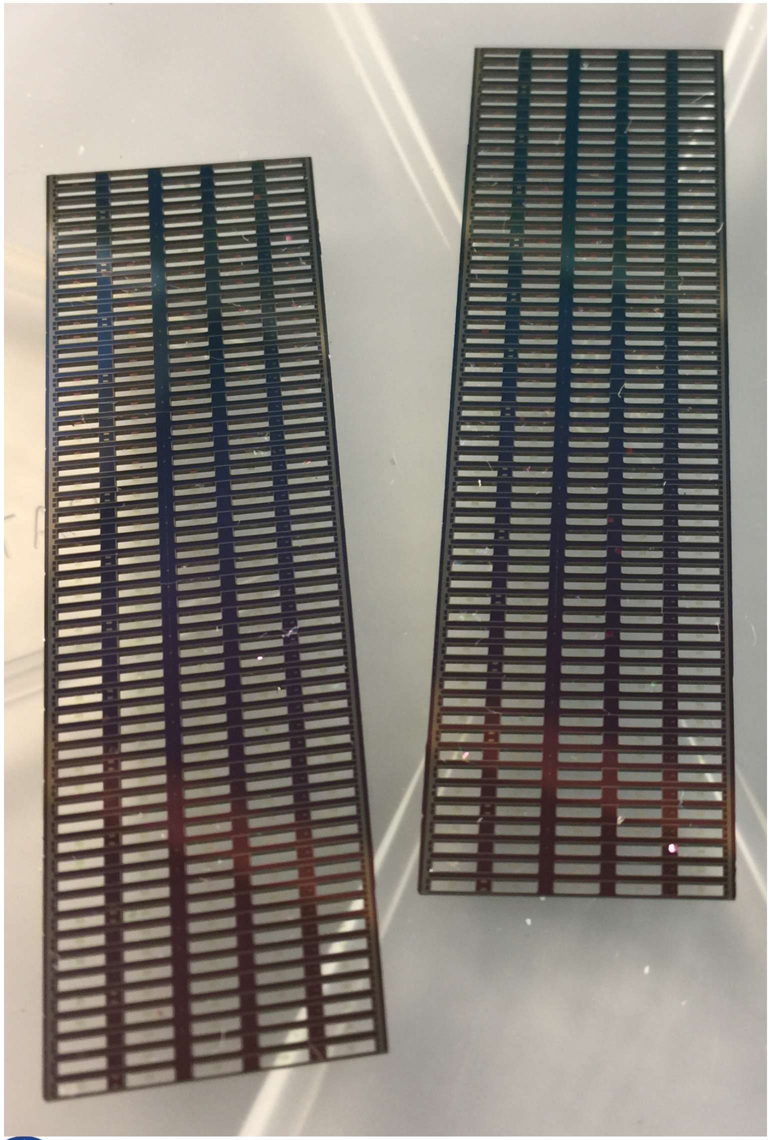


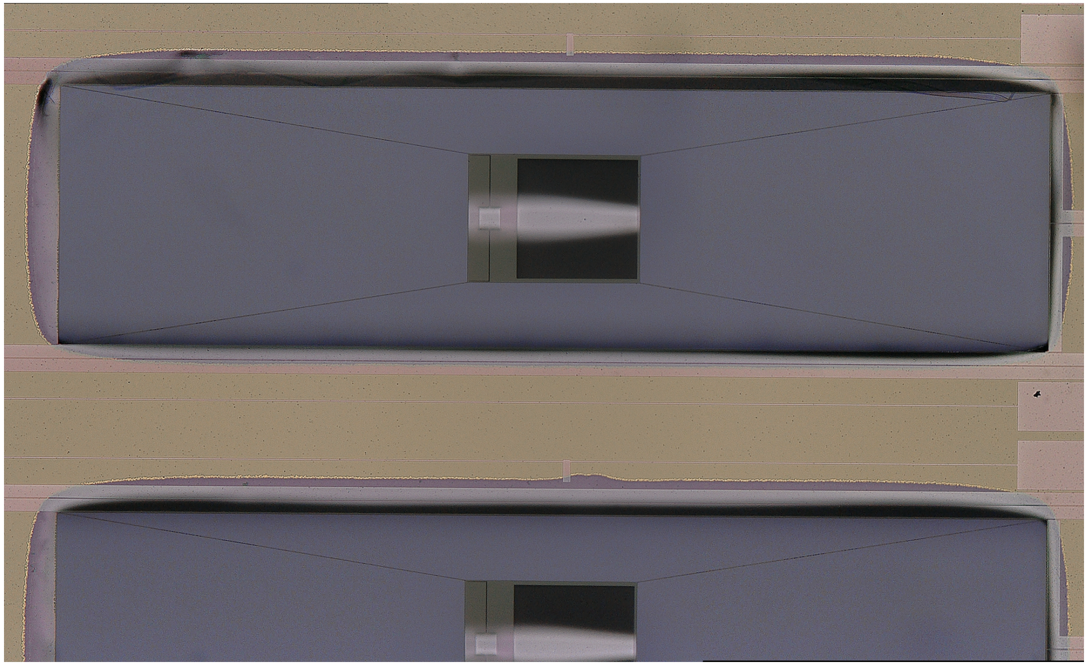


Source	Team Member	Process	Bilayer (nm/nm)	C_{tot} (fJ/K)	$C_{bilayer}$ (fJ/K)	C_{Si-N} (fJ/K)	C_v (10^{-18} J/um^{3}K)
Ref. [1]	JPL	Wet Release	Ti/Pt (2/50)	15.3	9	6.3	0.40
Ref. [1]	JPL	Wet Release	Ti/Pt (2/50)	12	9	3	0.31
Ref. [1]	JPL	Dry Release	Ti/Pt (2/50)	155	9	146	4.3
Ref. [1]	JPL	Dry Release	Ti/Pt (2/50)	180	9	171	5.0
Not published	JPL	Dry Release	Ti/Pt (2/50)	132	9	131	3.7
Ref. [2]	SRON	Wet Release	Ti/Au (2/50)	-	-	-	0.38
Ref. [3]	SRON	Wet Release	Ti/Au (2/50)	-	-	-	0.26

M. Kenyon

Updates on US detector progress





Zoom in to show individual pixel.
Metallic elements (Ti Au TES and Ta absorber) following SRON

5x55 sub-arrays with suspension suitable for BLISS sensitivity. **Very good electrical & mechanical yield**

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New Wet-release JPL array for BLISS SAFARI

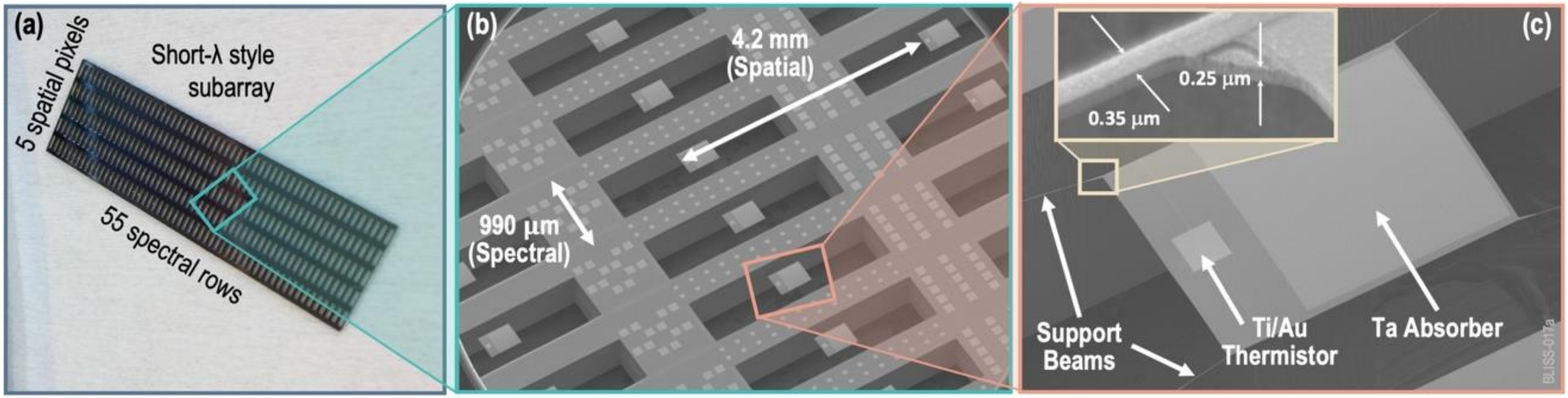
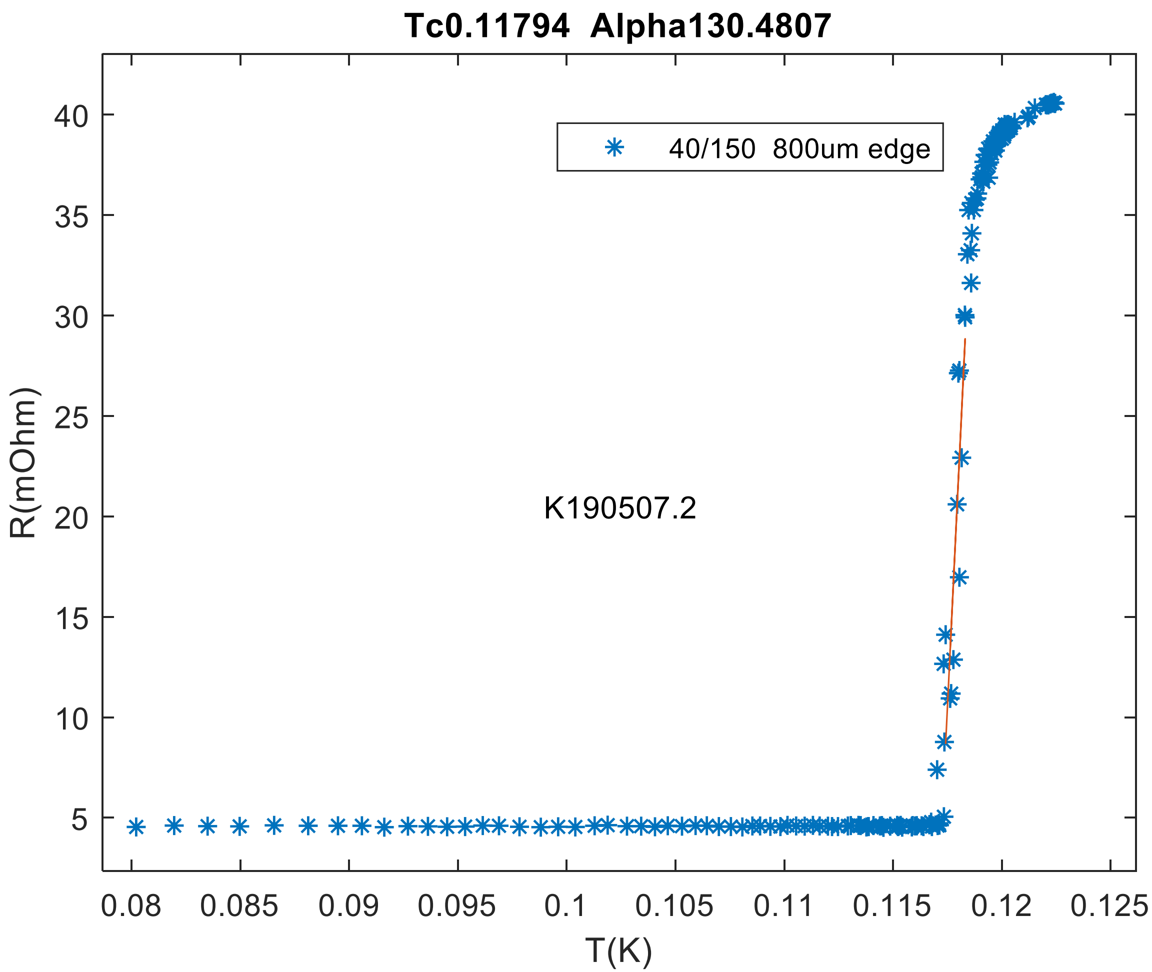


Figure E.1-6. (photograph a) Prototype 5 × 55 detector subarray with 94% pixel yield. (micrograph b) Prototype demonstrates design value spatial pixel pitch (4.2 mm) and a spectral pitch (0.99 mm) that is smaller (harder) than the 1.1 mm design value. (micrograph c) Bolometer design is identical for both GMs, all subarrays, and all pixels within a subarray. Four 0.35 µm wide × 0.25 µm thick × 2 mm long silicon nitride legs provide thermal isolation to a silicon nitride island. A 300 µm × 300 µm x 8 nm tantalum film couples to incoming radiation with low heat capacity. The thermistor is a superconducting 50 µm x 50 µm Ti(40 nm)/Au(150 nm) bilayer. The series titanium thermistor was not included in this prototype.

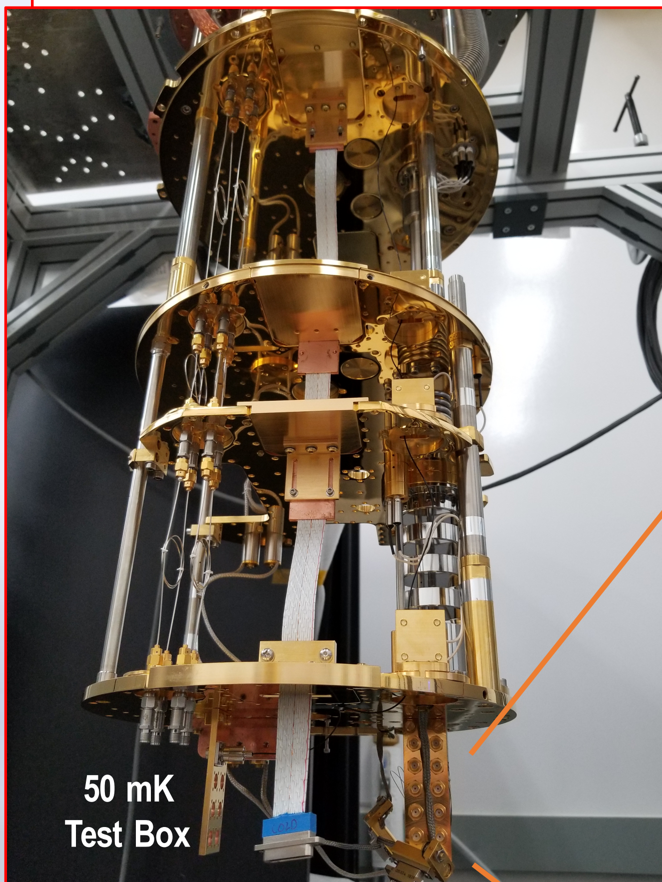
M. Kenyon

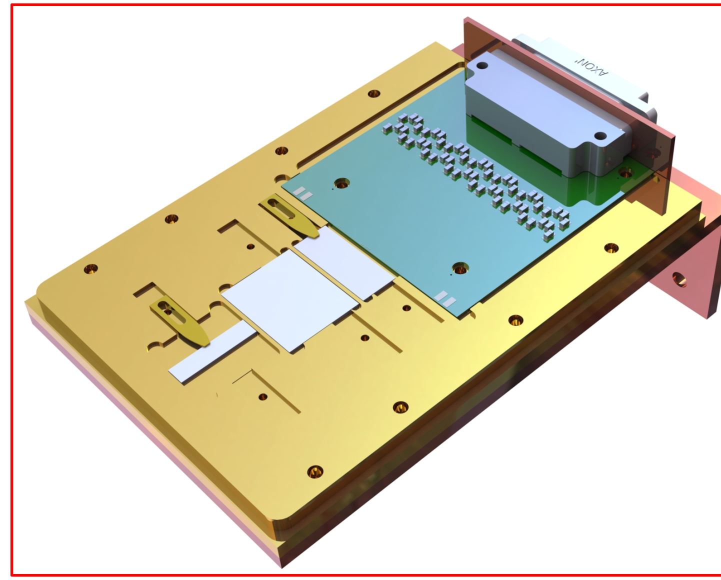
Titanium – gold Thermistors

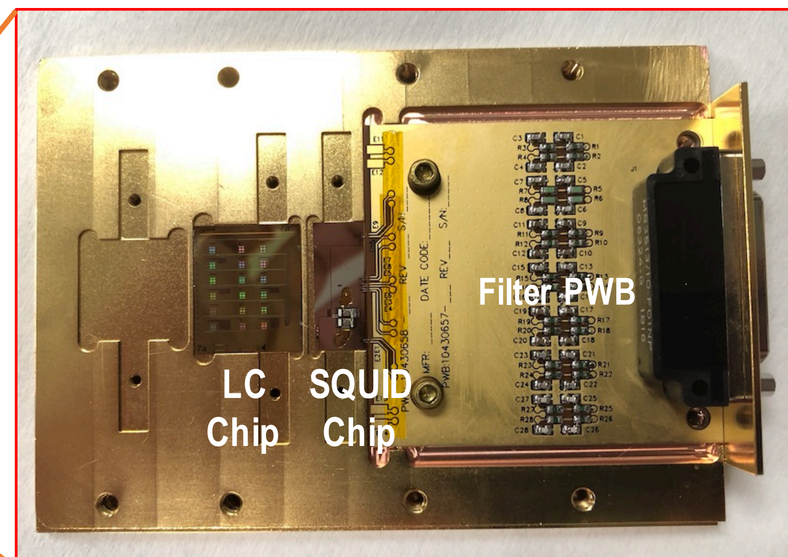


P. Echternach

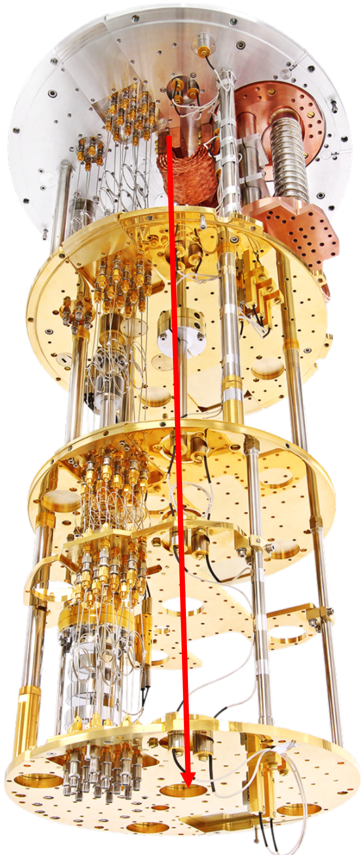
New JPL Testbed being commissioned.

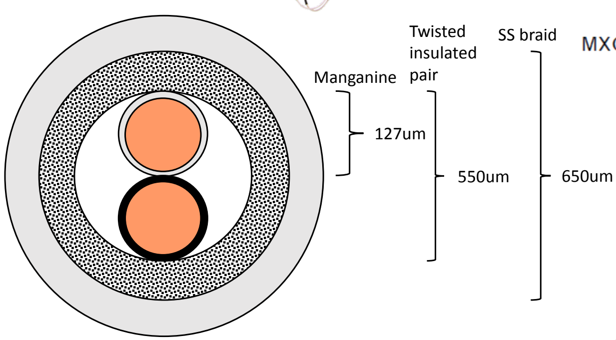


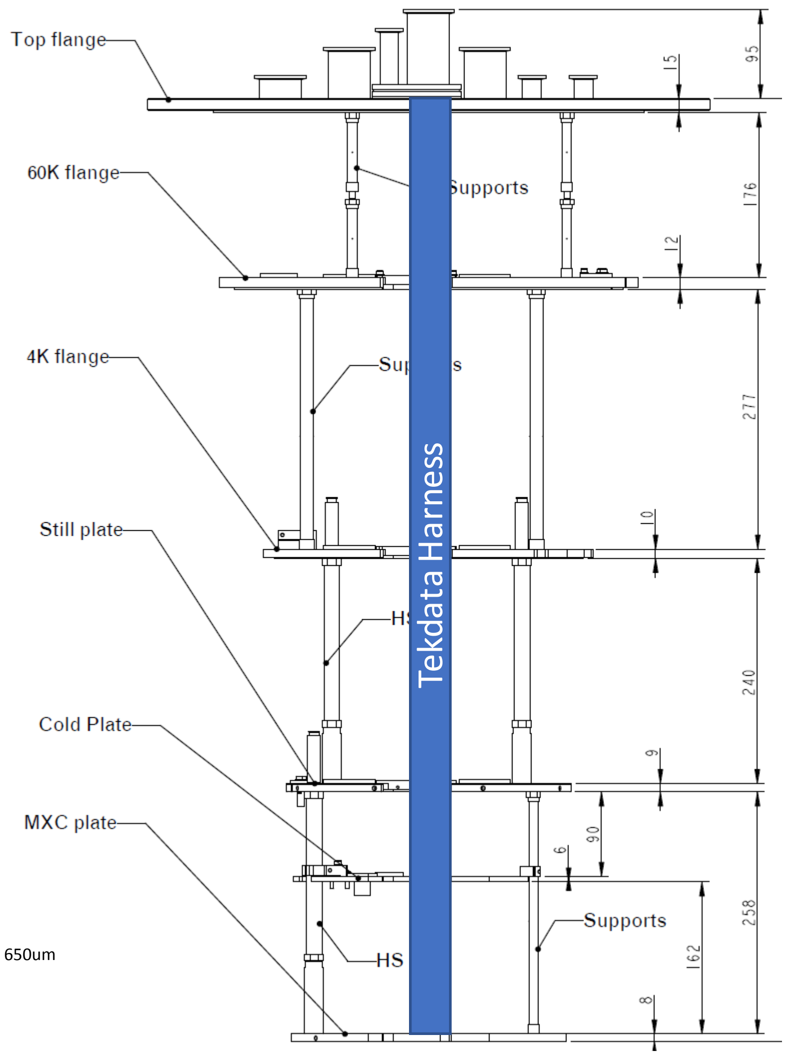




Wiring Harness – shielded twisted pair

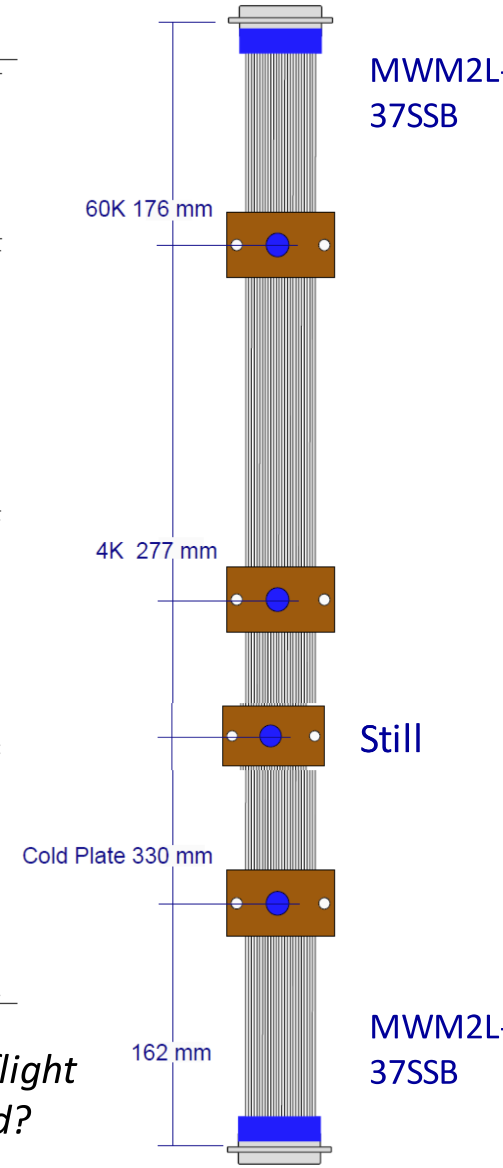




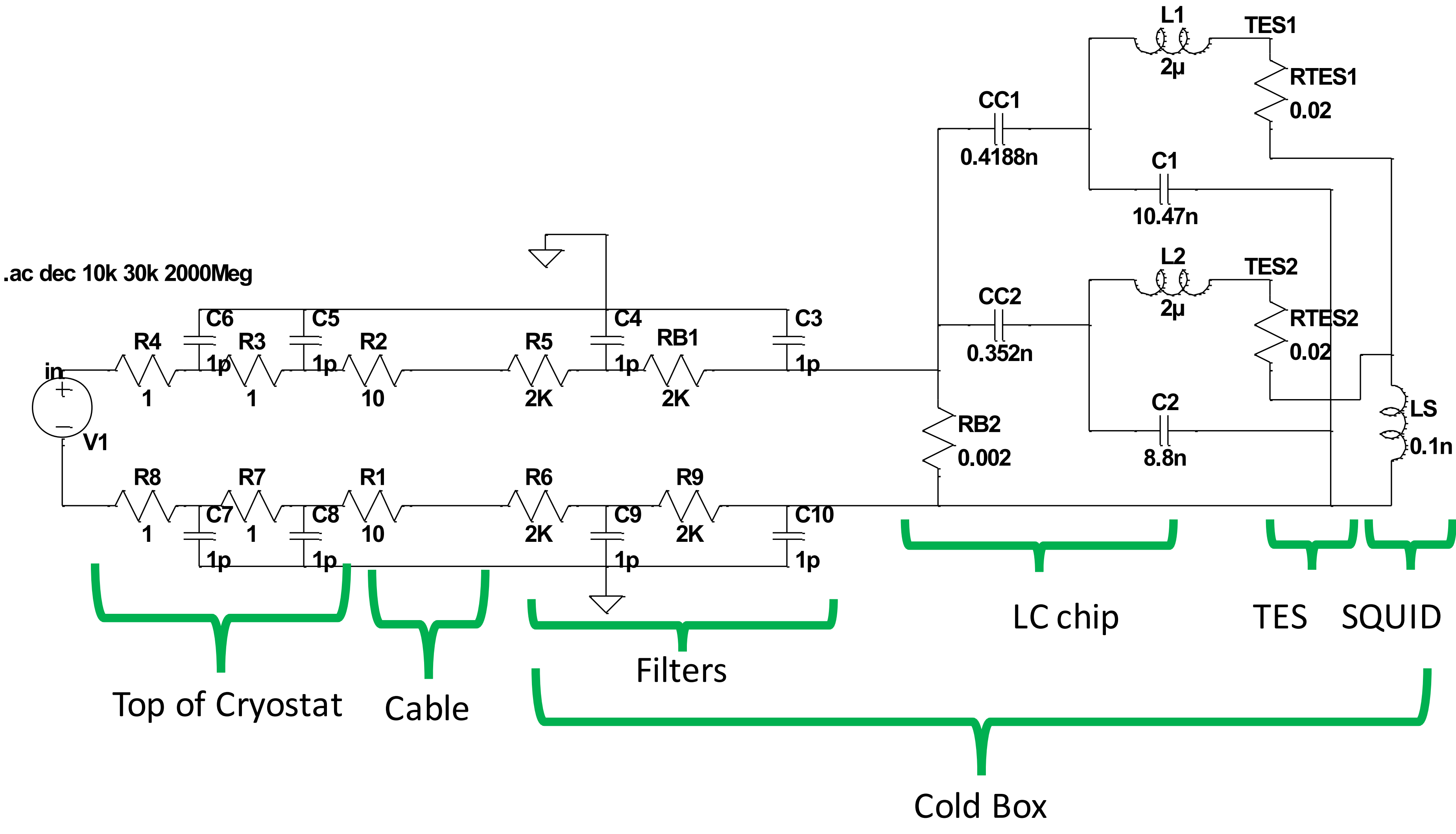


Shielded twisted pair would be ideal for flight instrument – can we handle the heat load?

Tekdata harness w/shielded twisted pairs



TES bias circuit modeled



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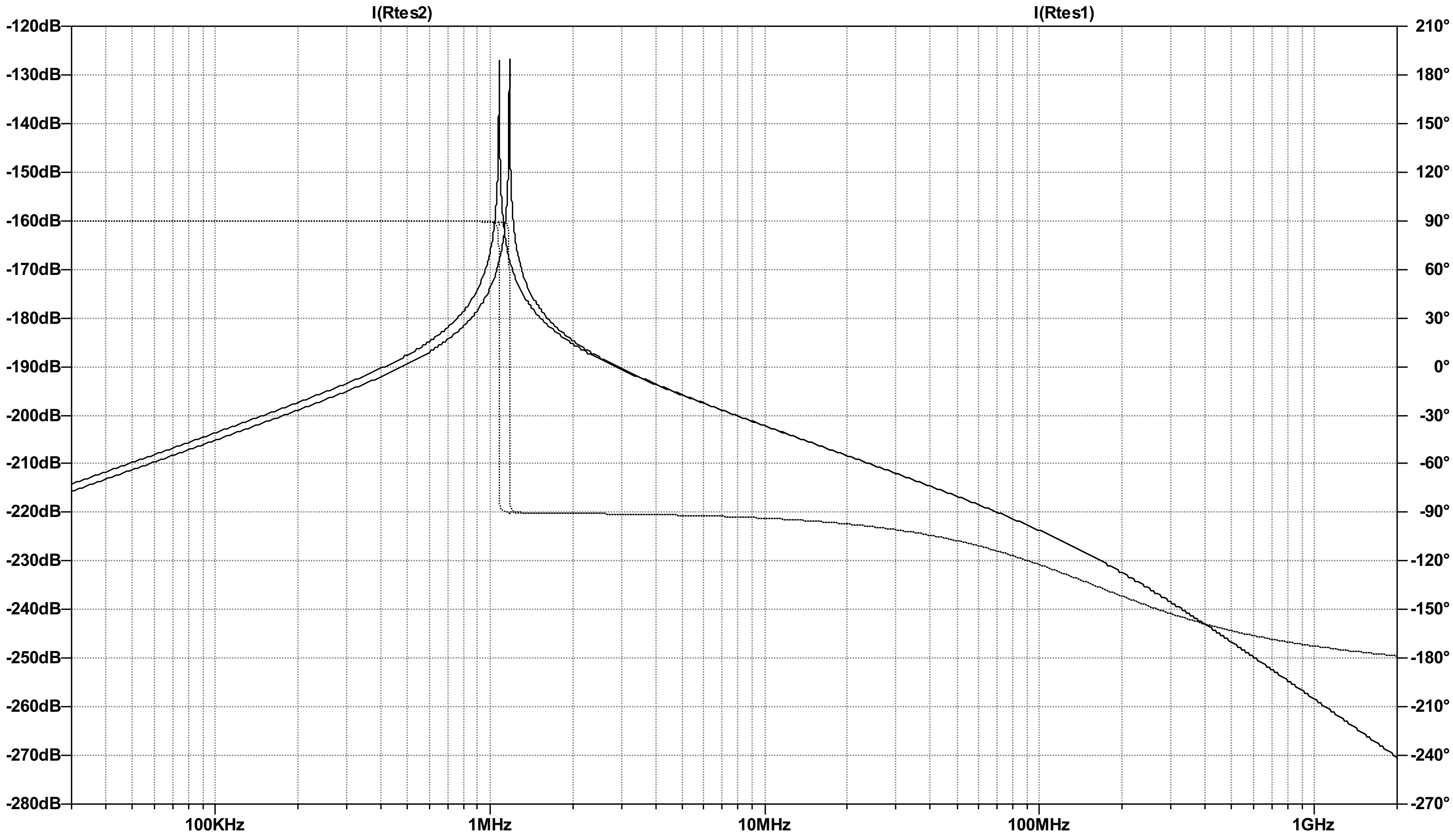

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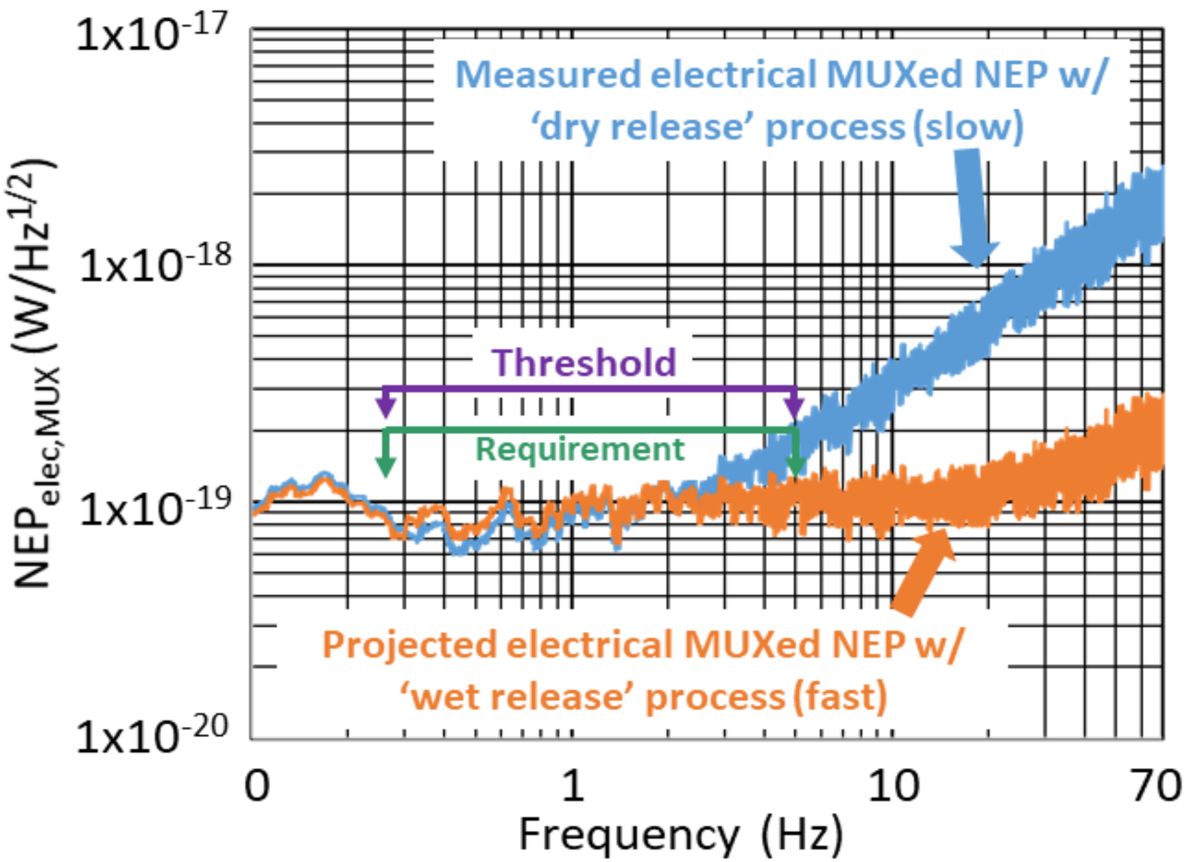
Anticipated device performance.



- Basic NEP already demonstrated
- Wet release process should improve speed by factor of 30.

Looking forward

- Demonstrate and integrate the SRON FDM readout system at 1-5 MHz
- Demonstrate dark NEP with Ti/Au 5x55 subarray
- Optical NEP demonstration
- Environmental testing (thermal, dynamics)
- Cosmic ray response