Thermal suspension of the X-IFU FPA

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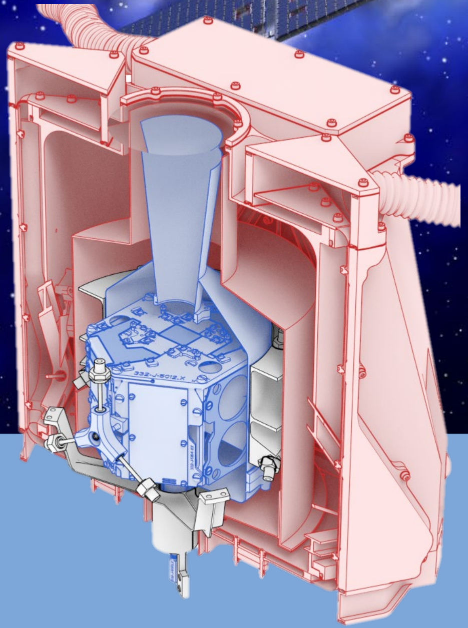
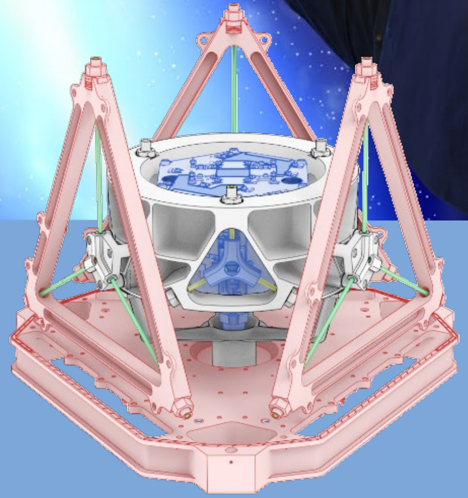
On behalf of the XIFU FPA team





SRON
Netherlands Institute for Space Research

Contents

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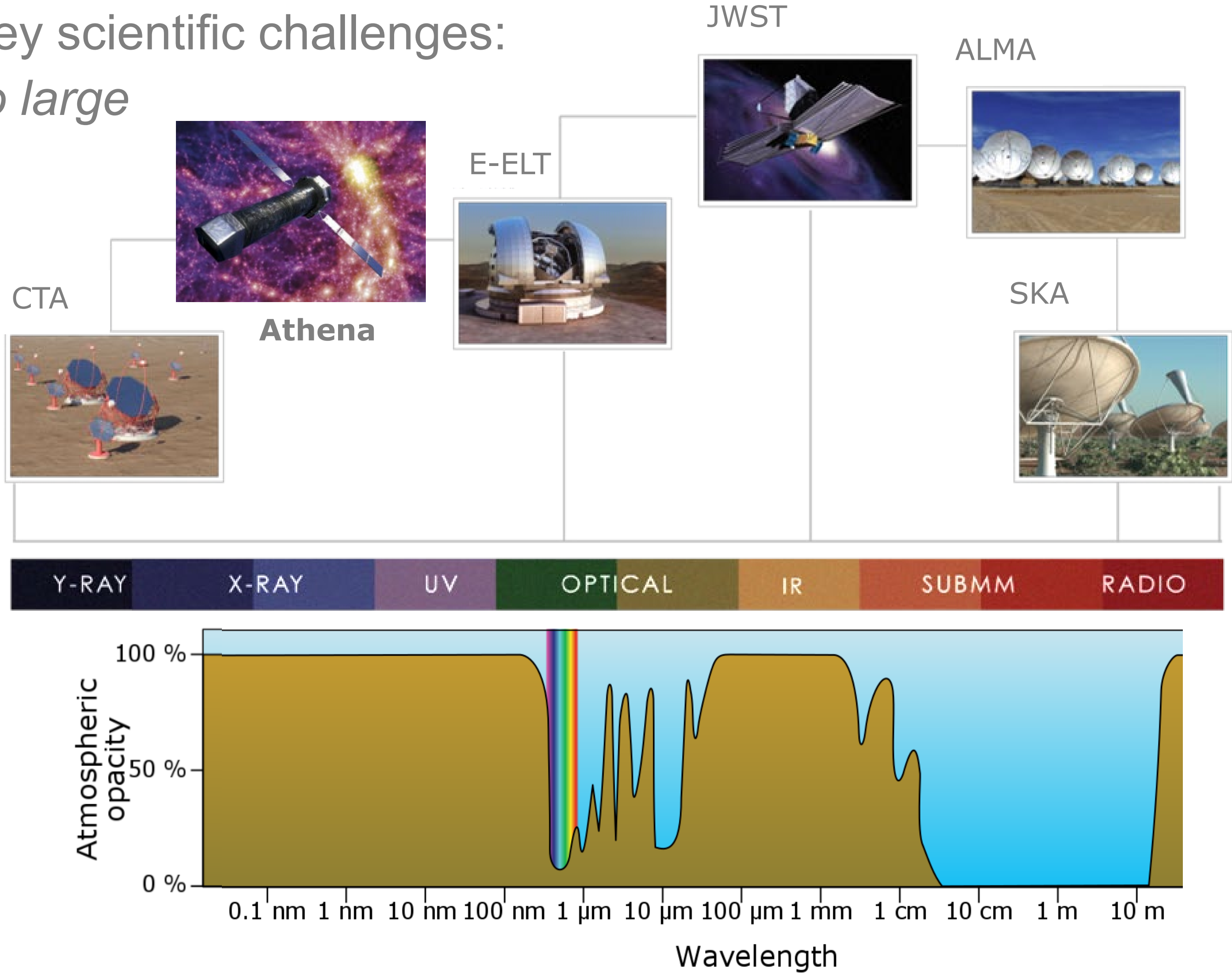
- Introduction of the ATHENA X-ray space observatory and its two instruments: XIFU and WFI
- The XIFU Focal Plane Assembly (FPA) including Kevlar thermal suspension
- Some ongoing developments to demonstrate suspension Technology Readiness:
  - Kevlar pre-tension during thermal cycling
  - Kevlar cord assembly relaxation
  - Potential issue of micro-vibration induced heating by Kevlar suspension

NTS Mecon:

- Optimization of high-strength end fittings for Kevlar cord fixation
- Characterization of suspension built with optimized end fittings
- Development of a reliable and reproducible manufacturing process

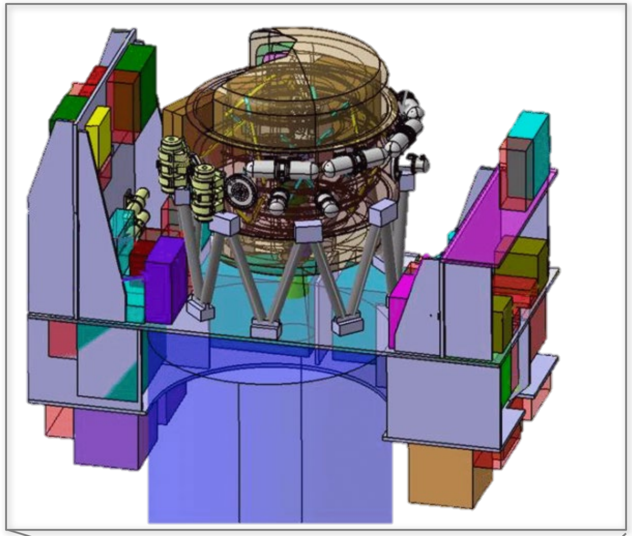
Athena: the next X-ray observatory

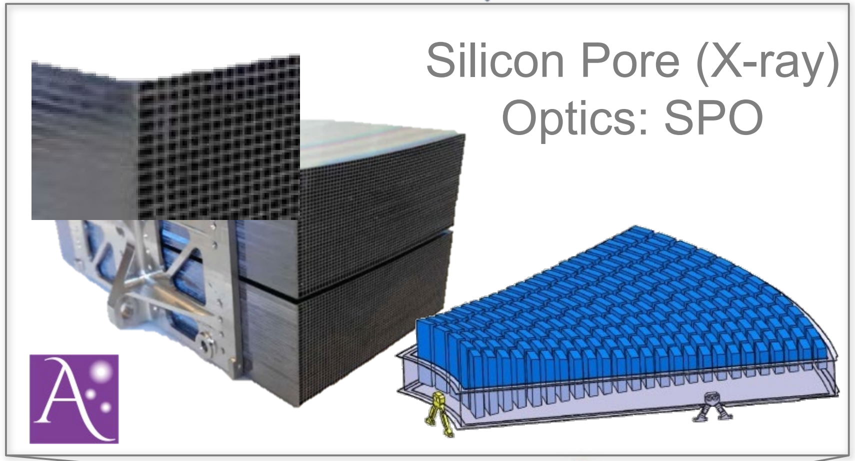
- Athena: Advanced Telescope for High ENergy Astrophysics
- In response to the scientific theme: "*The hot and energetic universe*"
- Observatory "L" class mission addressing key scientific challenges:
  - *How does ordinary matter assemble into large scale structures that we see today?*
  - *How do black holes grow and shape the Universe?*
- It combines a large diameter telescope with an X-ray imager and imaging X-ray spectroscope
- The observatory is open to the global scientific community



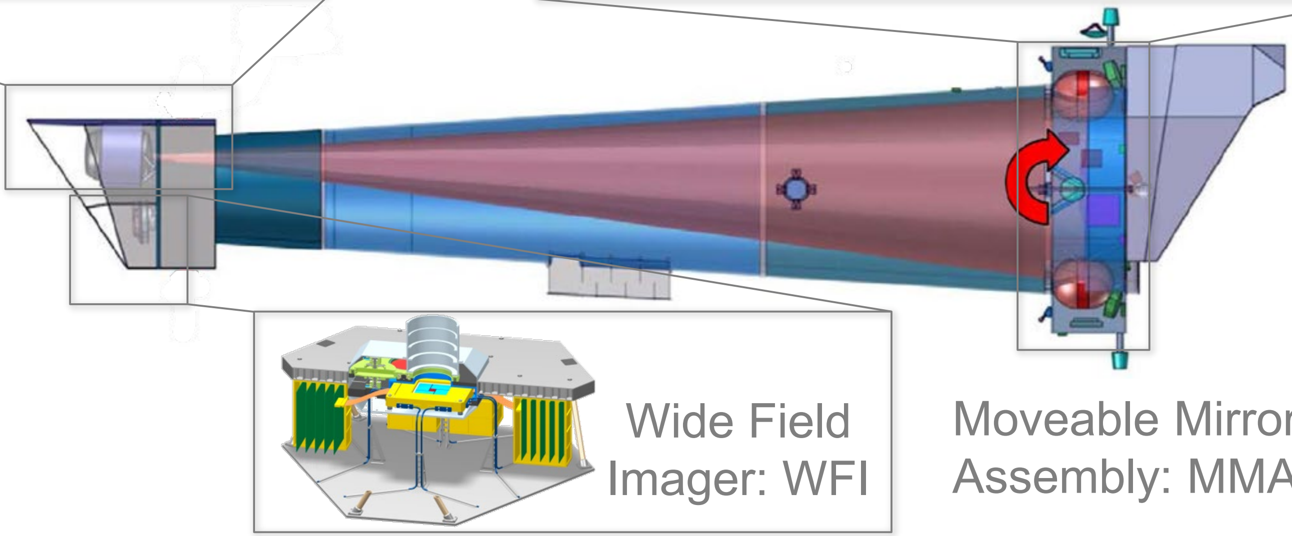
Athena satellite and its 2 instruments…

X-IFU instrument with electronics



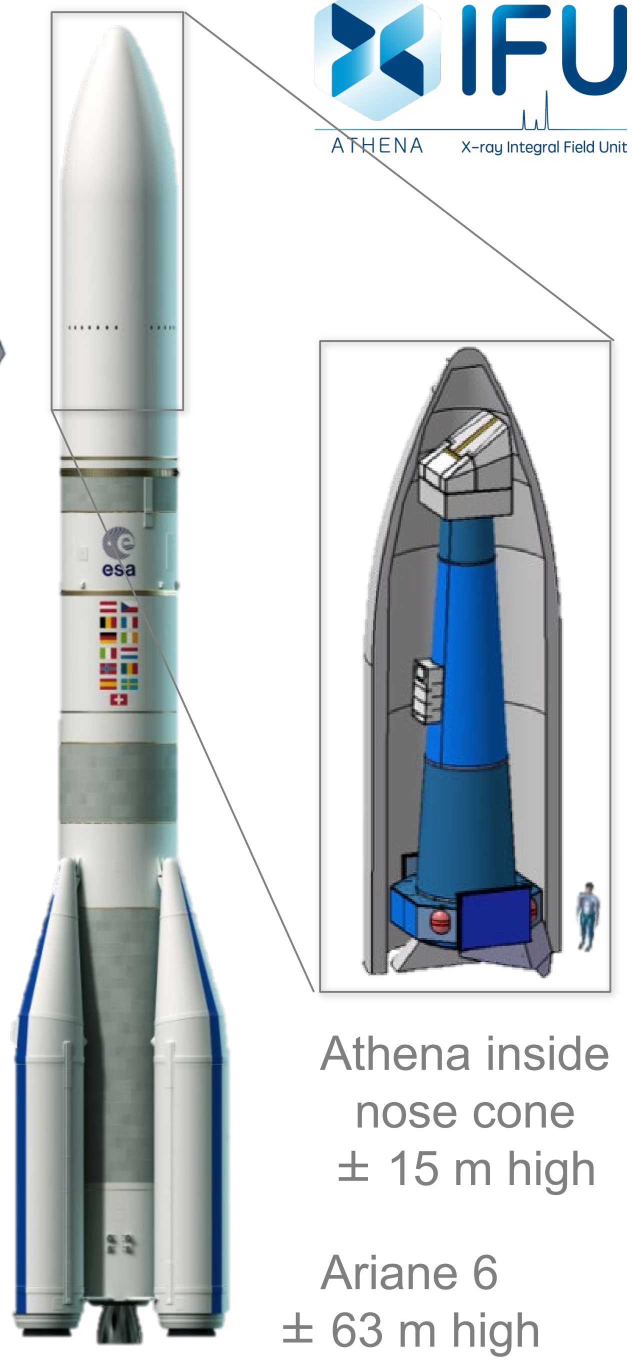


Silicon Pore (X-ray) Optics: SPO



Wide Field Imager: WFI

Moveable Mirror Assembly: MMA



Athena inside nose cone
± 15 m high

Ariane 6
± 63 m high

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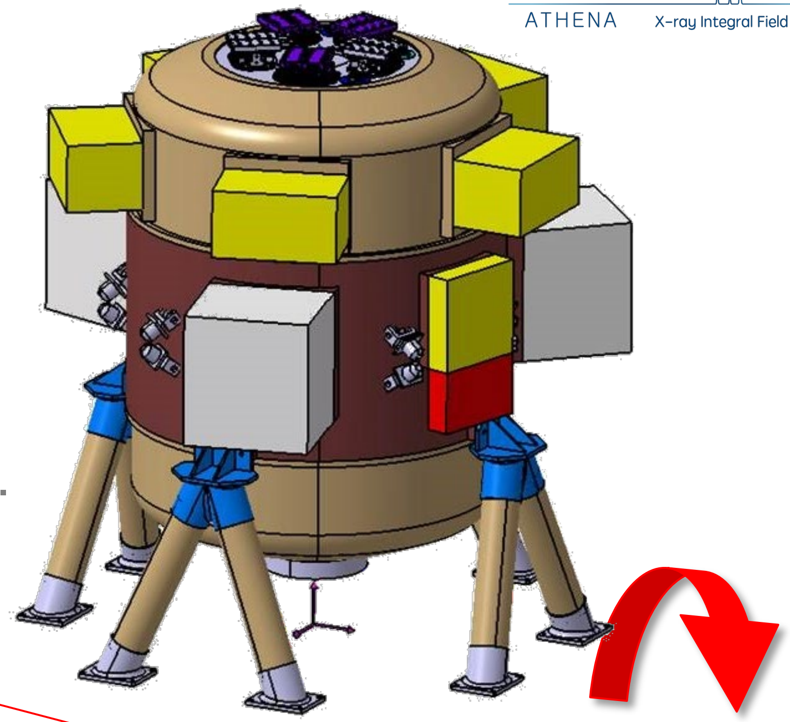
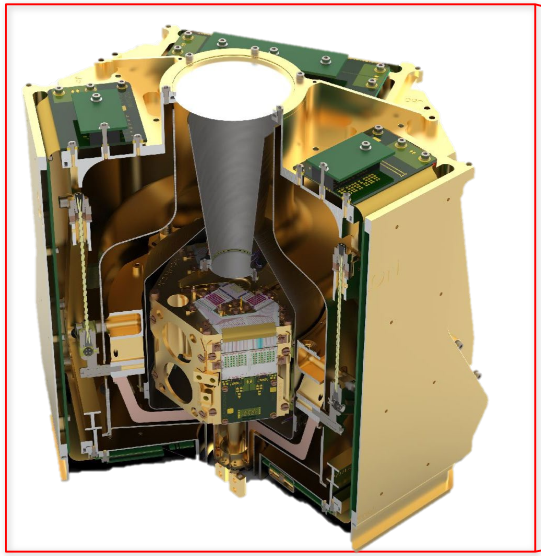
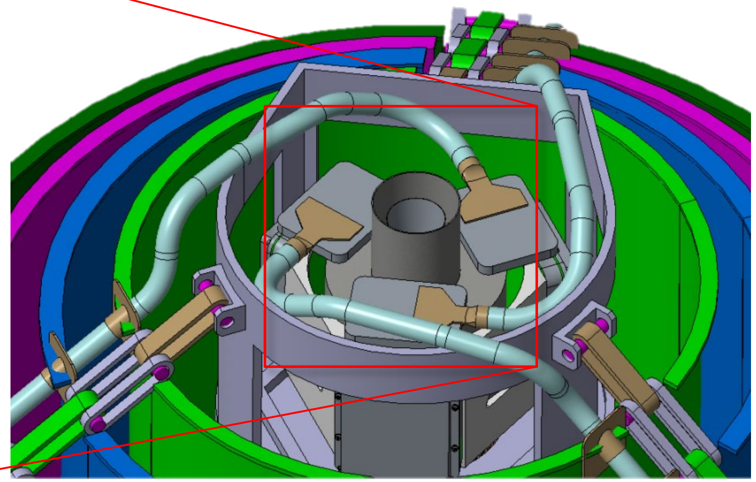
The X-IFU instrument and its Focal Plane Assembly (FPA)

Thermal challenges within the FPA:

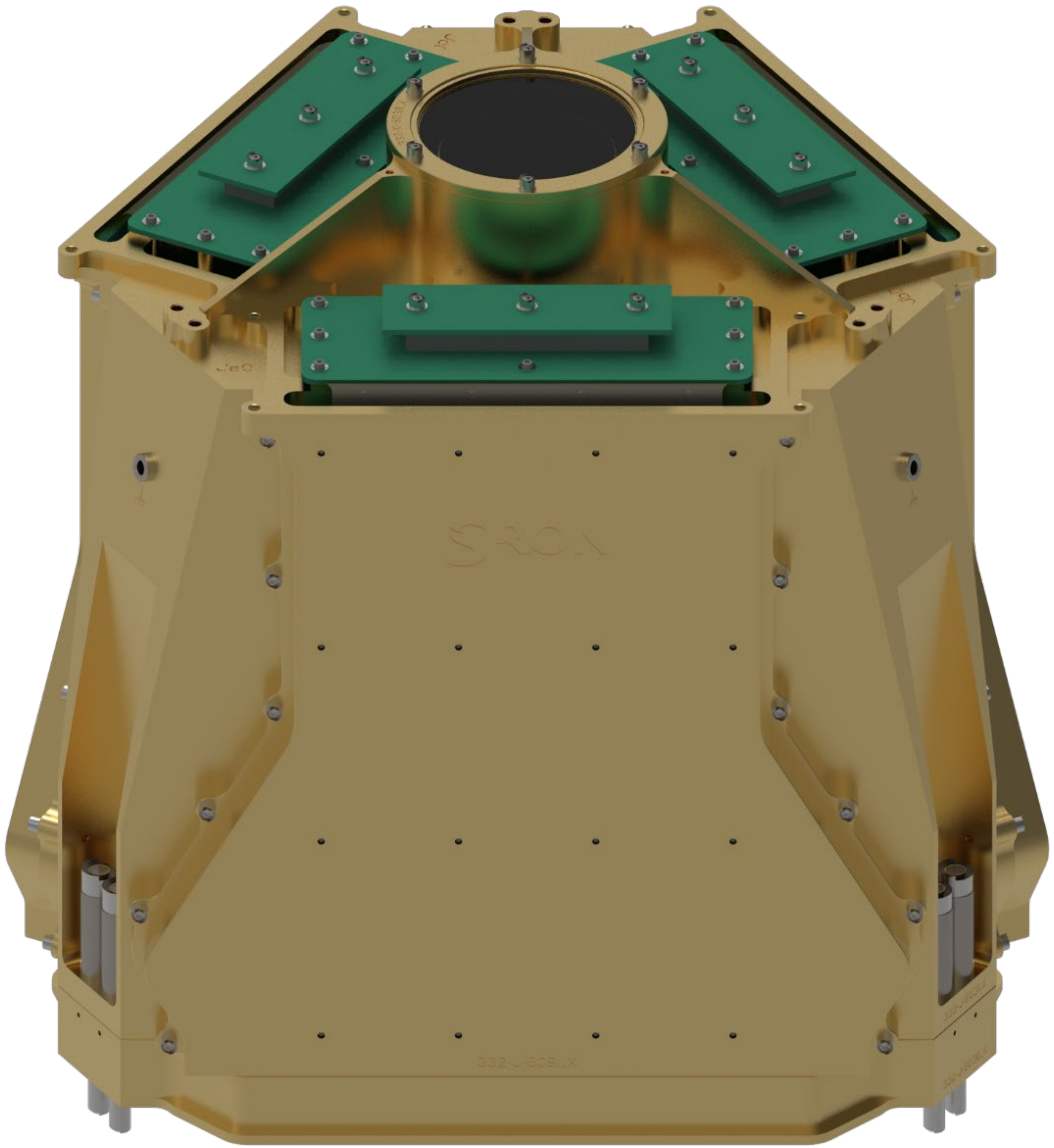
- The 3168 X-ray pixels need to be operated at T0=0.05 Kelvin to achieve the required energy resolution. Operating principle is based on superconducting transition sensing.
- To achieve the performance extreme temperature stability is required: < 0.9 μK rms during observations on T0.
- Less than 1 μW of cooling power is available at the detector stage.
- A thermal heat intercept is added at T1=300 mK.
- The T0 detector stage is mechanically suspended from the T1 stage using Kevlar cords.
- This suspension is optimized to withstand launch and minimum heat load.





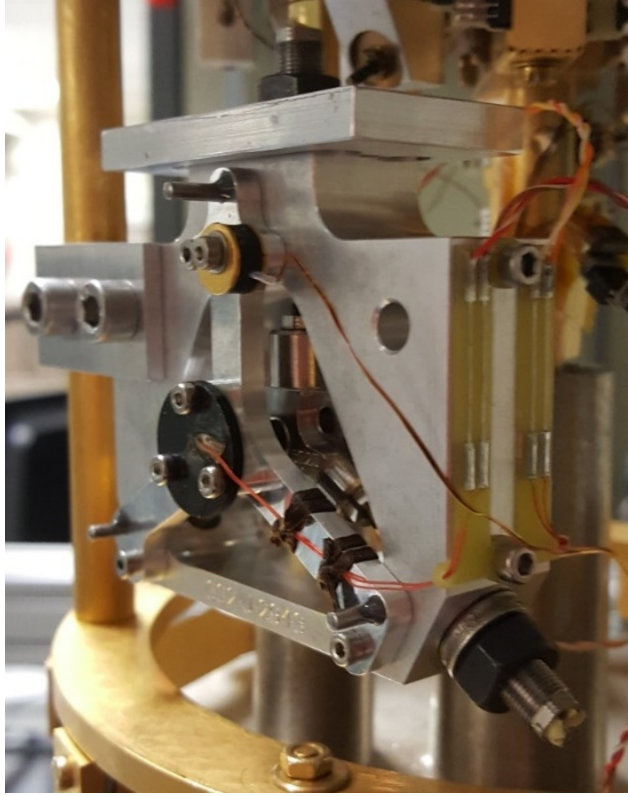


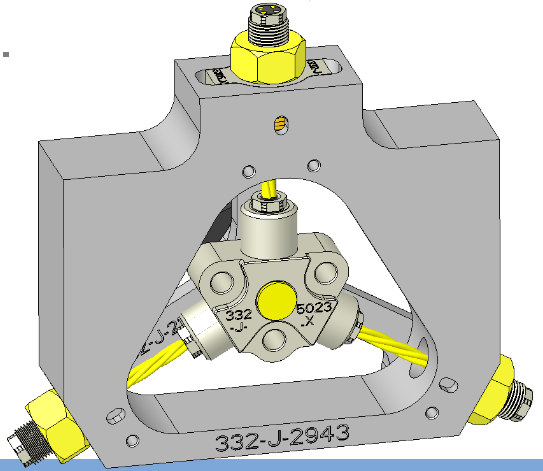
The FPA detector stage and double Kevlar suspension

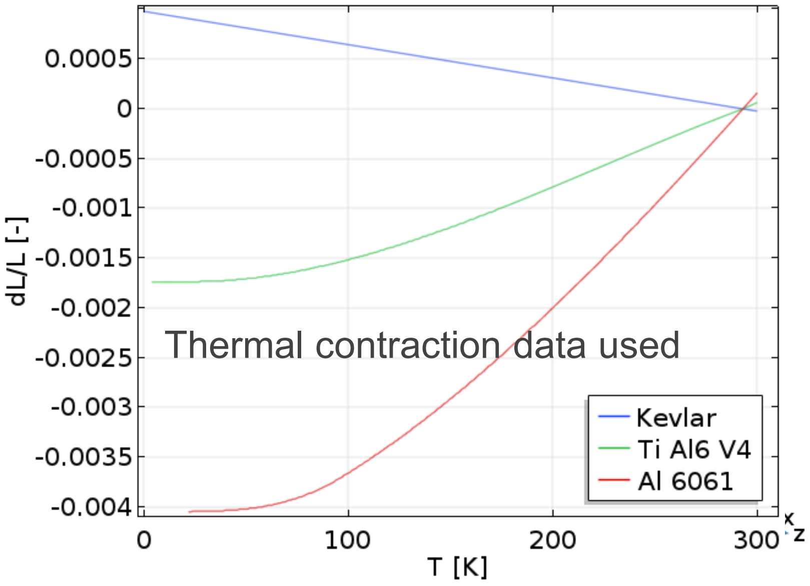


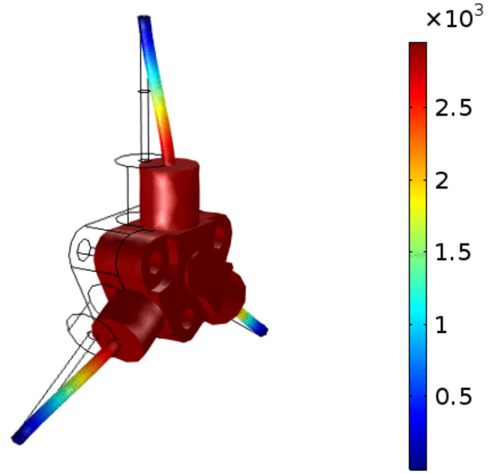
Kevlar pre-tension tests combined with thermal cycling I

- In this configuration f_n is dependent on pretension
- Isotropic Kevlar material model yields too high f_n (13%) at 293K
- With orthotropic material model this deviation is reduced to 1.8%
- Need to incorporate thermal contraction when comparing model to test results while cold
- Also Young's modulus variations are added for Al 6061 and Ti 6Al 4V (both order 30% change) Impact on f_n only go's by square-root of stiffness.
- Kevlar: only one source on thermal expansion at 4K found (dL/L = 0.09%)
- No literature found for stiffness change Kevlar 49 over T, assumed to be constant.

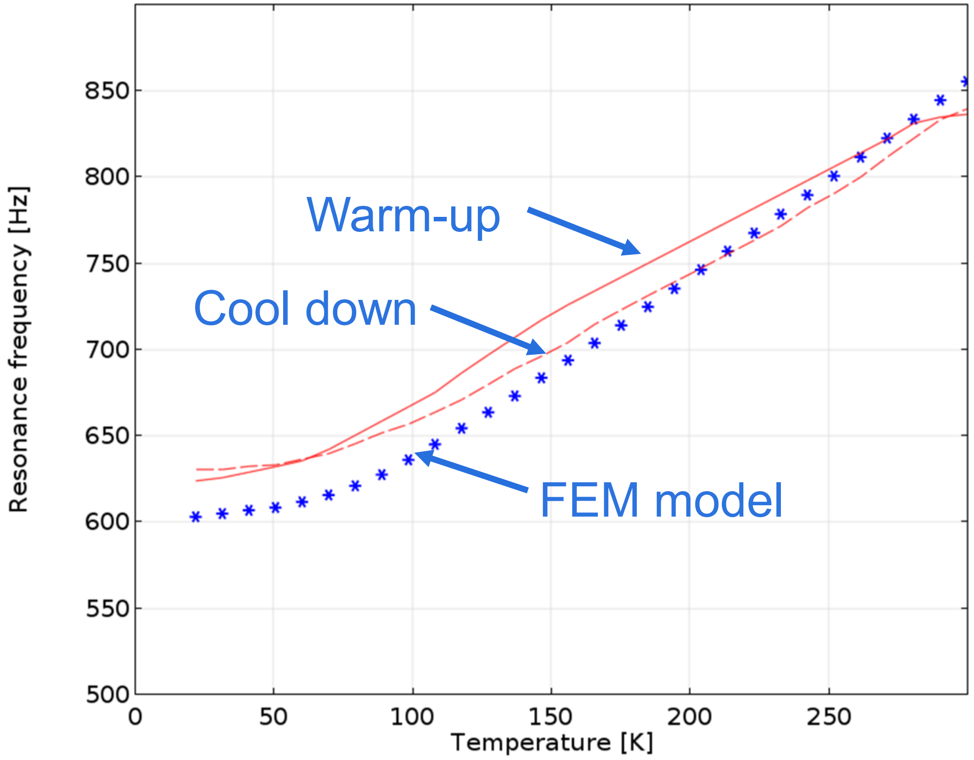


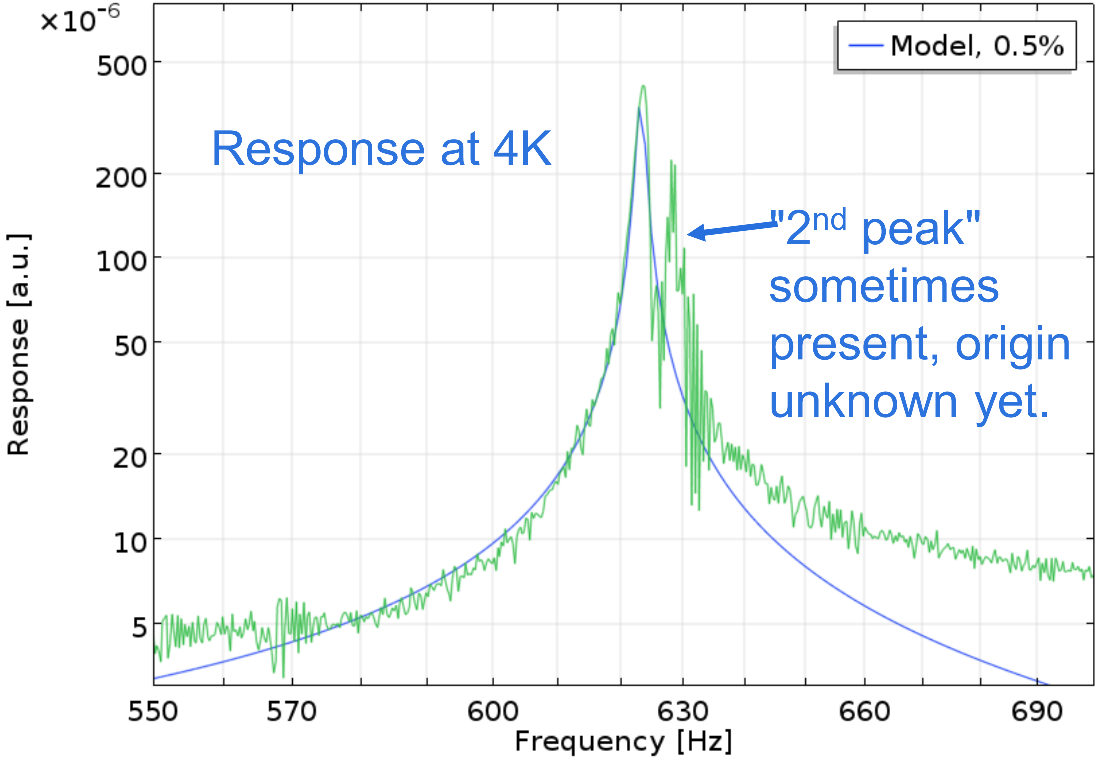






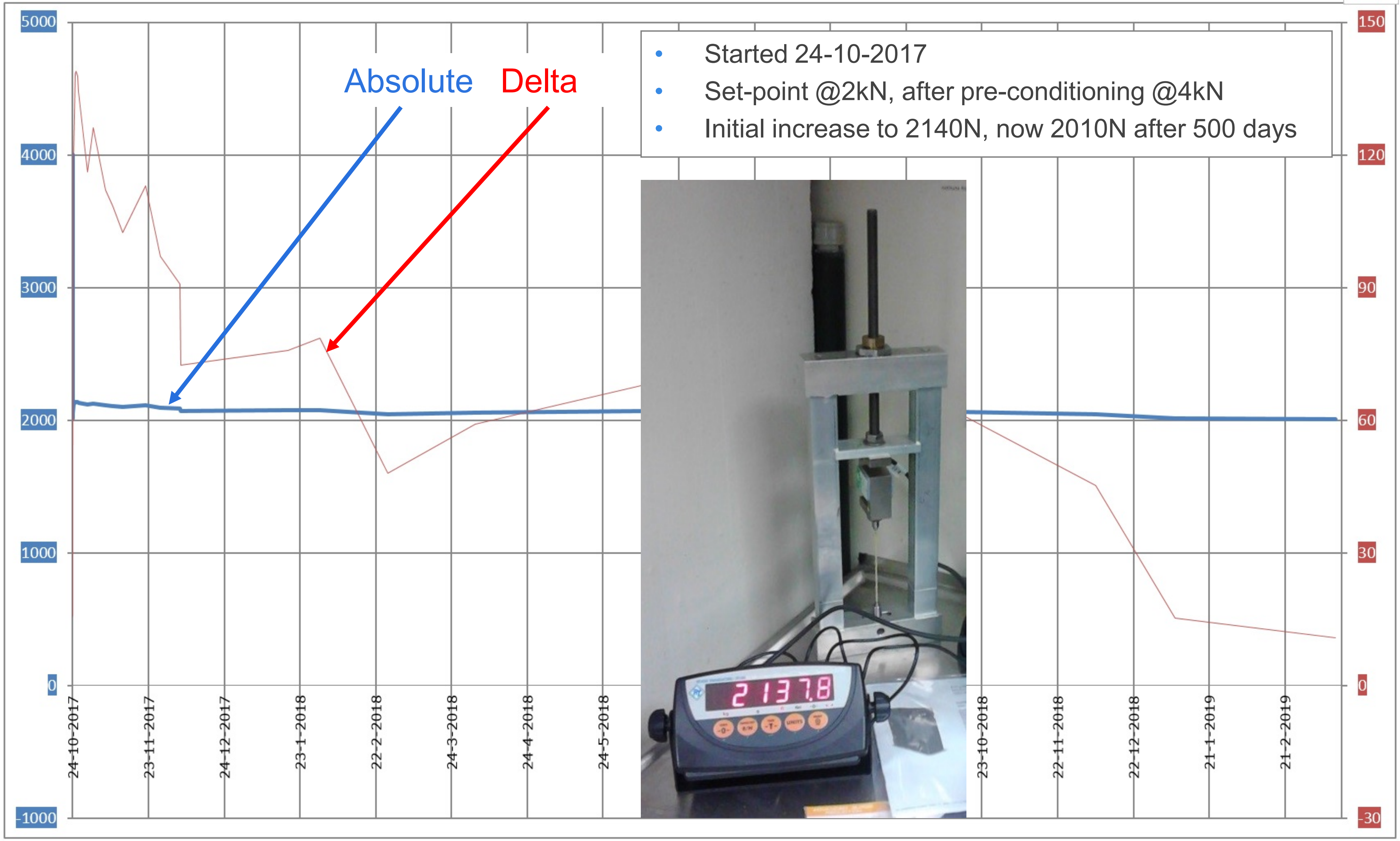
Kevlar pre-tension tests combined with thermal cycling II





- Frequency reduction model coincides reasonably with experimental result. Slope slightly more negative in model than in measurement. Possible cause:
  - Thermal expansion of Kevlar is slightly less than assumed 0.09%
  - Assumption of constant Young's modulus over T is wrong
  - A combination of the above effects
- Cold measurement shows low damping ratio, in this case 0.5%

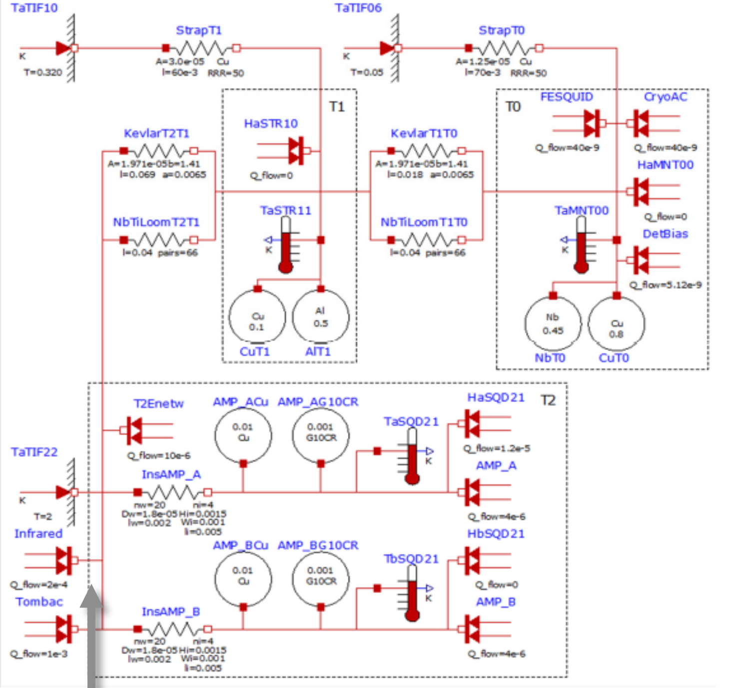
Kevlar relaxation test on single cord assembly



- Started 24-10-2017
- Set-point @2kN, after pre-conditioning @4kN
- Initial increase to 2140N, now 2010N after 500 days

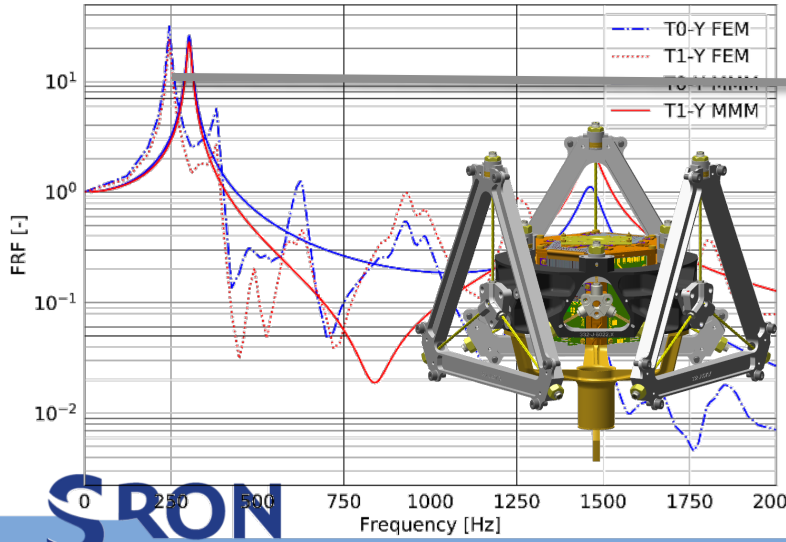
Micro-vibration induced heating by Kevlar suspension

- Most susceptible to temporal variations in vibration amp./freq./ph.
- Coupling mechanism can be better assessed by improving maturity of:
  - Thermal model
  - Mechanical model
- Experimental verification of models is essential for reliable results in coupled analysis
- Iteration of this loop is required for a reliable micro-vibration mitigation in future design updates

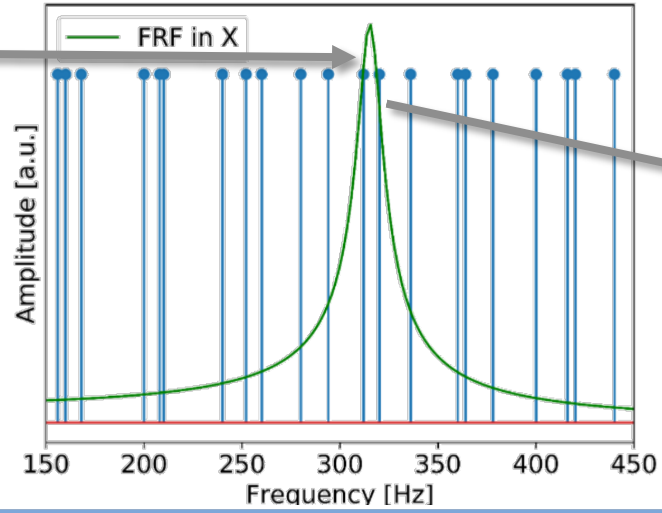


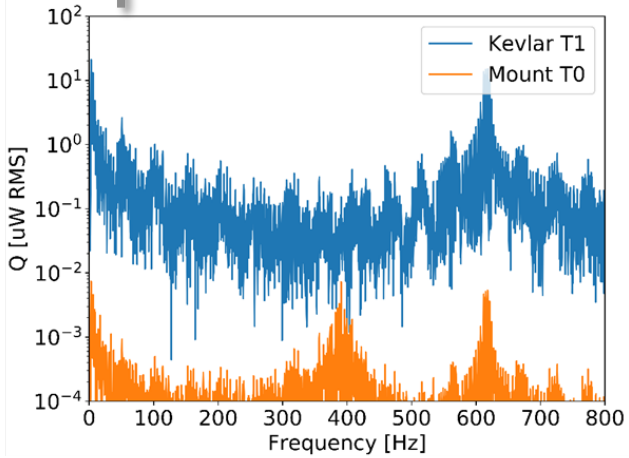
Assess impact of dissipation source (variations) in thermal model

Mech. FRF



Cooler harmonics around FPA f_1





Calculated dissipation spectrum, Intermodulation at low f

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