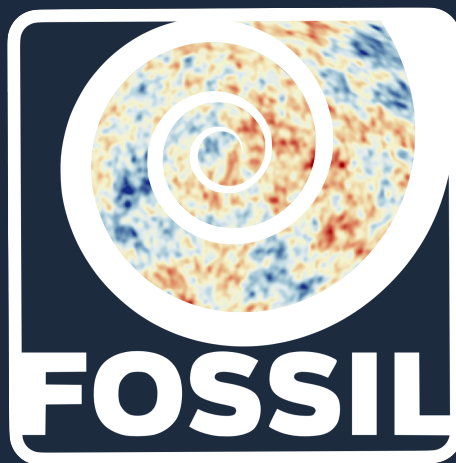
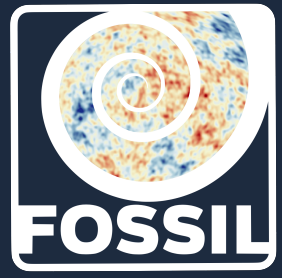




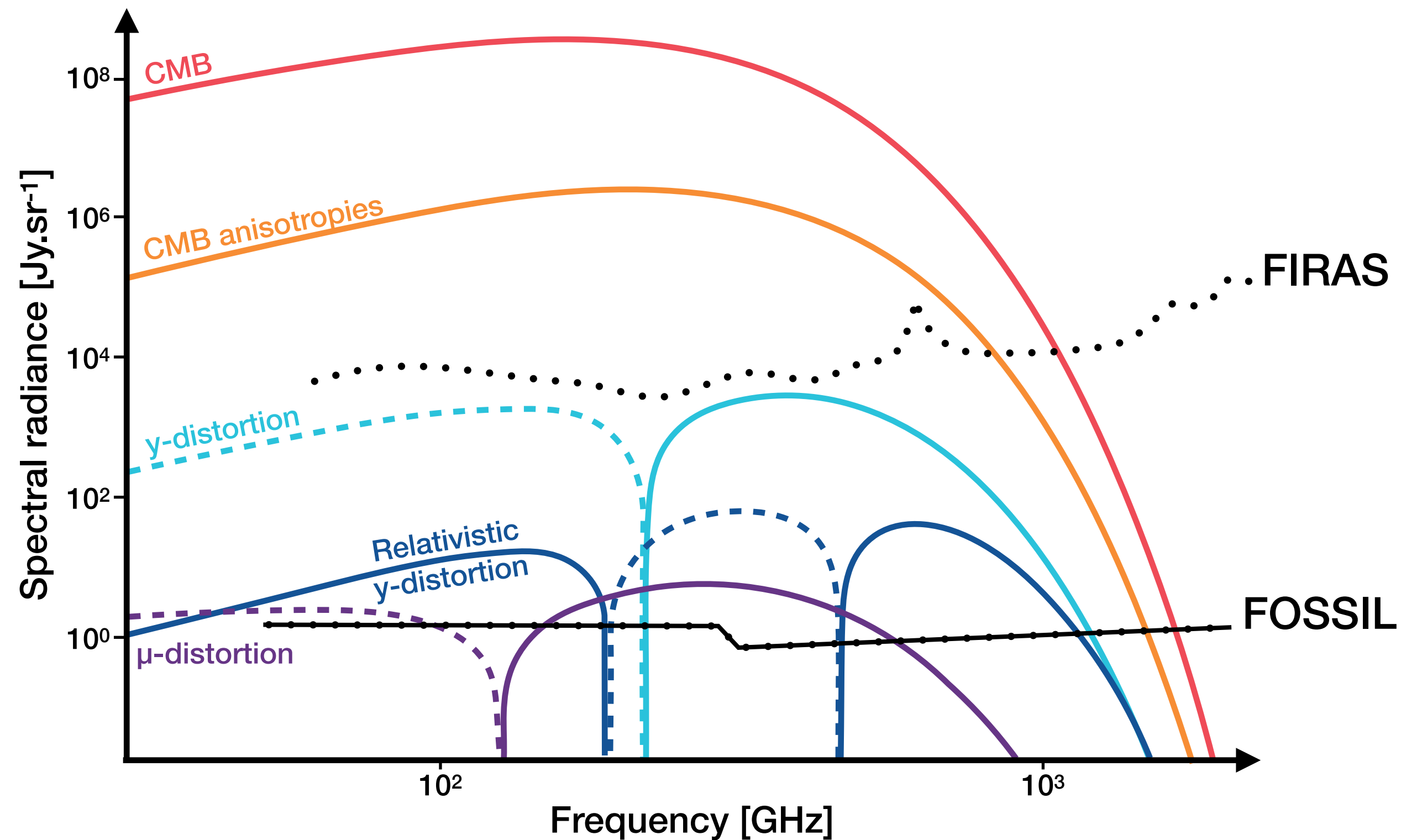
FOSSIL's preliminary thermal architecture FTS fOr CMB Spectral diStortion expLoration

Valentin SAUVAGE

Institut d'Astrophysique Spatiale 
on behalf of the FOSSIL collaboration



From *why* to *how* ...



x1000 beyond COBE/FIRAS

→ Detectors (50 mK)

*Two arrays at High Frequency
Two arrays at Low Frequency*

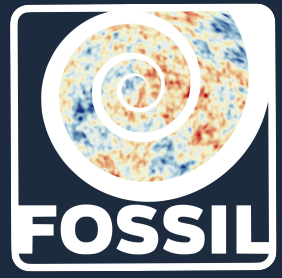
→ BlackBody Internal Reference

*Setpoint spanning 2.5 K → 2.9 K
Few μ K thermal fluctuation over two seconds*

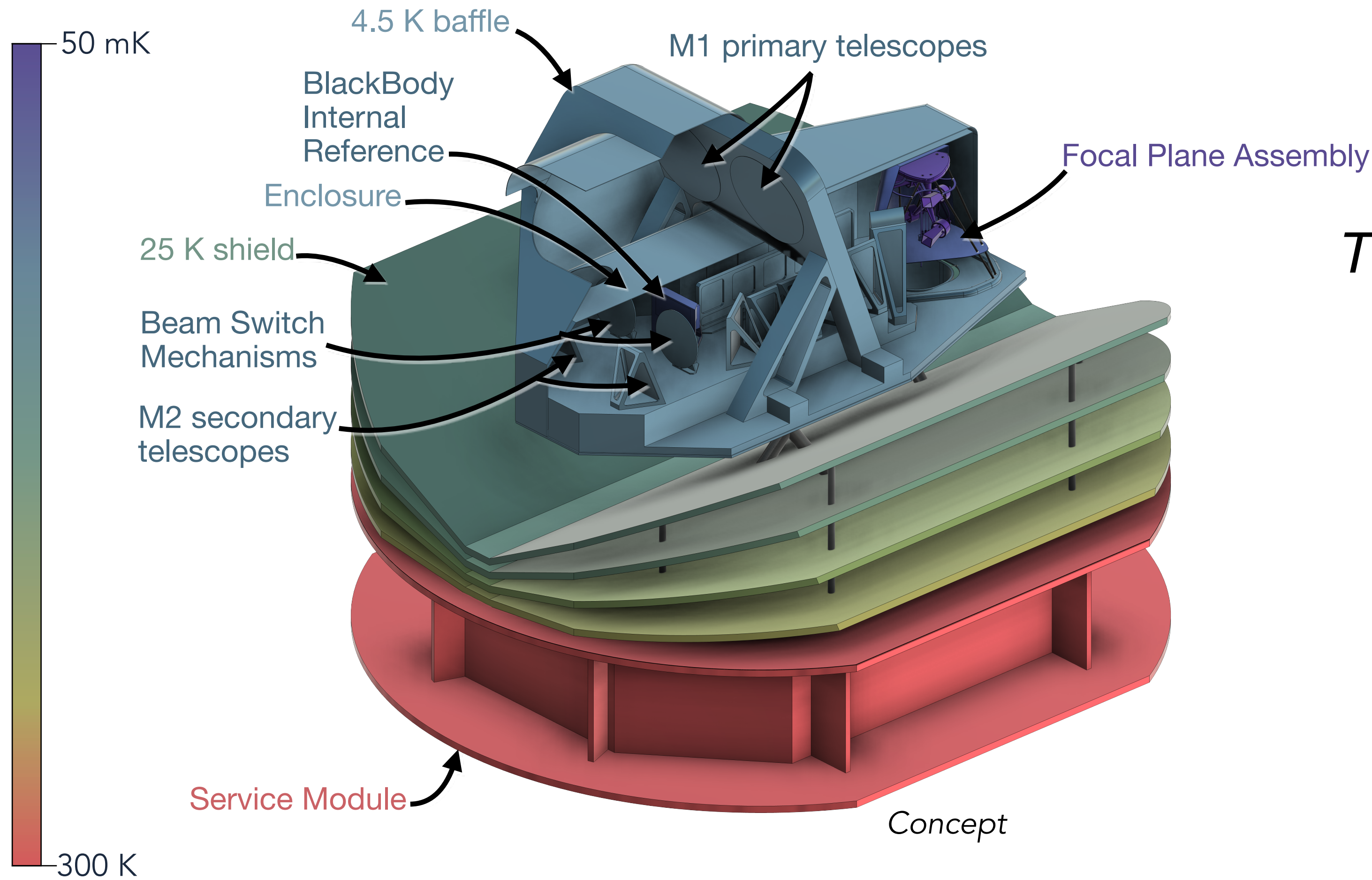
→ Instrument (Optics, quasi-optics, ...)

Cooled down at 4.5 K to limit self-emission

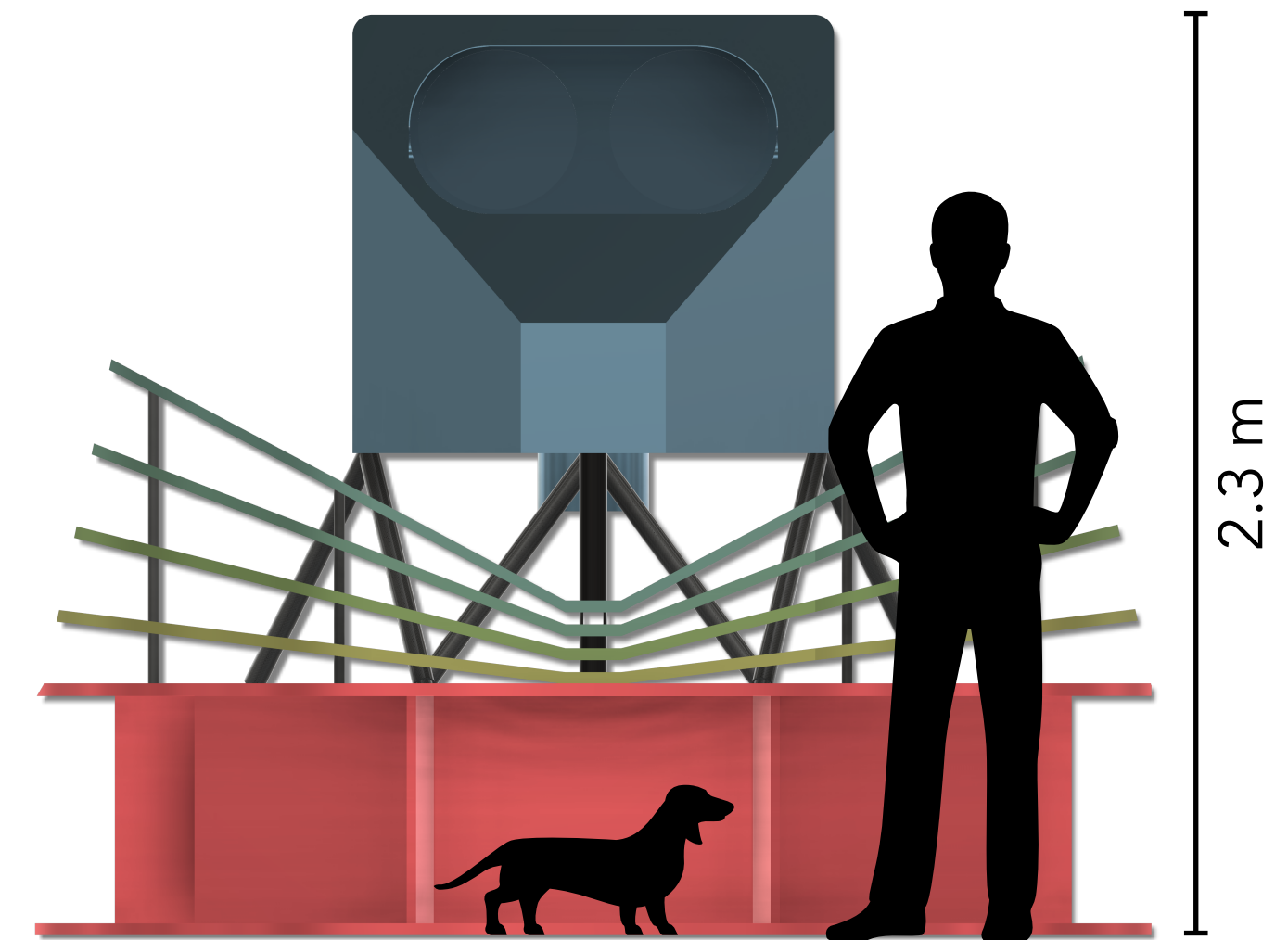
Drives the cryogenic chain requirements

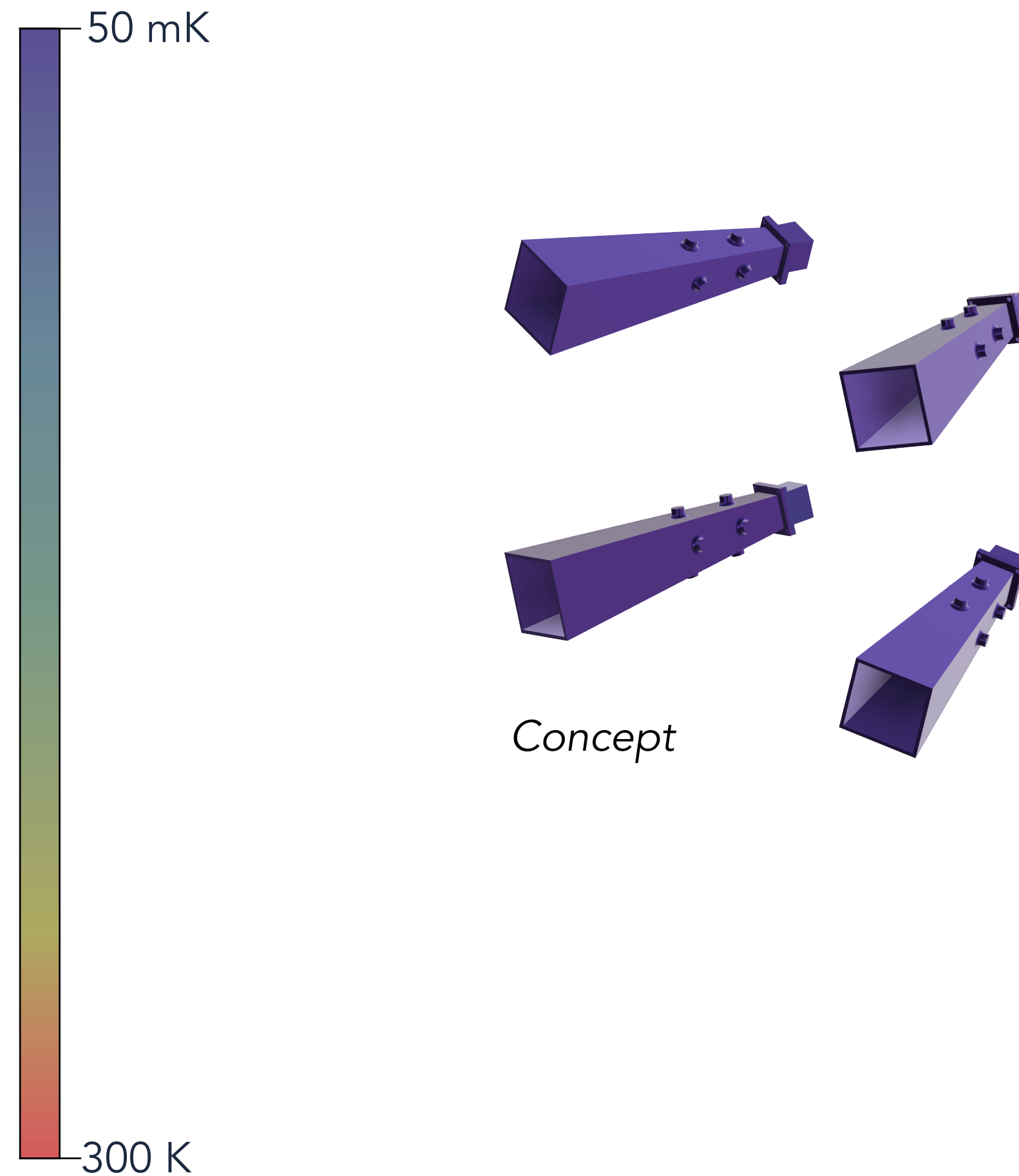


Design of FOSSIL

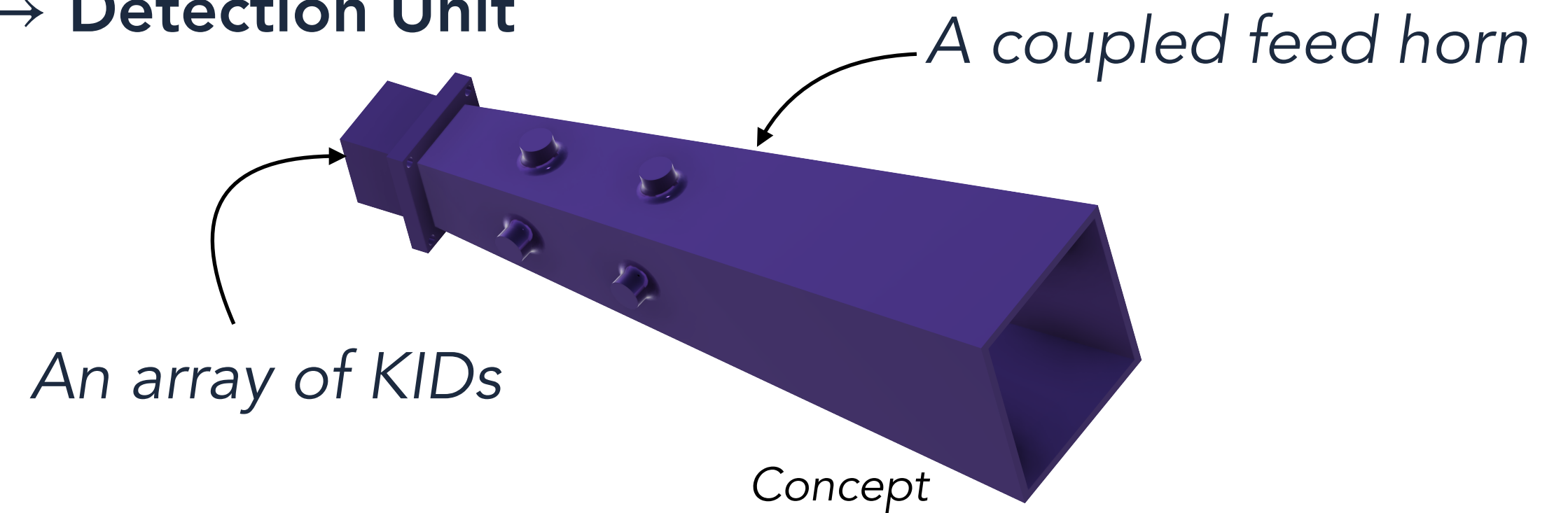


This is a baseline concept developed for the ESA M8 call.





→ Detection Unit



→ Multi-stage ADR (CEA/DSBT)

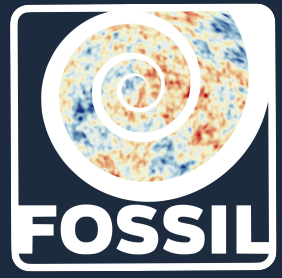
50 mK for 28 hours (80% of 35 hours)

870 nW of cooling power at 50 mK

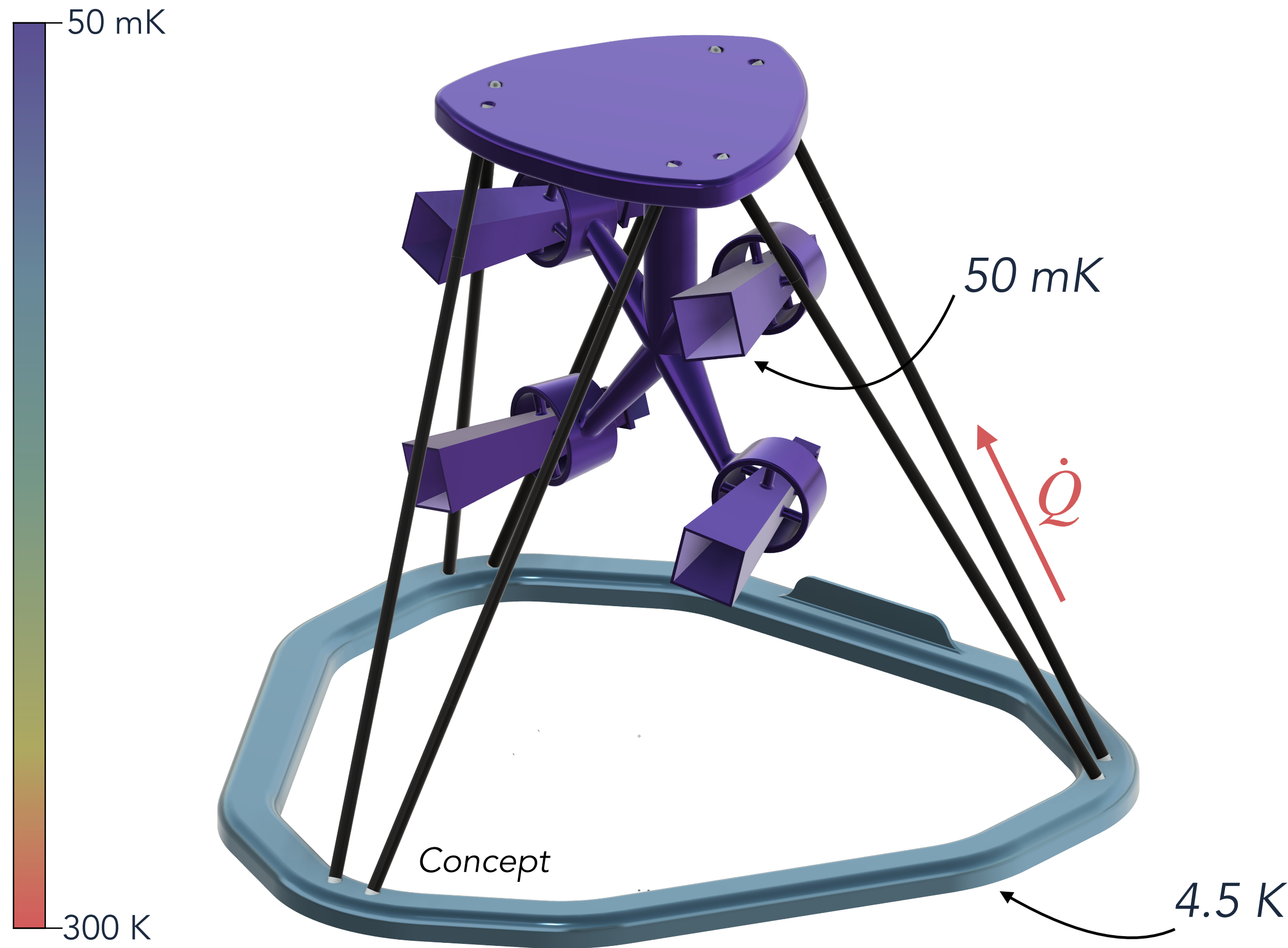
Developments for NewAthena/X-IFU

Benefits from SPICA/SAFARI and LiteBIRD studies

✓ 100 % margin (ESA recommendations): 430 nW



Focal Plane Assembly



→ Hexapod structure

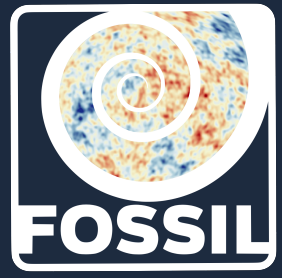
CFRP struts

- low thermal conductivity
- high strength
- lightweight

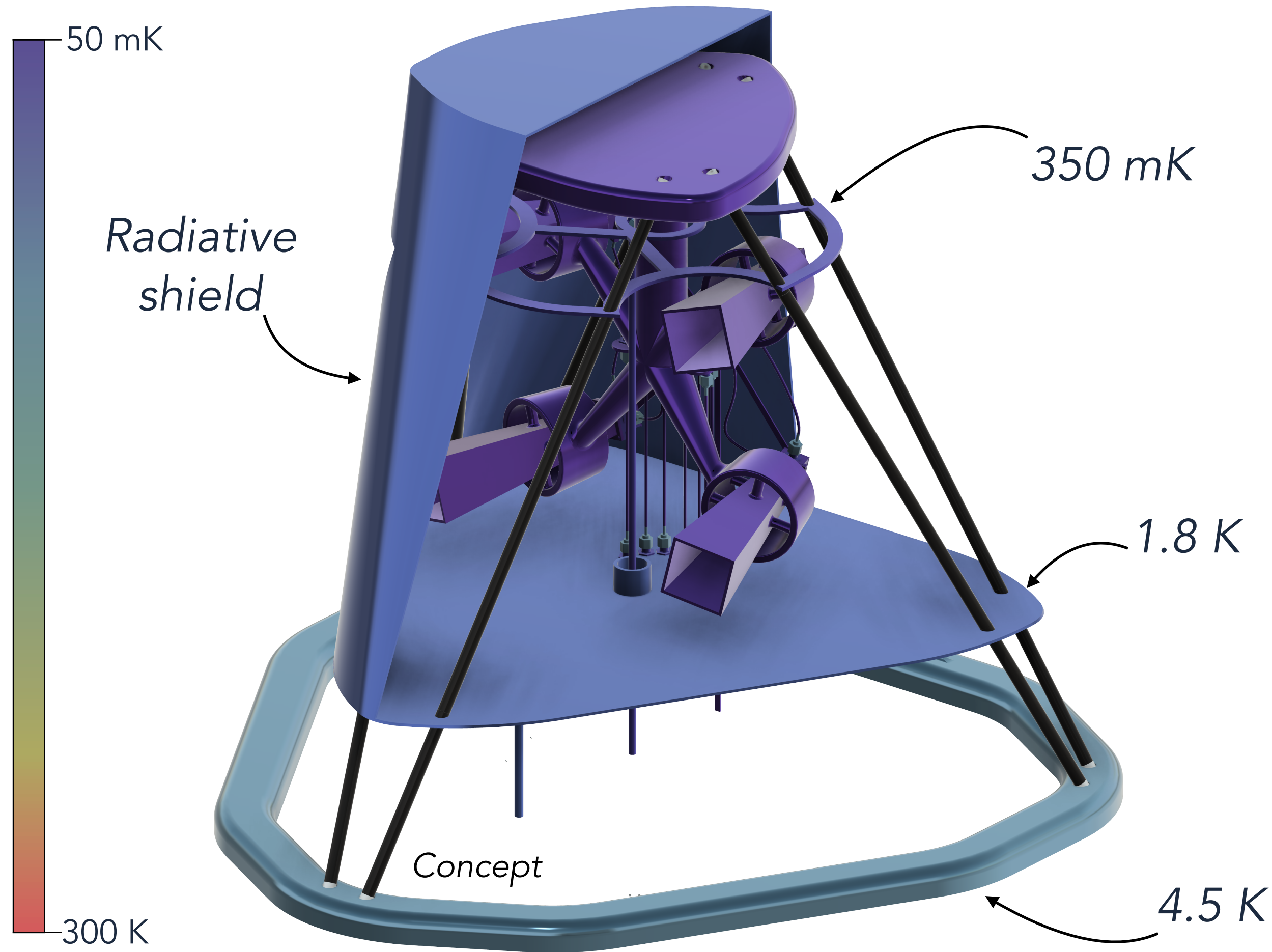
Aluminium interfaces

- superconducting below ~ 1 K
- lightweight

$\dot{Q}$ too high (ESA margins vs budget volume)
→ Need additional heat interception



Focal Plane Assembly



→ Heat interception at 350 mK

Multi-Stage ADR

Continuous

Uses 7.5 μ W of the 10 μ W

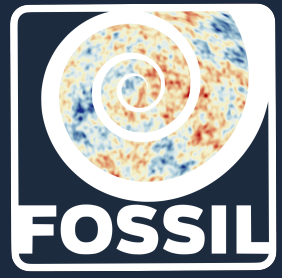
✗ 33% margin → goal 100% (ESA requirements)

→ Heat interception at 1.8 K

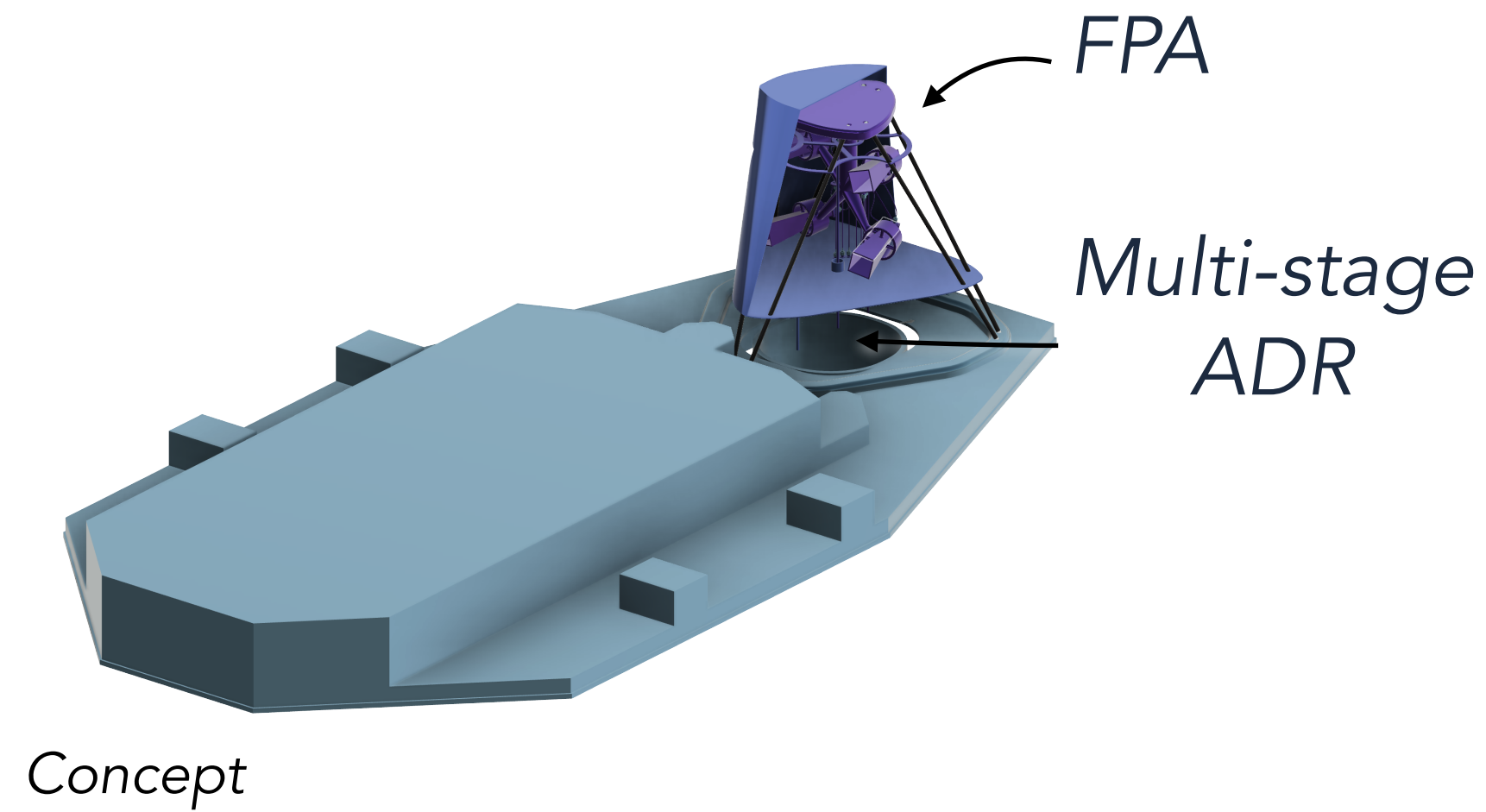
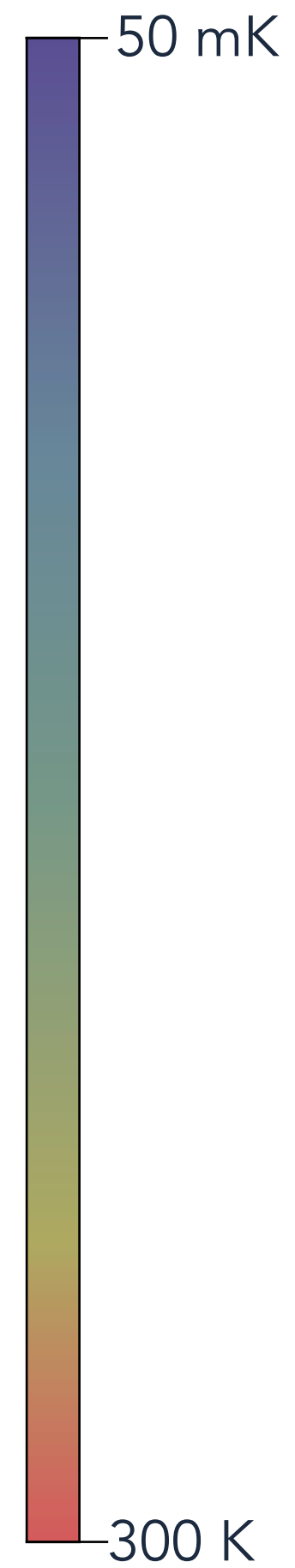
Multi-Stage ADR

Continuous

Uses 200 μ W of the 1 mW

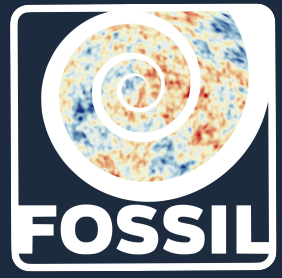


4.5 K bench

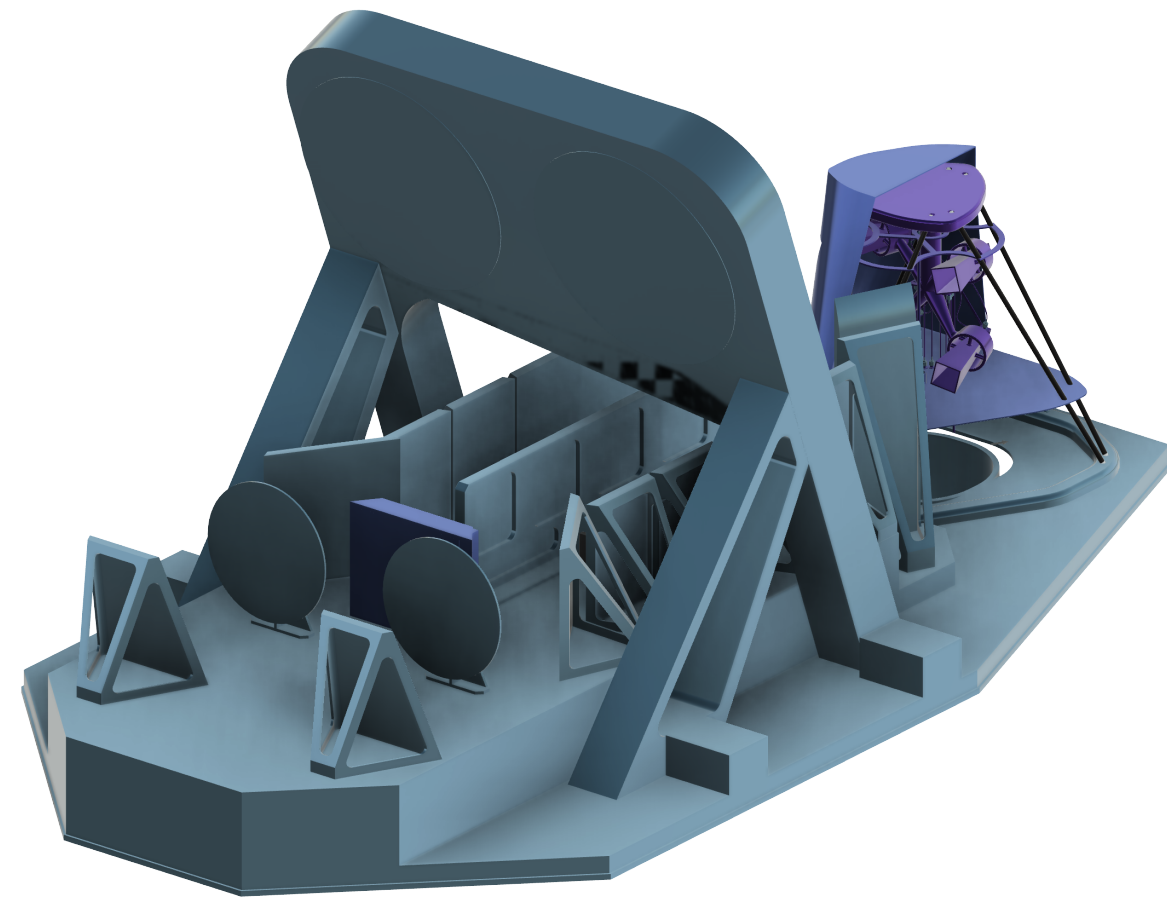


→ **Bench at 4.5 K**

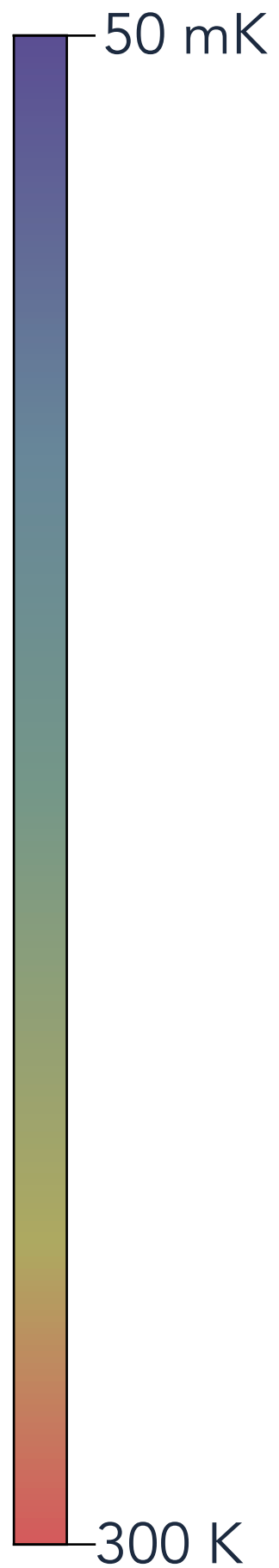
ESA developments (derives from Planck 4K JT cooler)
50 mW at 4.5K



4.5 K bench



Concept



→ Bench at 4.5 K

*ESA developments (derives from Planck 4K JT cooler)
50 mW at 4.5K*

→ Cooldown all the optics and quasi-optics elements

Telescopes, mirrors, FTS, polarizers, dichroic, ...

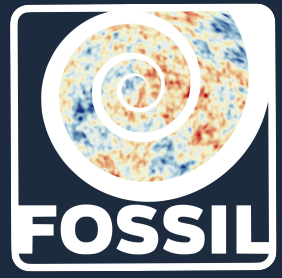
→ Cooldown all the mechanism

Two Beam Switch Mechanisms

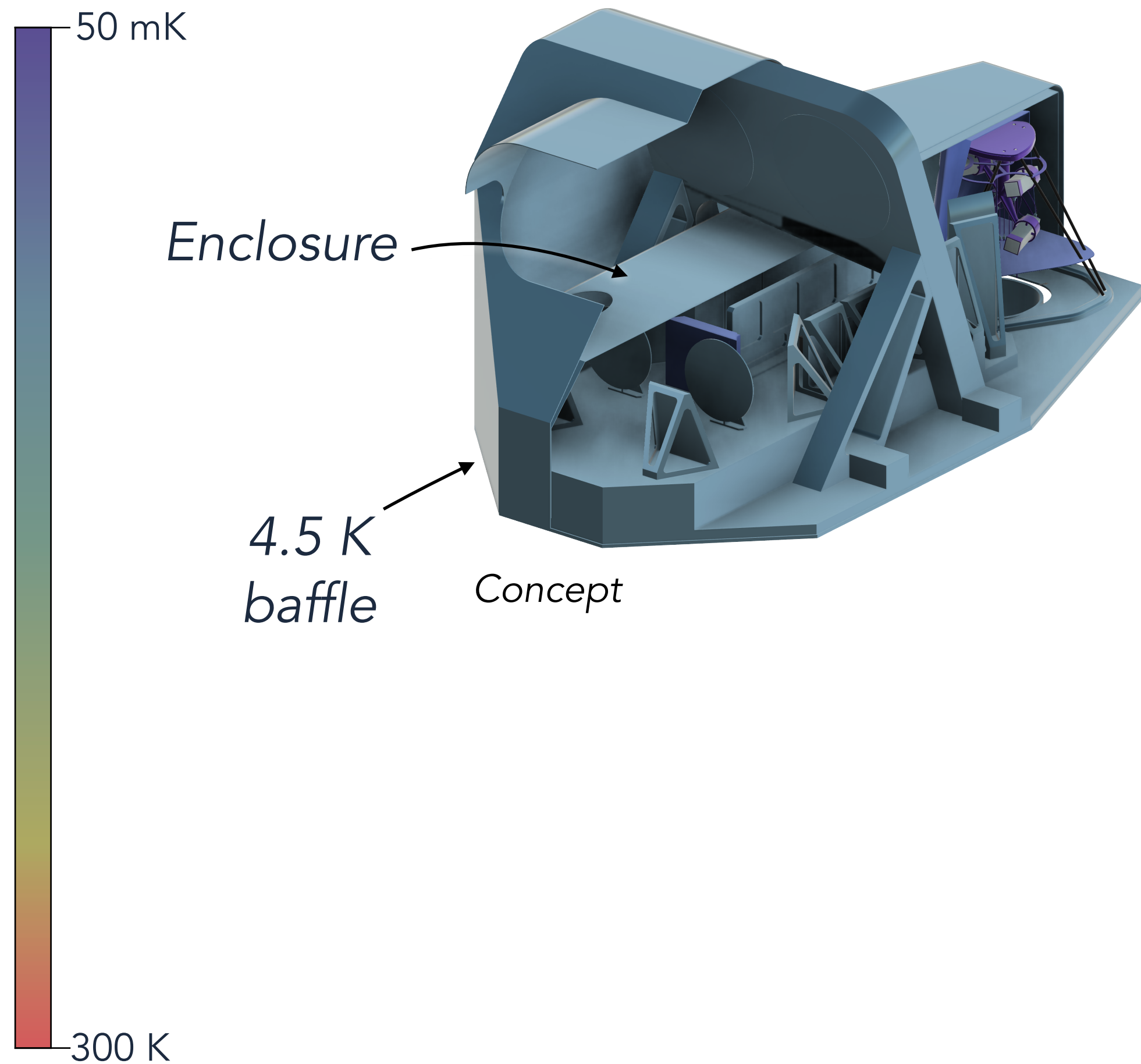
3 mW in total

FTS motor

1.5 mW in total



4.5 K bench



→ Bench at 4.5 K

*ESA developments (derives from Planck 4K JT cooler)
50 mW at 4.5K*

→ Cooldown all the optics and quasi-optics elements

Telescopes, mirrors, FTS, polarizers, dichroic, ...

→ Cooldown all the mechanism

Two Beam Switch Mechanisms

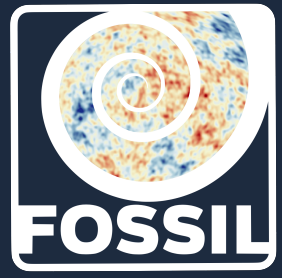
3 mW in total

FTS motor

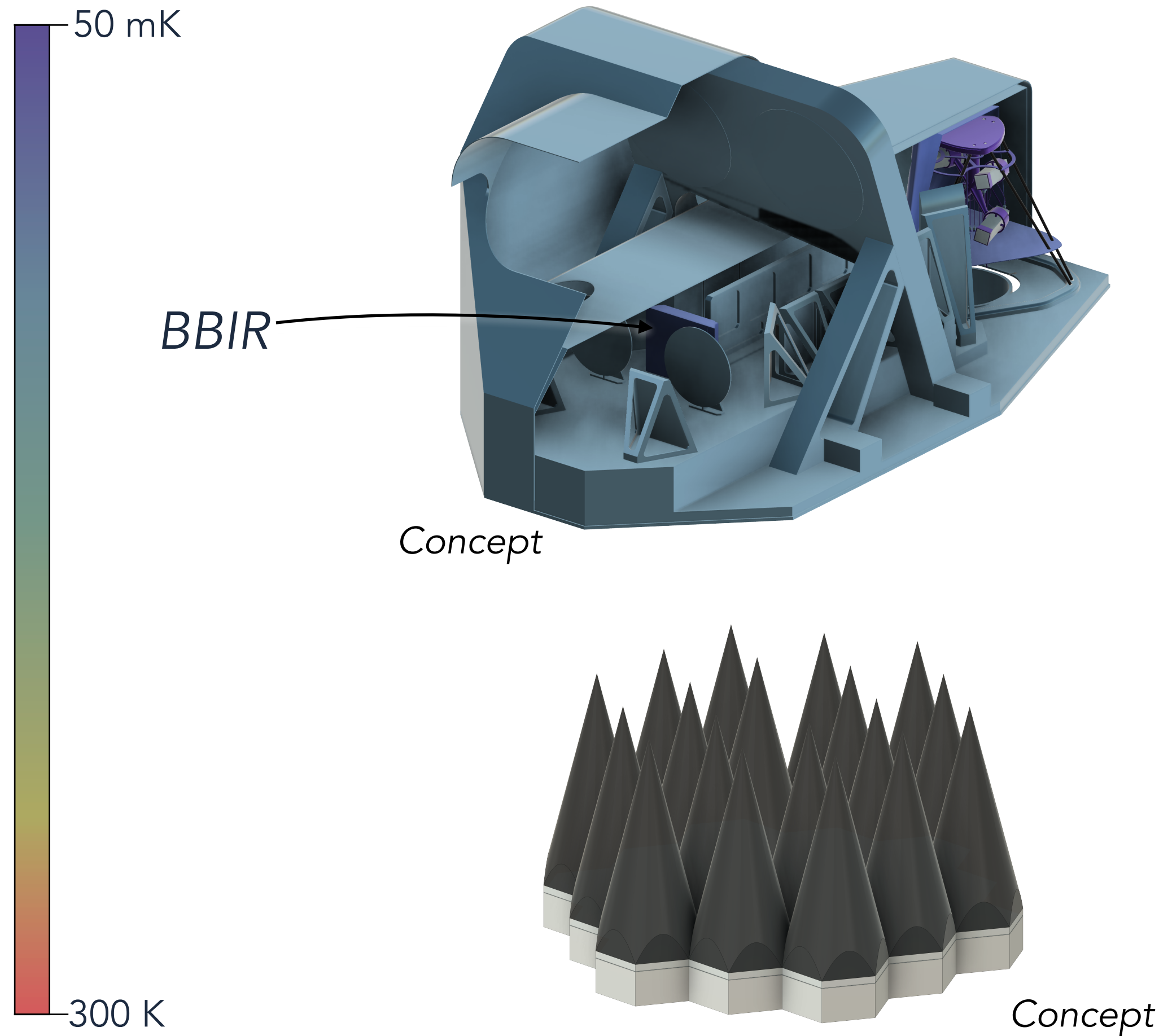
1.5 mW in total

→ Baffle and enclosure

Reduce the thermal load and the stray light



BlackBody Internal Reference



→ **BlackBody Internal Reference (BBIR)**

Setpoint spanning 2.5 K → 2.9 K

Heritage of PIXIE, ARCADE and MetOp

Cavity at 20 K for high frequency

Few μ K thermal fluctuation over two seconds

Temperature Monitoring and Control System (LiteBIRD)

→ **4.5 K interface**

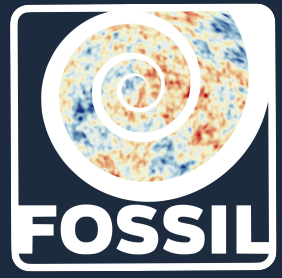
CFRP struts for isolation

→ **Heat interception at 1.8 K**

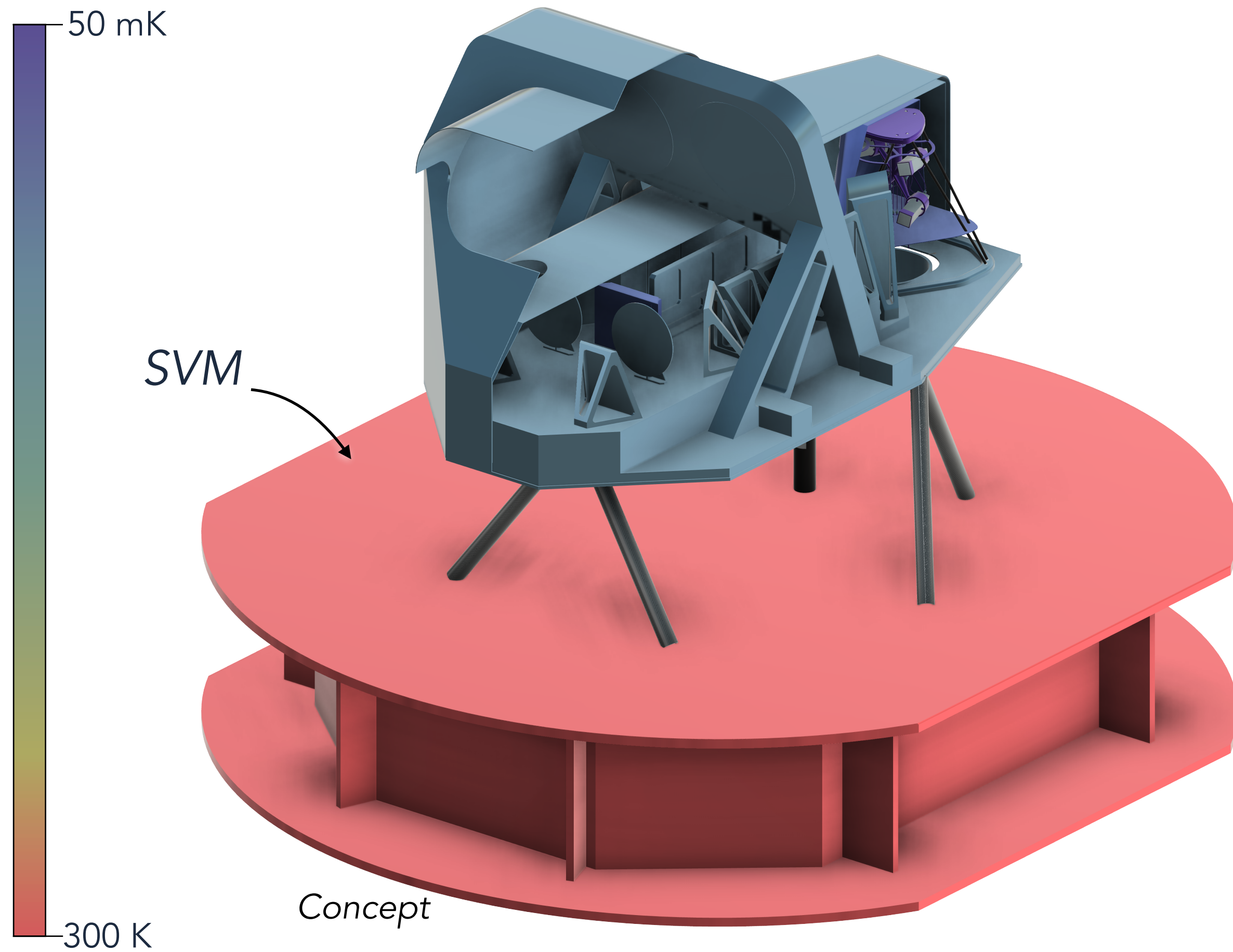
Multi-Stage ADR

Continuous

Uses 300 μ W of the 1 mW (Supports, cavity)



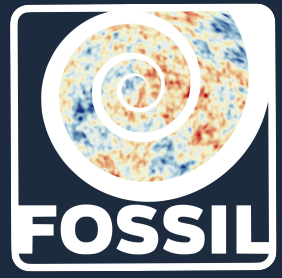
Service Module



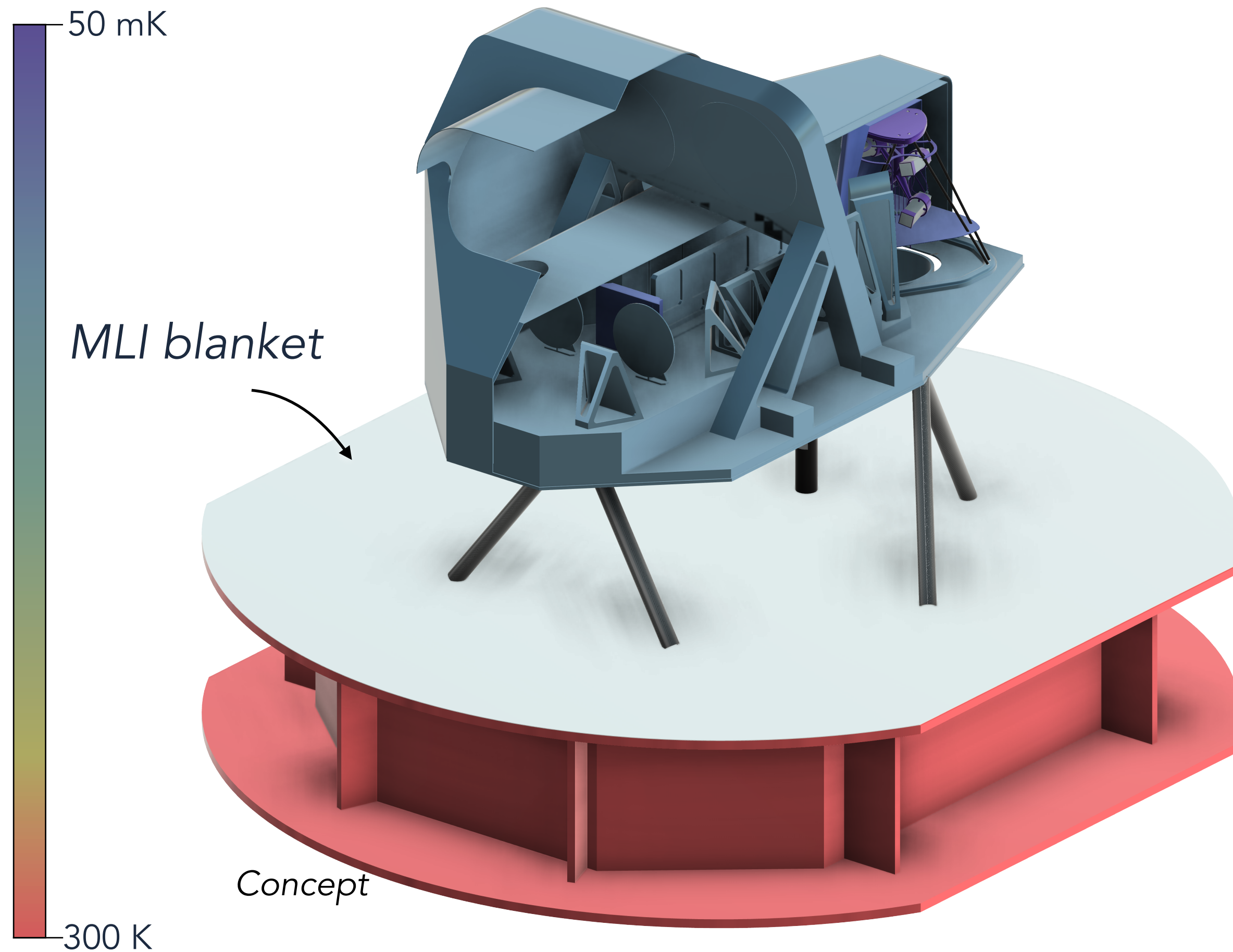
Service Module at 300 K
Instrument at 4.5 K

→ Hexapod structure (CFRP)
Planck and Ariel heritage

Conduction is too high
Radiation is even higher



MLI blanket

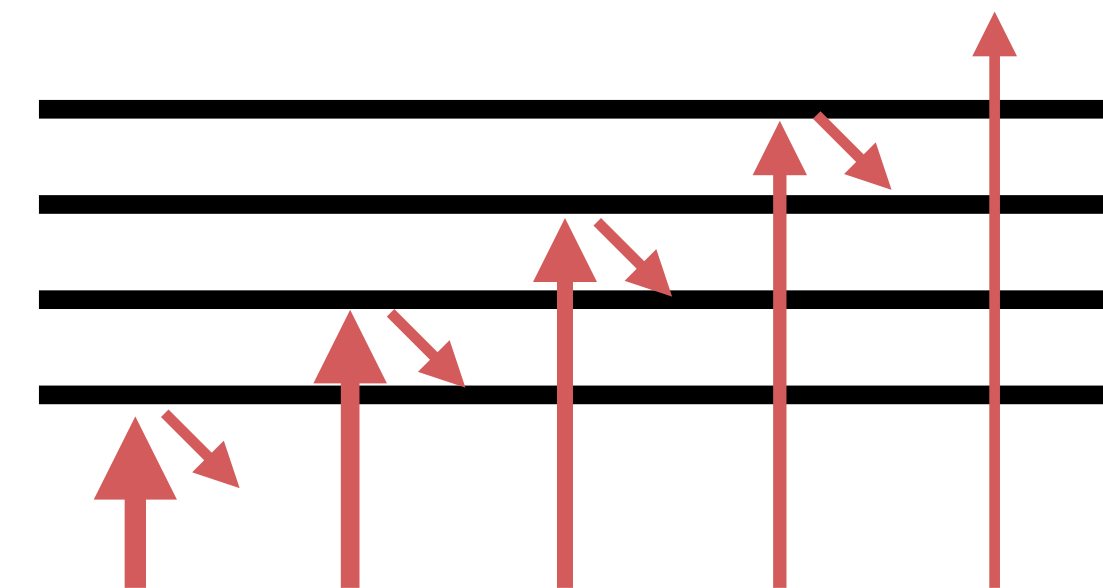


Service Module at 300 K
Instrument at 4.5 K

→ Hexapod structure (CFRP)
Planck and Ariel heritage

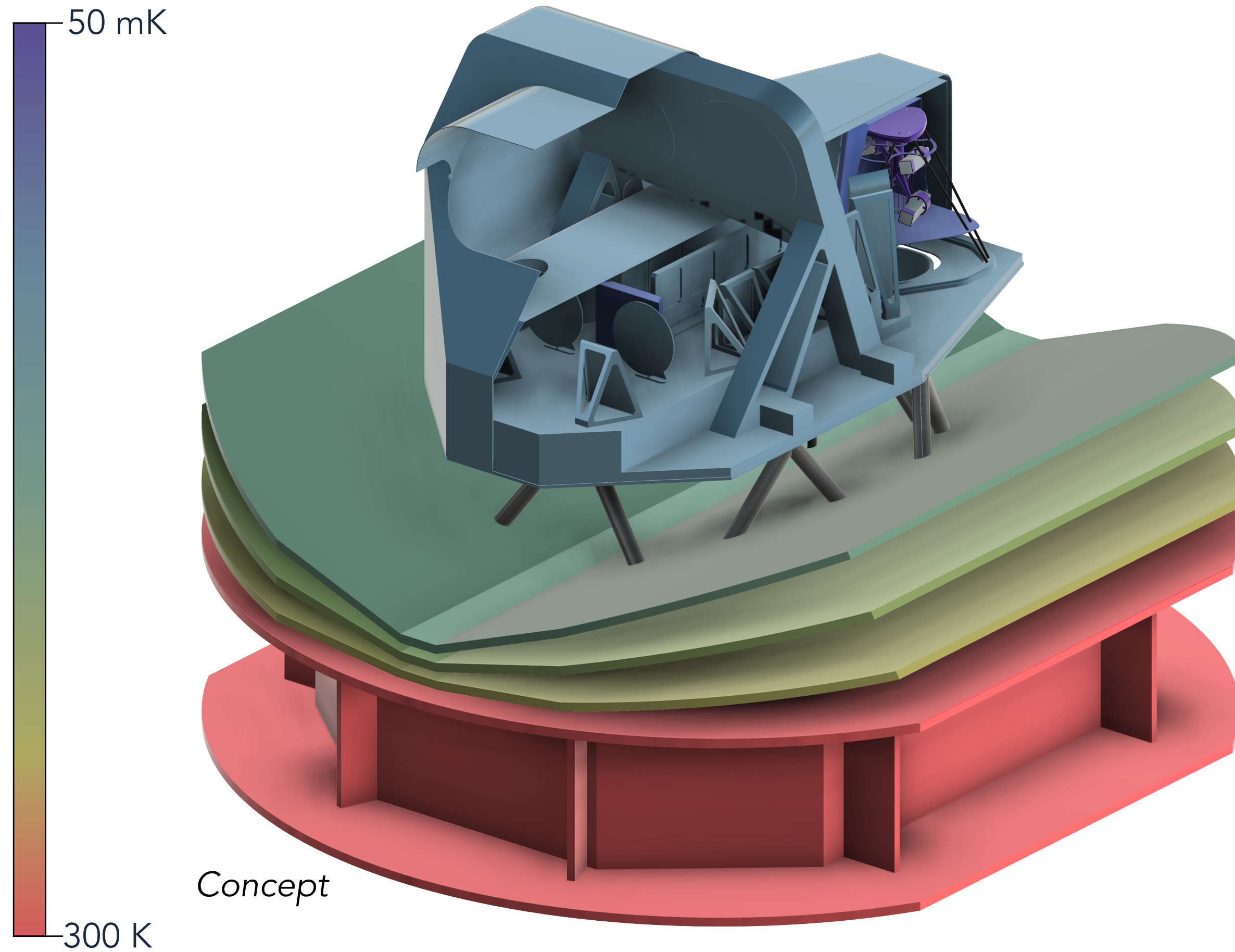
Conduction is too high
Radiation is even higher

→ Add MLI blanket to reduce the radiative load
Planck and Ariel heritage



$$\epsilon_{eff} = 0.008$$

Helps, but not enough



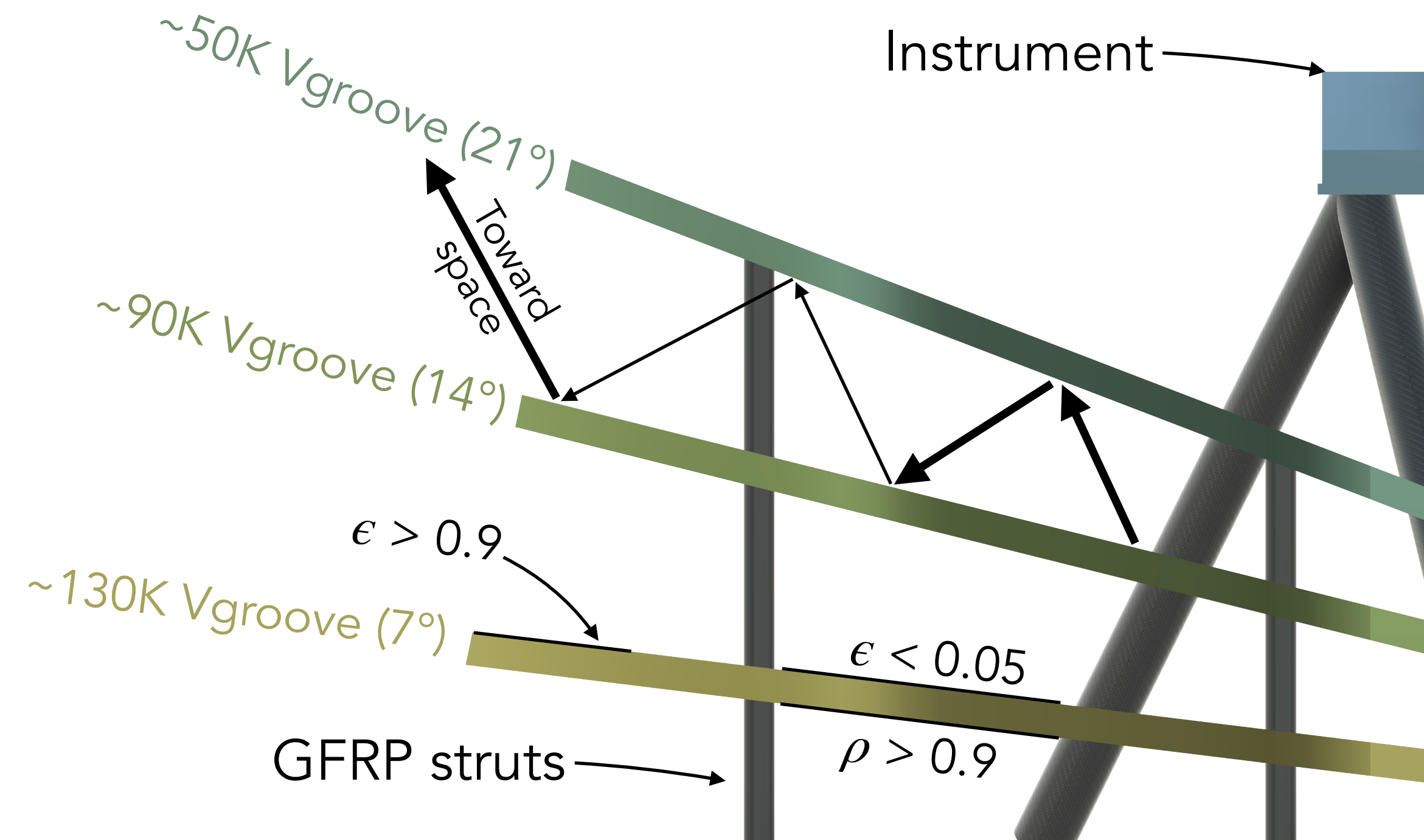
V-grooves

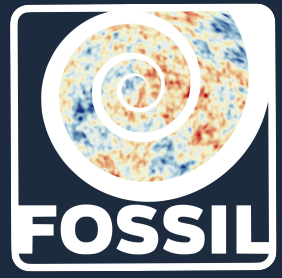
Reduce the load from the struts

Heritage from Planck and ARIEL

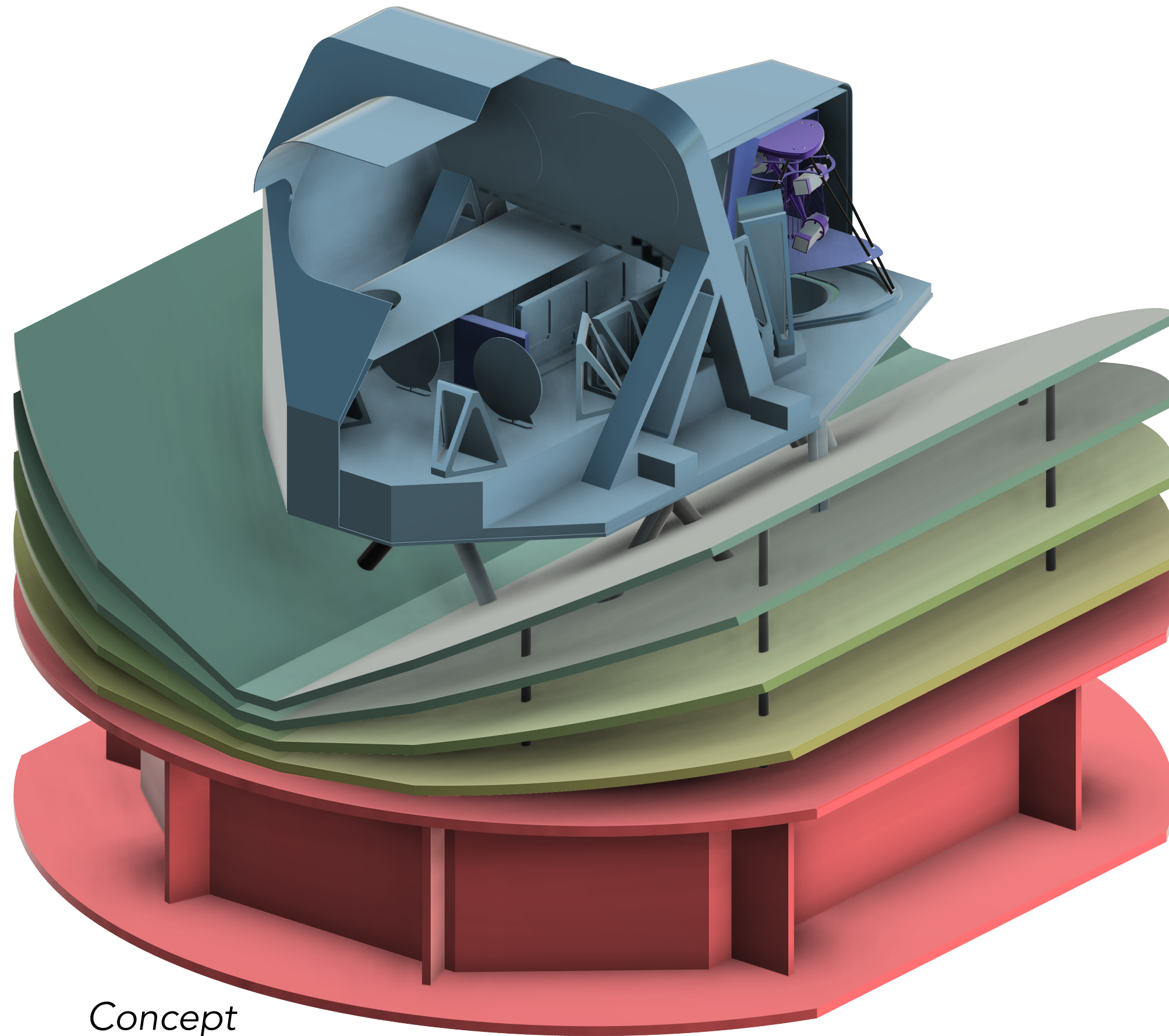
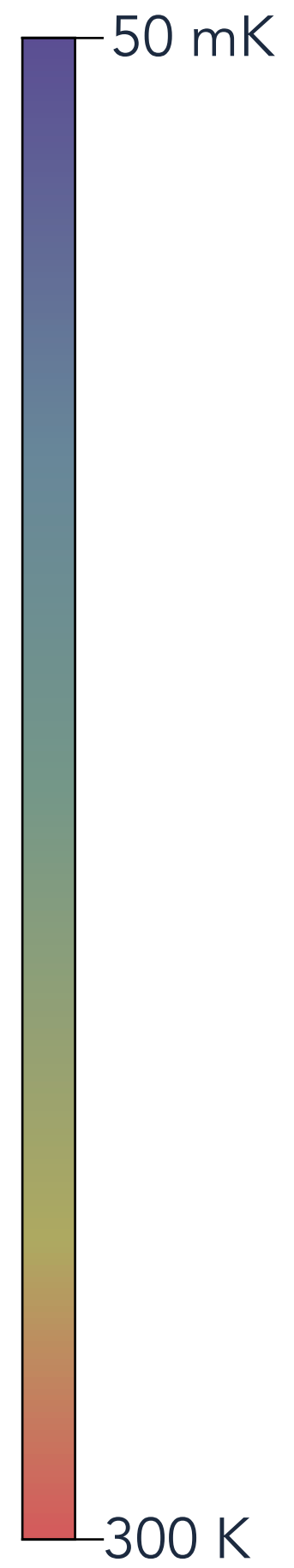
Aluminium panel supported by GFRP struts

ϵ : emissivity, ρ : reflectivity





25 K shield



25 K shield

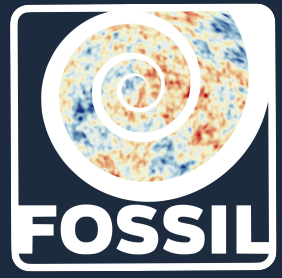
200 mW from ESA 4K cooler
Four Low Noise Amplifiers (40 mW)

~25K shield (22°)

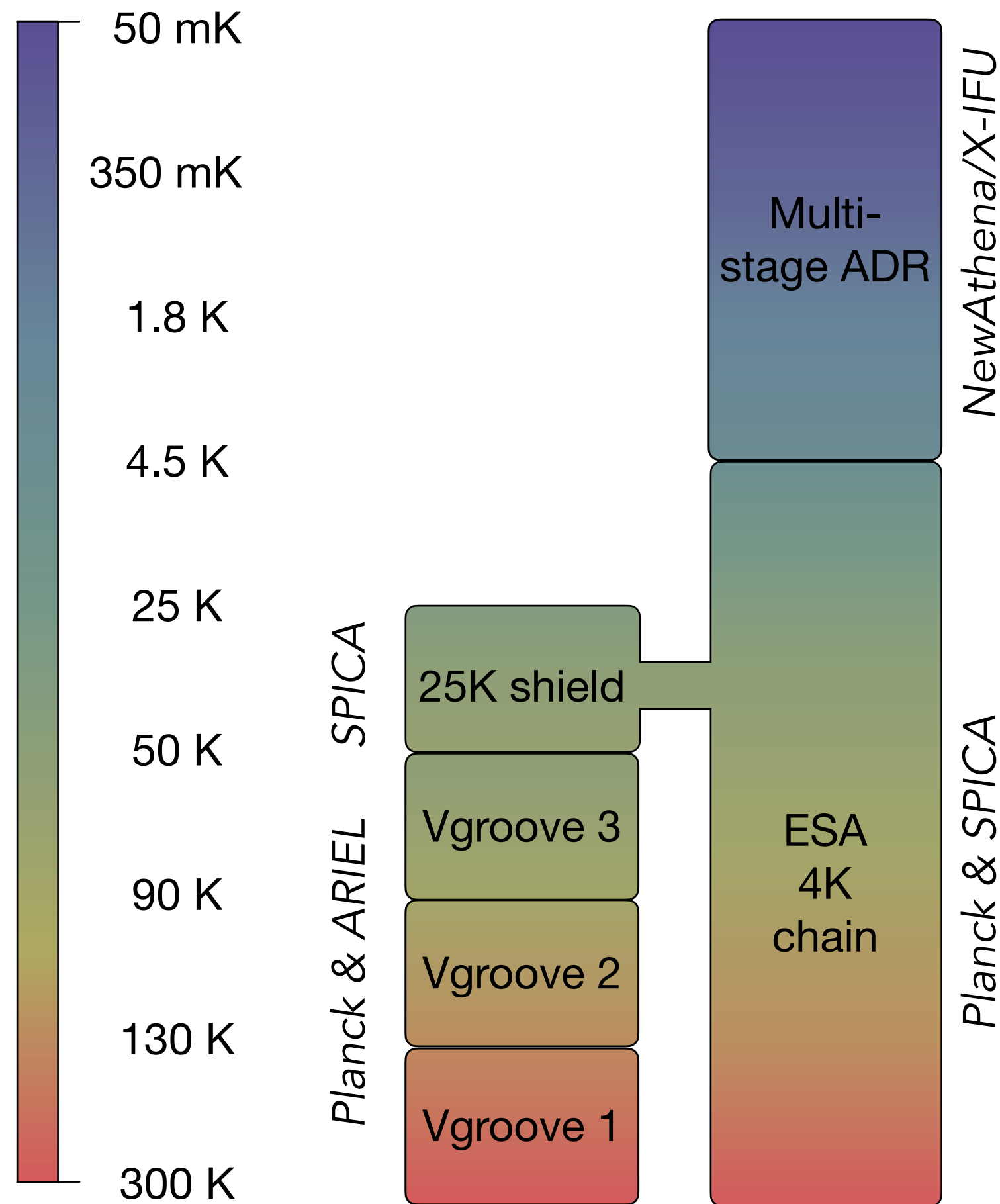
~50K Vgroove (21°)

~90K Vgroove (14°)

~130K Vgroove (7°)



The cryogenic chain



The preliminary thermal model shows the full chain (300 K → 50 mK) closes with **positive margins at every stage**, on **proven heritage** (Planck, ARIEL) and on-going developments/studies (X-IFU, SPICA, LiteBIRD).

→ **Everything will evolve in the next phase**
Stage temperatures, number of interception stages, materials, dimensions, all subject to trade-offs and optimisation.