LiteBIRD光学系の熱検討

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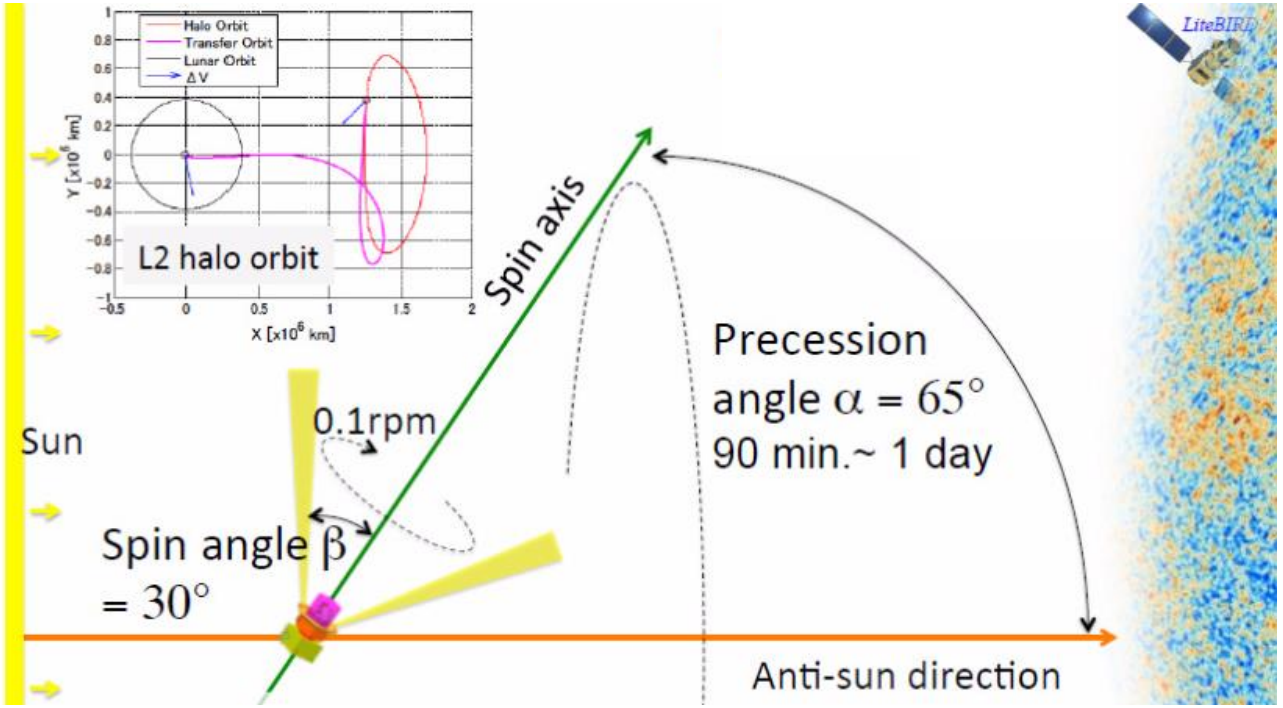
他LiteBIRD WG

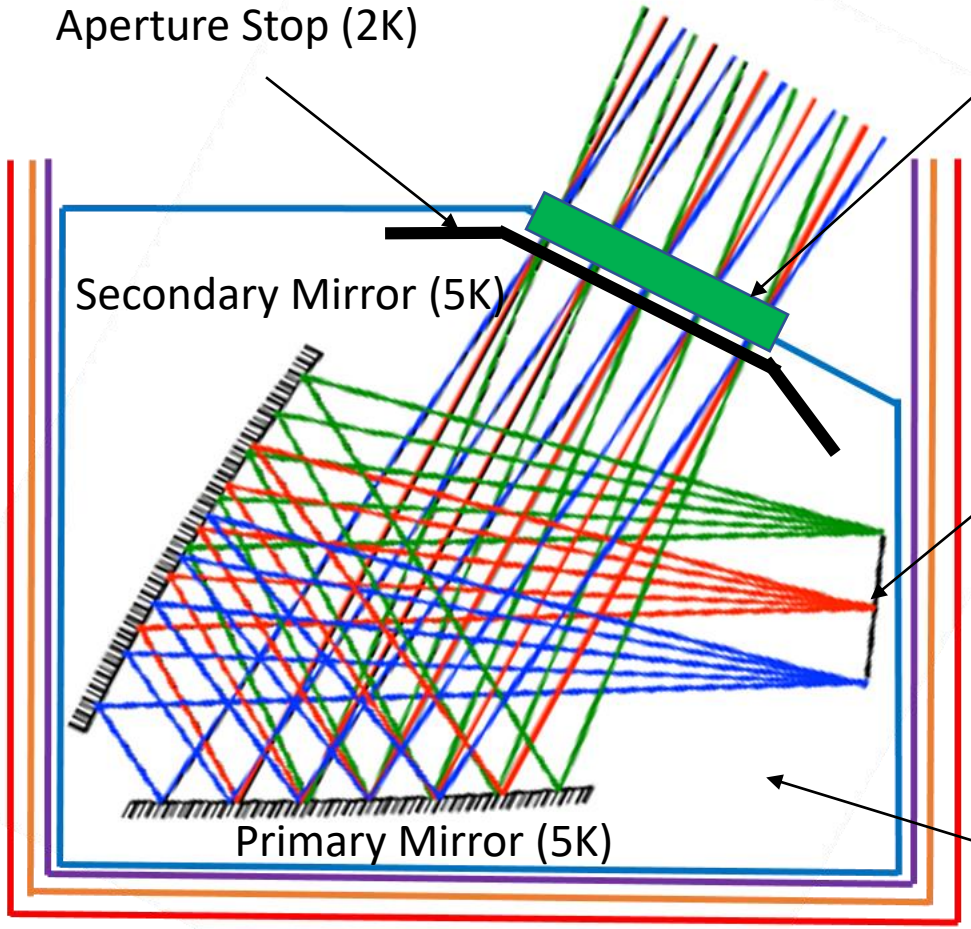
国立天文台

Introduction

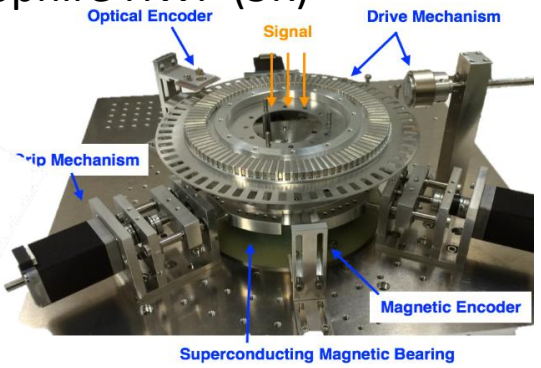


- LiteBIRDは太陽と地球のラグランジュポイント L2 (太陽から約15万km)で三年間の観測を予定
- 超伝導検出器 TES を0.1 K 以下に冷却しCMB偏光を超低ノイズで検出
- 熱ノイズを抑えるため、放射冷却と機械式冷凍機の組み合わせにより望遠鏡全体を低温冷却
- 検出器ノイズを抑えつつ効率の良い冷却系を検討する必要

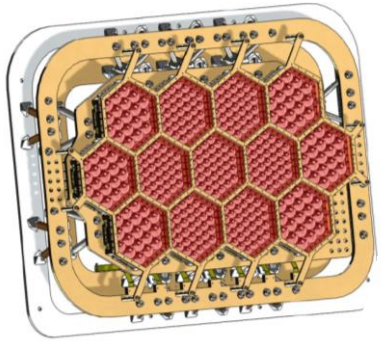
LiteBIRD 低温ミッション部

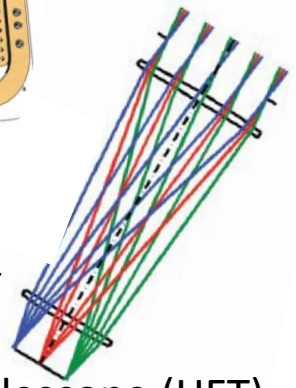


Sapphire HWP (5K)



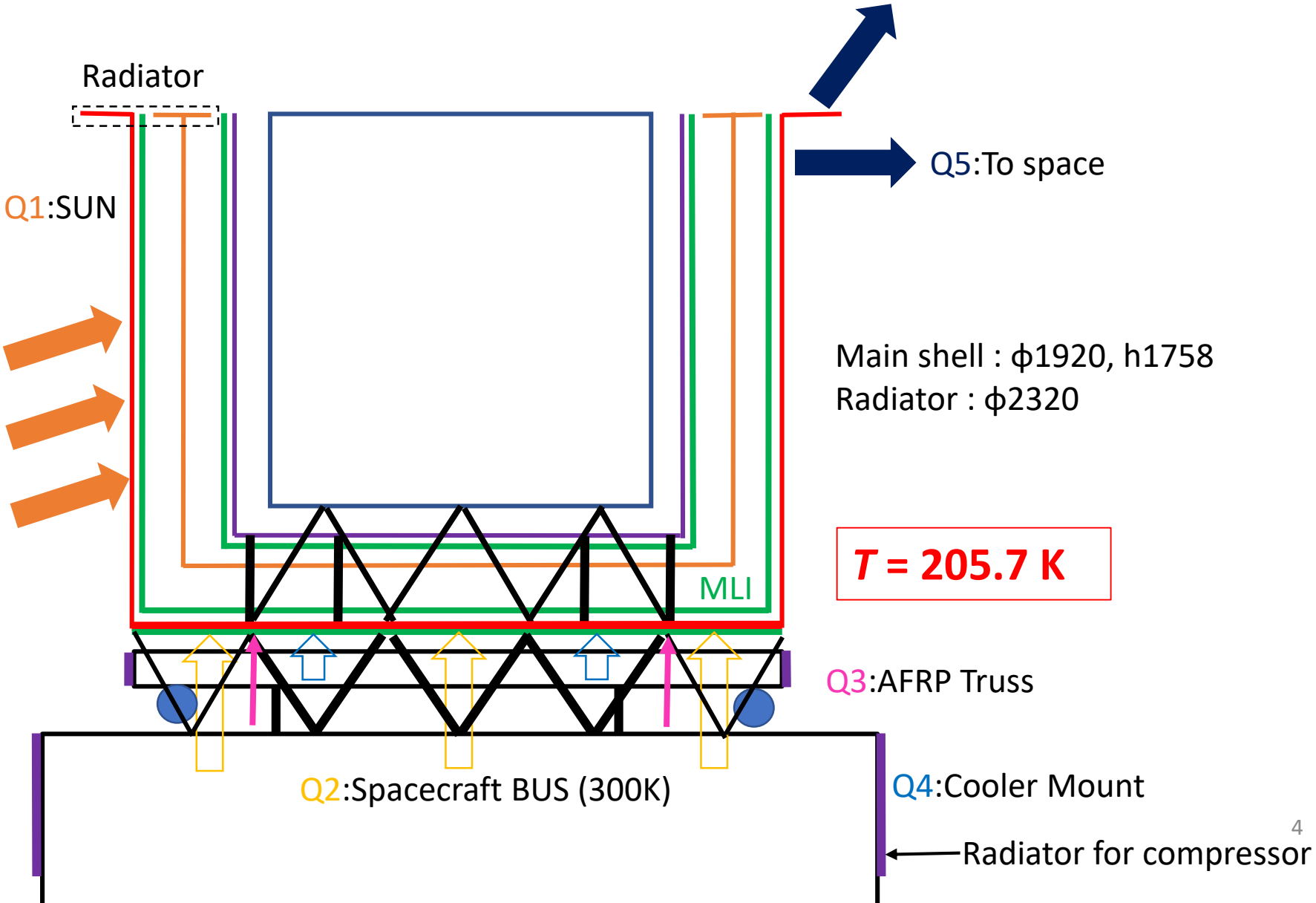
Focal Plane Detectors (<0.1K)
+ Lenslet + Low Pass Filter (2K)



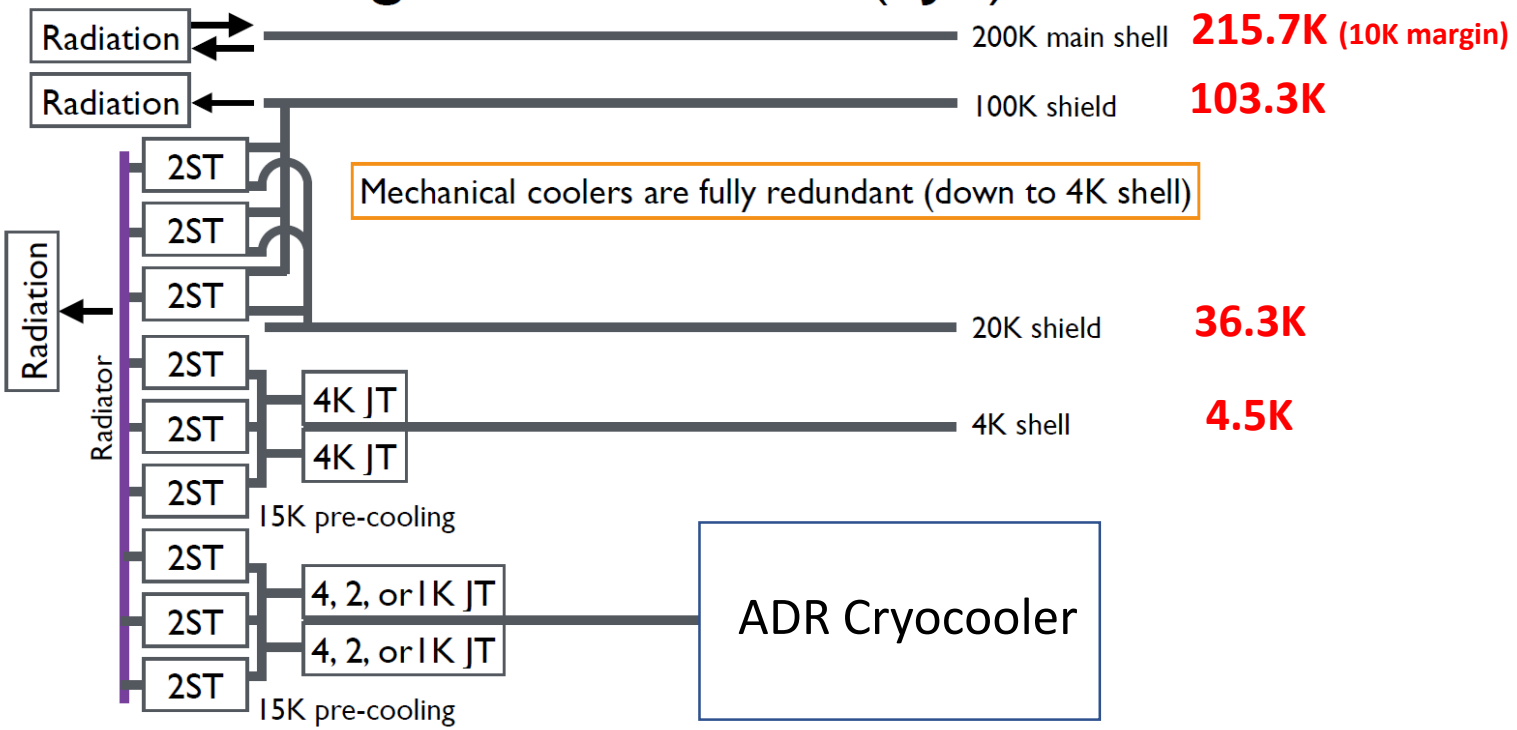


High Frequency Telescope (HFT)

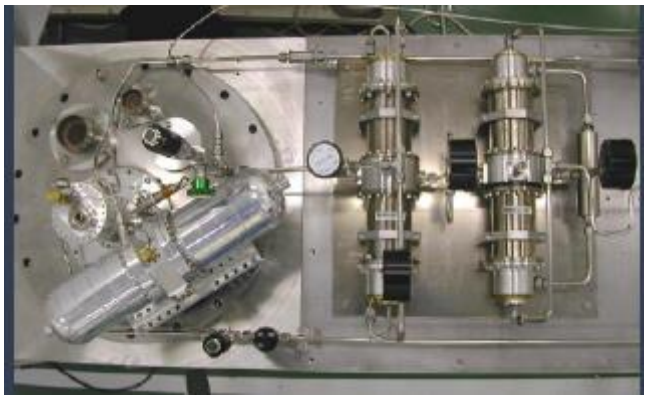
Thermal Inputs to 200K Main Shell

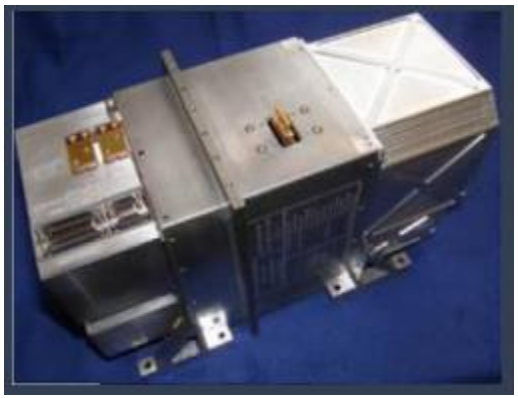


Cooling chain: 3SC+2x (2JT)



K.Mitsuda, B-mode from space (2015)

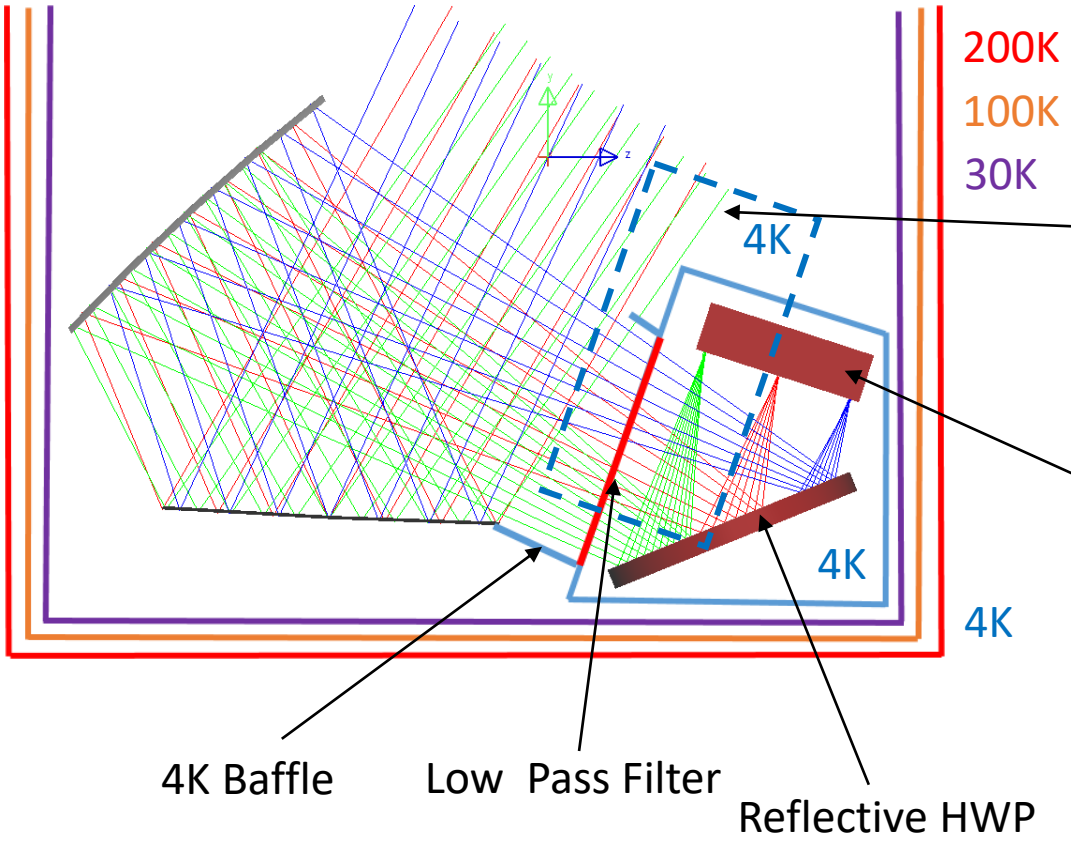




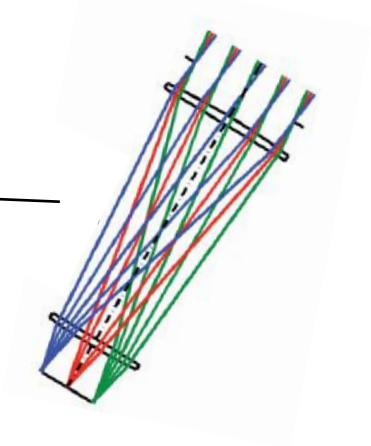
左: 2 段ST冷凍機 , シェル冷却 and JT 冷凍機予冷
右: JT 冷凍機 , 4K部冷却 and sub-K 冷凍機予冷

ADR : 検出器用sub-K 冷凍機

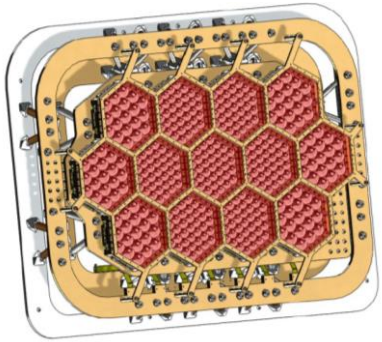
Open Structure Configuration



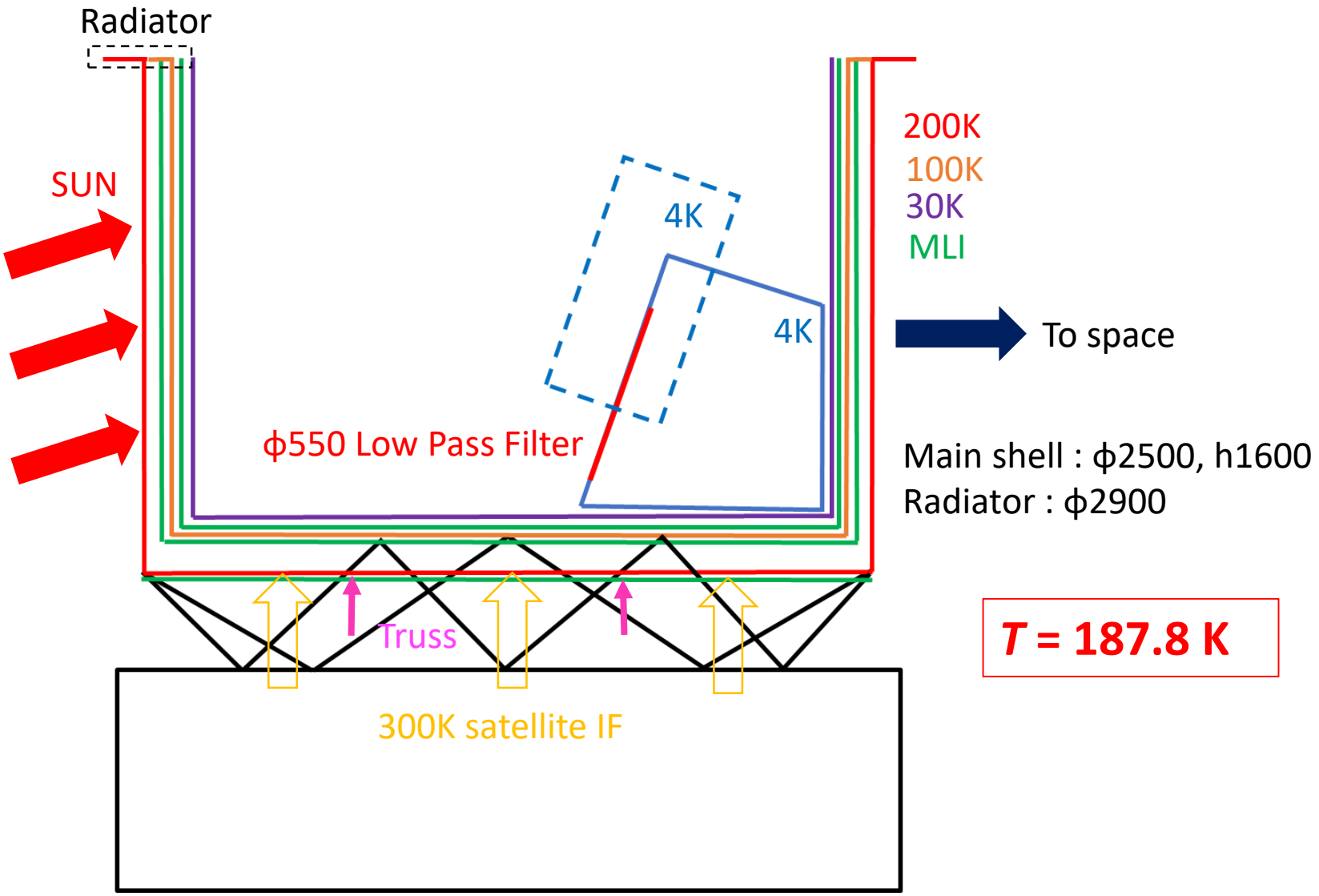
High Frequency Telescope (HFT)



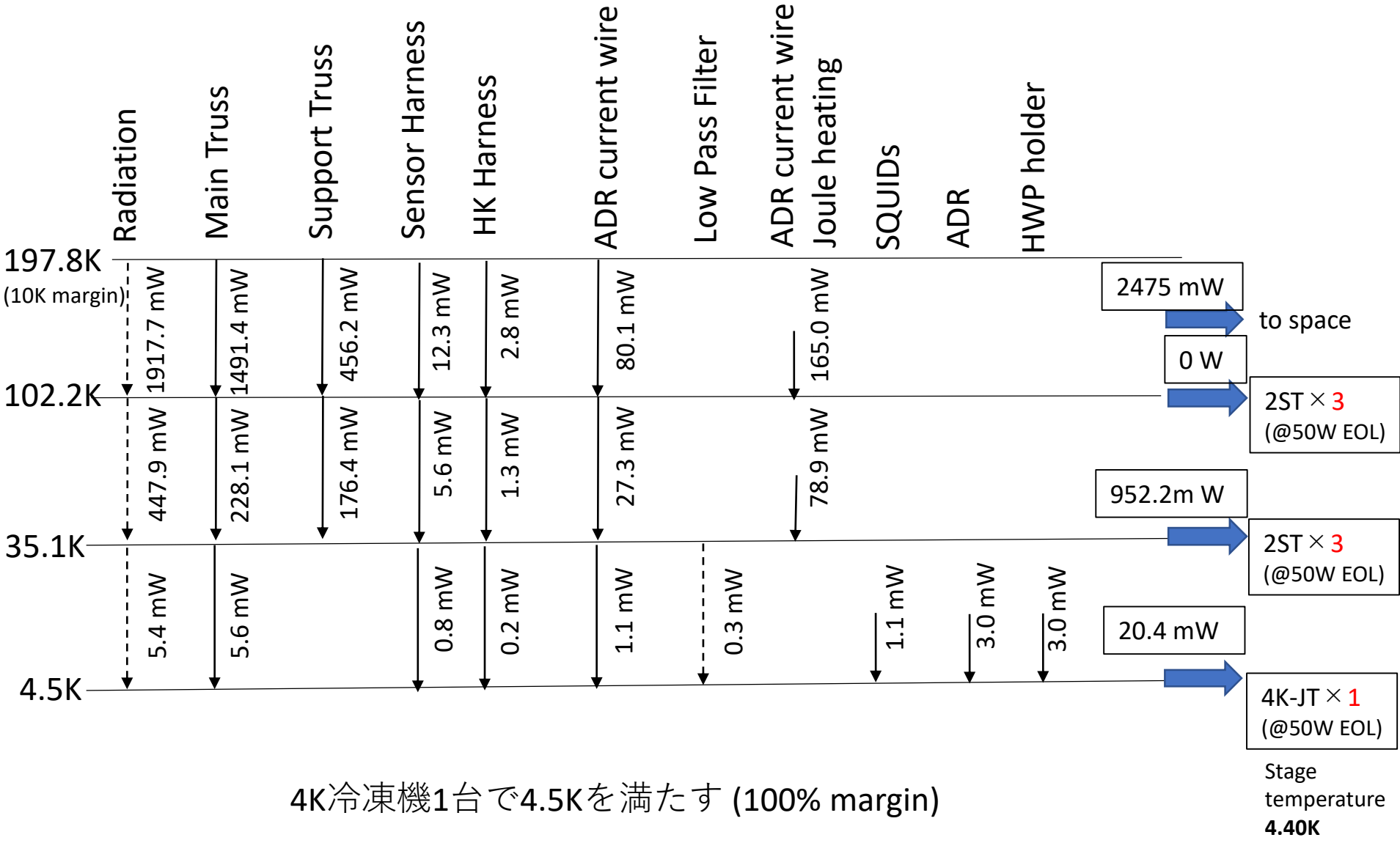
Focal Plane Detectors
+ Lenslet + Low Pass Filter



Thermal Inputs to 200K Main Shell

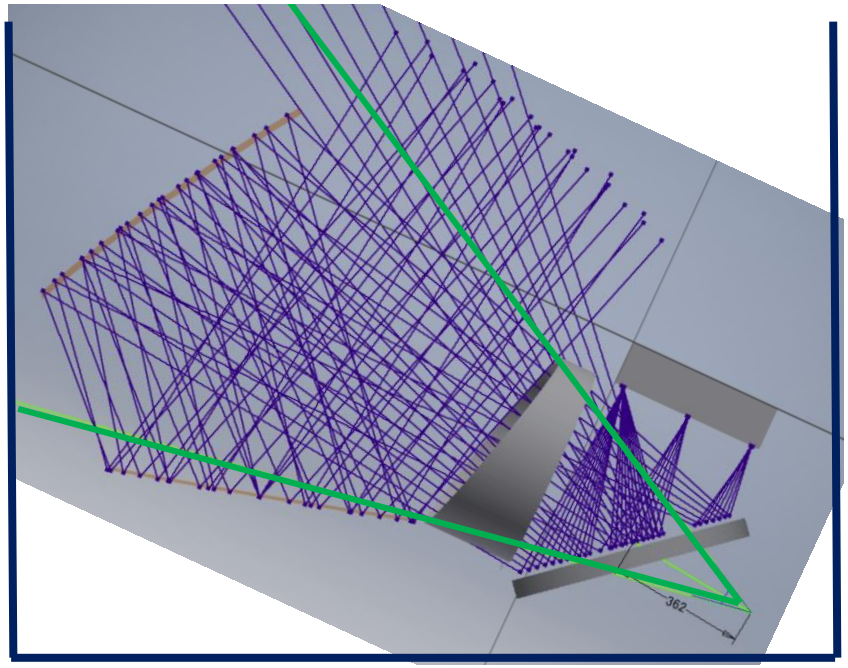


Heat flow diagram (Open Structure)

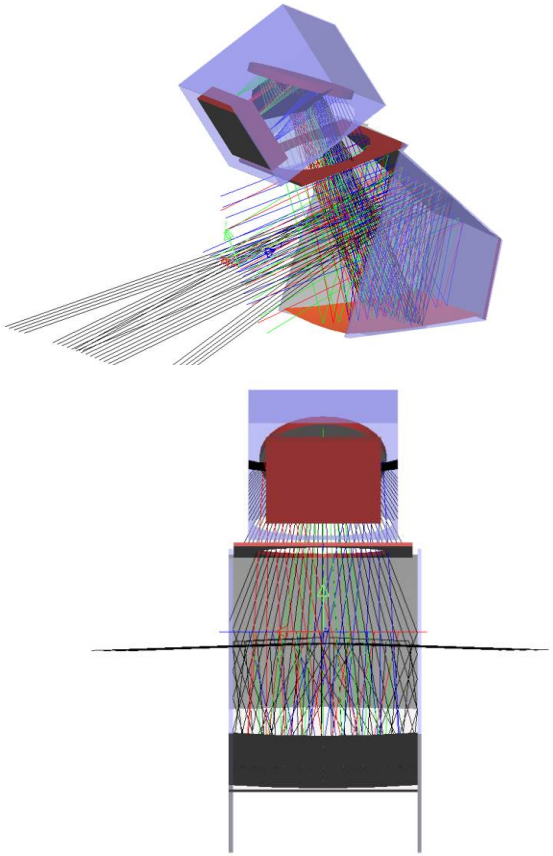


4K冷凍機1台で4.5Kを満たす (100% margin)

Thermal Loading from Outer Shell



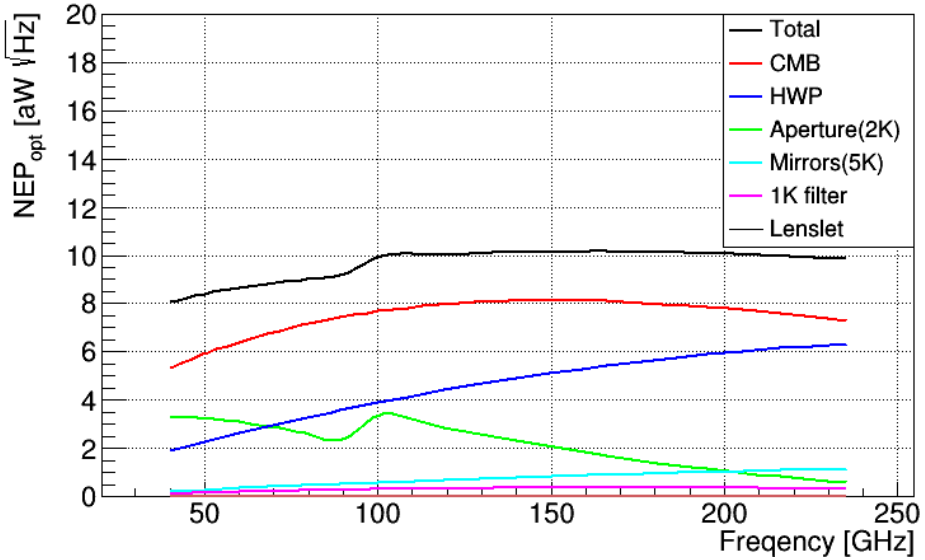
Open型ではシェル内壁からの熱放射が検出器の大きなノイズ源となる



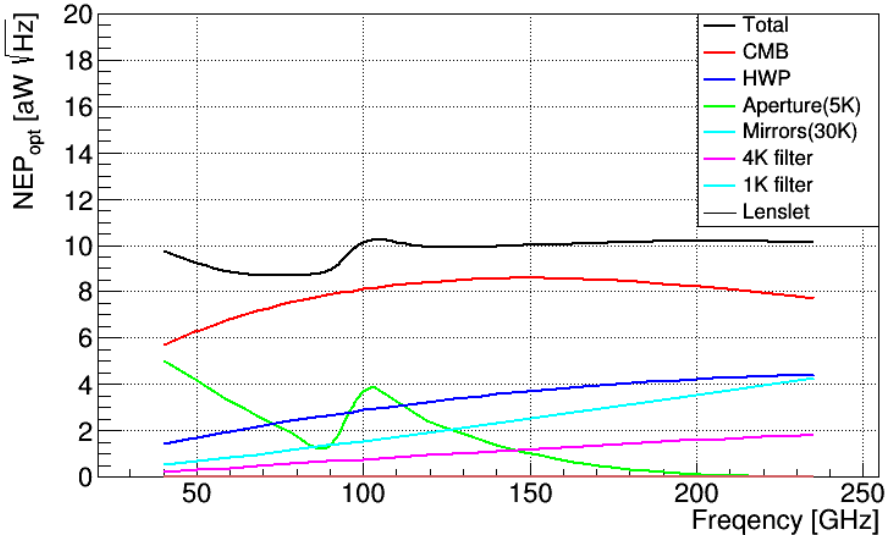
主鏡と副鏡間の背面、側面をミラー面で塞ぐことで高温の熱放射を遮蔽することが可能

NEP Calculation

5K Mirrors Option



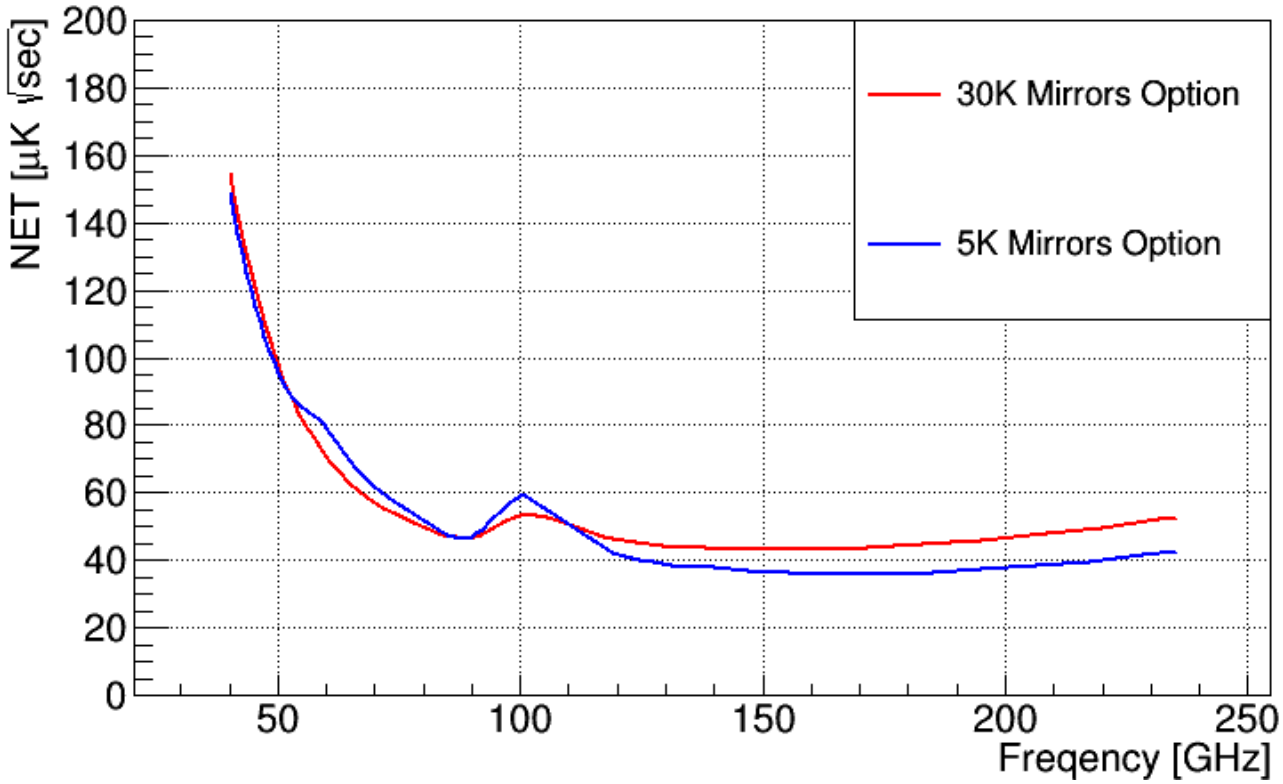
30K Mirrors Option



$\Delta\nu/\nu = 0.3$

No optical efficiency included

NET Comparison



検出器1素子あたりの感度比較

Summary

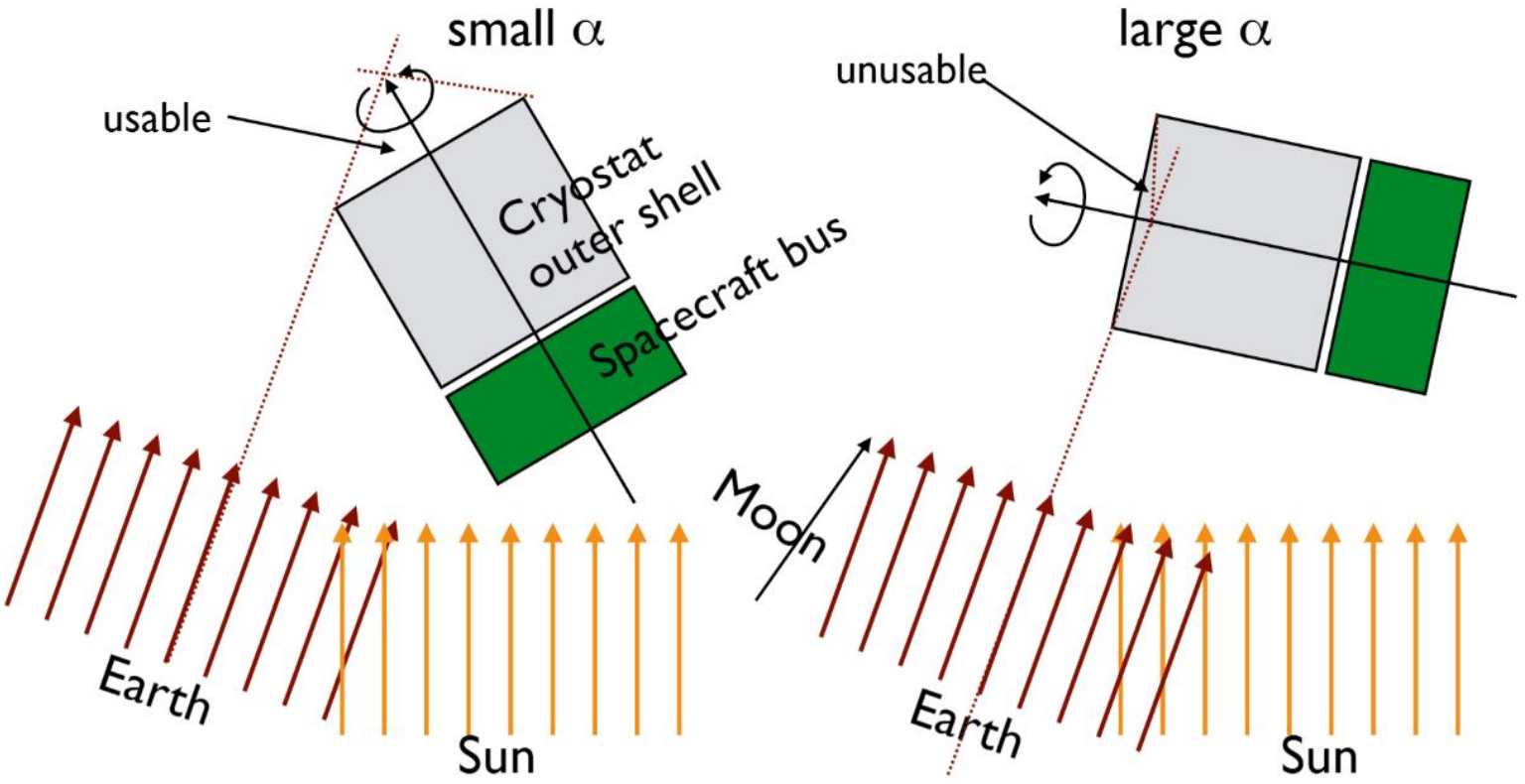
以下の2種類の光学系について検討を行った。

①光学系全体を5K以下に冷却する。
②HWPと検出器部のみを5K以下に冷却する。

①4K冷凍機2台構成。
　低ノイズ。

②4K冷凍機が1台構成。
　熱放射遮蔽のためミラー形状に工夫が必要。

Scan strategy and outer thermal design



Small α is better than large α in thermal point of view.

K. Mitsuda

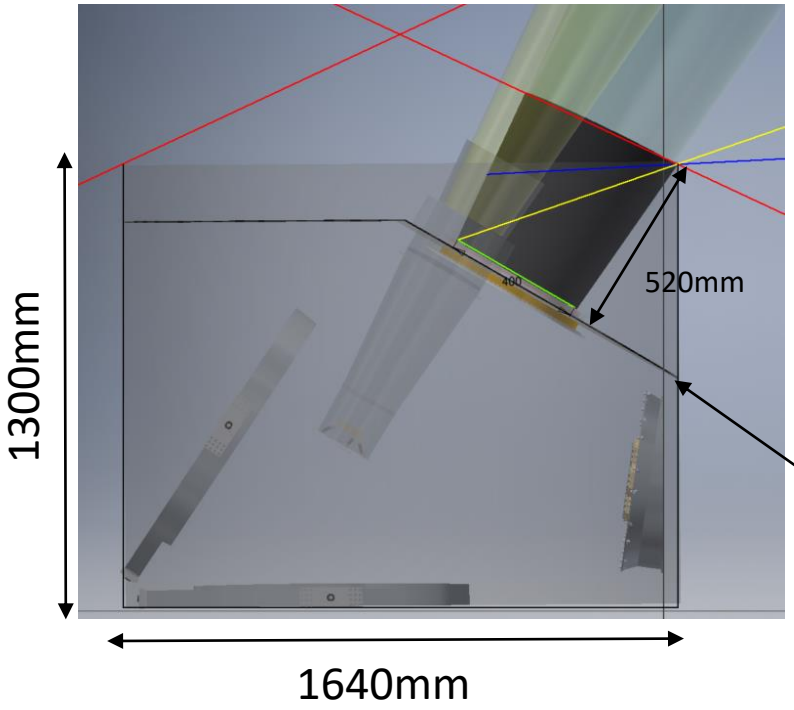
The shell size and the total mass of the satellite are also important parameters.

Incident angles of light from the Earth and Moon depend on the satellite obit.

Minimum size of the 4K shell

On Halo orbit

$\alpha = 65^\circ$, $\beta = 30^\circ$



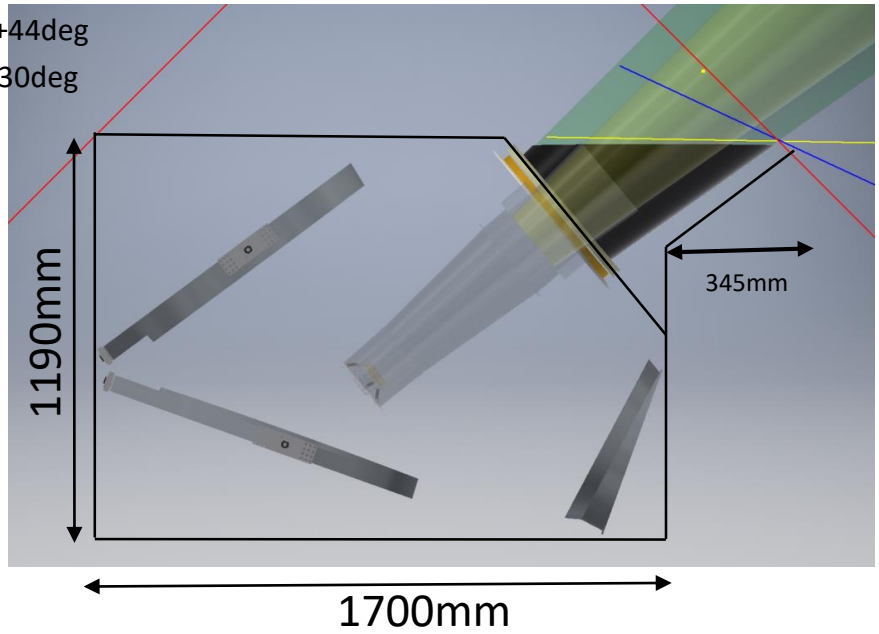
Moon: sun+44deg

Earth: sun+30deg

Sun

4K shell

$\alpha = 45^\circ$, $\beta = 50^\circ$



Sun to main shell : 890 W

Earth to 4K : 2.0 mW

Moon to 4K : 0.4 mW

Sun to main shell : 911 W

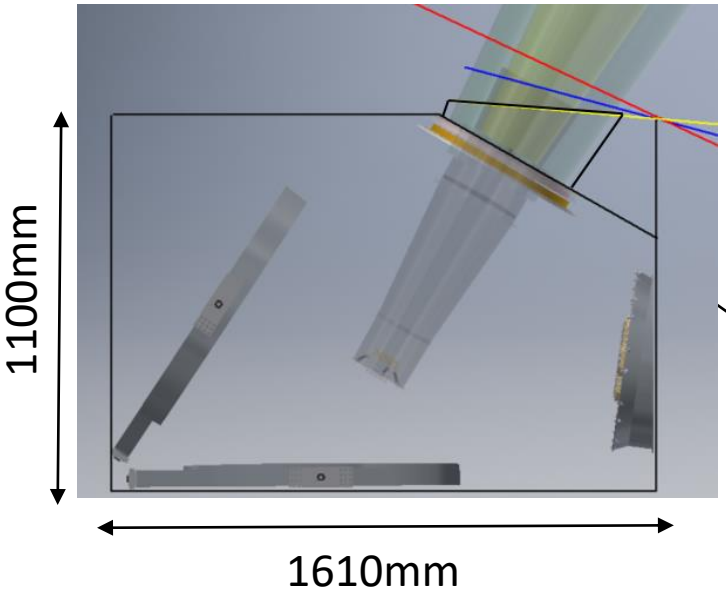
Earth to 4K : 0 mW

Moon to 4K : 0 mW

Minimum size of the 4K shell

On Lissajous orbit

$\alpha = 65^\circ$, $\beta = 30^\circ$



Moon: Sun+20deg
Earth: Sun+10deg
Sun

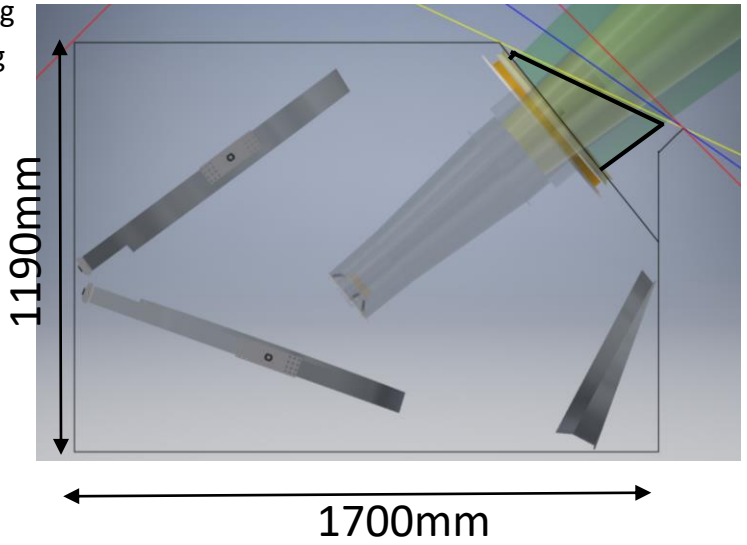
4K shell

Sun to main shell : 794 W

Earth to 4K : 0 mW

Moon to 4K : 0 mW

$\alpha = 45^\circ$, $\beta = 50^\circ$



Sun to main shell : 911 W

Earth to 4K : 0 mW

Moon to 4K : 0 mW