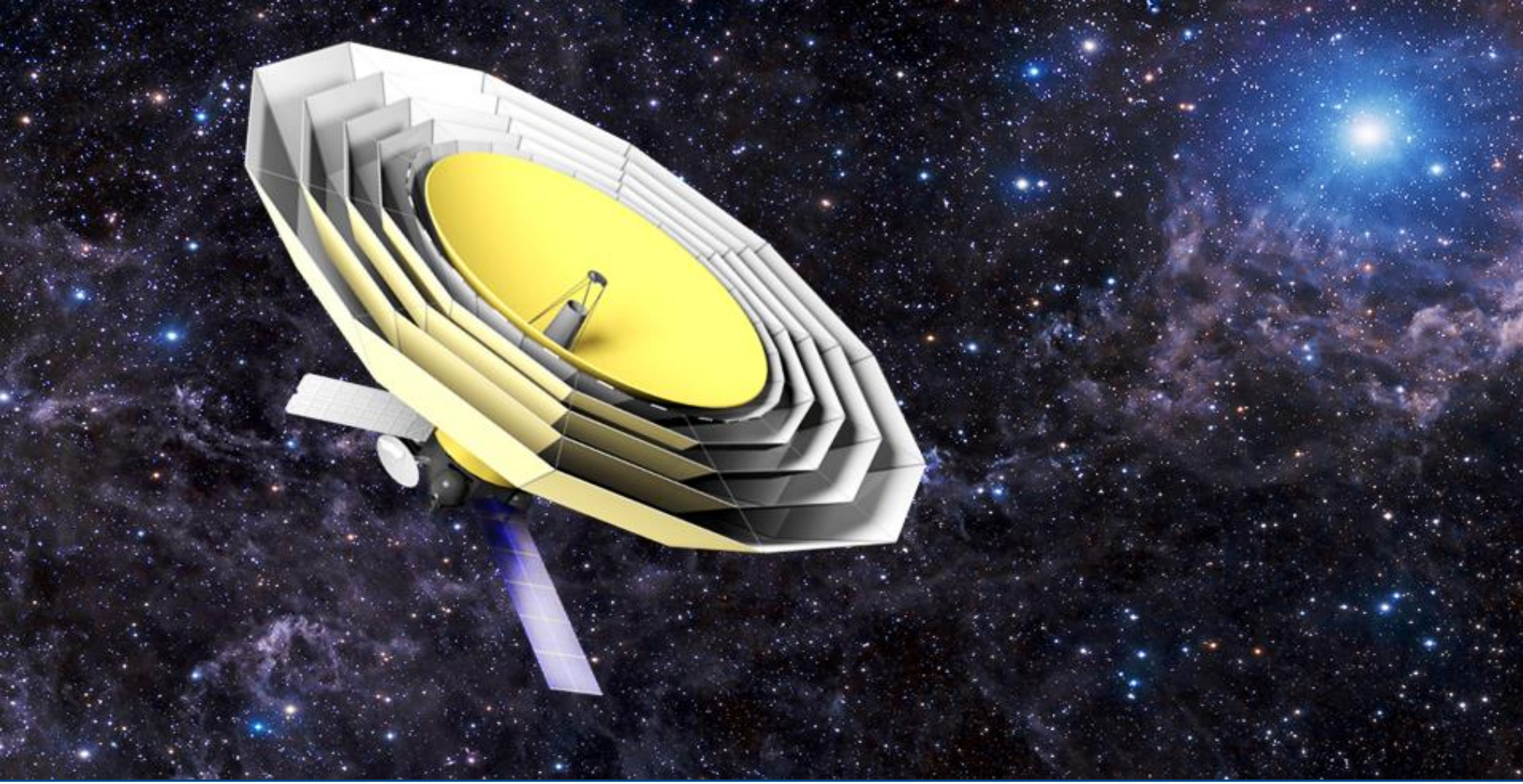


Thermal design of the Millimetron payload module

ASC LPI

RESHETNEV COMPANY

E. Golubev, on behalf of the Millimetron team

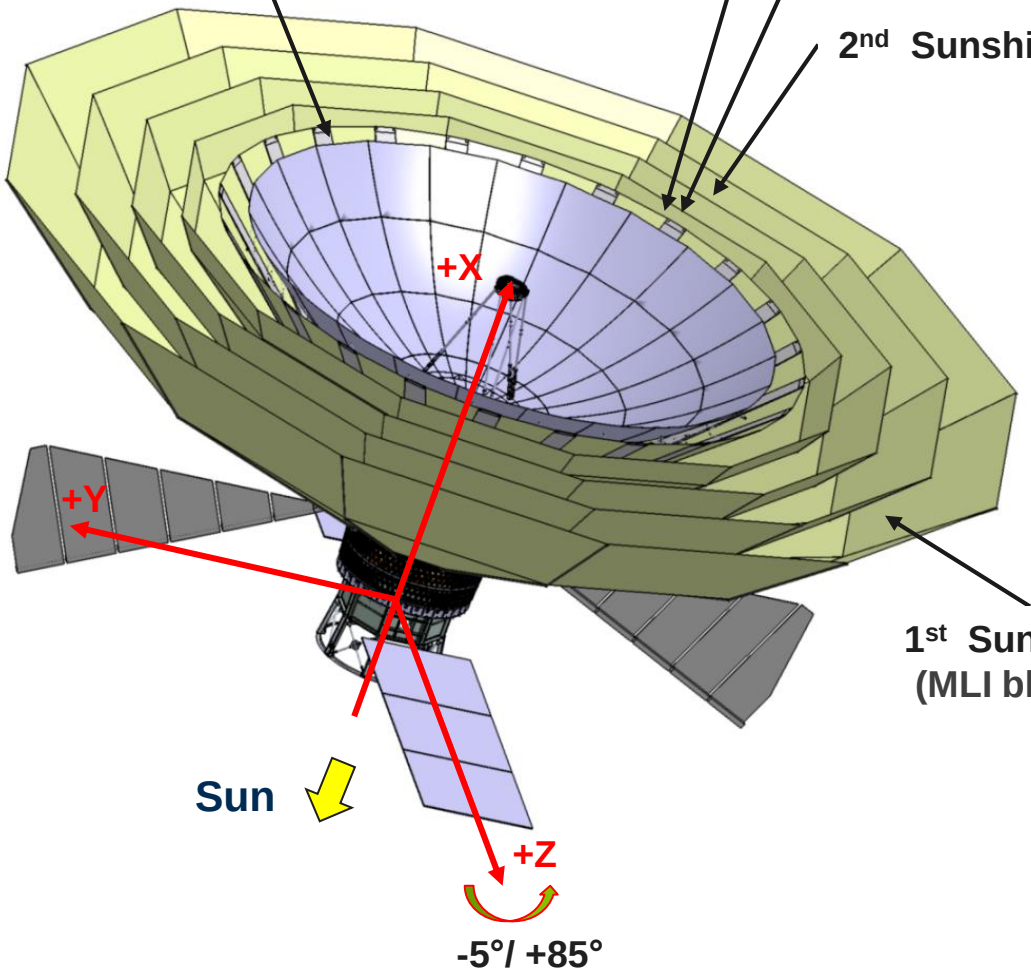
Millimetron Workshop 2019: Capabilities and Science Objective of Millimetron Space Observatory, 9-11 September 2019, Observatoire de Paris / LERMA, Paris

Sunshields

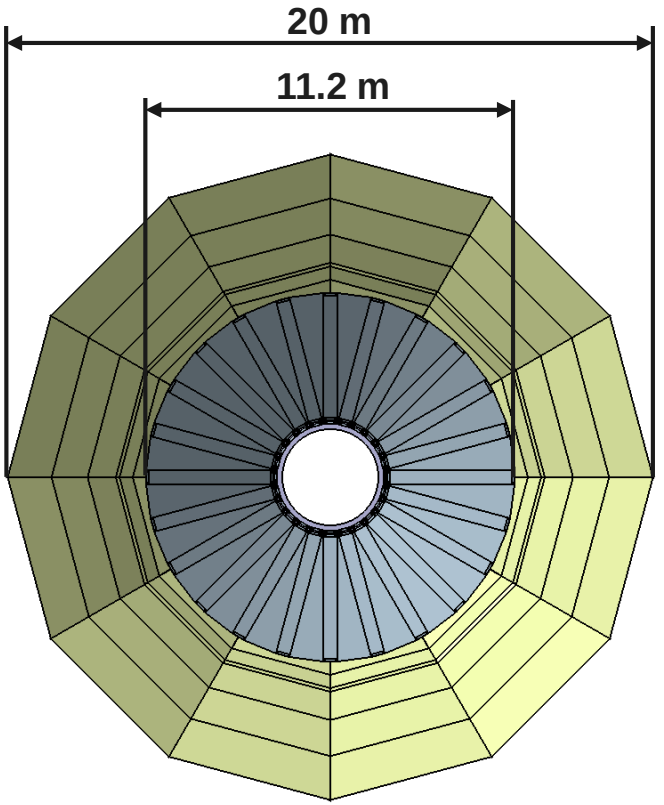
Cryoshield
(actively cooled down to 20K)

4th Sunshield
3rd Sunshield
2nd Sunshield

2-sided aluminum-plated Kapton films

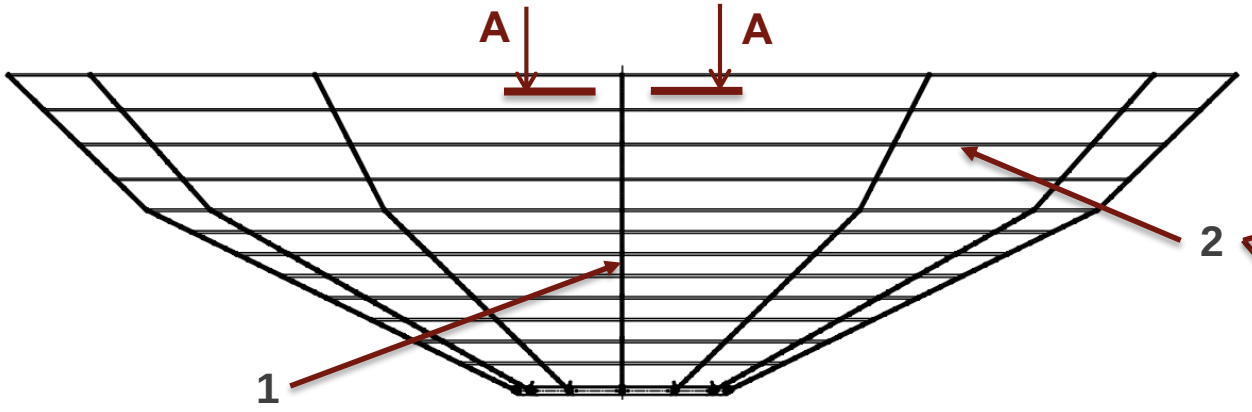


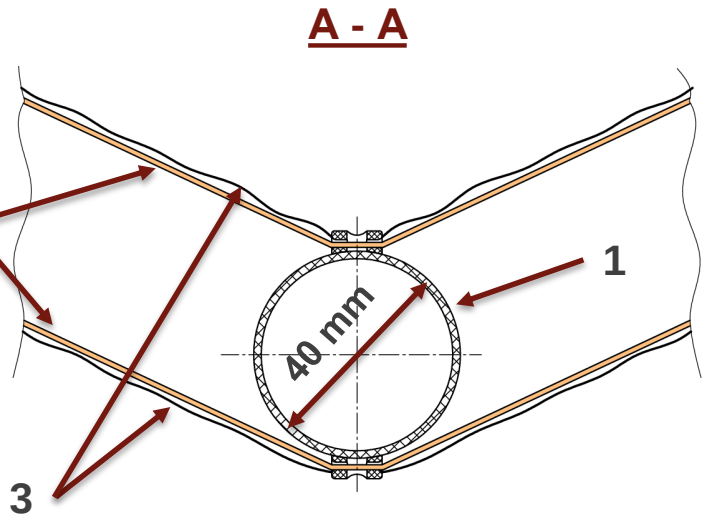
1st Sunshield
(MLI blanket)



Overall dimensions

Sunshield structure

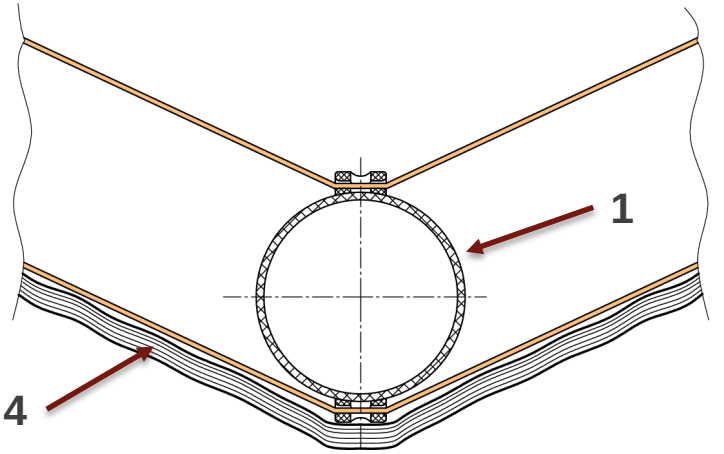




2nd,3rd, 4th Sunshields

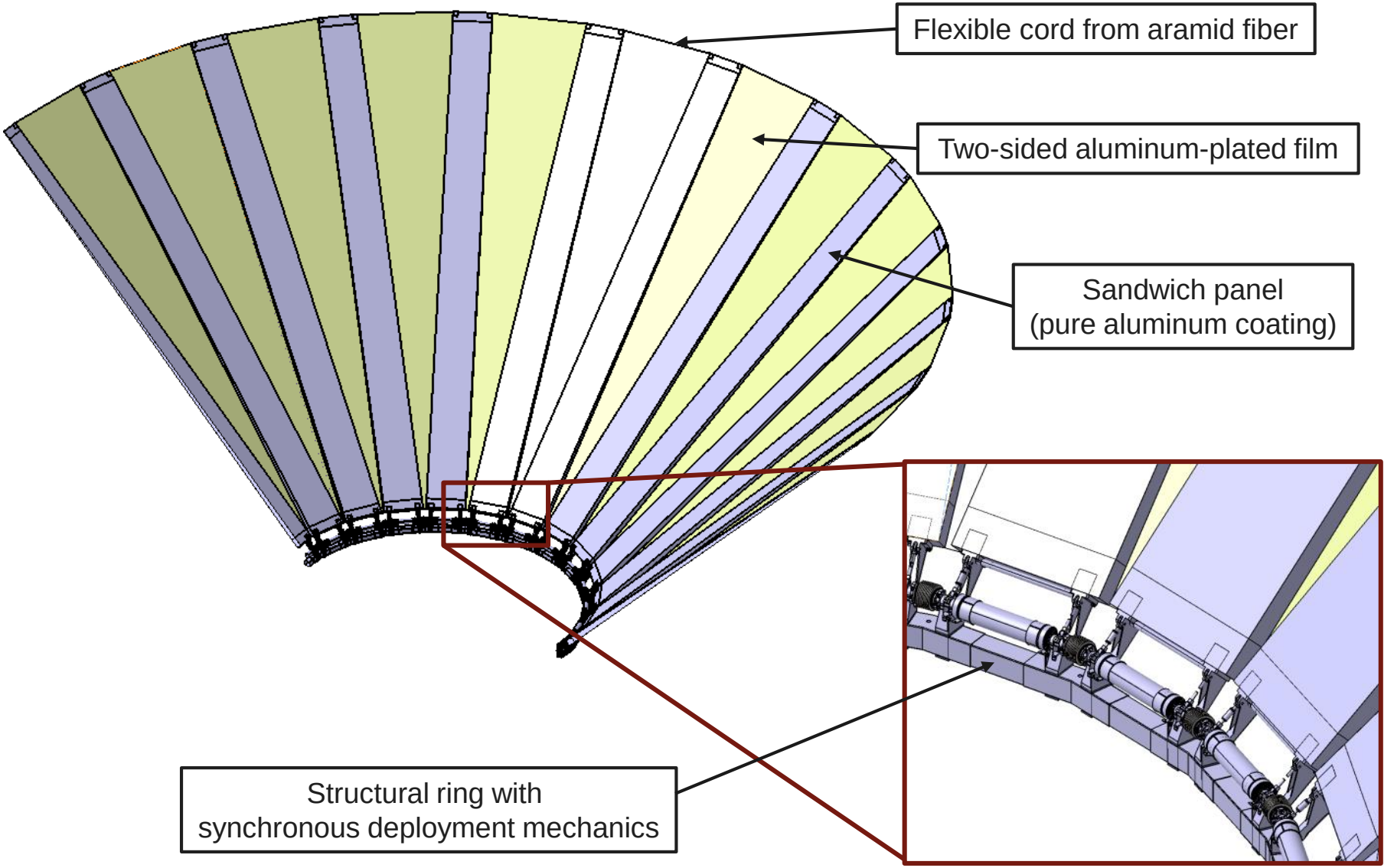
Sunshields consist of:

1. tubes from CFRP
2. flexible cord from aramid fiber
3. Two-sided aluminum-plated polyimide film
4. MLI (R=50 $\frac{m^2 \cdot K}{W}$)



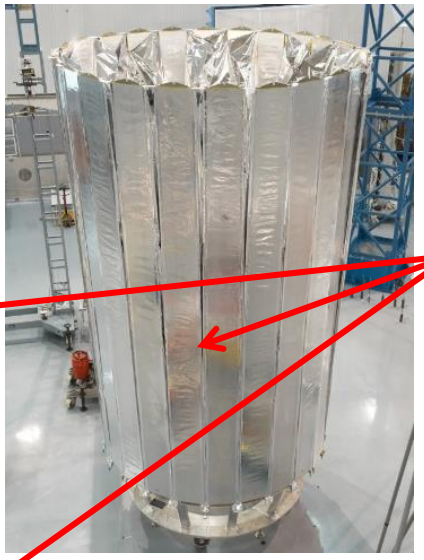
1st Sunshield (external)

Cryoshield structure



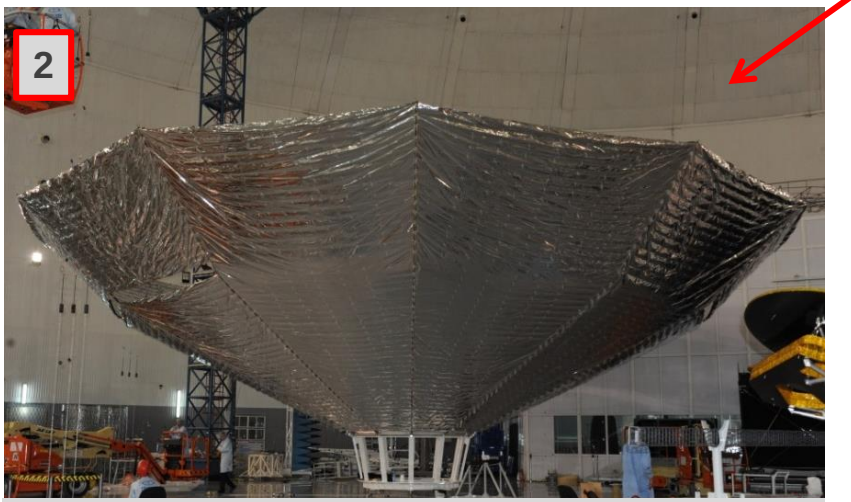
Development status

Mock-up of cryoshield (full-scale)



Objectives of tests:

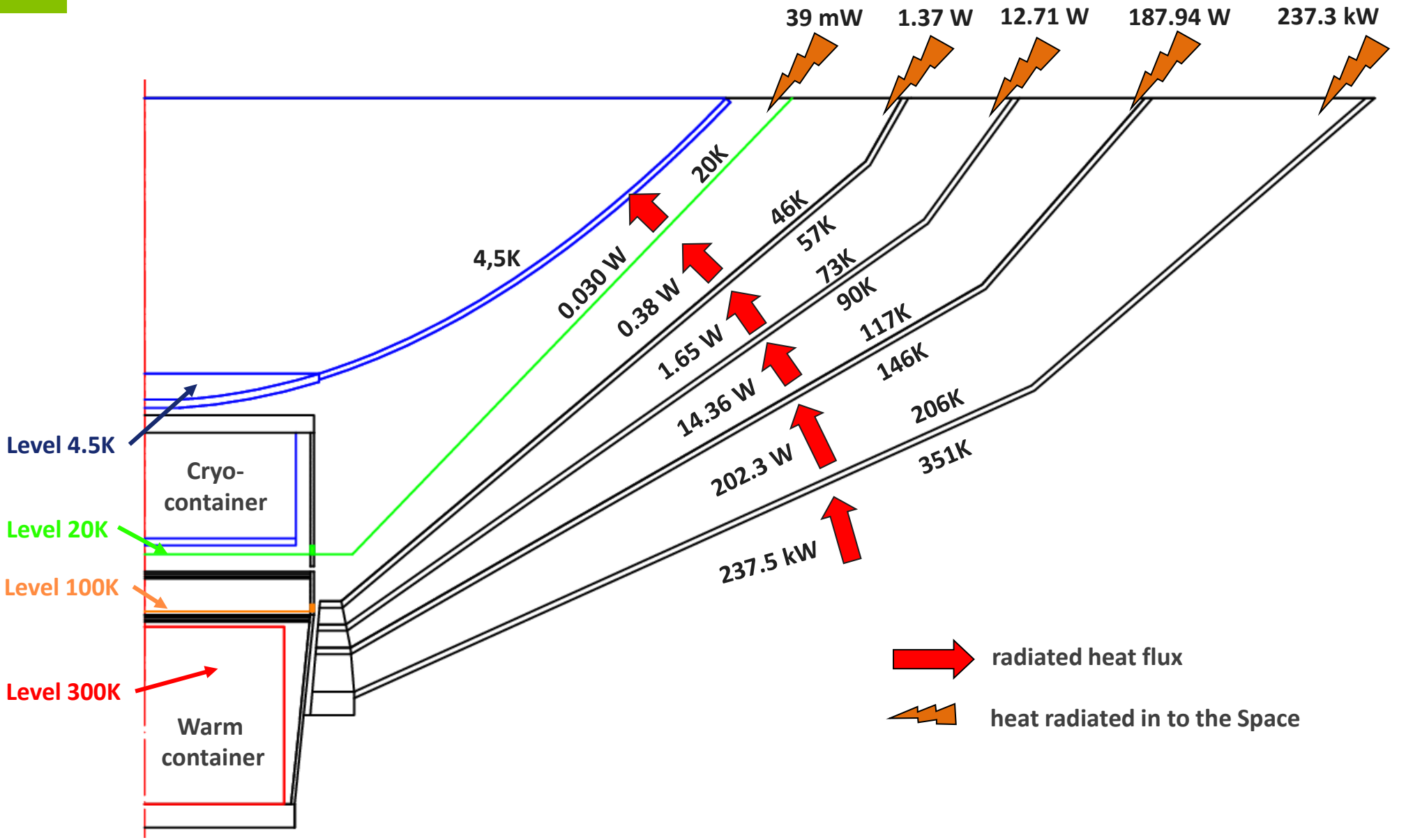
- film management
- film packaging
- deployment
- gravity offload system



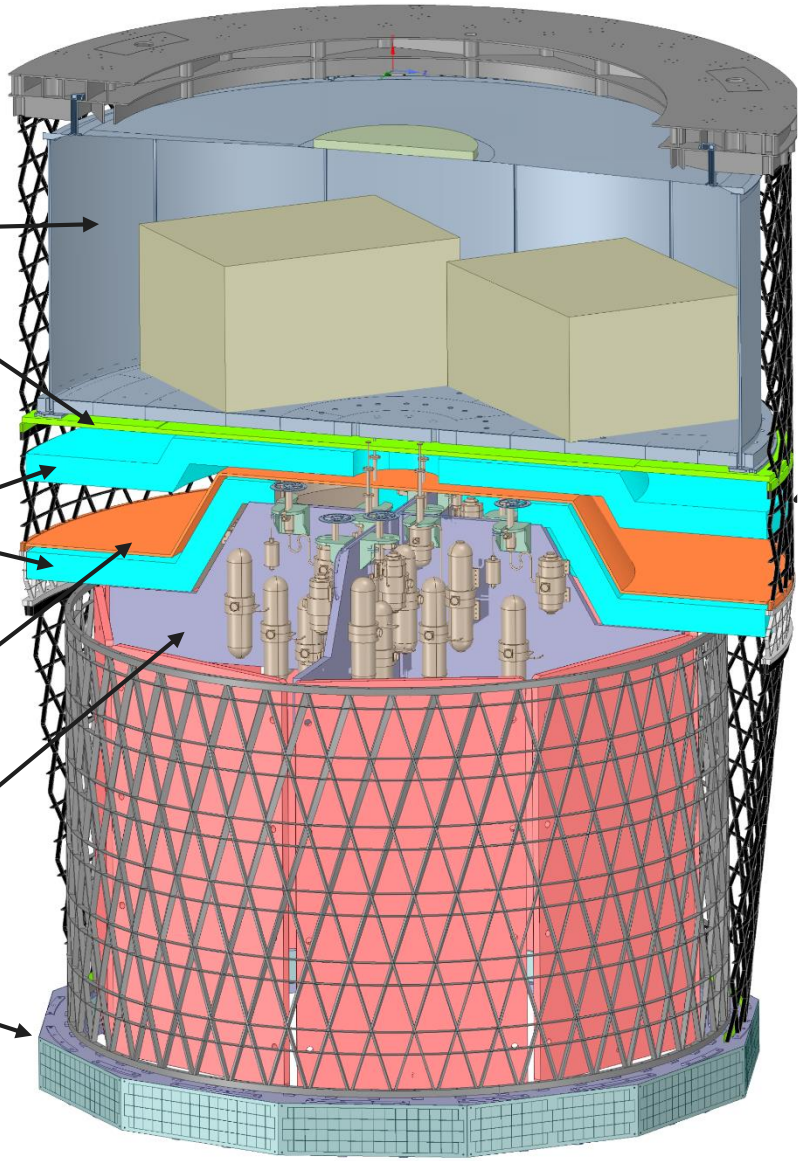
Mock-up of the 1st sunshield (full-scale)

Engineering model of the deployment system

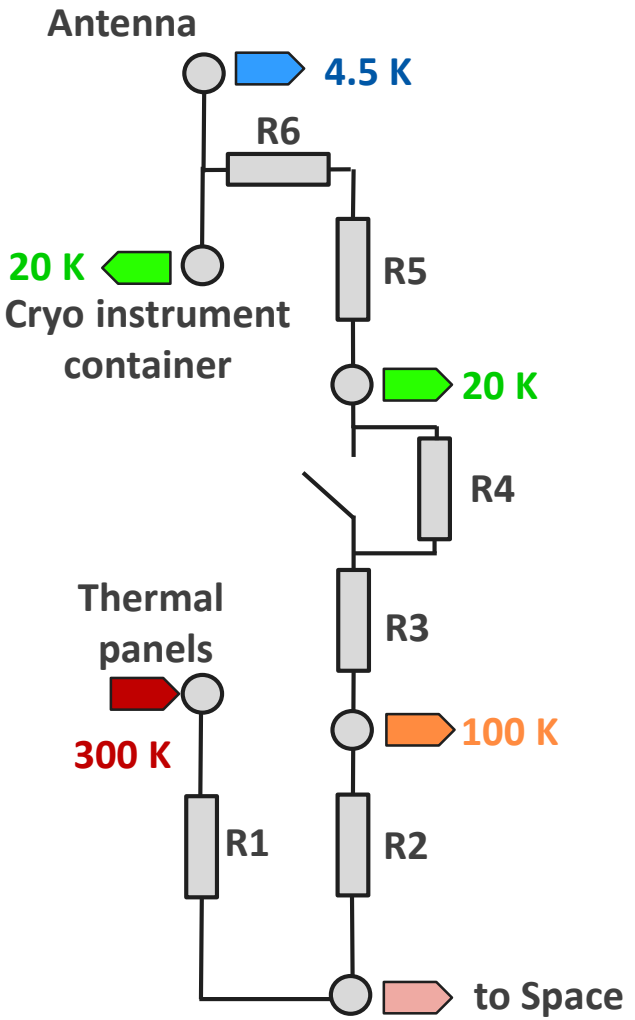
Effective Radiation cooling



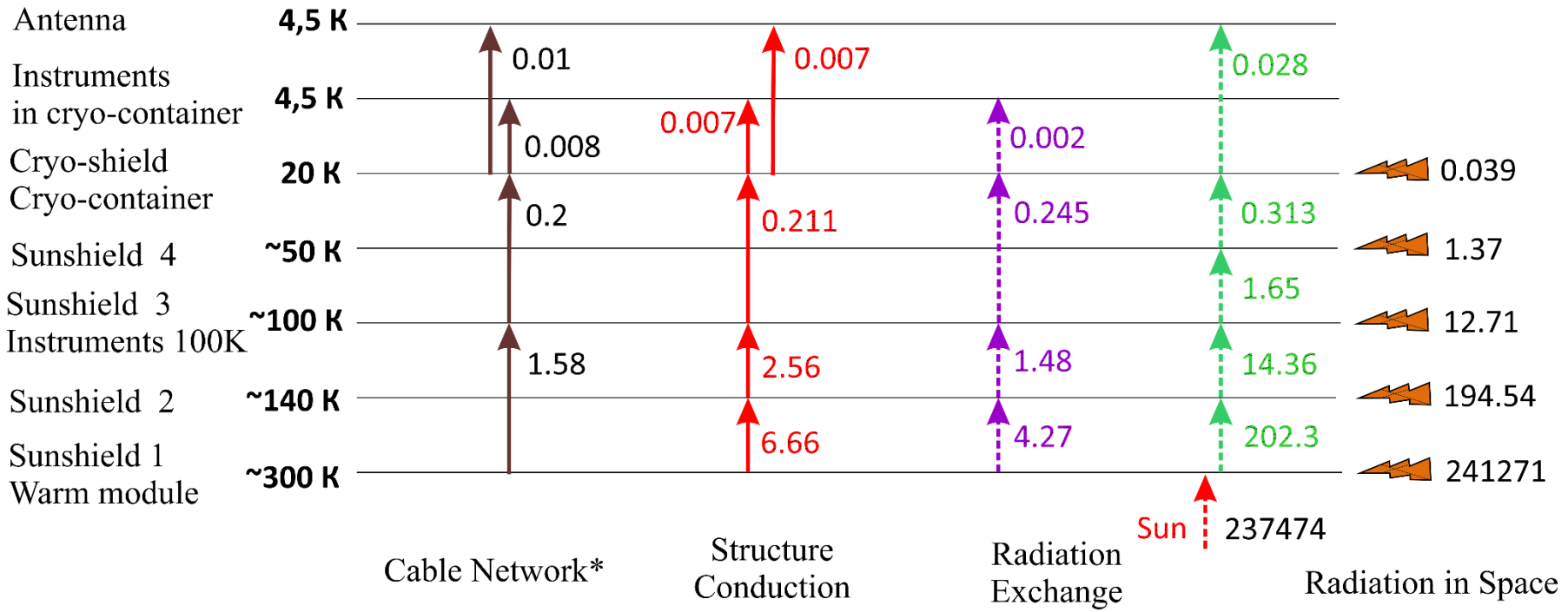
“Matreshka” design



Equivalent scheme of structure in terms of conductance



Preliminary heat flow map (calculated)



Unit: W

- Conducted Heat along wires
- Conducted Heat
- Net Radiated Heat between two groups in compartments
- Net Radiated Heat between two shields
- Absorbed Solar Heating
- Heat Radiated to Space

Budget of the heat loads on the temperature levels

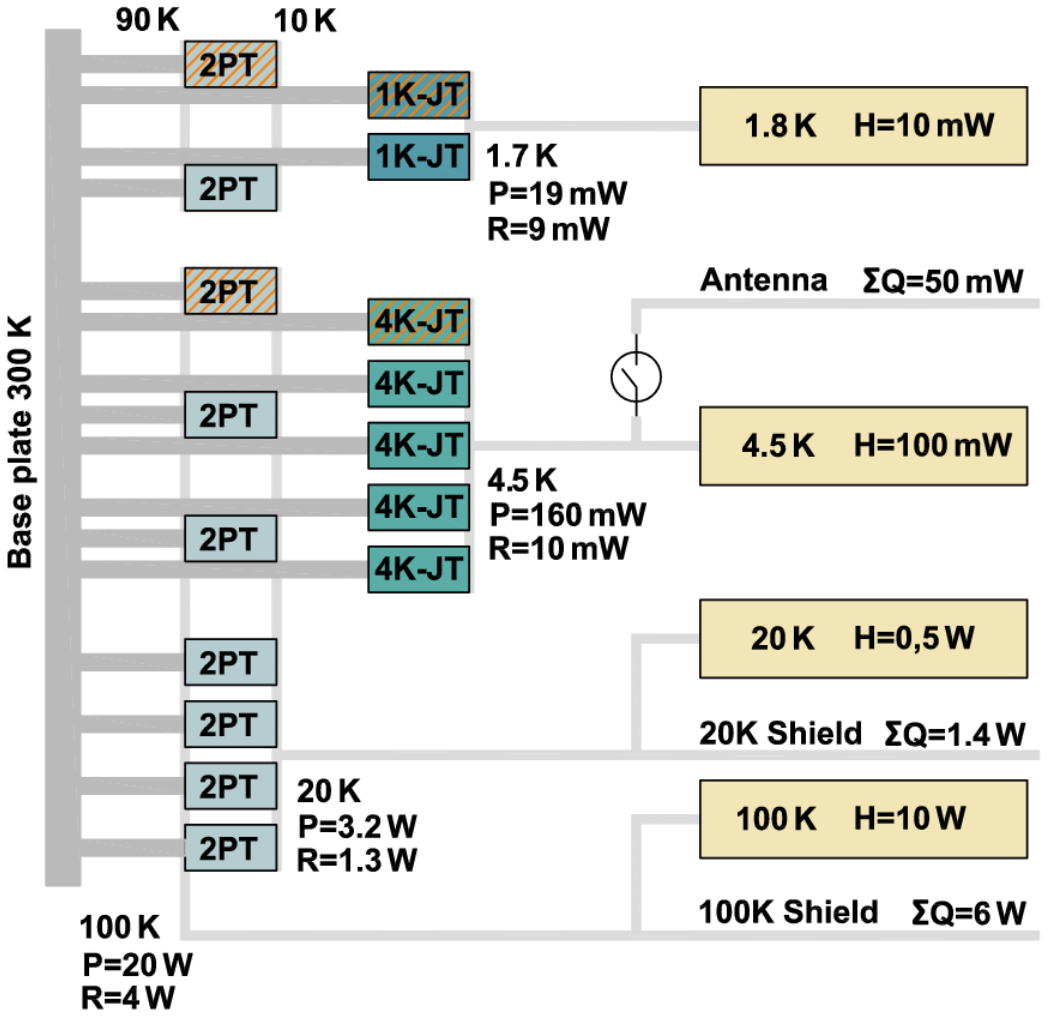
Level	Radiation Exchange, W	Structure Conduction, W	Cable network Conduction*, W	Heat Dissipation of instruments, W	ΣQ, W
1-2K	-	-	-	0.01	0.01
4K	0.030	0.002	0.018	0.10	0.15
20K	0.489	0.211	0.200	0.50	1.40
100K	1.480	2.940	1.580	10.00	16.00

* 100% margin estimated

What could be implemented up to date?

	Pulse Tube Cooler PT15K (Air Liquide)	2ST - Double stage Stirling cooler (Sumitomo H.I.)	4K-class Joule Thomson cooler (Sumitomo H.I.)	1K-class Joule Thomson cooler (Sumitomo H.I.)
			 Compressors (x2)  Cold Head →	Compressors (x4)  Cold Head → 
TRL	TRL5/6 (planned in 2019)	TRL8	TRL8	TRL5 (life time test is ongoing)
Cooling power	**800mW** at **20K** **5W** at **100K**	>**200mW** at **20K** >**1W** at **100K** (EOL)	**40mW** at 4.5K (EOL)	**10mW** at 1.7K (EOL) **19mW** at 1.77K (with PT15K precooling)
Input power	300 W	80 W at EOL	90 W at EOL	75 W at EOL
Mass	21 kg	9.5 kg	15 kg	28 kg
Life time	?	3 years (5yrs as a goal)	> 3 yrs (5yrs as a goal)	>5 yrs

How it could be realized? Active cooling system

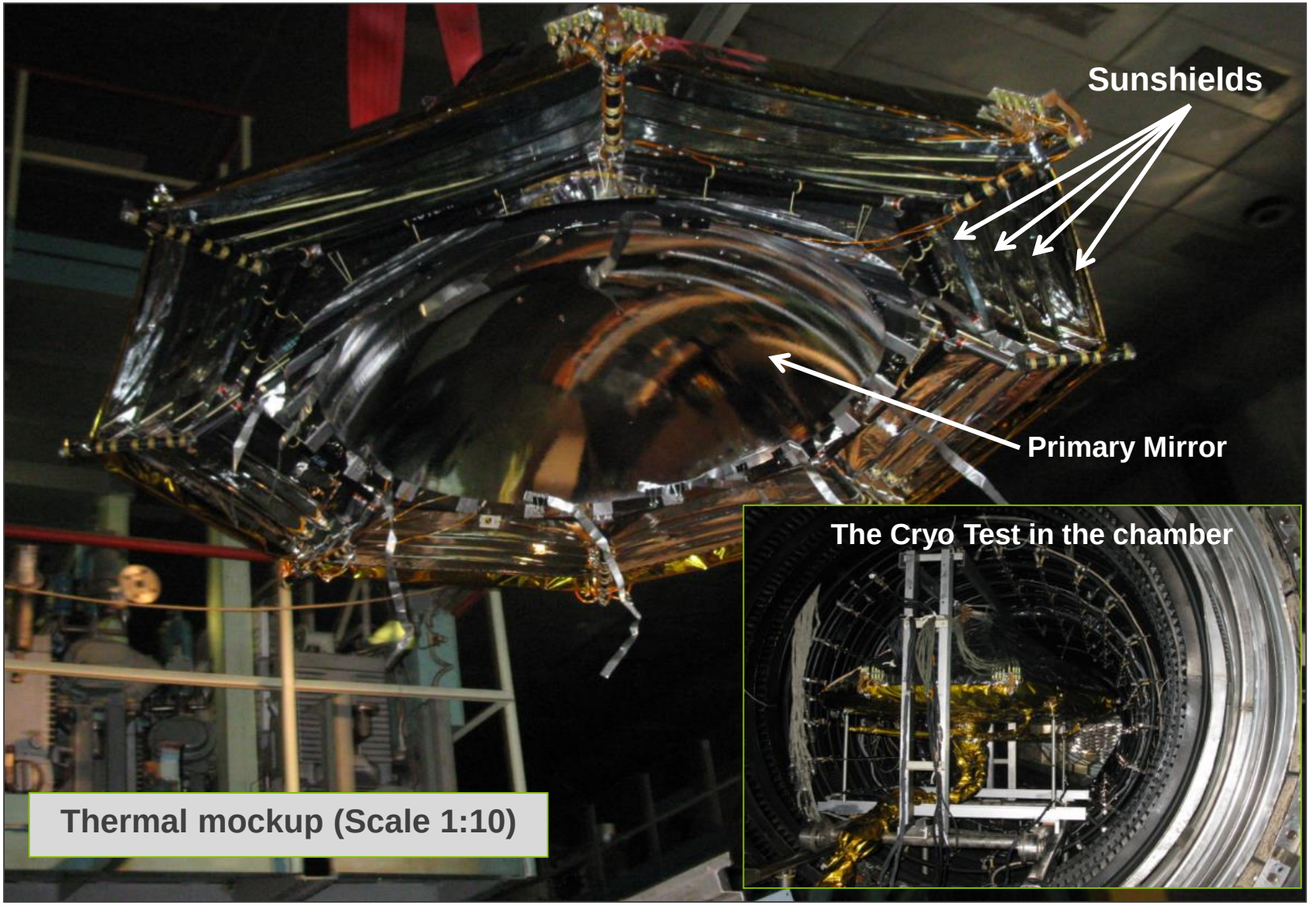


	Instruments
1K-JT	1K class J-T cryocooler
4K-JT	4K class J-T cryocooler
2PT	Double stage PT cryocooler
	Redundant cryocooler
	Thermal switch
P, W	Cooling power of a temperature level
R, W	Cooling power margin of a temperature level
H, W	Heat dissipation of instruments on a temperature level
ΣQ, W	Total parasitic heat load on a temperature level (conducted + radiated)

Summary of active cooling system

Cryocooler type	1-2 K (J-T)	4 K (J-T)	15 K (2PT)	20 K (2PT)	100 K (2PT)	Total
Cooling power, W	0,02	0,04	-	0,80	5,00	-
Input power*, W	75	90	300	300	-	**2535**
Mass, kg	28,0	15,0	35,0	35,0	-	**446**
Required amount of coolers	1	4	1	6	-	**12**
Redundant cooler	1	1	1	1	-	**4**
Total amount	2	5	2	7	-	**16**

Development status



Conclusions

- **The thermal design of the overall payload module and preliminary heat load budget has been developed**
- **Implementation of 15K PT coolers (Air liquide) and 1K-, 4K-class Joule Thomson coolers (Sumitomo H.I.) is one of the promising way to build the active cooling system**
- **First validation test with the scale model demonstrated the very critical parts of the thermal design**
- **Many aspects of the thermal design still need to be studied**

Thank you for attention!