Thermal Design

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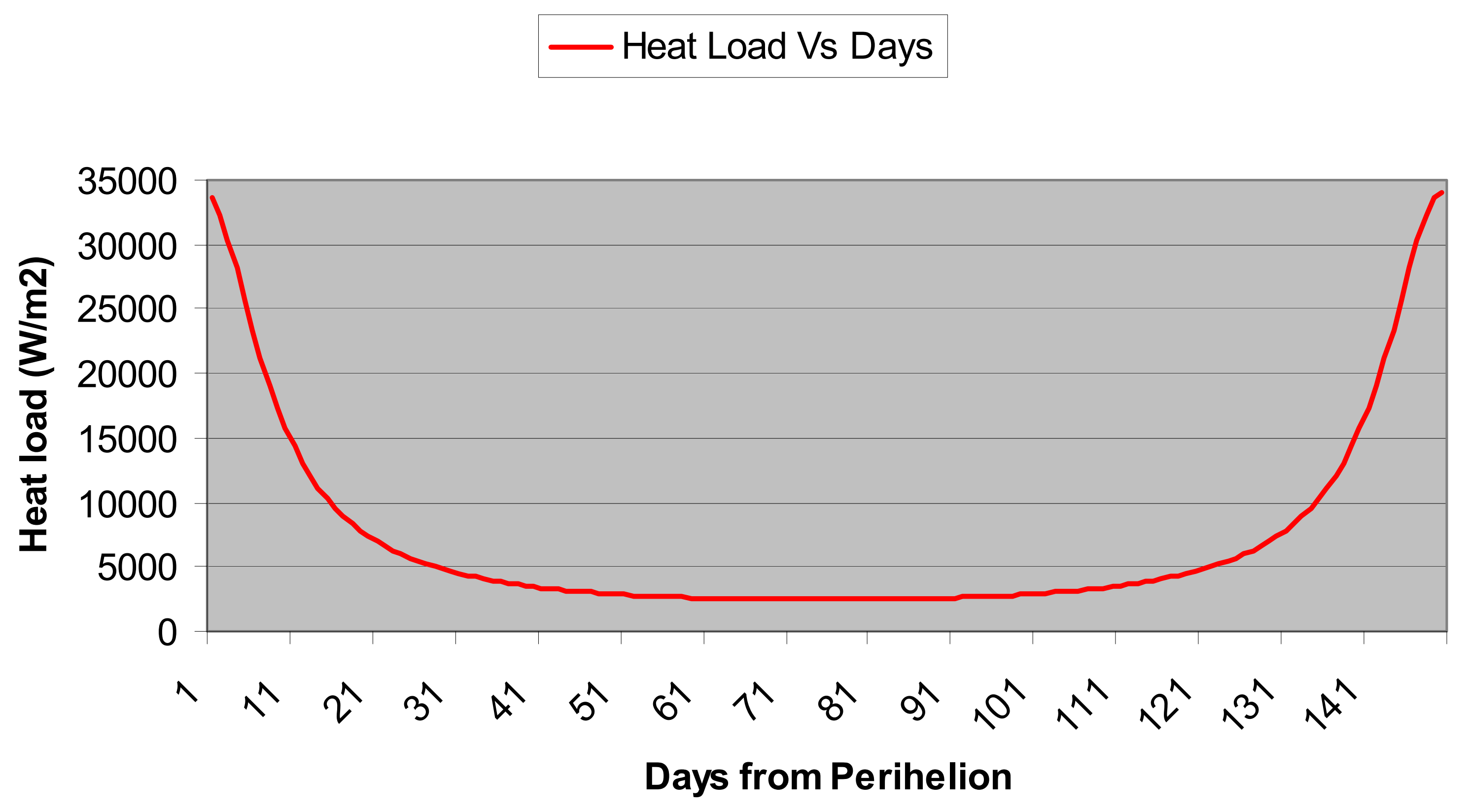
Topics

- EUS Thermal environment & requirements
- Steady State thermal analysis
- Transient thermal analysis
  - Parameters
  - Results
- Conclusion

Thermal Environment(1/2)

- During the nominal phase (0.2 to 0.8 A.U.), heat load varies from 2200W/m2 to 34000W/m2



EUS thermal requirements (1/2)

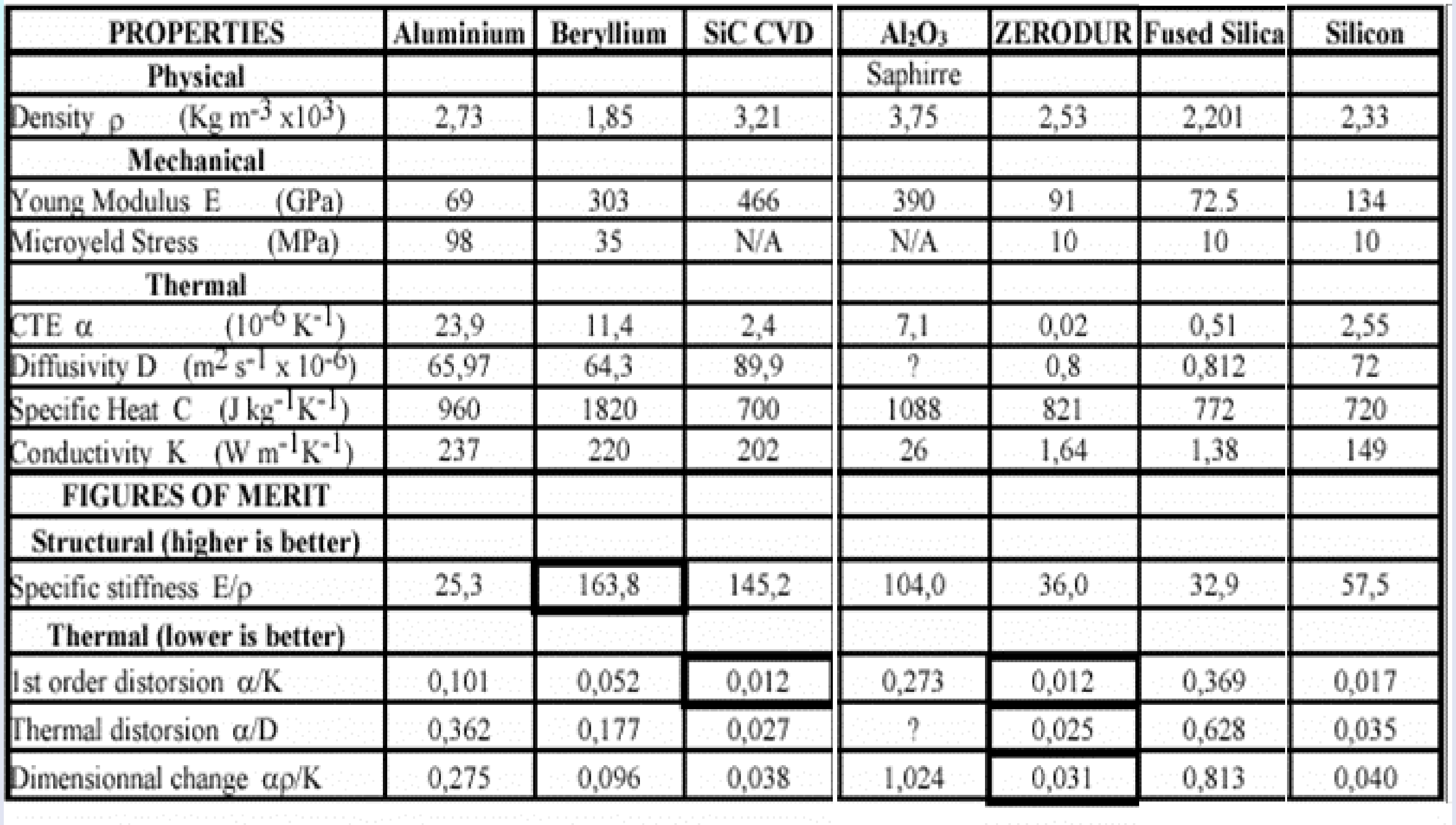
- The Radiator Area is limited by the footprint of the EUS casing (1.4m x 0.4m = 0.56m2)

- Coatings, and in particular multilayer coatings applied on mirrors have to be maintained in a reasonable range of temperature (below 100°C)

- The EUS should be cooled as much as possible with a passive control system because of the limited mass and power budget (also more reliable):
    - Radiators, Multi Layer Insulation, Thermal control coatings, …

EUS thermal requirements (2/2)

- A small part of energy has to reach the detector (few Watts)
- Materials used for mirror and structure have to be thermally stable:



PROPERTIES	Aluminium	Beryllium	SiC CVD	Al_2O_3	ZERODUR	Fused Silica	Silicon
Physical				Saphirre			
Density ρ (Kg m^{-3} $x10^3$)	2,73	1,85	3,21	3,75	2,53	2,201	2,33
Mechanical							
Young Modulus E (GPa)	69	303	466	390	91	72.5	134
Microyeld Stress (MPa)	98	35	N/A	N/A	10	10	10
Thermal							
CTE α (10^{-6} K^{-1})	23,9	11,4	2,4	7,1	0,02	0,51	2,55
Diffusivity D (m^2 s^{-1} x 10^{-6})	65,97	64,3	89,9	?	0,8	0,812	72
Specific Heat C (J $kg^{-1}K^{-1}$)	960	1820	700	1088	821	772	720
Conductivity K (W $m^{-1}K^{-1}$)	237	220	202	26	1,64	1,38	149
FIGURES OF MERIT							
Structural (higher is better)							
Specific stiffness E/ρ	25,3	163,8	145,2	104,0	36,0	32,9	57,5
Thermal (lower is better)							
1st order distorsion α/K	0,101	0,052	0,012	0,273	0,012	0,369	0,017
Thermal distorsion α/D	0,362	0,177	0,027	?	0,025	0,628	0,035
Dimensionnal change $\alpha\rho$/K	0,275	0,096	0,038	1,024	0,031	0,813	0,040

Steady State analysis (1/3)

- Assumptions:
  - Based on the worst hot case: 34000 W/m2
  - Radiator temperature fixed to 50 °C
  - Mirrors and Heat Stop temperature fixed to 61 °C
  - No view factors between the heat shield and the radiators

Steady State analysis

- Grazing incidence telescope

Incident flux on the telescope (W)	102,09
heat load on M1 (W)	102,33

M1 absorptivity	0,70
M2 absorptivity	0,10
rastering mirror absorptivity	0,25
total heat absorption on M1 (W)	71,63
total heat absorption on M2 (W)	2,92
total heat absorption on rastering mirror (W)	0,66
heat load coming from the rastering mirror to the slit	1,97
Minimum Total radiator area (m2)	**0,132**

M1 absorptivity	0,10
M2 absorptivity	0,70
rastering mirror absorptivity	0,25
total heat absorption on M1 (W)	10,23
total heat absorption on M2 (W)	61,24
total heat absorption on rastering mirror (W)	0,66
heat load coming from the rastering mirror to the slit	1,97
Minimum Total radiator area (m2)	**0,125**

Telescope design(2/2)

- Off-axis design

Incident flux on the telescope (W)	381,7
heat load on M1 (W)	263

M1 absorptivity	0,10
heat stop absorptivity	0,70
heat stop transmissivity	0,05
M2 absorptivity	0,83
total heat absorption on M1 (W)	26,30
total heat absorption on heat stop (W)	165,69
total heat absorption on M2 (W)	9,82
heat load coming from M2 to the slit	2,01
Minimum Total radiator area (m2)	**0,349**

M1 absorptivity	0,70
heat stop absorptivity	0,10
heat stop transmissivity	0,05
M2 absorptivity	0,50
total heat absorption on M1 (W)	184,1
total heat absorption on heat stop (W	7,89
total heat absorption on M2 (W)	1,97
heat load coming from M2 to the slit	1,97
Minimum Total radiator area (m2)	**0,331**

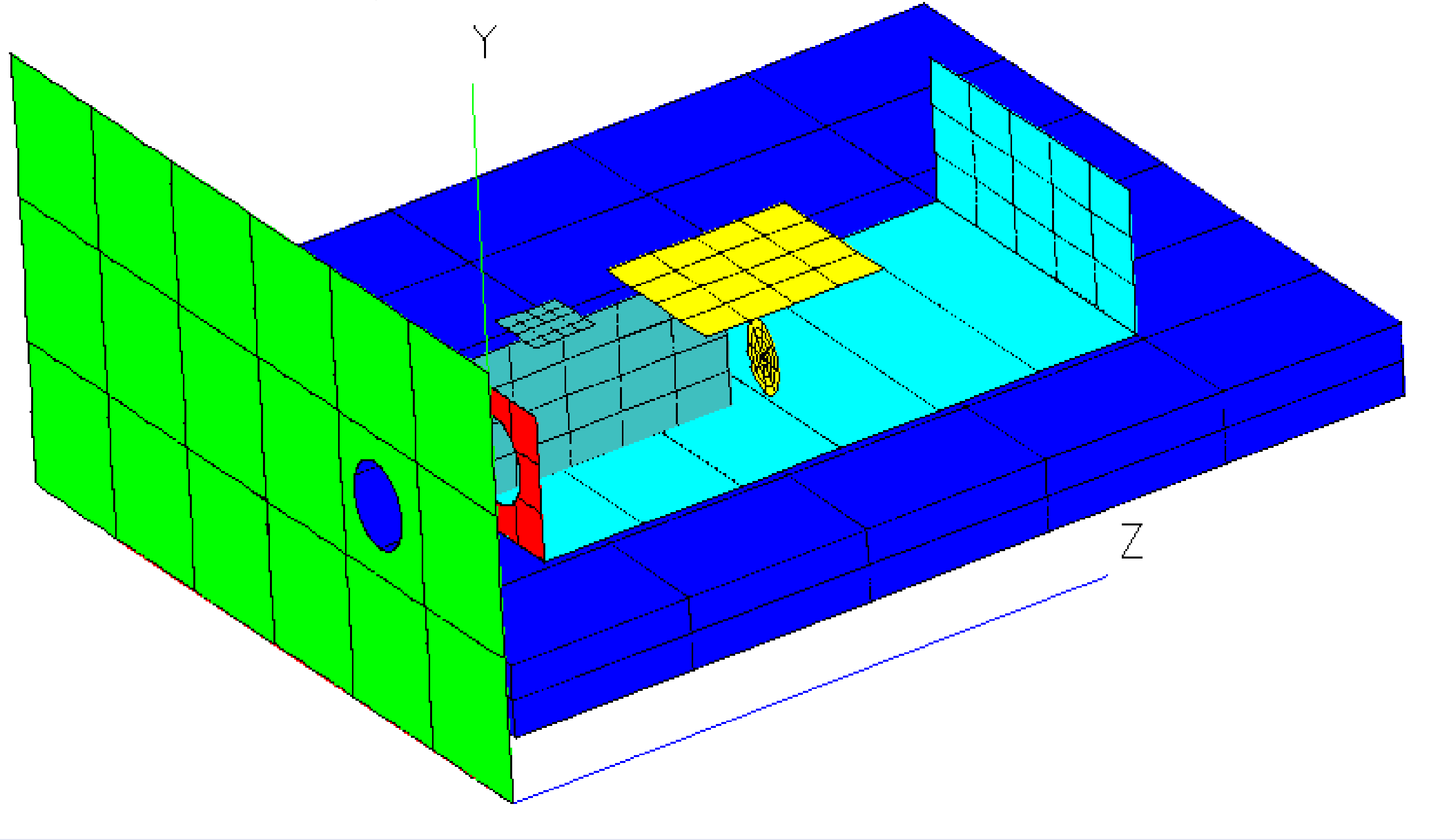
⇒ *The off-axis design is the most challenging one from a thermal point of view*

Transient simulation

- Based on the Off-axis telescope design
- Made with ESARAD/ESATAN and I-DEAS
- The simulation is based on the nominal phase orbit (0.2 to 0.8 A.U)
- The heat load is applied to the heat shield and the primary mirror
- There is no physical contact between the heat shield and the rest of the spacecraft

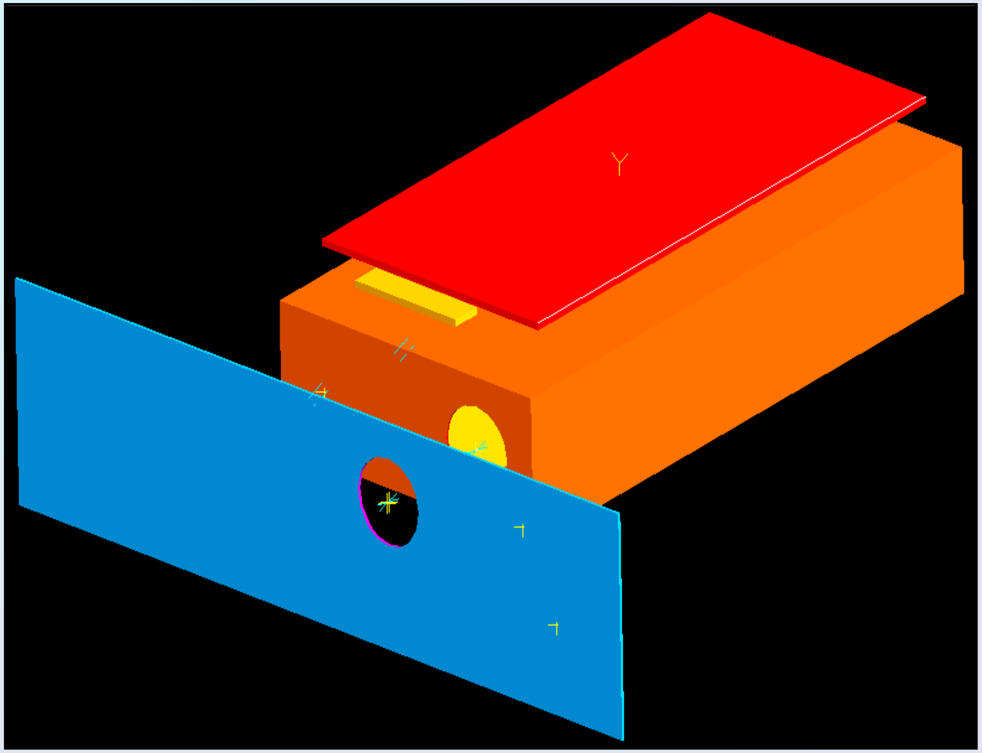
The geometric model (1/2)

- Different parts have been modeled:
  - The heat shield
  - The telescope casing
  - The mirrors and the heat stop
  - The radiators for the primary mirror and the heat stop



The geometric model (2/2)

- The area of the radiator has been fixed to the results given by the worst hot case steady state calculation:
  - 0.39 m2 for the M1 radiator area
  - 0.01 m2 for the heat stop radiator area



Model description

- Different coatings are applied on each face of the parts to control the temperature

Device	**Side 1**	**Side 2**
Heat shield	MLI	Gold coating
Radiator M1	Black paint	Teflon coating
Radiator Heat stop	Black paint	Teflon coating
Satellite Casing	MLI	
M1	M1_coating	M1_coating
Heat Stop	Aluminium	Aluminium
Telescope Casing	MLI	Black paint
Back telescope casing	White paint	Black paint

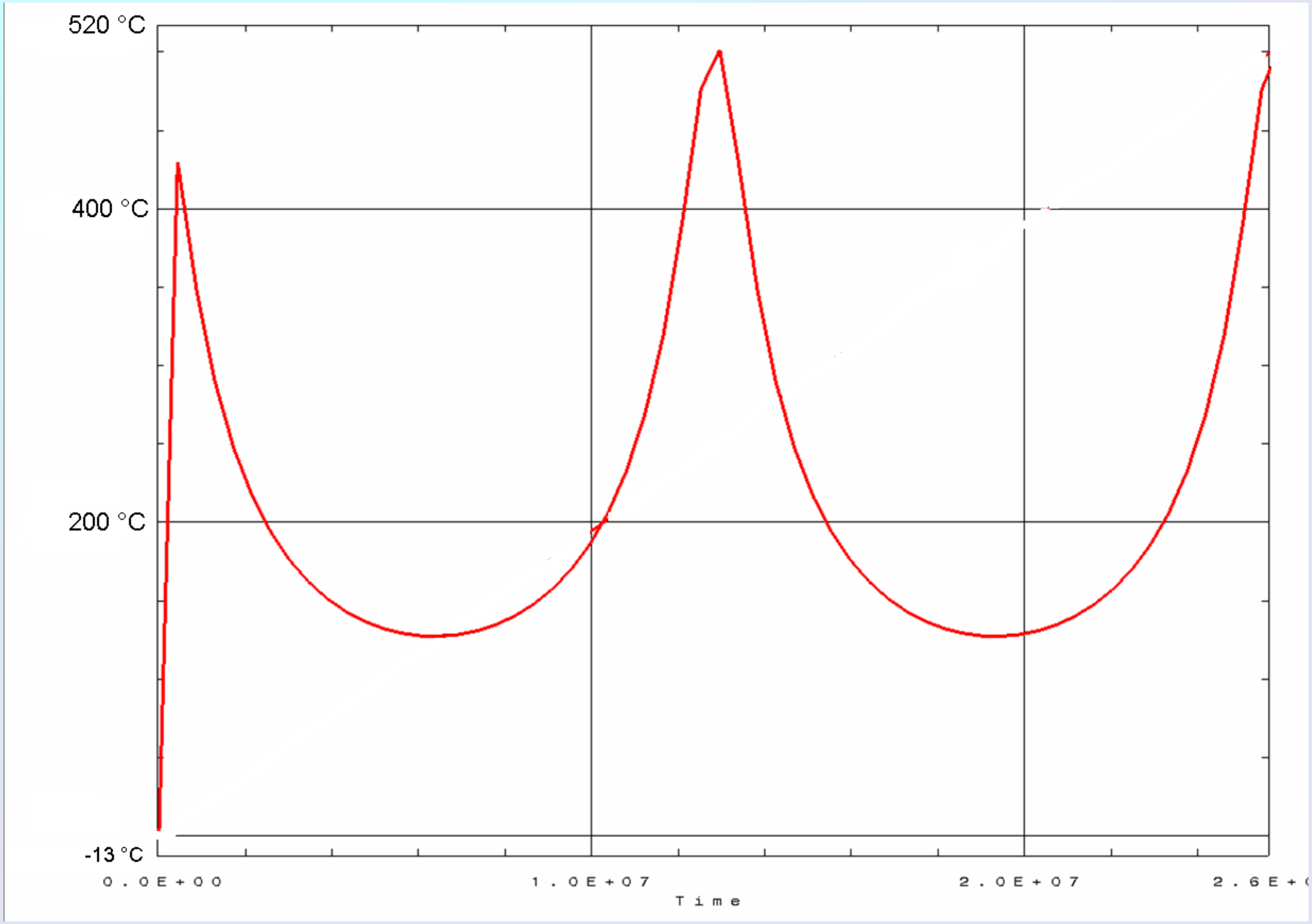
Thermal strategies

Three parameters have been studied in this simulation:

- the emissivity of the telescope casing and heat shield
- The absolute conductance between M1 and its radiator
- The absorptivity of M1

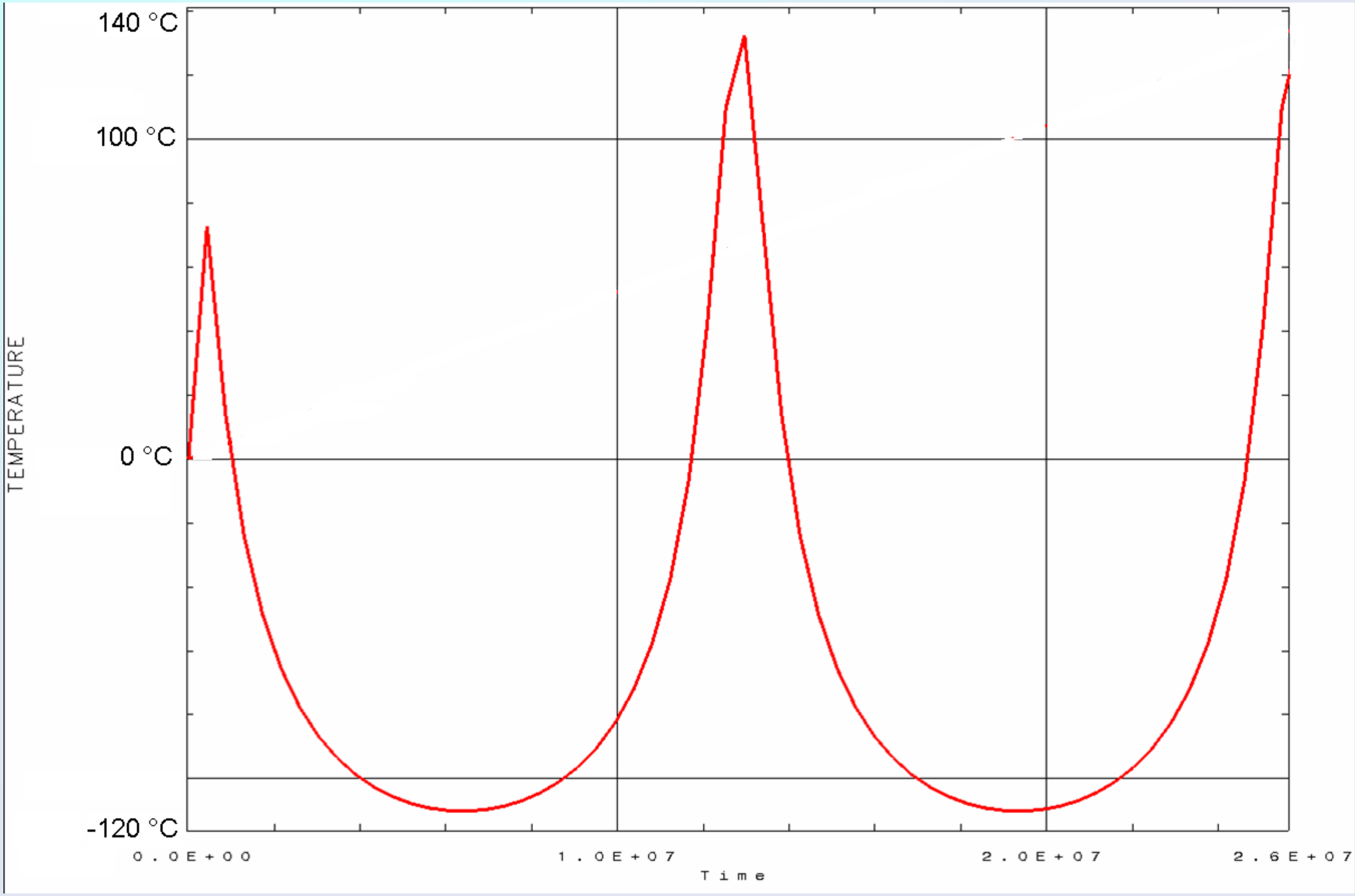
Results (1/4)

- M1 temperature without radiator:



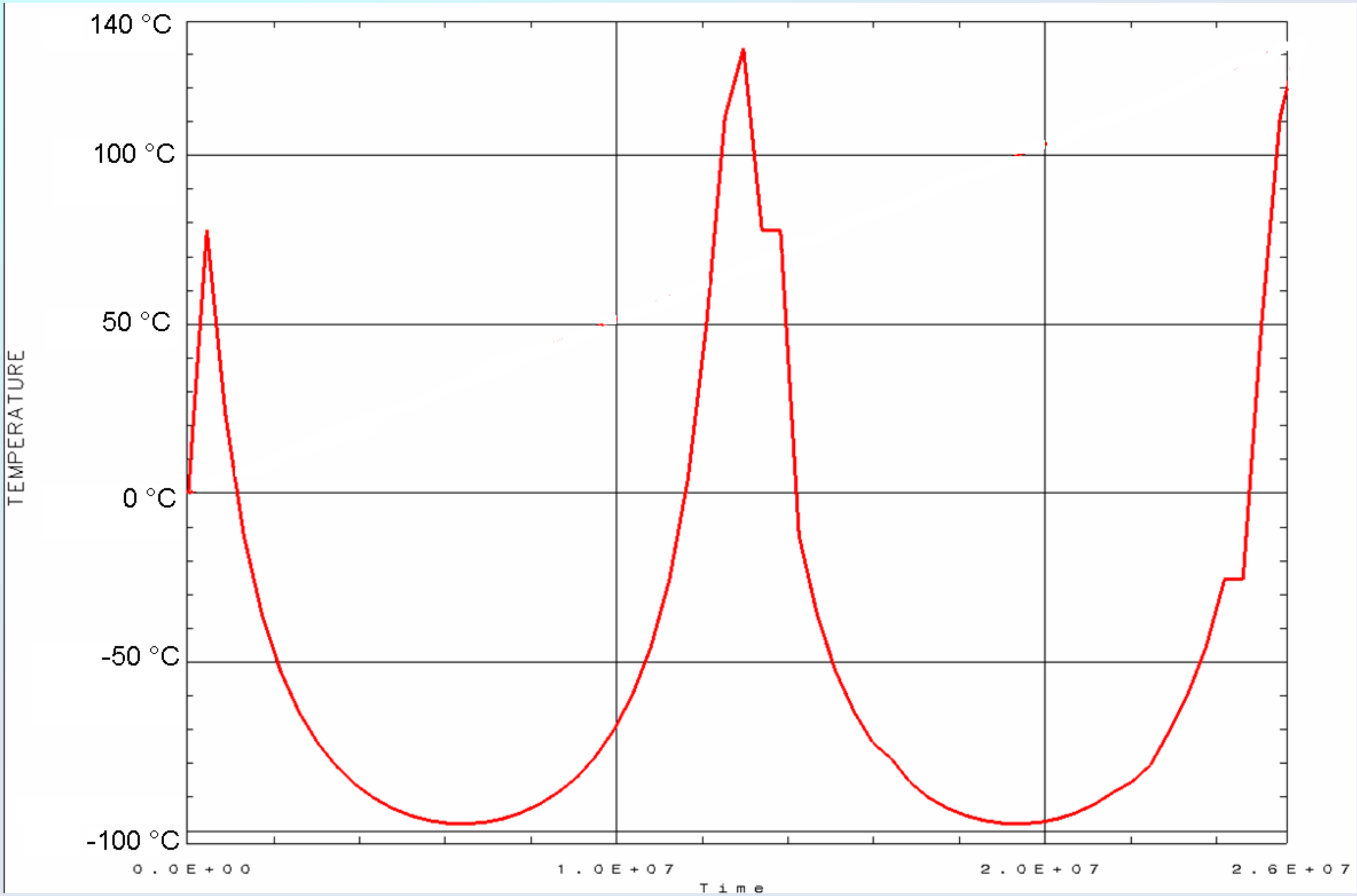
Results (2/4)

- M1 temperature with a conductance of 0.5 W/°C between the radiator and M1, a high emissive coating and M1 either lowly or highly absorptive:



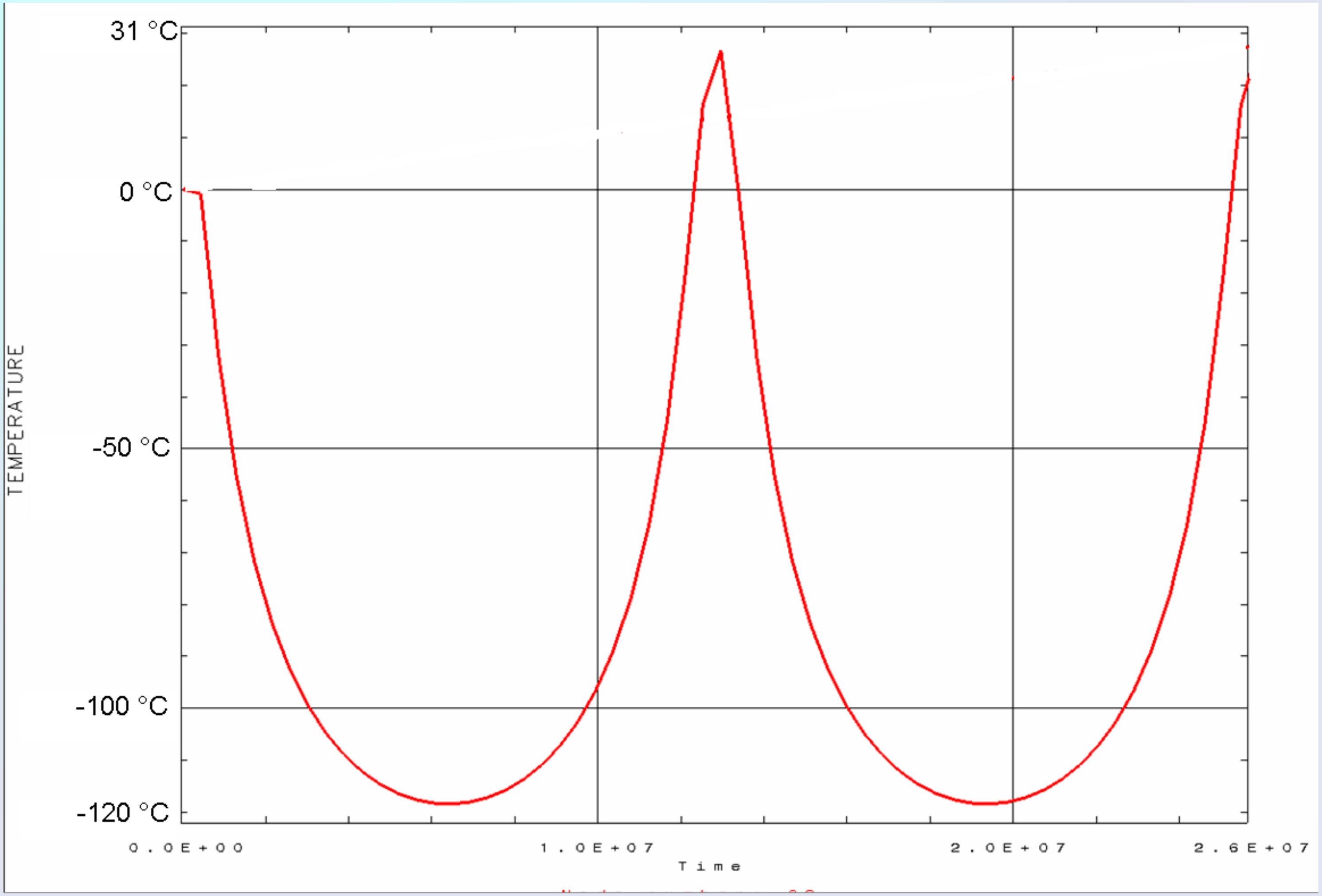
Results (3/4)

- M1 temperature with a low emissive coating on the heat shield, M1 lowly absorptive, and a conductance of 50 W/°C.



Results (4/4)

- M1 temperature with a high emissive coating (MLI) on the telescope, M1 either lowly or highly absorptive, and a conductance of 50 W/°C

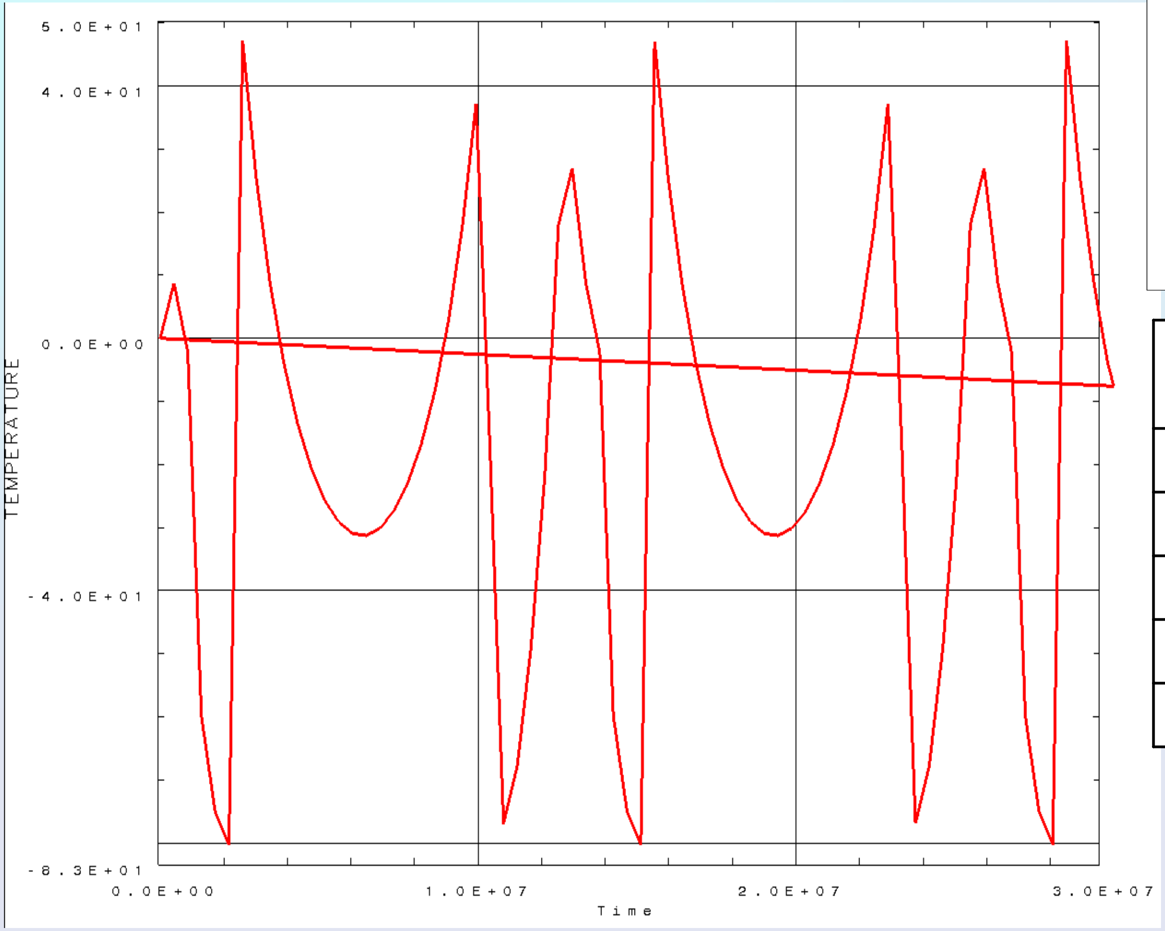


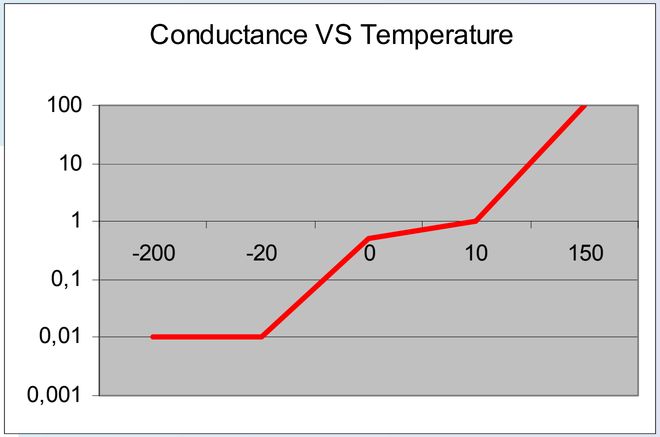
Comments

- With a good absolute conductance and a large radiator, it seems that the thermo-optical properties of M1 don’t have a big impact on its temperature.
- With a high emissive coating on the telescope casing and heat shield, the maximum temperature limit is in the requirements, but it is oscillating a lot.

Comments

- ⇒ necessary to put heat switches or Variable conductance heat pipe to control the temperature with a better accuracy




Conductance VS Temperature

Temperature (°C)	Absolute Conductance (W/K)
-200	0.01
-20	0.01
0	0.5
10	1.0
150	100

Future work

- Heat shield thermal analysis and design
- Detailed analysis of the temperature mapping on M1
- Variable conductance heat pipe implementation
- Parametric study of the model with Radiator area

conclusion

- Importance of heat shield thermal properties and mechanical mounting.
- The off-axis design seems feasible from a thermal point of view provided that:
  - the heat shield is conductively isolated
  - the required thermo-optical properties (alpha and epsilon) are achieved on the heat shield at the elevated temperatures
  - the required radiator area is accommodated
  - the necessary thermal links are provided between the M1 mirror and its radiator