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DIRECTION DES SYSTEMES ORBITAUX DE TOULOUSE
SOUS-DIRECTION SCIENCES

RPW ANT THERMAL BENDING CLASH WITH SPICE HRM REJECTED SOLAR BEAM & STACER AND HEAT SHIELD THERMO-OPTICAL PROPERTIES DEGRADATION LIMITS

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SOMMAIRE

1 DOCUMENTATION

1.1 APPLICABLE DOCUMENT

N.A

1.2 REFERENCE DOCUMENT

	Reference	Title
RD1	RPW_ICD_Antenna_030 REVISION: 3.4 DATE: 2016-07-24	RPW Antenna Mechanical Interface Control Document (MICD)
RD2	RPW_ANT_MECH_008 REVISION: 1.17 DATE: 11/30/2015	RPW Antenna Design Report
RD3	RPW_ANT_THERM_ANA_010 REVISION: 6.0 DATE: 05/05/17	Solar Orbiter RPW ANT Thermal Analysis

2 INTRODUCTION

This technical note reports the justification that the chosen Stacer material can withstand when full exposed to the sun from two distinct directions simultaneously. The second part of the technical note provides the thermos-optical properties degradation limit to maintain Stacer and Heat Shield within their acceptable temperature limits.

3 AFT AND M&P

The table bellows gives the Allowable Flight Temperatures (AFT) and Material & process limit for the Stacer and the Heat Shield [RD2].

	AFT (ANT Deployed)	Material & Process
Stacer	670°C	696°C
Heat shield	760°C	1000°C

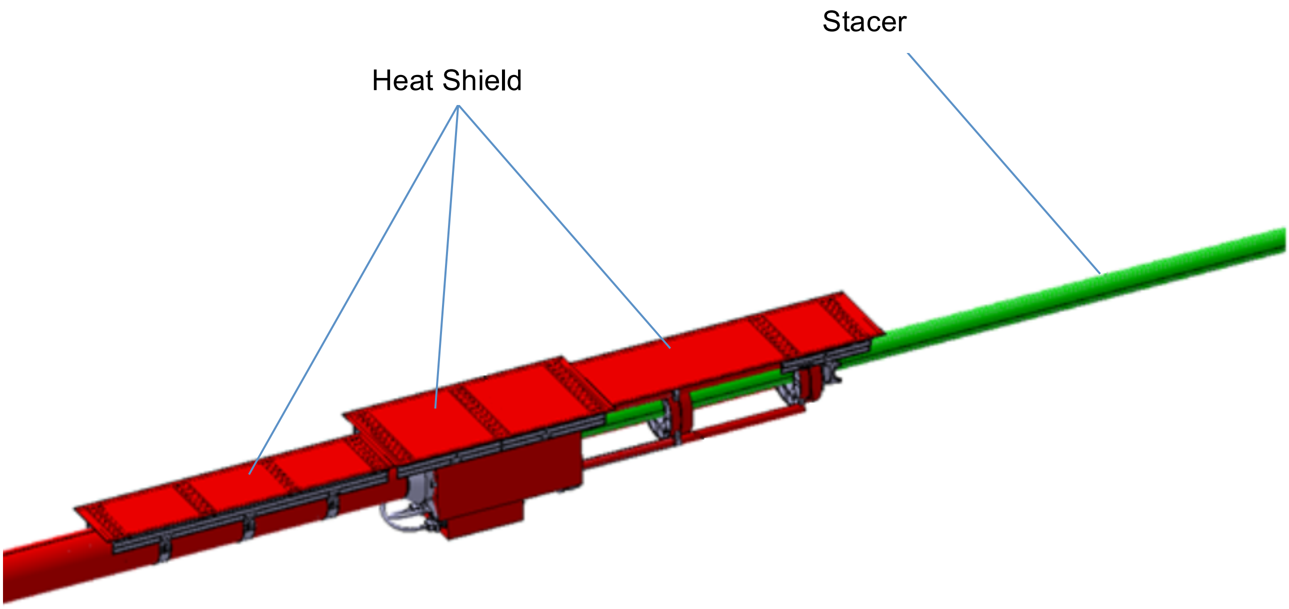

Figure 1- Stacer maximum local bending

4 ANT THERMAL BENDING CLASH WITH SPICE HRM SOLAR BEAM

4.1 CONTEXT

Deployed, the Stacer of each antenna is exposed to the direct solar illumination, leading the antenna to bend (see Figure 2 from [RD1]). While bending, the PZ antenna can interfere with the solar beam rejected by the Spectral Imaging of the Coronal Environment Heat Rejection Mirror, SPICE HRM, (see Figure 3 and appendix B). Consequently the PZ antenna is also exposed to an incident solar flux on its back side with the same intensity as the direct one on the front side.

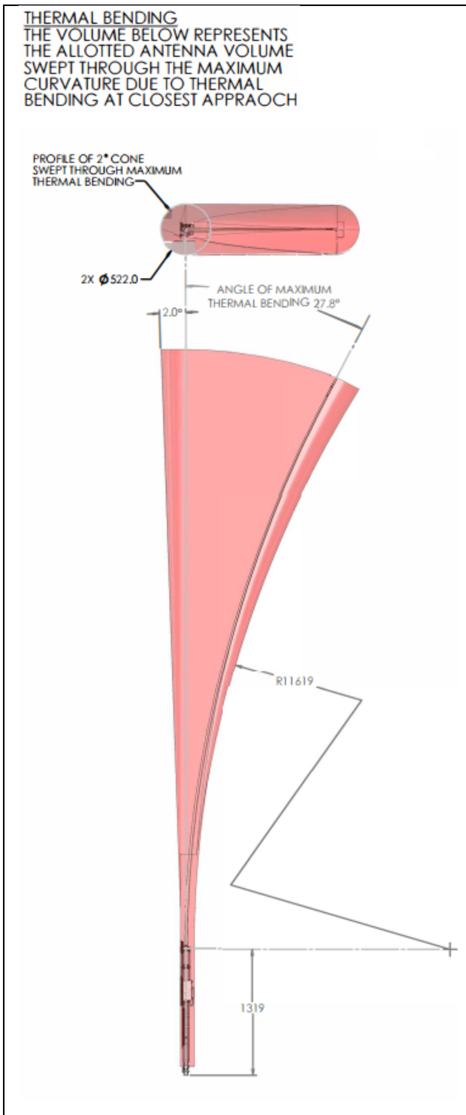

Figure 2- Thermal bending

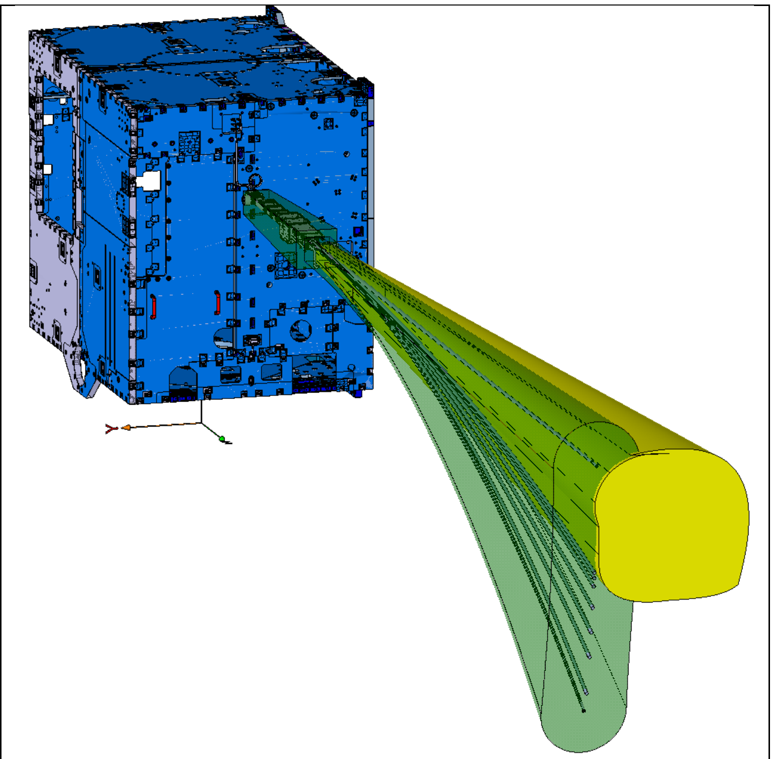

Figure 3- ANT Thermal bending clash with SPICE HRM rejected solar beam

4.2 MODELLING

To calculate the Stacer temperature, a slice of the stacer is modelled, circumferentially split in 6 thermal nodes, taken into account:

- Conductive exchanges on the circumference
- Internal radiatives exchanges (the stacer is locally on tube)
- Radiative exchanges with the space

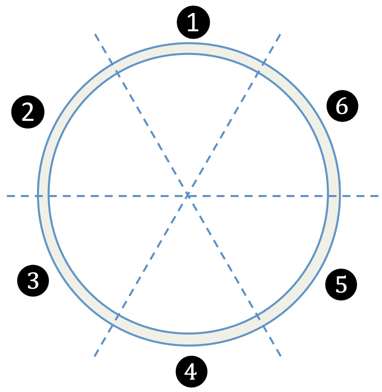

Figure 4- Stacer slice modelling

Assumptions:

- Adiabatic boundaries: The Stacer slice does not exchange with the other parts of the stacer (the top and bottom slides are assumed to be at the same temperature because exposed to the same environment)
- Slice physical characteristics extracted from [DR2]:
    - Thickness: 0.22 mm
    - Diameter: 41 mm
    - Conductivity: 11.5 W/mK (corrected value : 21 W/mK × 0.595)
    - Coating: Elgiloy (ε_{EOL}=0.13 / α_{EOL}=0.396)

4.3 THERMAL CASE DEFINITION

Nominal operation case (S/C pointing +X sun, no maneuver)

Solar constant at 0.28 AU: C_s = 17462 W/m2.

Solar fluxes from sun direction and from SPICE rejection direction are perpendicular.

Studied Stacer slice local bending angles θ: 0° to 90°C, thus:

- θ = 0° : Stacer exposed to direct solar flux only
- θ = 90° : Stacer exposed to SPICE rejected solar flux only
- θ = 45° : Stacer exposed both to direct solar flux and SPICE rejected solar flux

4.4 MODEL VALIDATION AND MARGING PHILOSOPHY

To validate the thermal model, the calculated temperature for a local bending angle θ = 0° is compared to the detailed thermal analyses results [RD2].

The worst calculated temperature is obtained for the front node (node #1) facing direct illumination: 545°C for 542°C obtained by detailed thermal analyses, thus 3°C of discrepancies.

The model been pessimistic, only the 20°C thermal uncertainties of the detailed model are applied on calculated results to obtain predicted temperatures.

4.5 RESULTS

Figure 5 gives the temperature variation versus the local bending angle both for the front and the rear sides.
Red and blue curves are naturally symmetric according a vertical axe and cross each other for θ=45° when the front and rear sides absorb the same flux density.
Worst temperatures are obtained at θ=25° (front side) or θ=65° (rear side) with 587°C that is distinctly within the design limit temperature 670°C [RD2].

Note that a quick analyze on Figure 6, shows that the local bending angle could not exceed 25°.

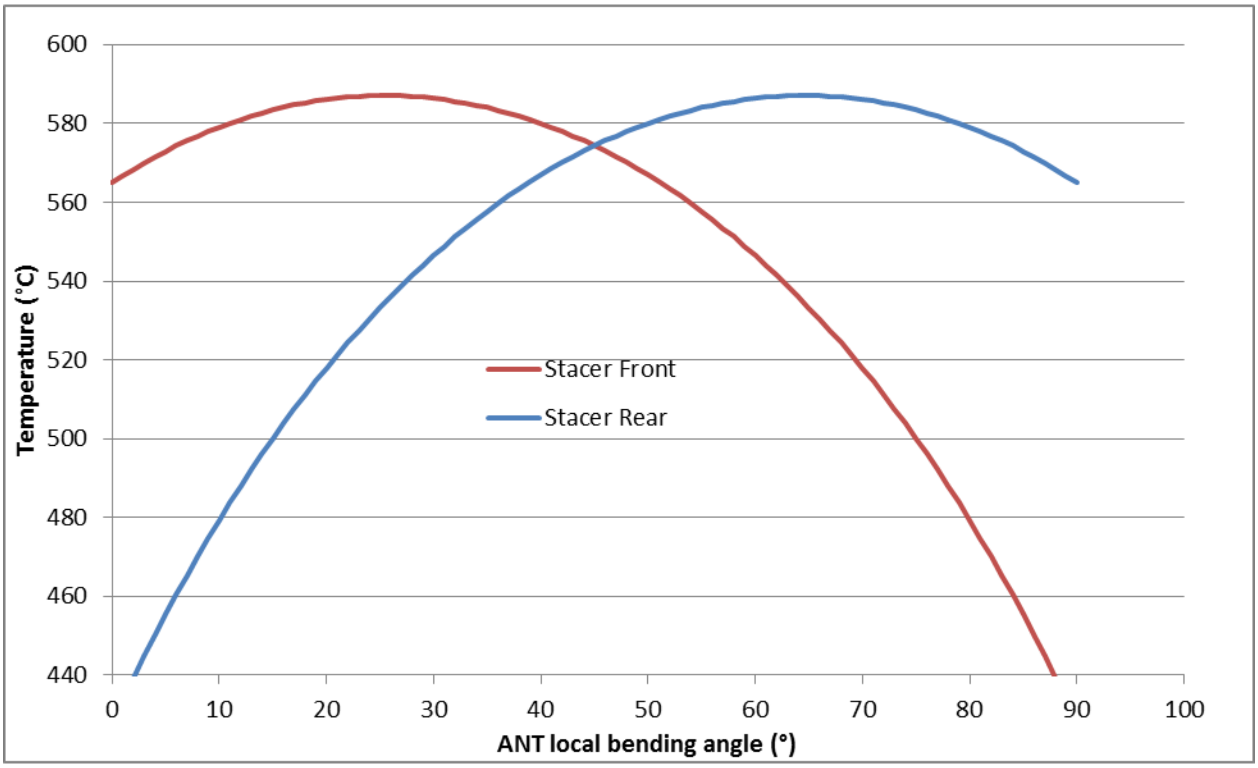

Figure 5- Stacer front and rear sides temperature versus local bending angle

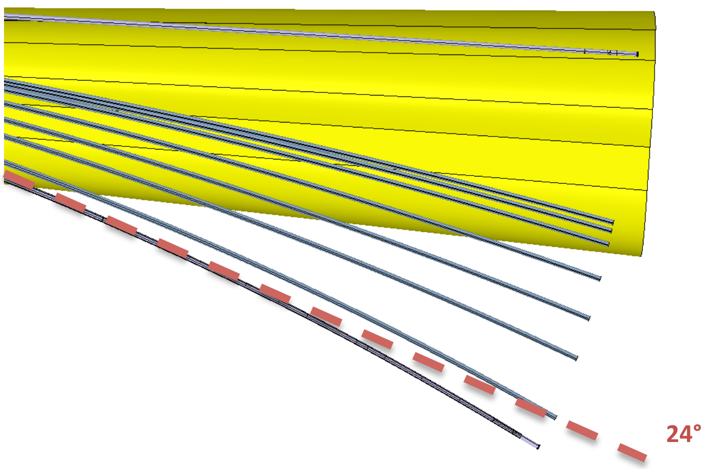

Figure 6- Stacer maximum local bending

5 THERMO-OPTICAL PROPERTIES DEGRADATION LIMITS

The thermos-optical properties degradation limit is given as the maximum ratio $\alpha_{EOL}/\varepsilon_{EOL}$ admissible for the antenna elements with regards to AFTs and Material & process (see table §3).

The maximum ratio $\alpha_{EOL}/\varepsilon_{EOL}$ admissible is estimated:

- for the stacer, using the modeling presented in the current reports (see §4.2),
- for the heat shield, assuming an energy balance of a Niobium plate exposed to the solar flux (see appendix A)

The estimation of the thermos-optical properties degradation limit is
- $\alpha_{EOL}/\varepsilon_{EOL}$ = 4.9 for the stacer.
- $\alpha_{EOL}/\varepsilon_{EOL}$ = 2.2 for the heat shield.

6 CONCLUSION

This analysis distinctly shows that the deployed Stacer can withstand an exposure to the sun from two distinct directions simultaneously while bending. The thermal bending profile of the deployed Stacer provided by [RD2] must be updated in order to take into account the SPICE HRM solar beam.

The thermos-optical properties degradation limit to maintain Stacer and Heat Shield within their acceptable temperature limits are:
- $\alpha_{EOL}/\varepsilon_{EOL}$ = 4.9 for the stacer.
- $\alpha_{EOL}/\varepsilon_{EOL}$ = 2.2 for the heat shield.

Note that if contamination leads to darken surfaces, that is acceptable for the antenna because that means a ratio $\alpha_{EOL}/\varepsilon_{EOL}$ = 1, which is admissible.

7 APPENDIX

7.1 APPENDIX A – MODELING OF A SUN EXPOSED NIOBIUM PLATE

- Solar constant at 0.28 AU: C_s = 17462 W/m2.
- Coating: Pure Niobium
- Thermo-optical properties at high temperature: ε_{EOL}=0.3 , α_{EOL}=0.46 ([RD3])

Energy balance: $T_{eq}[°C] = \sqrt[4]{(\frac{\propto . C_s}{\varepsilon . \sigma})} - 273$

Validation (see table hereafter): The estimation is higher compared to the detailed thermal model, because the antenna heat shield multilayers efficiency leads to heat flux leaks rejected on the back side of the protection.

The model been pessimistic, only the 20°C thermal uncertainties of the detailed model are applied on calculated results to obtain predicted temperatures.

	Estimation	**Detailed thermal model**
Shield temperature @0.28 AU	556°C	540°C