

ANTENNA THERMAL ANALYSIS OF AEROBRAKING PHASE A TASI APPROACH

THALES ALENIA SPACE ITALIA – ANTENNA DEPARTMENT

D. SCIULLI



TABLE OF CONTENTS

1 Introduction

2 Antenna Thermal Analysis
Objectives

3 Aerobraking

4 Commercial Software Capability

5 Antenna Thermal Analysis

6 Antenna Results

7 Conclusions

INTRODUCTION

The objective of this presentation is to show how efficient the use of commercial software can be to implement correctly the mission and the environment constraints, in place of spending time to develop dedicated tools and/or subroutines to assess and verify the thermal design of the Antenna during an aerobraking phase

Project Requirements and Environmental Conditions

/// Project

Antenna mounted on the spacecraft external panel

/// Mission

Interplanetary, with aerobraking phases

/// Thermal Design Requirements

- ! To maintain all the antenna item temperatures within the operative and non-operative temperature range, guaranteeing the integrity and functionality during all the mission phases

ANTENNA THERMAL ANALYSIS OBJECTIVES

- / Prove that the thermal design is robust and all the antenna items are capable to resist to the harsh environment in orbit.
 - / Provide a guidance on the development of the dedicated technologies to optimize antenna thermal performance.
 - / Identify those antenna orientations or spacecraft attitudes that define the technological limits of the antenna in order to allow the spacecraft GNC (guidance & navigation control) team to effectively plan the correct maneuvers and drag pass without an excessive heating of the antenna itself.
- /// Added challenge: in the frame of Phase A and B of a project development, the analyses must be performed rapidly and reliably taking into account the tight project schedule**

AEROBRAKING

- Aerobraking is a technique used in space missions that involves using a planet's atmosphere to slow down a spacecraft. The spacecraft will dip into the atmosphere briefly on each orbit, the atmospheric drag on the spacecraft will slow it down.
- In particular it is used to reduce the eccentricity of an elliptical orbit with less fuel than just the firing of the spacecraft engine.
- Alternatively, aerobraking can occur at destination for those missions aimed at the study of the surface and interior of the planets (i.e. landing)

Pros

Save the amount of propellant carried and therefore optimize vehicle design mass

Cons

Have a direct impact on the subsystem thermal control as the aerodynamic heating occurs during the drag-pass phase

Since the Antenna is located on the external part of the spacecraft, it is greatly affected by the heat generated during the aerobraking maneuvers

THERMAL COMMERCIAL SOFTWARE CAPABILITY 1/4

/// Overview

To rapidly and reliably implement the Aerobraking phenomena in the Antenna thermal analysis, the approach has been to use the Free Molecular Heating (FMH) software feature

The current thermal software used in TASI Antenna Department has the capability of modeling Free Molecular Heating (FMH) by using the RadCad radiation modules that computes radiation exchange factors within the thermal model and with the environment

Free Molecular Heating occurs at very low density where the mean free path of the gas molecules is large compared to the distance between the vehicle surfaces. Typically, this occurs at the end of the launch phase, after fairing jettisoning, when the atmosphere is rarefied enough such that the molecules no longer act as a fluid: free molecules collide onto a surface and the kinetic energy of the molecule is transferred to thermal energy on the surface.

Usually the aerothermal flux relative to the drag pass phase is a known input data described in the project thermal specification that can be used for the thermal analysis.

THERMAL COMMERCIAL SOFTWARE CAPABILITY 2/4

/// Modeling the FMH interaction and Aerobraking

In the software there is no need to implement the interaction of the vehicle surfaces with the incident molecules, but the only input data to set is the heat flux generated by FMH. The flux has to be applied to the vehicle surfaces on which the velocity vector is incident and the amount of heating depends on the projected area in the direction of the velocity vector.

↓

Same input for the Aerobraking modeling!!

↓

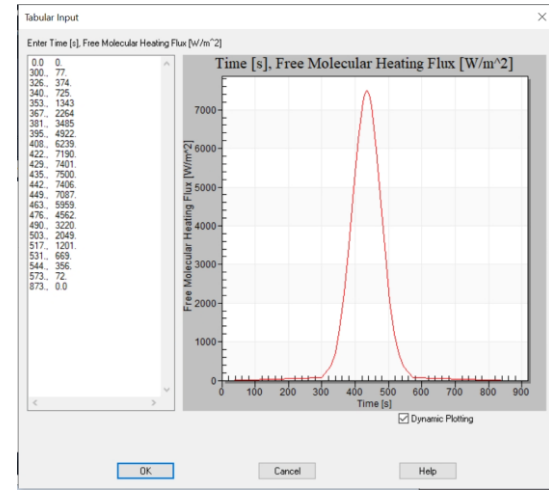
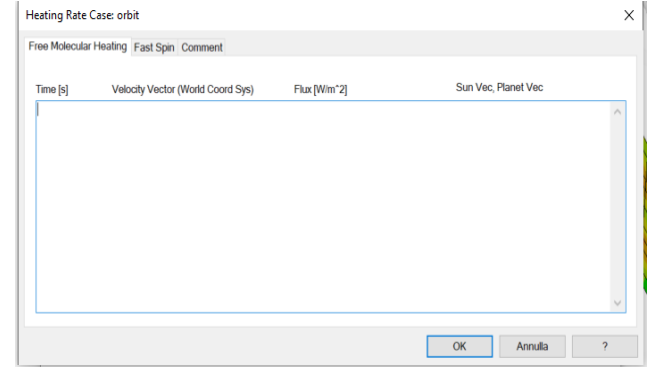
The velocity vector → a result of the orbital mechanics section of the same model!

The heat flux value → user defined input!

THERMAL COMMERCIAL SOFTWARE CAPABILITY 3/4

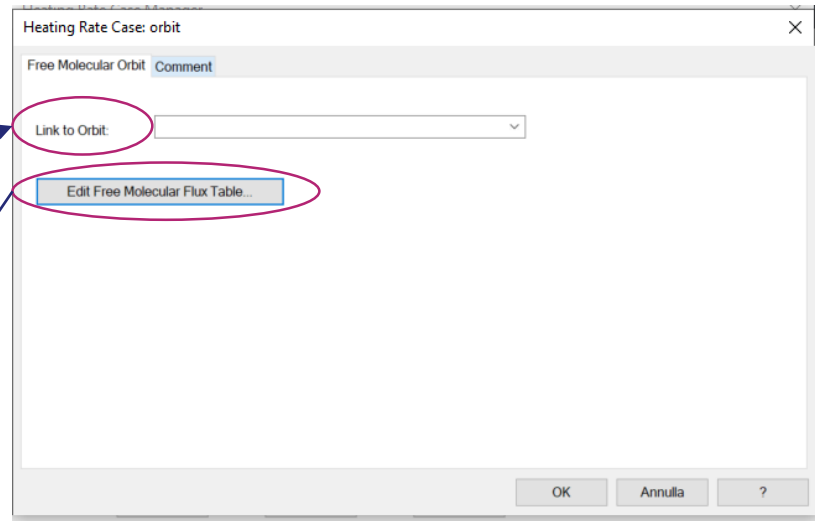
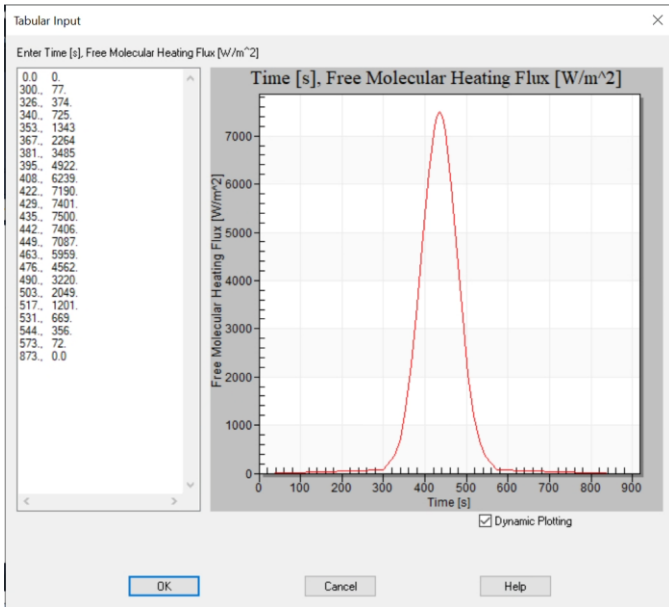
/// FMH dialog table is inside the Heating rate dialog box and the input to set are:

- Time
- Normalized velocity vector in the vehicle's coordinate system
- Normalized solar vector and planet vector for tracker positioning in case trackers are being used
- Imposed flux at that time



THERMAL COMMERCIAL SOFTWARE CAPABILITY 4/4

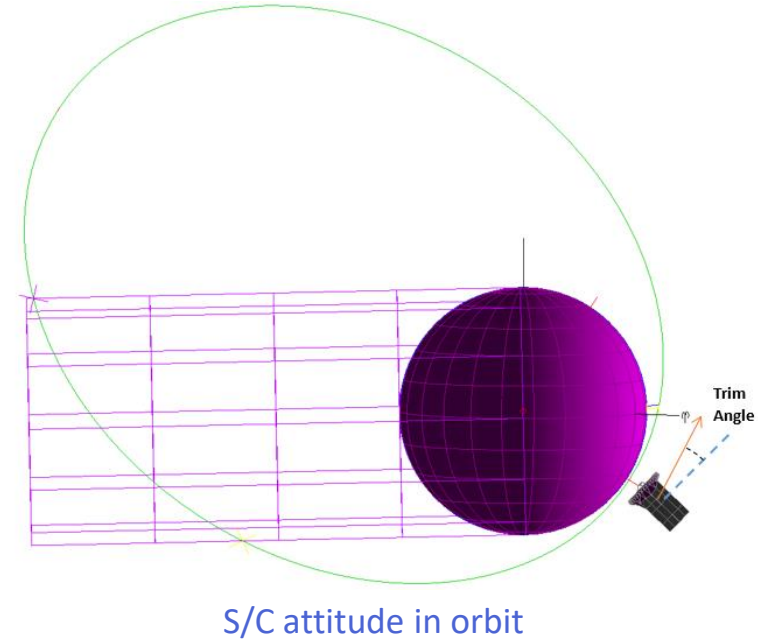
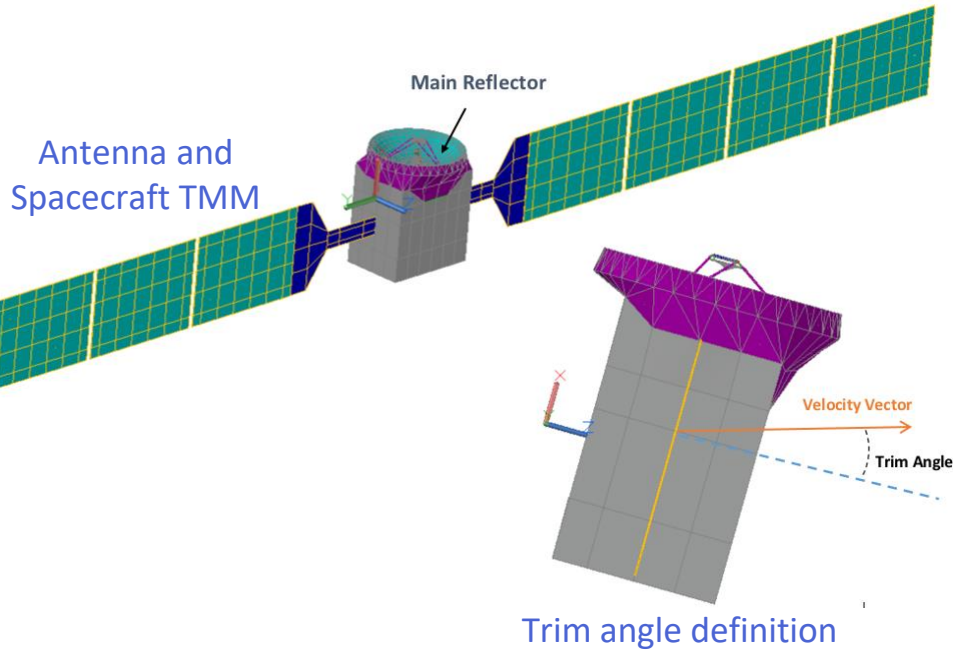
/// A further simplification in the approach has been to link the reference orbit relative to the maneuver during the drag pass in place of defining a dedicated solar vector and planet vector.



Trade-off studies are performed to test and refine the approach and ensure that the Aerobraking phenomenon has been implemented correctly. In detail the following tests have been done:

1. Perform analyses without solar, albedo and infrared heat flux but only with the aerothermal flux in order to check if:
 - The software really implements the aerothermal flux as expected and the temperature trends of the antenna items are consistent with the flux trend along orbit set as input data
2. Perform analyses during the drag pass modifying spacecraft attitude in order to check and verify that:
 - The aerothermal flux has been applied in the correct direction respect to the different antenna surfaces exposition
3. Perform analyses to identify the orbital positions in terms of angle (true anomaly) and time in order to:
 - Pinpoint the initial and final time of the drag pass phase as well as the periaxis position. The periaxis position is an important point of the orbit since it represents the nearest position with respect to the planet, therefore it corresponds to the maximum spacecraft dipping into the planet atmosphere. It is the time/position at which the maximum peak of the aerothermal heating occurs.

- Fixed Antenna mounted on S/C TopFloor
- S/C attitude during the aerobraking phase → Fixed Trim Angle from the Z-axis in the X/Z plane



1. Perform analyses without solar, albedo and infrared heat flux but only with the Aerothermal flux in order to check if the model feature really implements the aerothermal flux as expected and the temperature trends of the antenna items are consistent with the flux trend along orbit set as input data.

Assumption

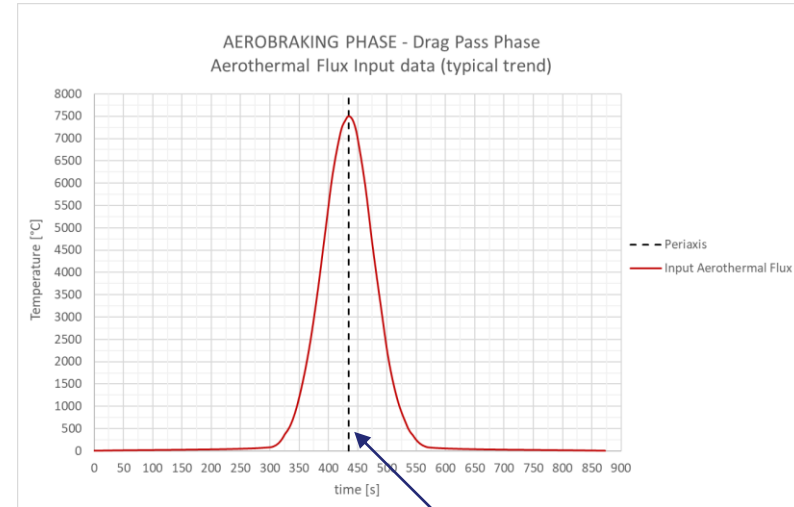
- S/C Attitude → Fixed Trim Angle of 10 deg from the Z-axis in the X/Z plane
- Aerothermal Flux with short duration and high peak

Sensitivity analysis implementing

two different analyses with different input data:

CASE 1 → aerothermal flux only

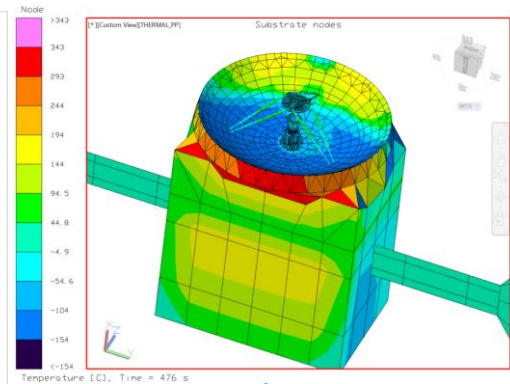
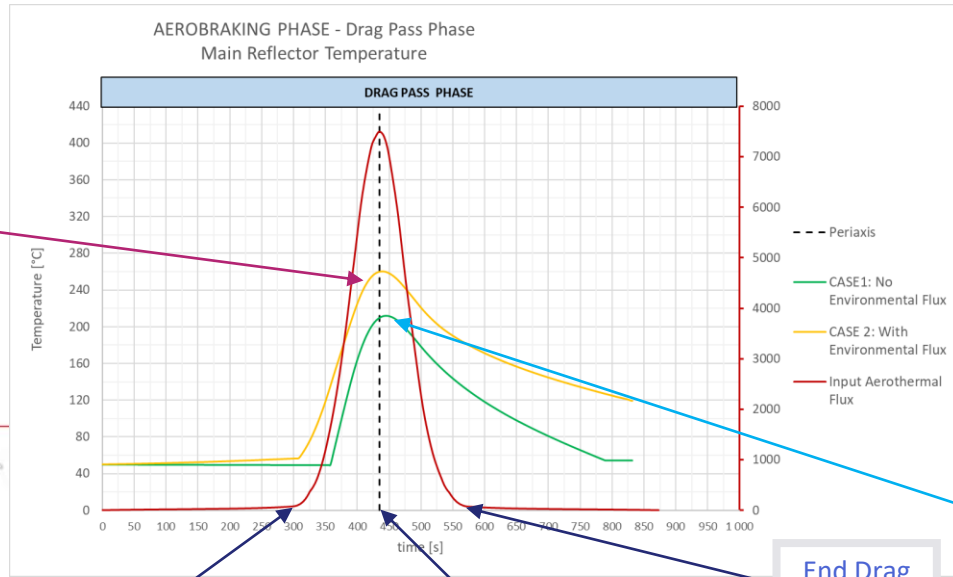
CASE 2 → aerothermal flux + environmental flux
(Solar, albedo, IR fluxes)



Periaxis

Antenna Reflector Temperature trend and contour maps during the Drag Pass

Case 1: Aerothermal flux with environmental flux



Aerothermal flux without environmental flux

Start Drag Pass

Periaxis

End Drag Pass

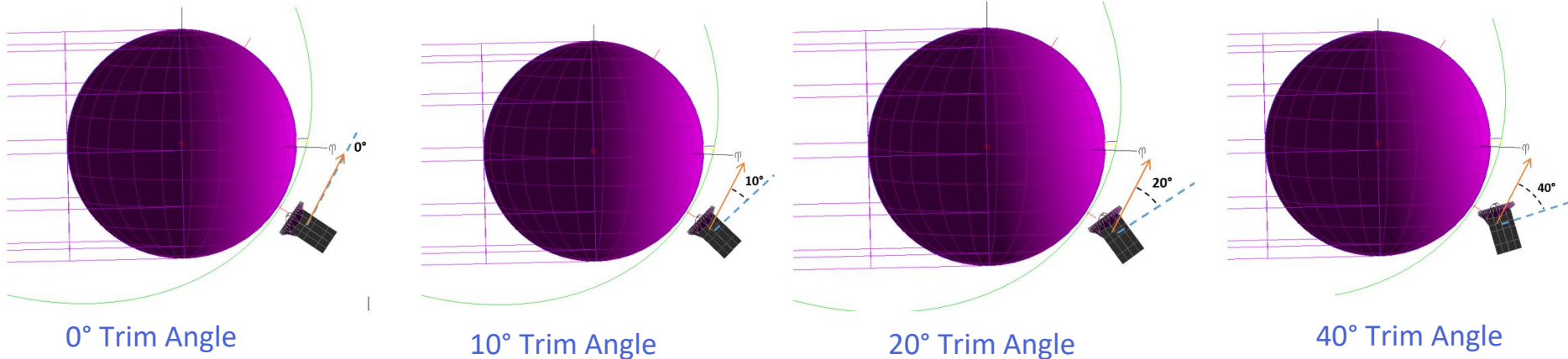
Conclusion → The aerothermal flux is implemented correctly. The antenna Reflector temperature trend is consistent with the input aerothermal flux.

- 2. Perform analyses during the drag pass modifying spacecraft attitude in order to check and verify that the aerothermal flux has been applied in the correct direction with respect to the different antenna surfaces

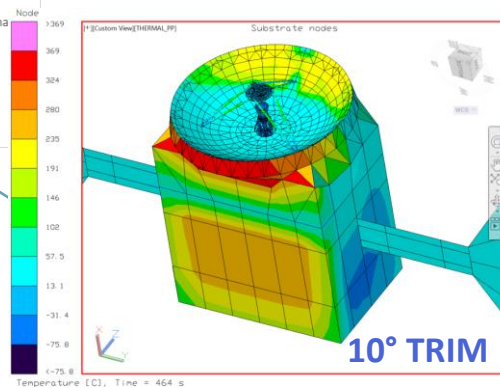
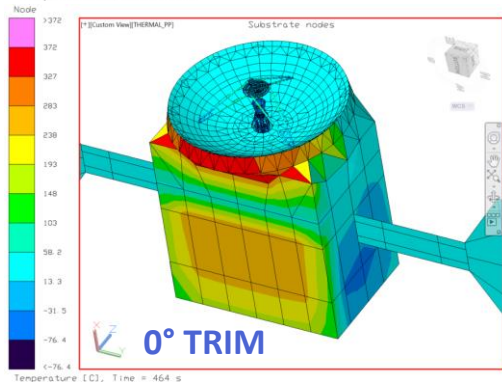
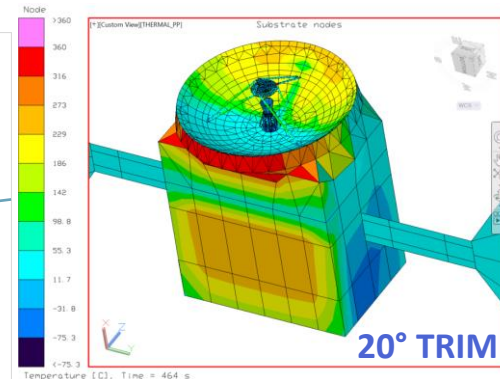
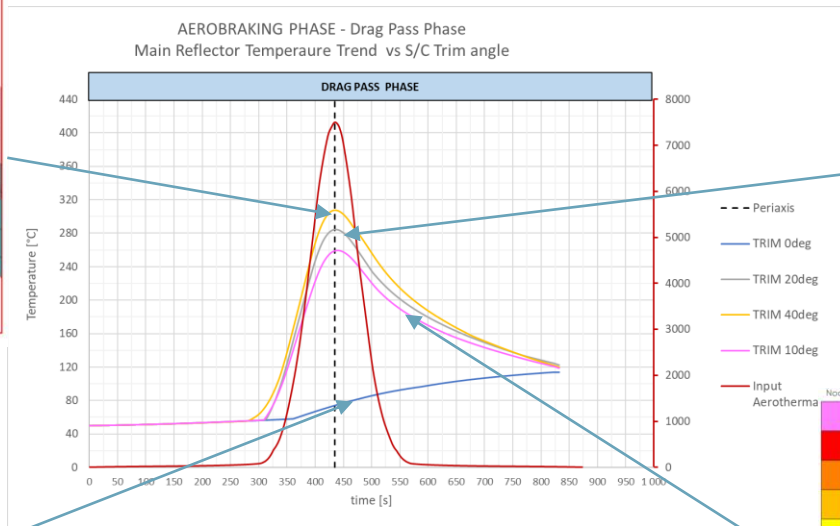
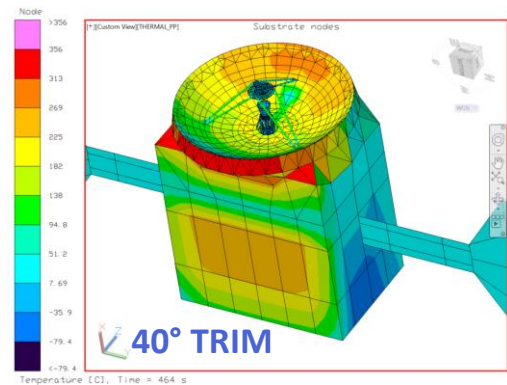
Assumption

Aerothermal Flux → fixed trend

Sensitivity analysis varying the S/C Trim Angle → the S/C attitude has been set to have different trim angles from the Z-axis in the X/Z plane (0°, 10°, 20°, 40°)

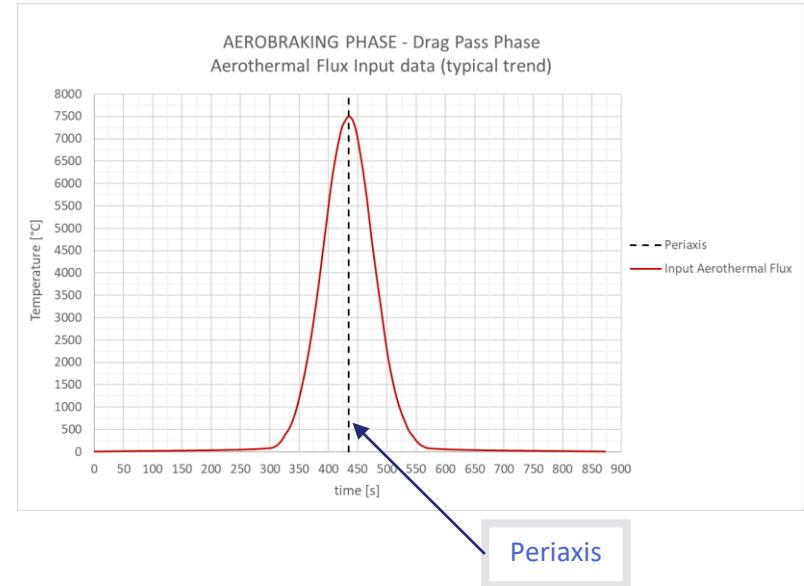
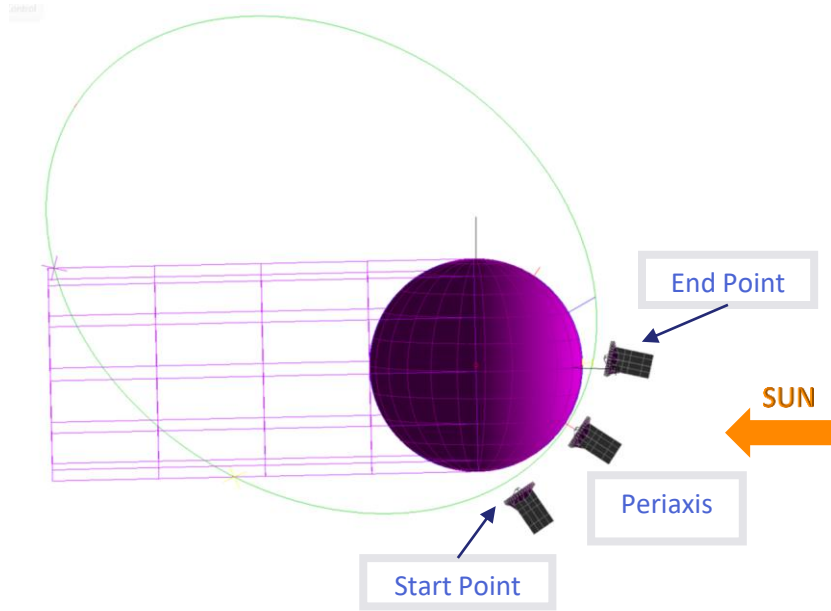


Antenna Reflector Temperature during the Drag Pass vs different S/C trim angle:

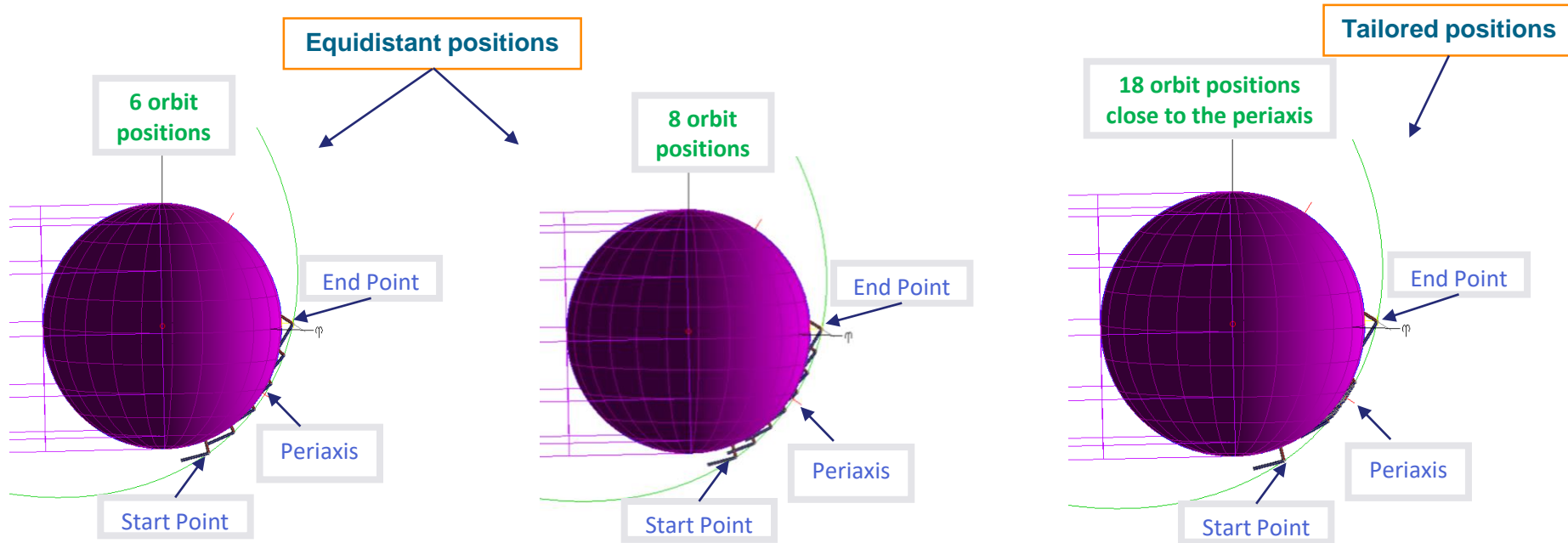


Conclusion → The aerothermal flux is implemented correctly with respect to the surfaces involved in the direction of the velocity vector

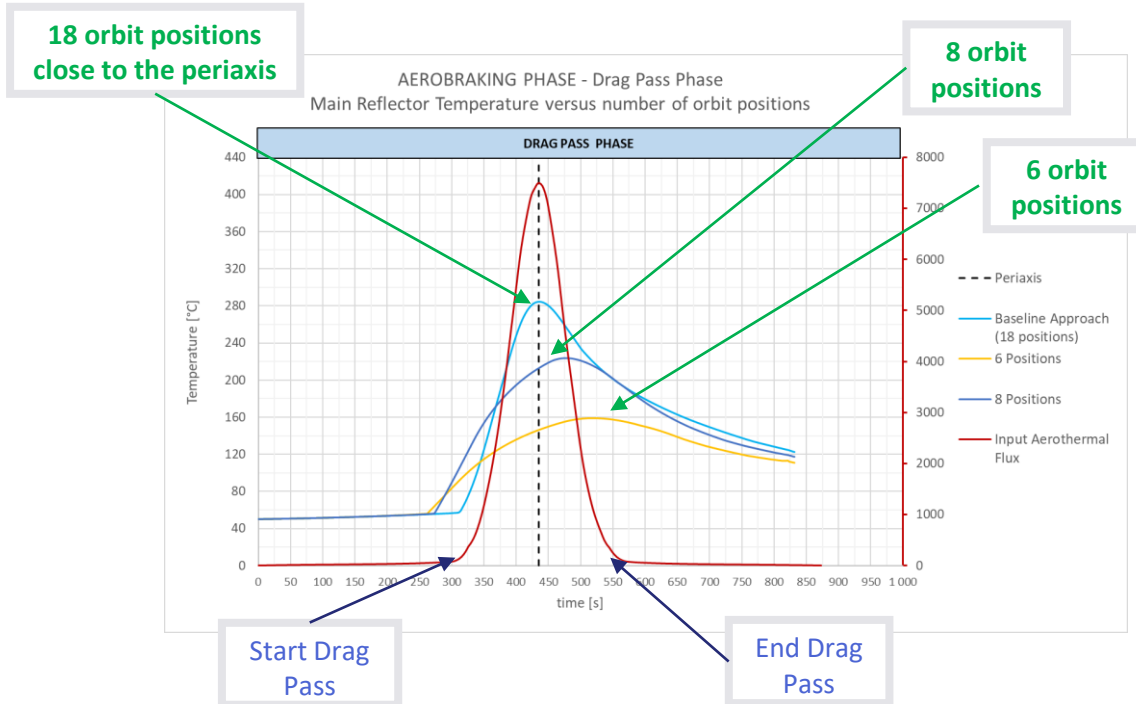
3. Perform analyses to identify the orbital positions in terms of angle (true anomaly) and time in order to pinpoint the initial and final time of the drag pass phase, as well as the periaxis position.



Three different analyses → increasing the number of the positions on orbit for which the heating rate is calculated. In the first two cases an equal interval breakdown has been set (which is the standard methodology) while in the last one a list of specific positions has been set close to the periaxis position in order to calculate the heating due to aerothermal flux with a higher accuracy around the input peak flux.



The calculated temperature of the reflector over time demonstrates that only with a number of positions concentrated close to the periaxis it is possible to match the peak of aerothermal flux provided as input.



Conclusion → The aerothermal flux is implemented correctly only by using a number of orbital positions concentrated around the periaxis.

CONCLUSION

The method shown allows to implement correctly the mission and the environmental constraints in the thermal analysis of an Aerobraking phase, without the time-consuming need to develop dedicated tools and/or subroutines.

In the frame of the initial developments of a project, this technique allows to provide an effective, rapid and reliable response in terms of thermal performances, in order to help plan the correct spacecraft maneuvers and drag-pass without generating excessive heating on the object of interest and define a valid preliminary thermal design.