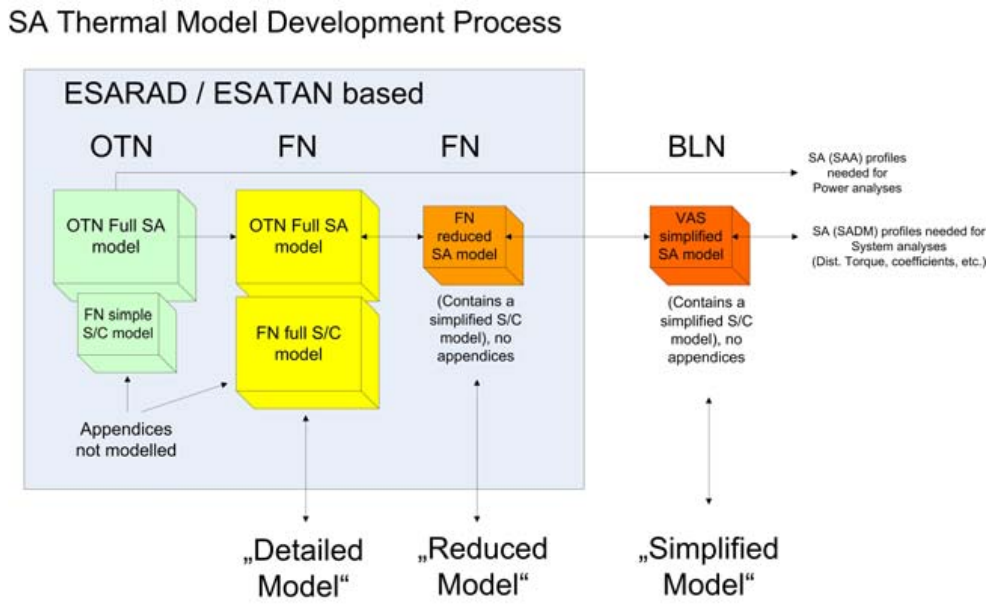
Appendix R

Mercury Planetary Orbiter Solar Array Thermal and Power Modelling

Martin Altenburg
(Astrium GmbH, Germany)

Abstract

BepiColombo is a major joint European and Japanese mission to send a planetary explorer to Mercury. As such BepiColombo is exposed to high thermal loads. One of the most critical subsystems on BepiColombo is the MPO Solar Array.
This presentation gives a short overview of the "simplified" thermal solar array model, which has been derived from the "detailed" and "reduced" model and is used to analyse thermal and power performance on the spacecraft. The "simplified" model uses the attitude and position of the spacecraft and SADM with respect to Mercury to determine the temperature of the hottest solar array cell. The "simplified" model will be used by ESA to generate solar array drive profiles in the course of mission planning.



The presentation will look into two different approaches for solving the thermal network. The first is applied by the "reduced" solar array model, with an interface script for solving temperature dependent moving geometry iterations with ESATAN TMS. The second approach is followed by the "simplified" solar array model, which uses an independent mathematical description of the thermal loads from Sun and Mercury on the Spacecraft without relying on classical thermal analysis tools. Results obtained by these two approaches are compared vice versa and with results calculated by the "detailed" model in consideration of numerical effort and accuracy of the temperature results. In addition, a short outlook for the further development of the "simplified" model and the power model will be given.

26th European Space Thermal Analysis Workshop

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Mercury Planetary Orbiter Solar Array Thermal and Power Modelling

Martin Altenburg, Dipl.-Ing.
Thermal Engineering and Analysis

BepiColombo

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Mercury Planetary Orbiter Solar Array Thermal and Power Modelling

- Trajectory to Mercury
- SA development process
- SADM profile generation
- Comparison detailed & simplified model (GMM)
- I/F to power model
- Summary

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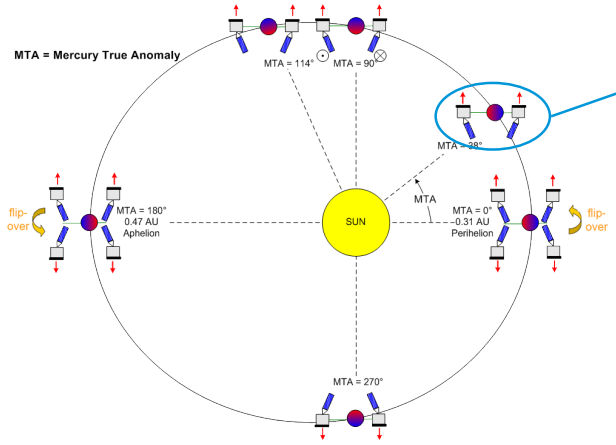
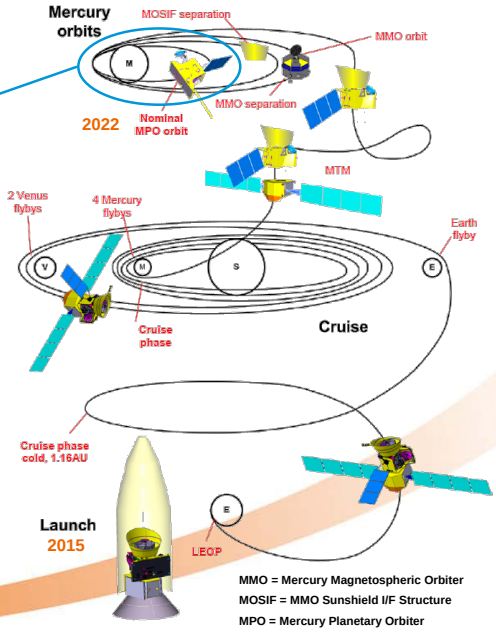
BepiColombo Trajectory to Mercury





- **Harsh Mercury Environment**
  - **max. Solar flux: 14448 W/m²**
  - **max. Mercury IR: 4500 W/m²**
  - **max. Mercury Albedo: 600 W/m²**

MMO = Mercury Magnetospheric Orbiter
MOSIF = MMO Sunshield I/F Structure
MPO = Mercury Planetary Orbiter
MTM = Mercury Transfer Module

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Page 3

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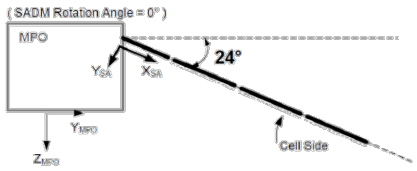
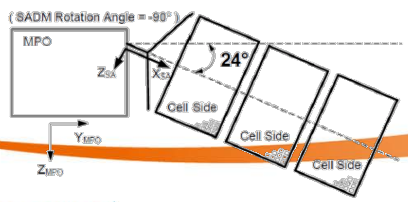
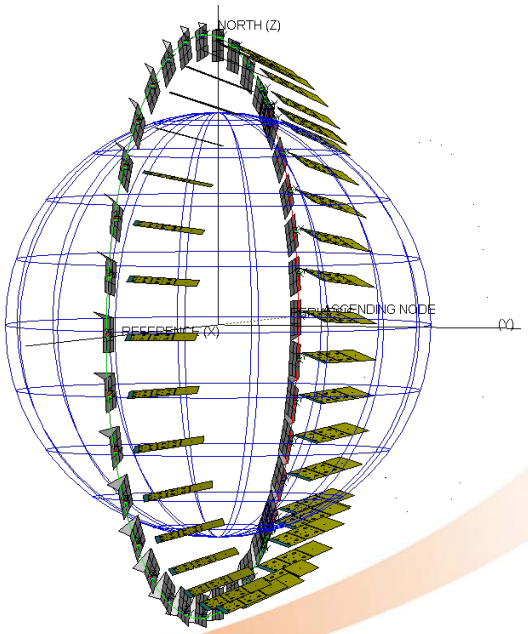
BepiColombo SADM profile



*The solar array shall remain within design temperature conditions considering a sun distance from **1.13AU** to **0.298AU**.*

*To achieve this, the solar array may be off-pointed from the sun about its rotational axis up to any off-pointing angle as necessary to maintain the maximum SCA (solar cell assembly) operational temperature below **190°C** during nominal modes and below **205°C** for 600h during safe/ survival mode.*





Exemplary SADM profile (MTA 0)

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SA (PDR) development process

detailed model ~ #3500	reduced model ~ #100	Simplified model ~ #100
=	=	=
• full SA model • complex S/C MLI → GMM & TMM	• reduced SA model • simplified S/C MLI → GMM & TMM	• simplified SA model • simplified S/C MLI → vertices & material & properties
+	+	+
• individual GR calculation based on current SADM angle • non-parallel Sun rays • with capacity	• individual GR calculation based on current SADM angle • non-parallel Sun rays • without capacity	• look-up tables from ESARAD for GRs, steps of 1 deg • parallel Sun rays • without capacity
↓	↓	↓
• Thermal design • Verification • Input for power analysis	Tool for development of the simplified model	• SADM profile generation • Input for power analysis • Model for Operations

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Page 5

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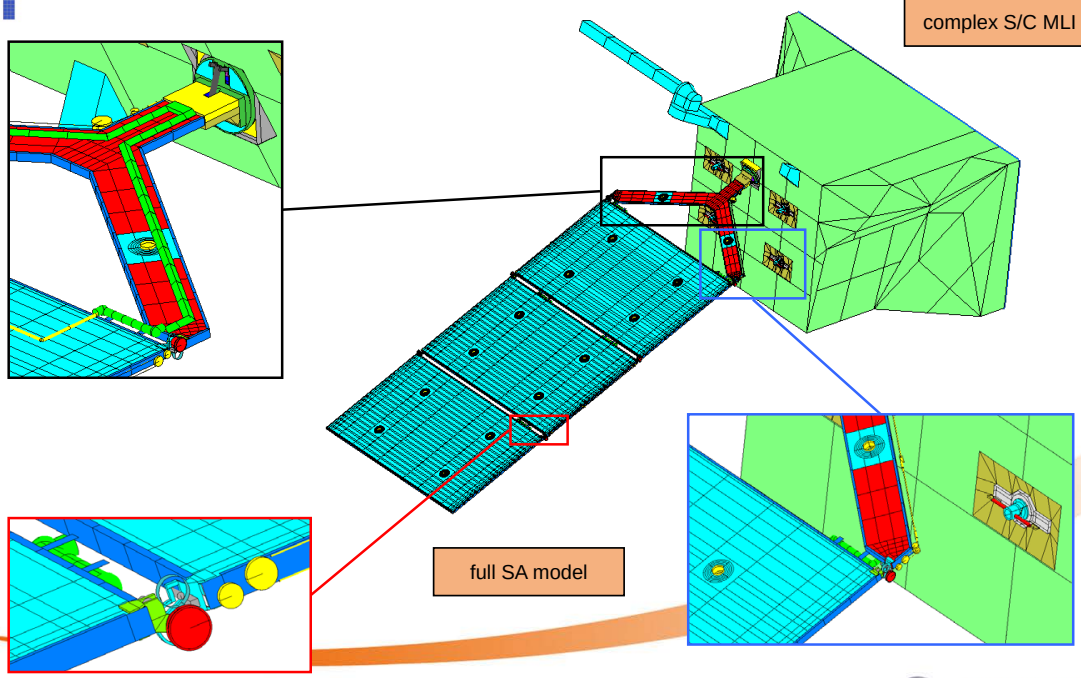
Detailed SA model (CDR)



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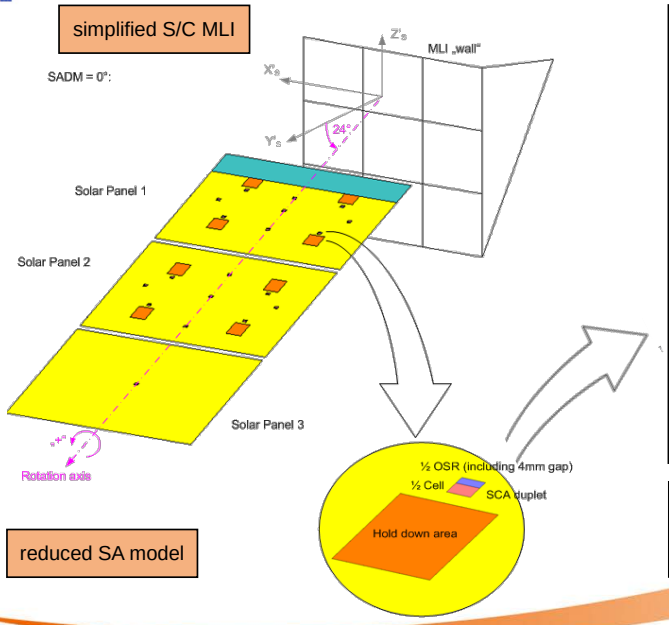
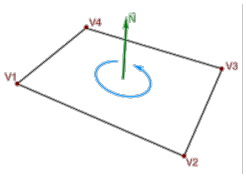
Reduced & simplified SA model

simplified S/C MLI



reduced SA model

```
...
$ Vertices;
# ID; X2; Y2; Z2; Location
1211;-0.555;1.61985;0; # SCA 121x
1212;-0.555;1.63985;0
1213;-0.555;1.65235;0
1214;-0.515;1.65235;0
1215;-0.515;1.63985;0
1216;-0.515;1.61985;0
...
$ Nodes;
# ID; Label; Vertices; Optical ID; Node size [m²]
1210;P1_SCA1_cell;1211;1212;1215;1216;104;0.0008
1211;P1_SCA1_osr;1212;1213;1214;1215;103;0.0005
...
```



simplified SA model (vertices, material, properties)

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Page 7

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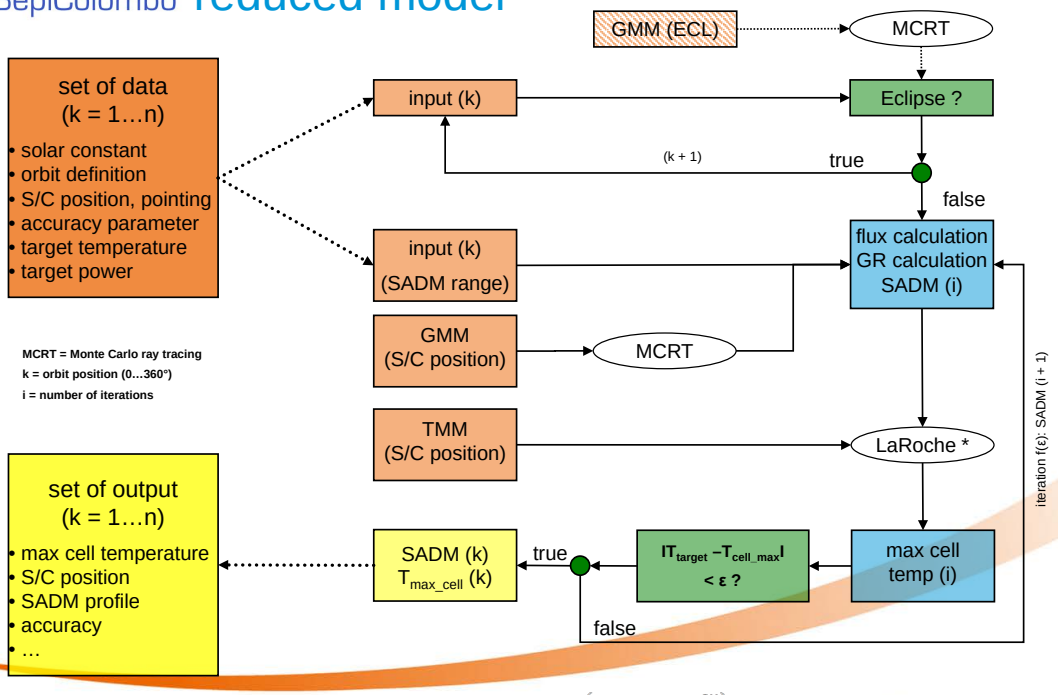
SADM profile generation – reduced model



* $I_{UV,cell}(SAA) = \cos(SAA) \cdot \left(1 - (1 - \cos(SAA))^{1+\frac{SAA}{w}}\right)$ with $w = 15°$

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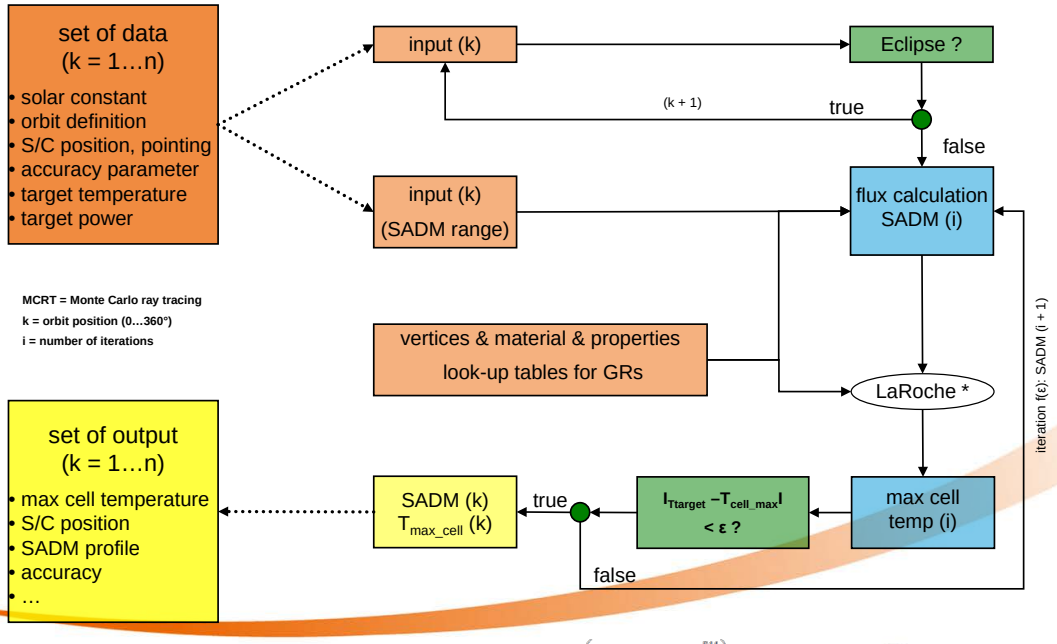
SADM profile generation – simplified model



* $I_{UV\_cell}(SAA) = \cos(SAA) \cdot \left(1 - (1 - \cos(SAA))^{\frac{SAA}{w}}\right)$ with $w = 15°$

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Page 9

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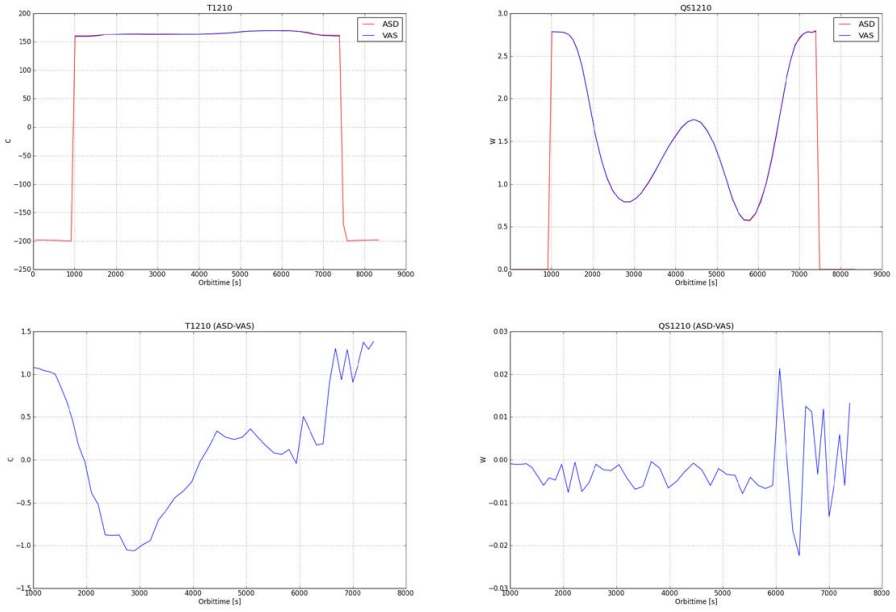
Comparison (reduced & simplified model)



MTA 0: #1210, Panel 1, SCA1, Cell

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Page 10

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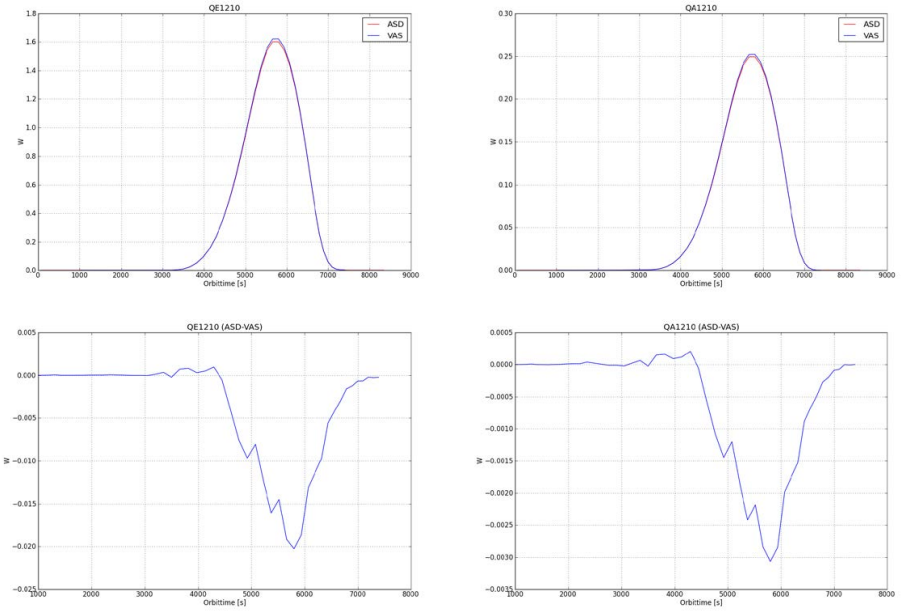
Comparison (reduced & simplified model)



MTA 0: #1210, Panel 1, SCA1, Cell

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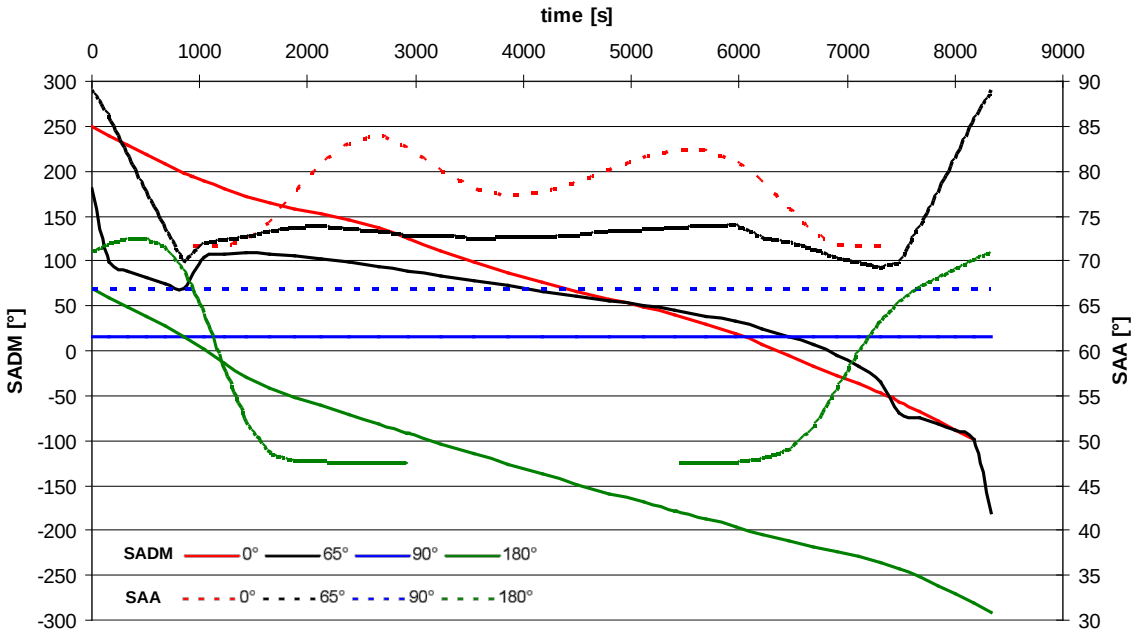
SADM & SAA over MTA



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BepiColombo I/F to power model

- Exchange file
  - Trajectory information
  - For every trajectory point:
    - Quaternions describing S/C attitude and SADM rotation angle
- Processed and imported into Power-Systema
- SAA computed by Power-Systema matches with SAA computed by thermal engineering
- NOT part of interface, but implemented in Power-Systema:
  - Cosine correction for power and temperature computation
  - Planet geometry and temperature distribution
  - View factors and illumination of geometrical surfaces

BepiColombo Summary

- Development of simplified SA model (PDR status) to support operational actions (ESA)
- Verification of simplified model against reduced and detailed model (PDR status)
- Calculation of SADM profiles, with less computational effort (reduced: 2 - 3 days / simplified: 15 – 30 min) und (identical) high accuracy
- Easy SADM profile and temperature prediction for interesting MTAs (without using thermal S/W and also possible without thermal skills)

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Improvement

- GMM/TMM:
  - Iteration of maximum, minimum angle or fluxes for target temperature (SA, antenna, …) or power (SA)
  - SADM velocity time tables
  - Parameter cases for GMM (each orbit position)
- Post-processing of moving geometry:
  - Visualisation of angle vector
  - “Ray to Face”: output of numbers, not only visualisation

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Page 15

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