Appendix B

Thermal modeling of a non-uniform solar beam in ESATAN-TMS

Scott Morgan
(EADS Astrium, United Kingdom)

Abstract

Due to the non-uniformities present in some test facility solar beams, a method has been developed to account for the variations in intensity experienced across a test object. This presentation discusses a few different methods that have been used to model this within ESATAN-TMS using the inbuilt transmissivity function, and the results obtained from the analysis.

Thermal modelling of a non-uniform solar beam in ESATAN-TMS

Astrium UK

Scott Morgan // 20/10/12

All the space you need

ASTRIUM
AN EADS COMPANY

Contents

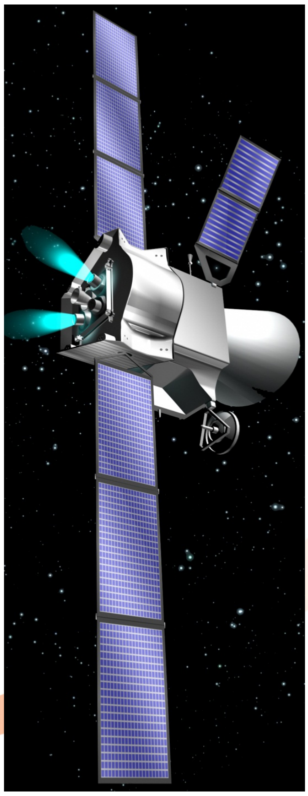
- Background
- The problem
- Solution 1
- Solution 2
- Results
- Conclusion

All the space you need

ASTRIUM
AN EADS COMPANY

Bepi Colombo

- Bepi Colombo is an ESA mission to Mercury, launching in 2015
- It is effectively 3 spacecraft stacked on top of each other
  - MTM – Mercury Transfer Module
    - Propulsion module, including attitude control thrusters and Xenon electric propulsion system
  - MPO – Mercury Planetary Orbiter
    - ESA science module, studying the Internal structure, Geology, Element composition and Polar ice.
  - MMO – Mercury Magnetospheric Orbiter
    - JAXA science Module, studying the Magnetic field of Mercury and the inner solar system

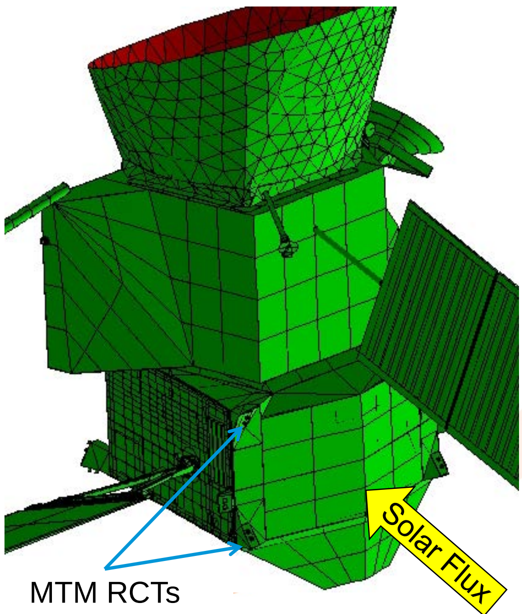


All the space you need

ASTRIUM AN EADS COMPANY

MTM RCTs

- The MTM attitude control system requires reaction control thrusters (RCTs) pointing towards the Sun
- Therefore the thruster nozzle is exposed to up to 11 Solar constants of flux in a steady state environment
- As a result, significant thermal design work has been necessary to control the temperature of the RCTs in this environment

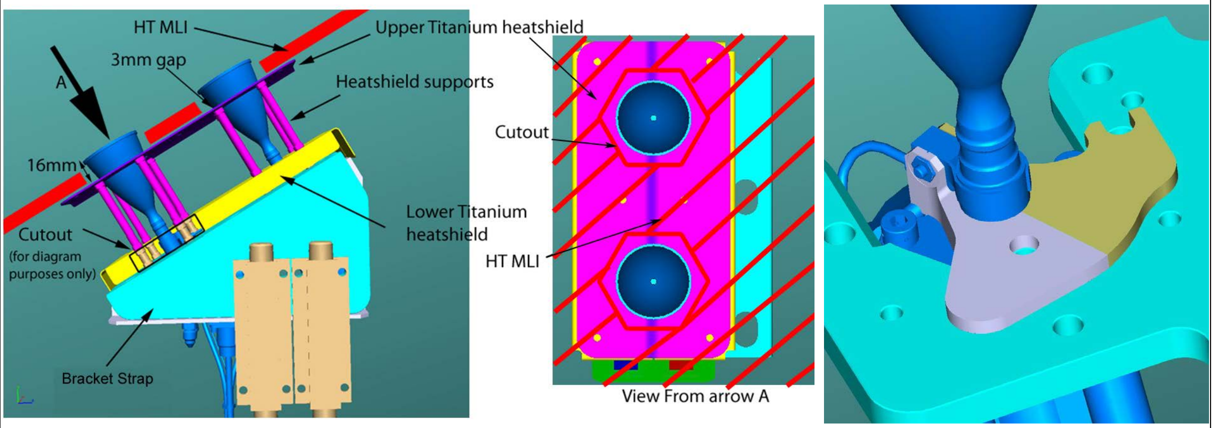


All the space you need

Date - 4

ASTRIUM AN EADS COMPANY

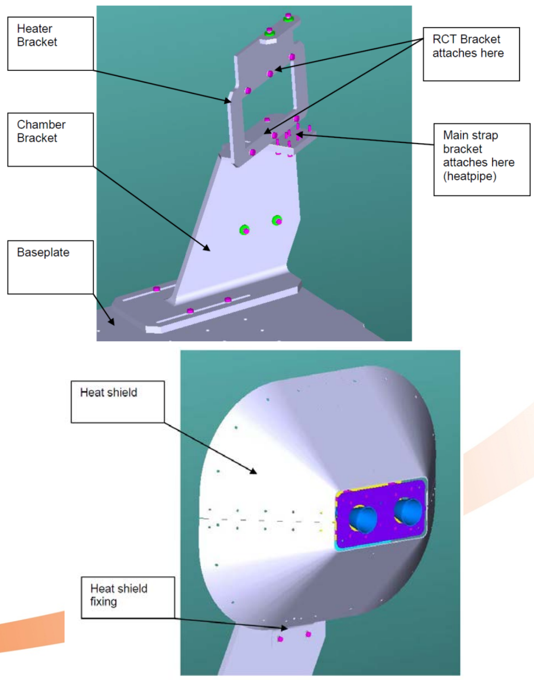
RCT Design Work



- The main thermal design strategy was to;
  - Reduce the amount of flux absorbed by the thruster
  - Remove as much heat as possible via a radiator mounted heatpipe

RCT Test

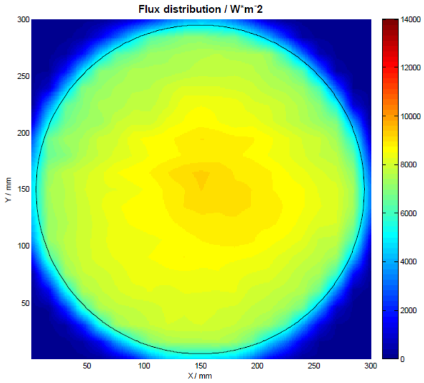
- Once a design was found that was predicted to work, the entire setup needed to be tested in order to have confidence in the model.
- Therefore a solar simulation test was designed to test a thruster pair and its associated thermal hardware
- The heatpipe was replaced with a large Aluminium strut, that doubled as a support for the hardware
- Due to the flight MLI (made from Nextel) not being permitted in the chamber, an LAE MLI blanket was used instead
- This MLI was supported by a conical Titanium heatshield to account for the missing MLI support structure



All the space you need

The Problem

- The solar beam intensities from some chambers are not uniform
- This leads to modelling errors and uncertainties, which complicate and impede correlation activities
- Therefore a better method is needed to model solar simulation beams more accurately

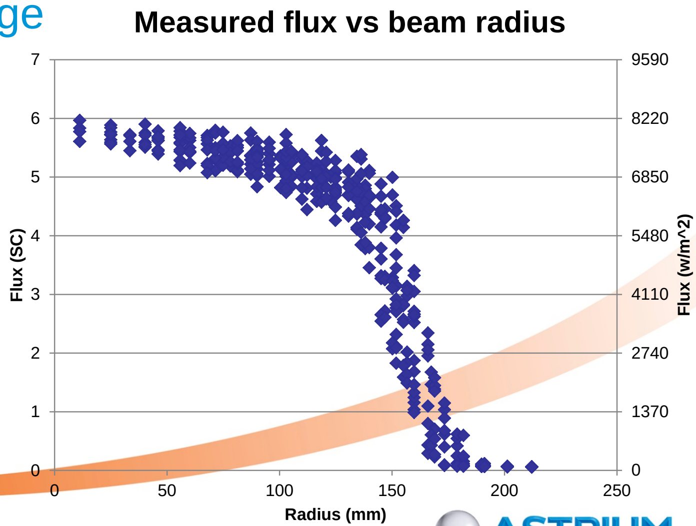


All the space you need

ASTRIUM
AN EADS COMPANY

The Problem

- The main non-uniformity in the beam of some solar simulators is a drop off from the centre of the beam to the edge
- Also the “edge” of the beam is usually not distinct, but decreases over a region of space

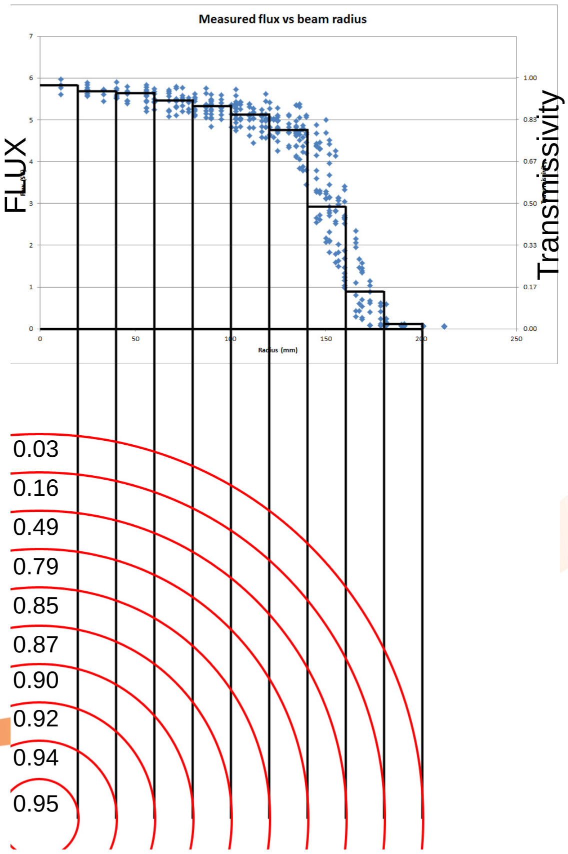


All the space you need

ASTRIUM
AN EADS COMPANY

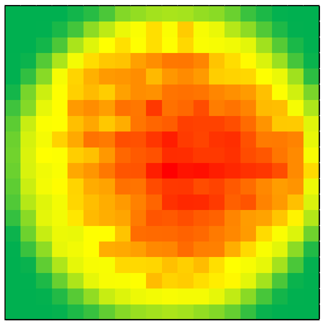
Solution 1 - “Rings”

- A solution to this problem is to pass the uniform flux generated by ESATAN-TMS through concentric rings of variable transmissivity
- These rings decrease in transmissivity at larger radii from the centre, thus scaling the flux.

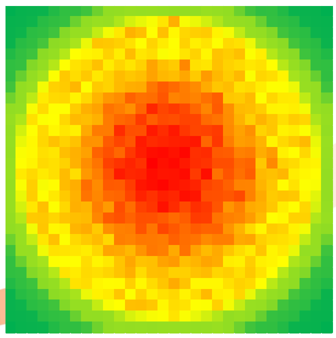


Solution 1 – “Rings”

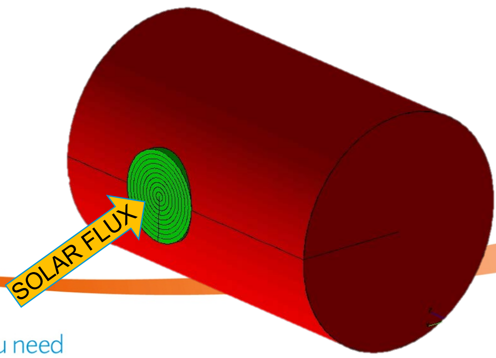
- Results for flux distribution is shown here, compared to original measured data
- Decrease in intensity at large radii is well modelled
- Good average agreement
- Fails to take into account local hotspots in beam



Measured solar flux from test

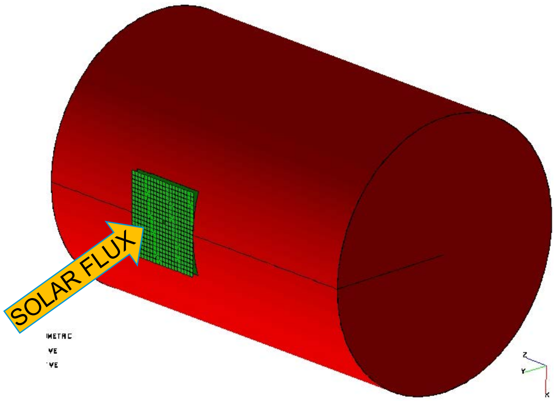


Simulated solar flux from model



Solution 2 - "Grid"

- Use a grid of variable transmissivity shells.
- This allows modelling of local hotspots
- Downside is that this method adds 100s of shells to a simulation

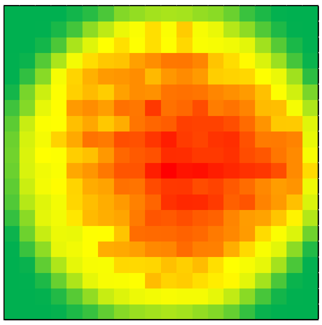


All the space you need

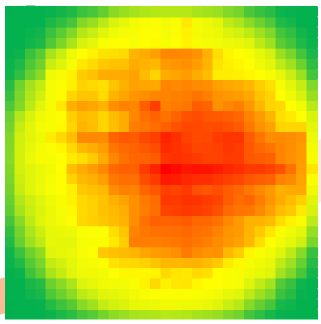
ASTRIUM
AN EADS COMPANY

Solution 2 – "Grid"

- Very good agreement between test data and simulated flux
- Local hotspots on the beam are accurately modelled



Measured solar flux from test



Simulated solar flux from model

All the space you need

ASTRIUM
AN EADS COMPANY

Results - Correlation

- The correlation results for the most important locations on the RCTs is shown in the table below. Note that the grid method was used for this correlation

	Test - Model temperature delta (°C)				
Label	TP01	TP02	TP03	TP04	TP05
TC3 - Injection head ring	-0.2	1.5	1.2	0.8	0.9
TC4 - Injection head	-0.9	-0.9	0.1	-1.3	0.8
TC6 - Valve Manifold	2.9	3.0	3.4	3.8	0.6
TC8 - Injection head ring (no IHS)	-3.1	-2.1	-1.7	-3.9	1.1
TC9 - Injection head (no IHS)	-2.7	-2.6	-0.4	-1.2	0.0
TC11 - IHS RH (near thermal strap bracket)	1.2	1.4	1.9	0.7	0.7
TC12 - Thermal Strap bracket (near IHS RH)	0.0	0.0	0.8	-0.8	0.7

- The results show a small deviation between test and model temperatures
- It also shows good agreement through different phases, which includes having the thruster at different orientations in the chamber
- This shows that the solar beam is well understood and well modelled

All the space you need

ASTRIUM
AN EADS COMPANY

Conclusion

- Two methods of modelling the variation of flux intensity of solar simulation beams has been presented
- The “ring” method
  - Takes into account the drop in intensity from the centre of the beam
  - Doesn’t model local hotspots
  - Uses a small number of extra shells
- The “grid” method
  - Takes into account both the drop in intensity from the centre and the local hotspots
  - Uses a large number of extra shells
- Both methods increase the accuracy of solar simulation modelling and therefore improve the precision and correlation of thermal models
- The “grid” approach was used successfully in the correlation of the Bepi Colombo sun facing RCTs

All the space you need

ASTRIUM
AN EADS COMPANY