BepiColombo

Thermal Protection to Survive at Mercury

July 6th , 2017

Mauro Patroncini – Thales Alenia Space Italia

ThalesAlenia Space
a Thales / Leonardo company

BepiColombo Project : Thales Alenia Space involvement and responsibilities

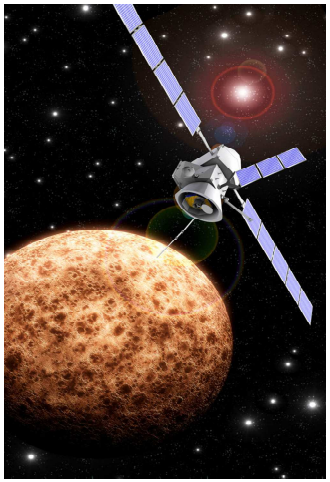
- Thales Alenia Space Italia is part of the BepiColombo Core Industrial Team, led by Airbus Defense & Space, and its responsibility includes:
  - **TT&C S/S**
  - **MPO Thermal control S/S**
  - **Power distribution & harness S/S**
  - **Solar Array mechanisms**
  - **System Assembly Integration and Tests** (STM, PFM)
  - **Launch campaign support**

- Thales Alenia Space Italia has also directly developed the following equipment
  - **DST** (X / Ka Deep Space Transponder)
  - **HGA** (X / Ka High Gain Antenna)
  - **OBC, FCE** (On-board computers)
  - **SSMM** (Solid State Mass Memory)

  and Science Instruments
  - **MORE** (Radio Science)
  - **ISA** (Spring accelerometer)

BepiColombo Project : Thermal Challenges

The design of the MPO Thermal Control S/S has been driven by the specific challenge of this Mission which is the extreme thermal environment in combination with the chosen orbit and the nadir pointing attitude of the spacecraft.



Solar Flux from the Sun
up to 14500 W/m^2
(more than 10 times the
solar flux around Earth)

⇒ External temperatures up to 450 °C

Infrared and Albedo Flux
from Mercury hot surface
up to 5500 W/m^2

Due to this environment, new dedicated technologies had to be developed starting from 2006 (start of Phase C/D) for:

- thermal control material (MLI, Coatings)
- externally exposed equipment (Antennas, Mechanisms)

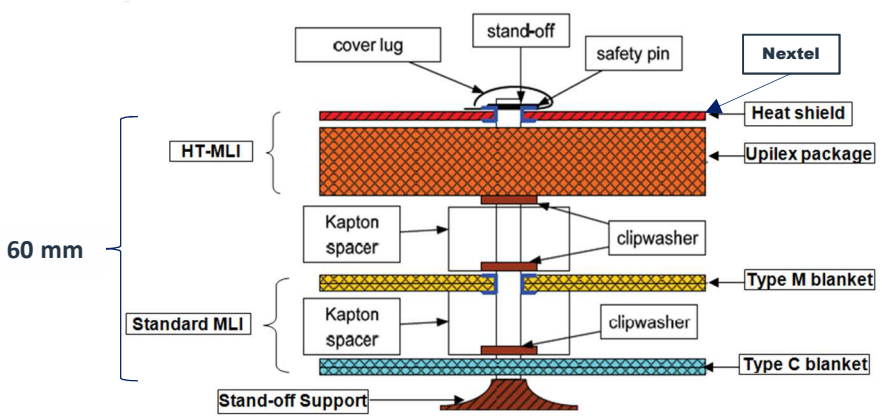
BepiColombo Project : Thermal Protections Developments – HT MLI

Specifically designed High Temperature MLI

- Capability to withstand up to extreme thermal gradients (450 °C external and 60 °C internal)
- Excellent insulation capability (higher than 99%)
- Low ratio between absorbed and emitted energy (α/ε= 0,29 @ BOL, < 0,57 @ EOL) to reduce the temperature when exposed to sun
- Limited degradation of thermo-optical properties due to UV radiation
- Low emission of particulate (to not damage the optics and the exposed Instruments)

Multiple barrier MLI configuration (MPO)

- Triple stack of MLI blankets, typical thickness 60 mm
- HT MLI with Double Nextel heat shield
- Proper Kapton spacers to provide micrometeorite protection



July 6th, 2017
Ref. = BC-ALS-HO-00068
Template Ref.= 87208327-BID-TAS-EN-004

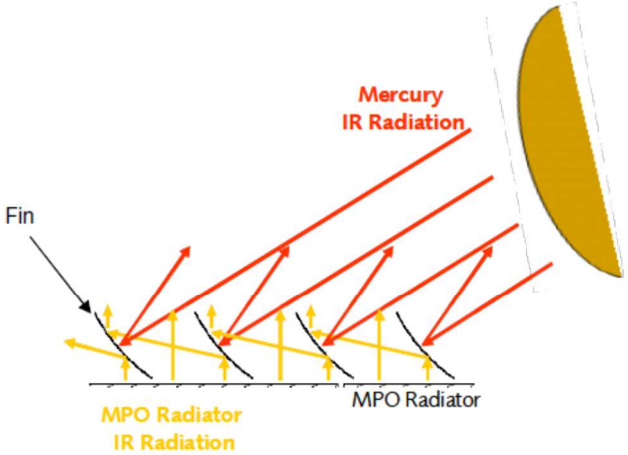
BepiColombo Project : Thermal Protections Developments – HT MLI

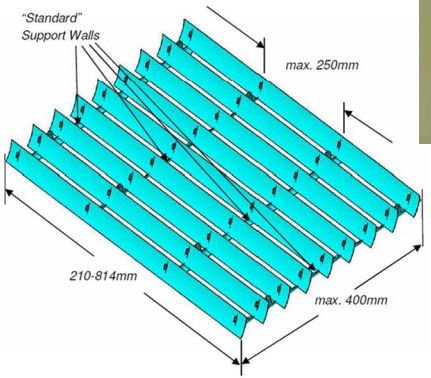
All MLI installed for the MCS Acoustic Test

BepiColombo Project : Thermal Protections Developments – MPO Radiator

Dedicated MPO radiator design

- Covered with curved Ag coated Titanium fins to reflect the Infrared Flux from Mercury while ensuring the transfer of the internal heat to the external space

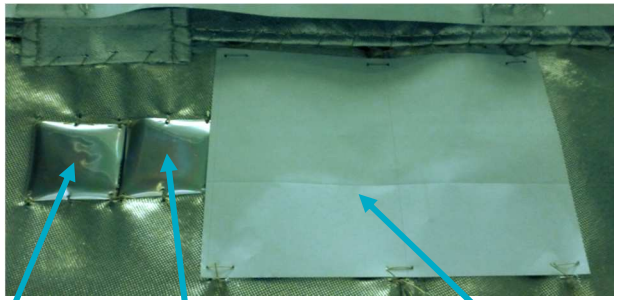




July 6th, 2017
Ref. = BC-ALS-HO-00068
Template Ref.= 87208327-BID-TAS-EN-004

BepiColombo Project : Thermal Protections Developments - Coatings

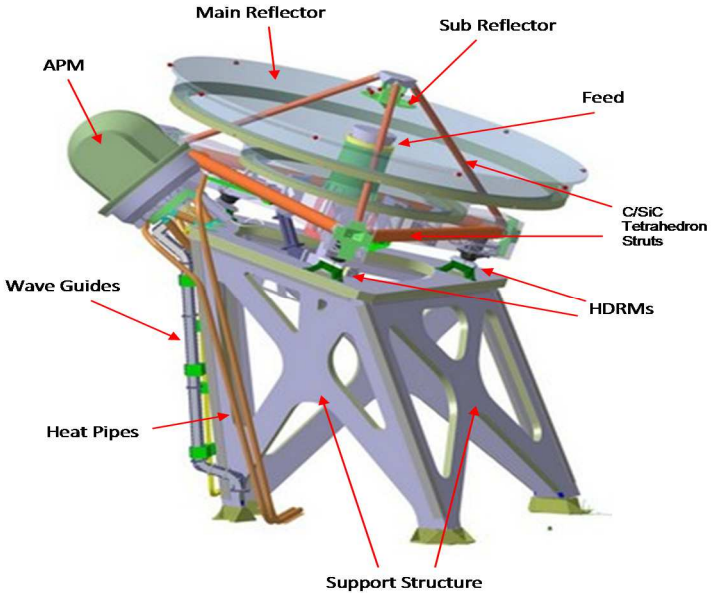
- **High temperature thermal coatings**
  - CREO Coating (multi layer optical) for titanium used on HGA (RF Feed & HDRM), Deployable Thermal Covers (α/ε= 0,22 @ BOL, 0,33 @ EOL)
  - Ceranovis Coating (ceramics white coating) used on HGA, Anti-contamination foils around Instruments, 22 N Thruster, Solar Array Thermal Box. (α/ε= 0,27 @ BOL, 0,79 @ EOL)
- with the following properties:
  - resistance to very high temperature
  - favorable ratio between absorbed and emitted energy
  - low degradation of thermo-optical properties over time



BepiColombo Project : Thermal Protections Developments - HGA

- Dual Band (X / Ka) High-Gain Antenna steerable on two axis and 1,1 m diameter
- Very high Phase Stability (2.2 mm over 1000 sec.) to allow also Radio Science in the harsh thermal environment of the orbit around Mercury
- Specific technologies adopted to minimize thermal distorsion and depointing

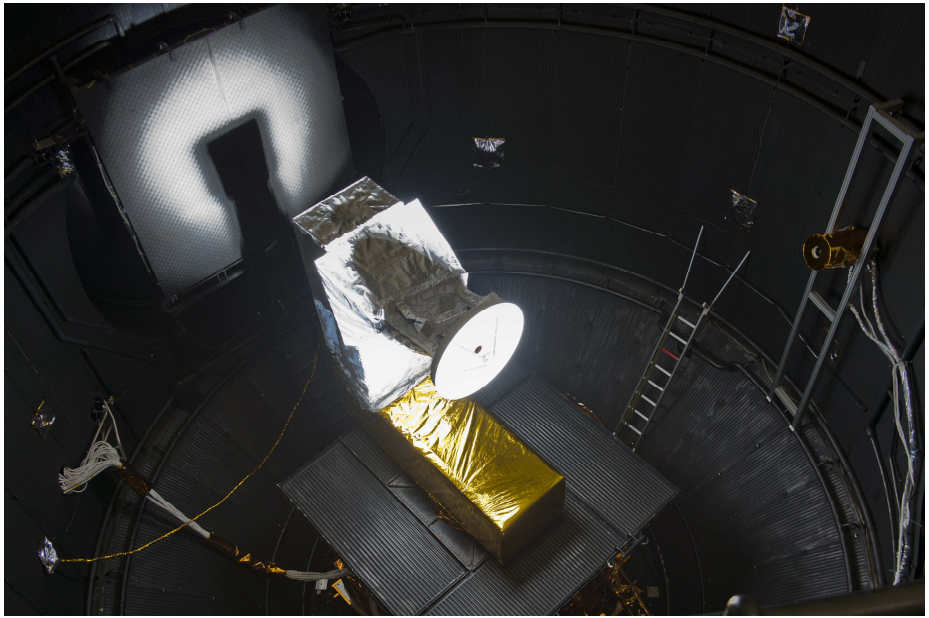
- **Titanium reflectors coated with ceramic thermal coating** to survive up to 450°C
- **Gold Plated Titanium RF Feed** with a multi-layer optical thermal coating
- **C/Sic struts for high stability** to sustain the Secondary Reflector
- Specially developed **RF coating** (Ag on Titanium) for waveguides to minimize losses at high temperature
- **High temperature mechanism** for precise pointing



BepiColombo Project : Thermal Protections Developments - HGA

- Tested at Assembly level at 10 Solar Constants to prove the thermal design.
  Test done in the Large Space Simulator chamber at ESTEC.

- Thermo-elastic distortion tested in Argon environment up to 120°C to correlate the Thermo-elastic distortion model.
  Test done in a test facility in Thales Alenia Space Rome specifically designed for this purpose.



High Gain Antenna in LSS for the Solar Simulation Test

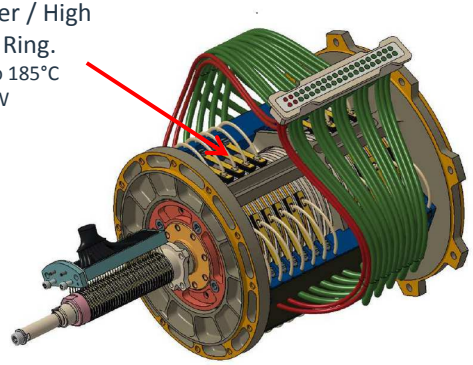
BepiColombo Project : Thermal Protections Developments - Mechanisms

High temperature technologies for mechanisms

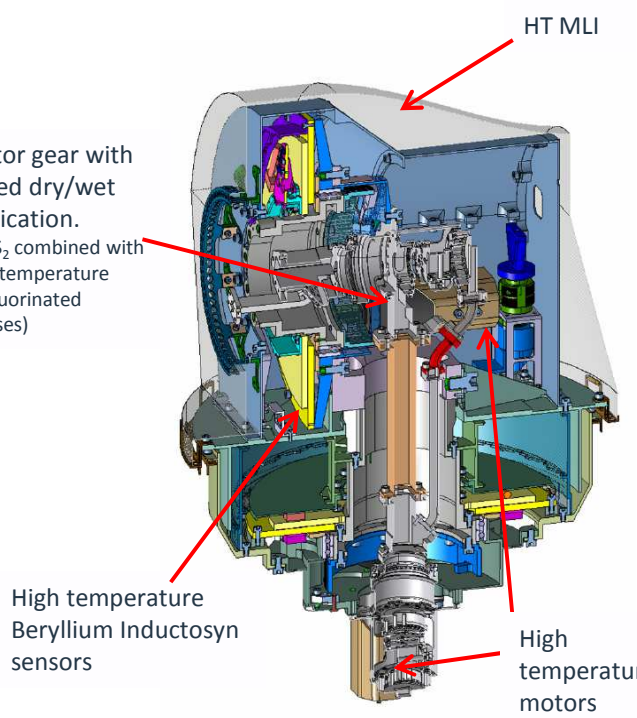
- used for HGA, MGA, SADM
- developed to withstand extreme operational temperature (+200°C to -80°C) while providing high pointing accuracy.

Special “High power / High temperature” Slip Ring.

- Temperature up to 185°C
- Power up to 7,5 kW



MPO/MTM Solar Arrays Drive Mechanisms



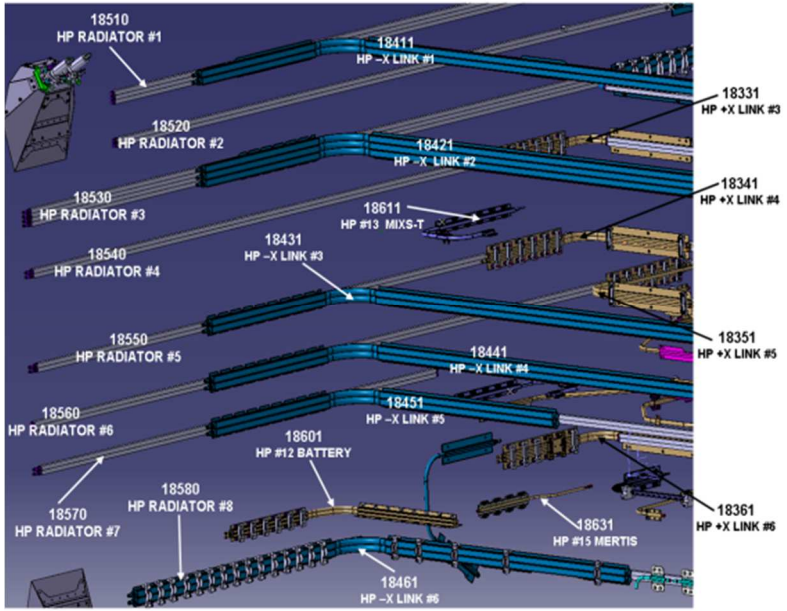
HGA/MGA Pointing Mechanisms

July 6th, 2017
Ref. = BC-ALS-HO-00068
Template Ref.= 87208327-BID-TAS-EN-004

BepiColombo Project : Thermal Protections Development – Heat Pipes

- **Complex heat pipes network**
  - embedded in MPO main structure and Radiator
  - surface mounted on MPO and MTM main structures

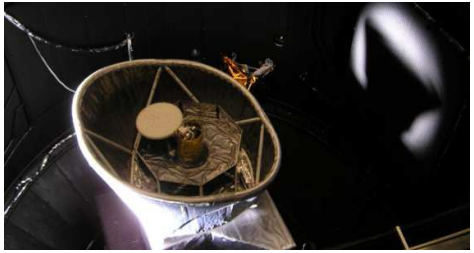
Aluminum pipes with an Ammonia working fluid to transport to the radiator the heat absorbed from the environment and dissipated by the internal units.



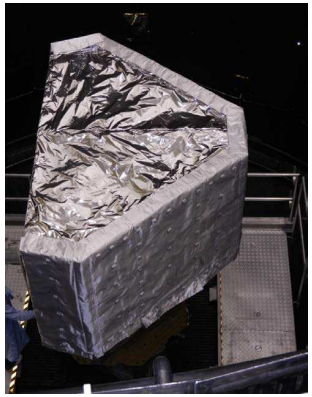
July 6th, 2017
Ref. = BC-ALS-HO-00068
Template Ref.= 87208327-BID-TAS-EN-004

BepiColombo Project : Thermal Protections Developments – System Verification

The Large Space Simulator test facility at ESTEC has been specifically modified to simulate the Sun illumination at Mercury planet (10 times the Sun intensity as in Earth Orbit).

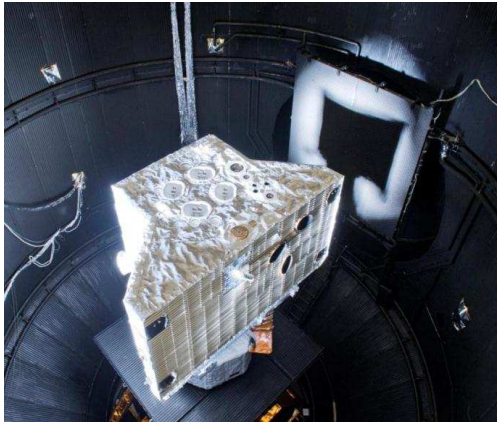


MOSIF STM Test: Dec. 2010

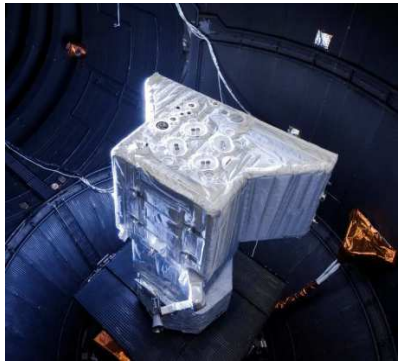


«Big Size» MLI Tests: Sep. – Oct. 2012

MTM STM Test: Mar. 2013



MPO PFM Test: Dec. 2015



MPO STM Test: Dec. 2012

MTM PFM Test: Nov. 2017

ThalesAlenia Space
a Thales / Leonardo company