Overview of Advanced Materials and Surface Activities at ESA

- **A selection of some topics…**

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Technical and Quality Directorate

ESTEC (European Space Technology and Research Centre)
ESA (European Space Agency)

With inputs of Materials Technology Section on metallic materials

EIROFORUM WAMAS MEETING @ CERN – 19-20/11/2013

Technical and Quality Management

D/TEC

Systems, software and Technology

Electrical Engineering

Mechanical Engineering

Product Assurance and Safety

Requirements

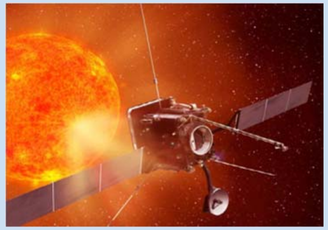
Integrated support

Functional support

Independent review

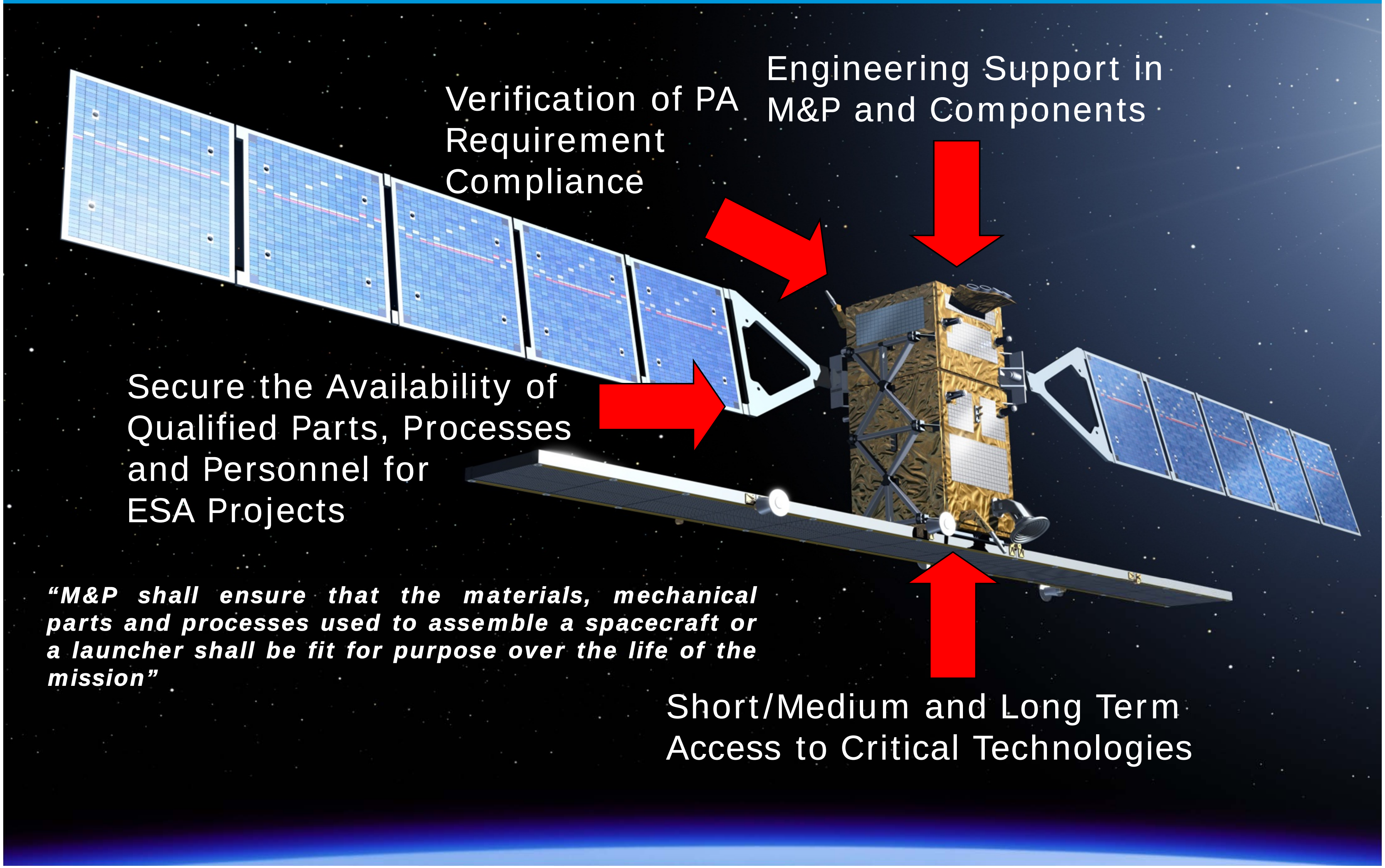
Technology development

Programme Directorates



with our industrial/ academic partners and our know-how

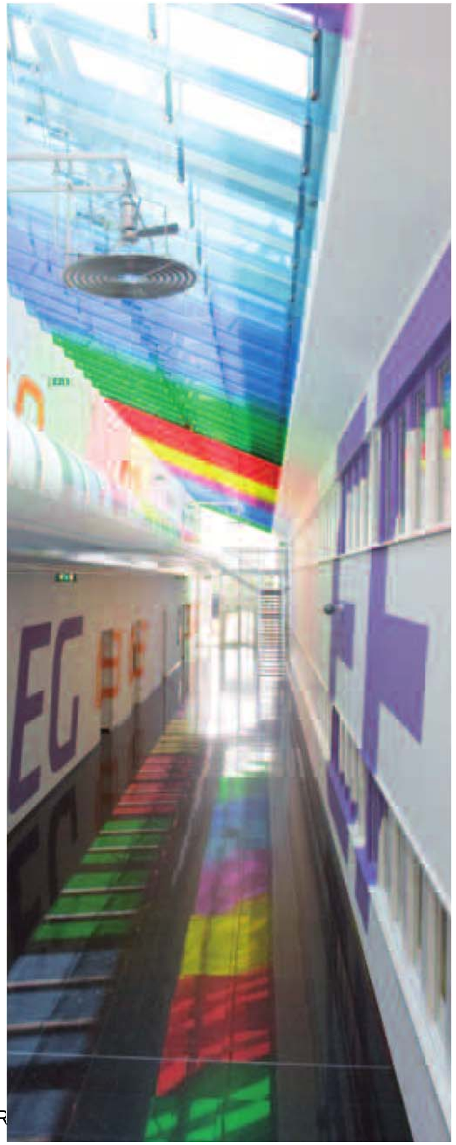
Our (M&P) Remit


Verification of PA Requirement Compliance
Engineering Support in M&P and Components
Secure the Availability of Qualified Parts, Processes and Personnel for ESA Projects
Short/Medium and Long Term Access to Critical Technologies
"M&P shall ensure that the materials, mechanical parts and processes used to assemble a spacecraft or a launcher shall be fit for purpose over the life of the mission"

Materials and Electrical Components Laboratory

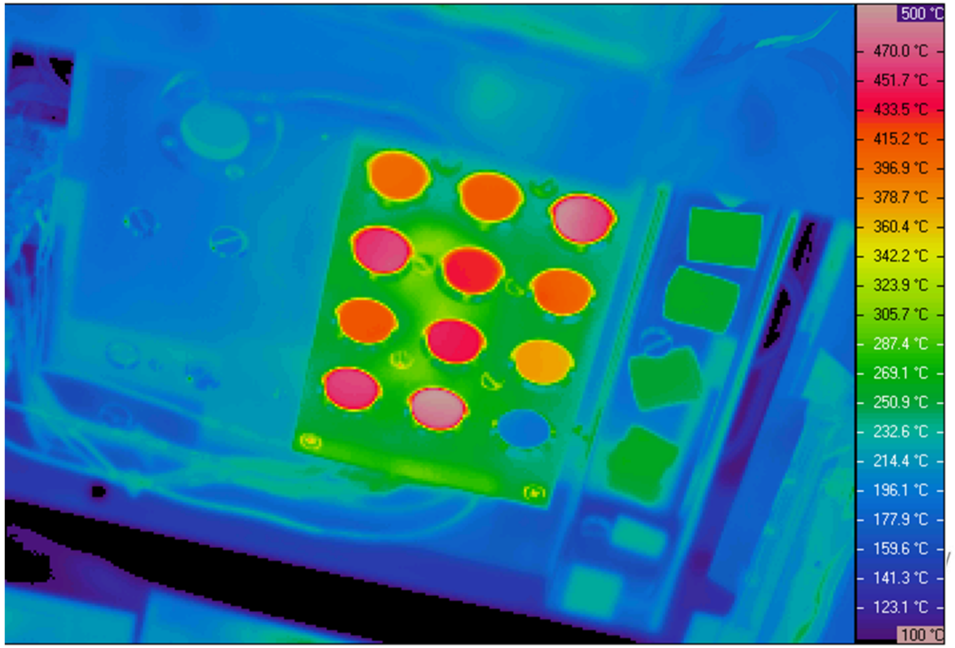
- The Laboratory provides to the European Space Community the facilities and expertise to investigate fitness for purpose of parts, materials and processes to be used for space applications.
- Main objectives of the Laboratory are:

1. M&P support through hardware testing in simulated space environment.
2. Development of tools and standards, certification authority for space M&P in Europe.
3. Network with external laboratories
4. **Qualification of materials, validation of processes including electronic materials**
5. Independent M&P support for failure investigations (on-ground and in-orbit anomalies).
6. **Space environmental simulation and effects** (e. g. vacuum, temperature, radiation).
7. **Inhabited environment testing** (e. g. toxicity, flammability).
8. **Ground environment** (e. g. long duration storage effects).
9. **Cleanliness and contamination control**, including chemical and physical analysis.
10. **Corrosion, Thermo-mechanical testing including fatigue and fracture mechanics**.
11. **Non-destructive evaluation**.



Materials and Electrical Components Laboratory
"A Pillar of Know How"

- EM (Electro-magnetic) Radiation (UV/VUV) with high intensity combined with particle radiation (electrons / protons) simultaneously @ High/Low temperature
- Enables synergistic materials evaluation with in-situ measurement systems
- Sources can act simultaneously,
- Testing done from -150C to 500C of samples

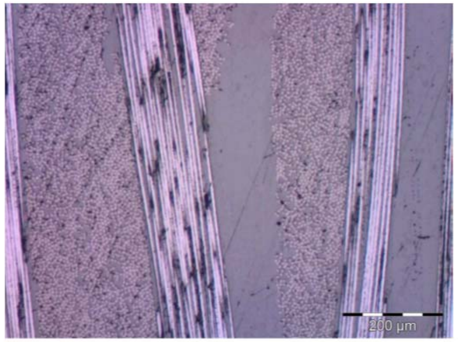


A space mission typically starts with a launch
Materials Needs for a Launcher
Drivers: Mass, stiffness.....

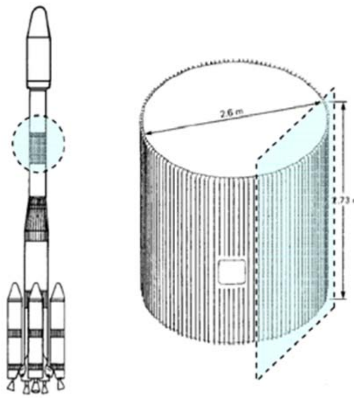
Vega: 13.02 2012 first launch

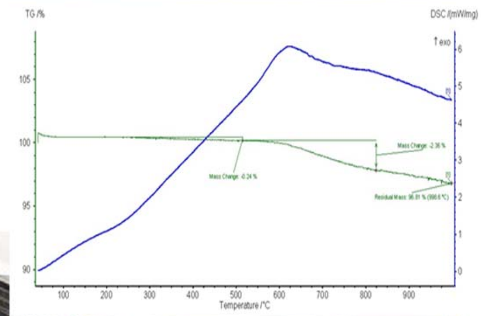
Materials & Processes for future launchers
Drivers: Mass, stiffness.....

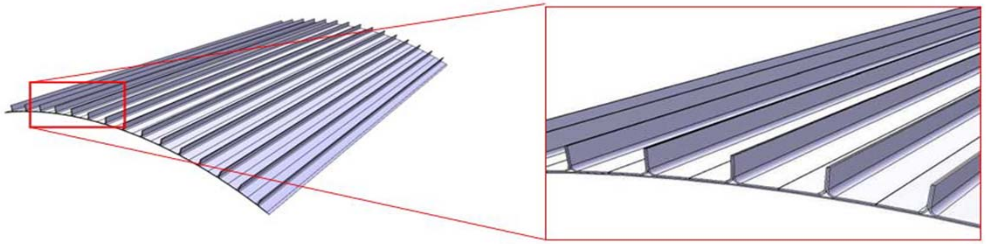
PI composite

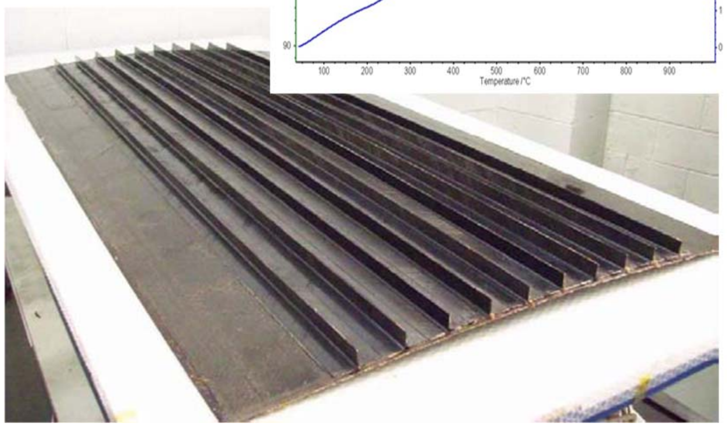


- Tape laying of thermo-plastic composites
- Out of Autoclave Processing of thermo-plastic materials
- New CF/ PEEK composites for space applications
- Evaluation of CF/PEKK composites
- HT Composites for 300 -350C continuous use temperature incl. RTM





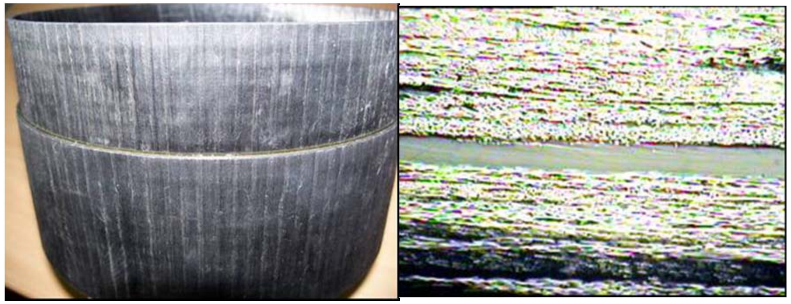




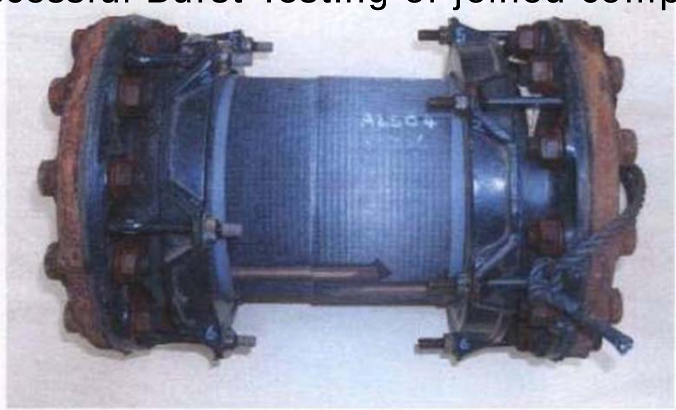
Performed in collaboration with TEC-MSS

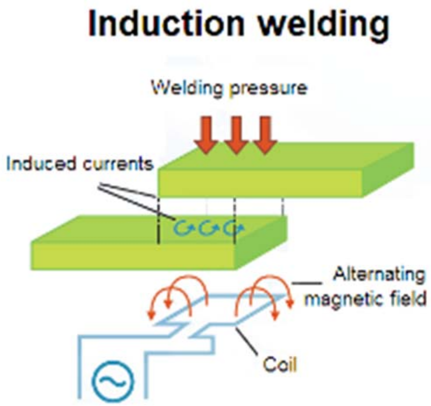
Materials & Processes for future launchers
Drivers: Mass, stiffness…..

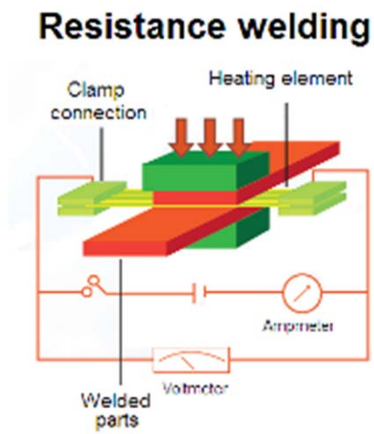
- Development of Joining Technologies for Composite Materials
- Assessment of Welding and Liner Technologies for Thermoplastic Composite Tanks
- Analysis of Microcracking and Permeability in CF/PEEK Linerless Cryogenic Tanks
- Investigation of an Inexpensive Polymer Liner for CF/PEEK Cryogenic Tanks"



Successful Burst Testing of joined composite

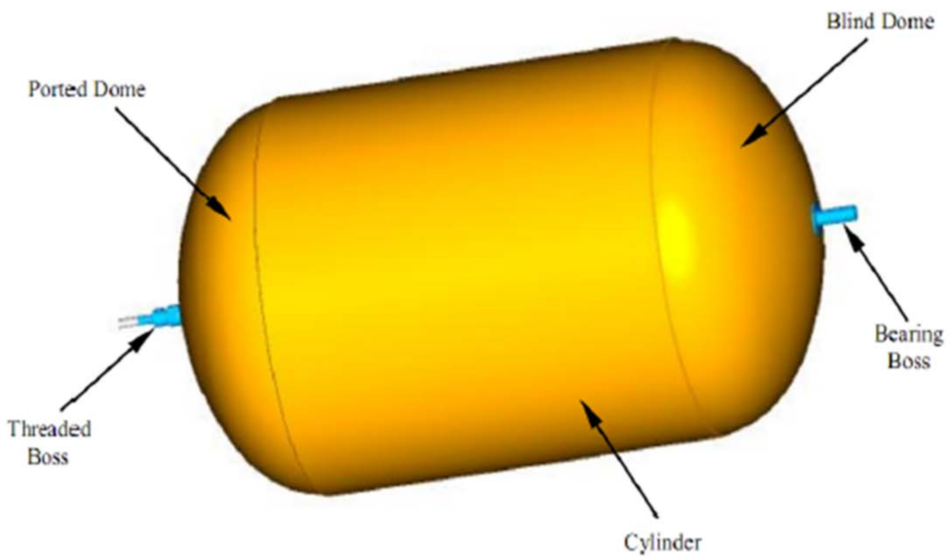


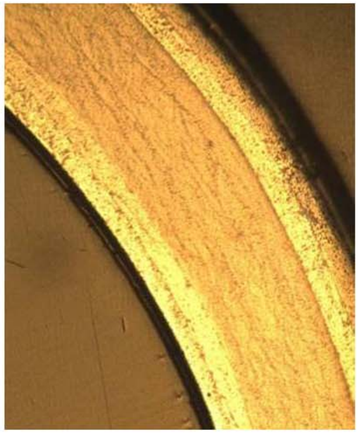


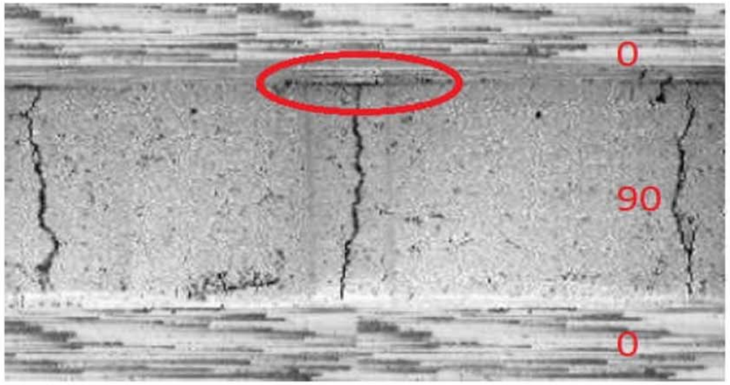


Materials & Processes for future launchers
Drivers: Mass, stiffness.....

- Assessment of Welding and Liner Technologies for Thermoplastic Composite Tanks
- Analysis of Microcracking and Permeability in CF/PEEK Linerless Cryogenic Tanks
- Investigation of an Inexpensive Polymer Liner for CF/PEEK Cryogenic Tanks
- **LOX and LH2 temperature compatible!**





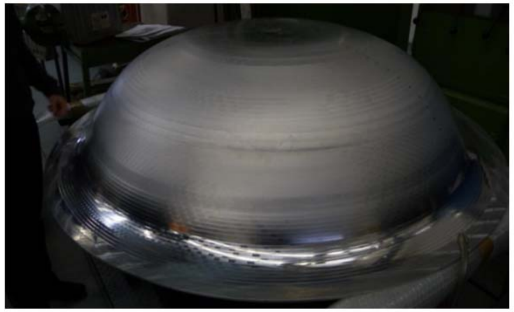


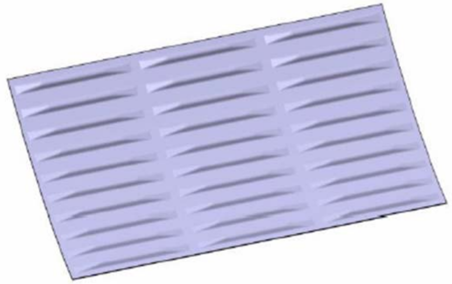
Materials & Processes for Future Launchers
Drivers: Mass, stiffness.....

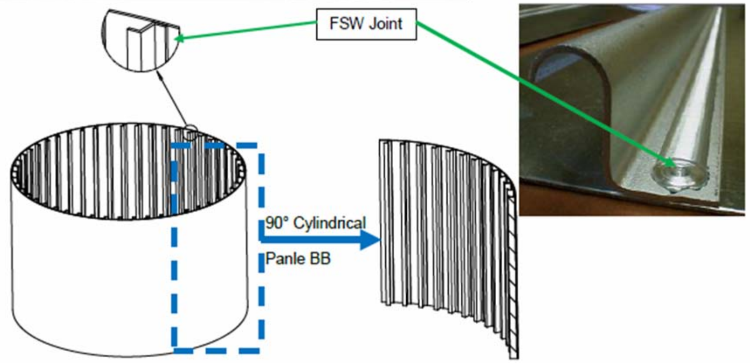
- Metallic Propellant Tank using Al-Li alloy
  - Spin formed Dome
  - Formed Cylindrical Panels
  - Friction Stir Welded Joints
    - Thick plates
    - Curved panels
    - AA2195 with AA2219
  - Roll Forged Rings
  - Peen forming

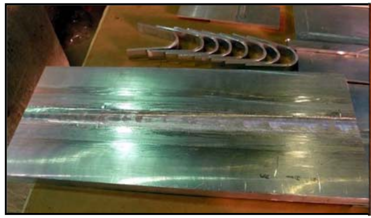
- Metallic Interstage
  - Corrugated cylinder panel
  - Cylinder Panel with Extruded Profiles
  - Wave stiffened skin panels
  - FSW of skin panels
    with integrally machined stiffeners

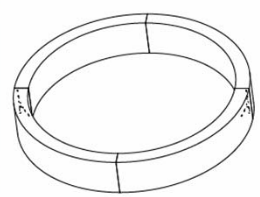
Performed in collaboration with TEC-MSS











Materials & Processes for future launchers
Drivers: Mass, stiffness.....

- Dome technology: forming trade-offs between spin forming and gore panels forming
- Welding techniques: FSW and TIG
- Different design options considered

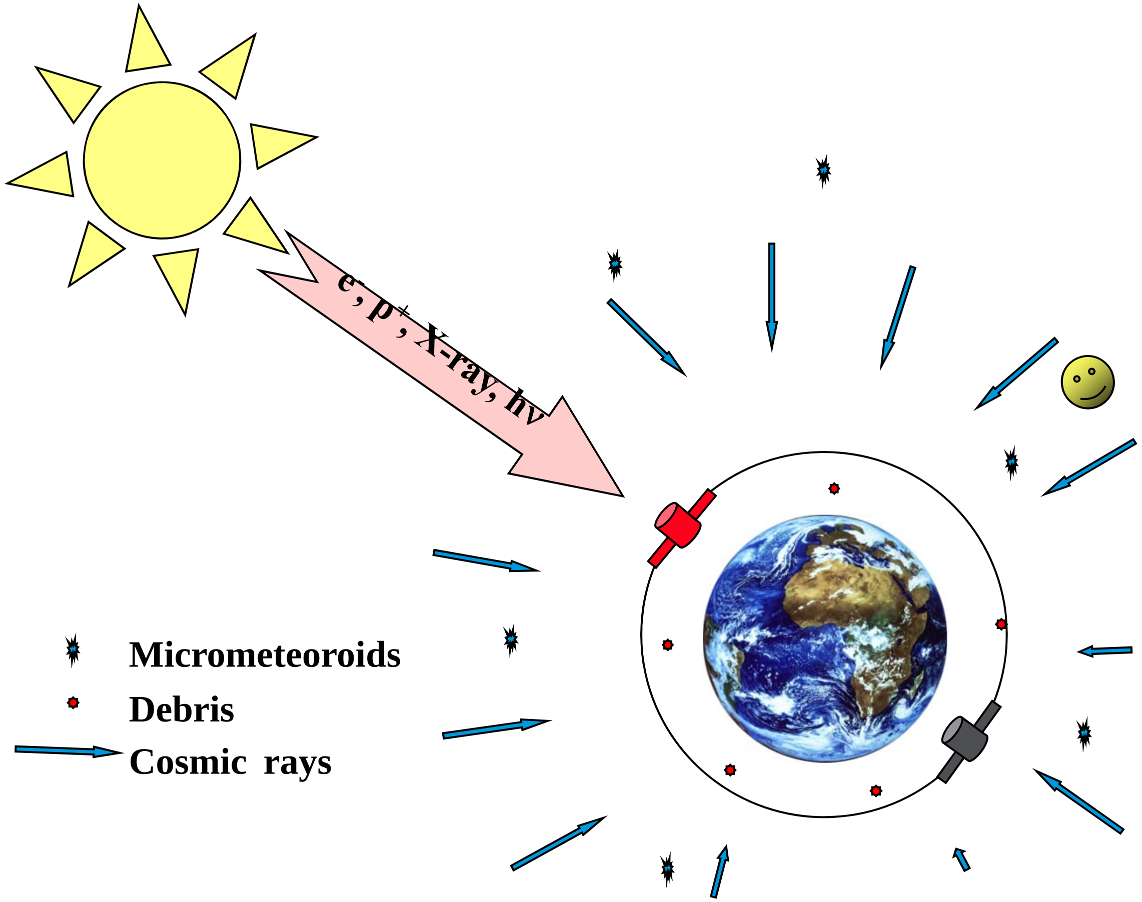
Design option	SF / FSW	DA Reference	SF / ch. mill. / FSW	GP / FSW	GP / TIG
Dome manufacturing	Spin-Forming (SF)	Spin-Forming with ch. Milling to 2.2 mm	Spin-Forming with chem. Milling (SF, ch.mill.)	Gore panels (GP)	Gore panels (GP)
Welding technology - meridional welds	-	-	-	FSW	TIG
Welding technology - circumferential welds	FSW	FSW	FSW	FSW	TIG

Ariane 5 tank domes TIG + Gore Panels

- For phase 2, reference: spin forming, alternative: gore panels
- Trade-off mainly performed on mass, RC and NRC criteria
- Main drivers:
    - Manufacturing limits (currently above design rqts)
    - Knock down factor associated to welding technology
- From preliminary analysis and for the given loads / geometries:
    - Lightest solutions: GP / FSW, SF / ch. mill. / FSW
    - Low RC expected from SF / FSW, but higher NRC
    - TRL lower for SF / FSW for circumferential welds

H-IIA tank domes SF + Ch. Mill.

Requirements in flight



Vacuum

Temperature
(isothermal/cycling)

Radiation

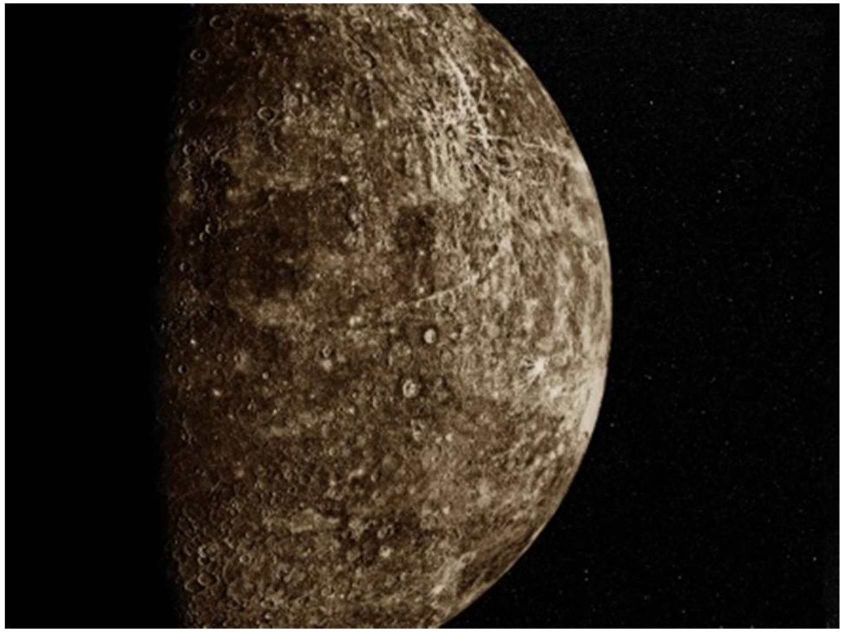
Space Debris

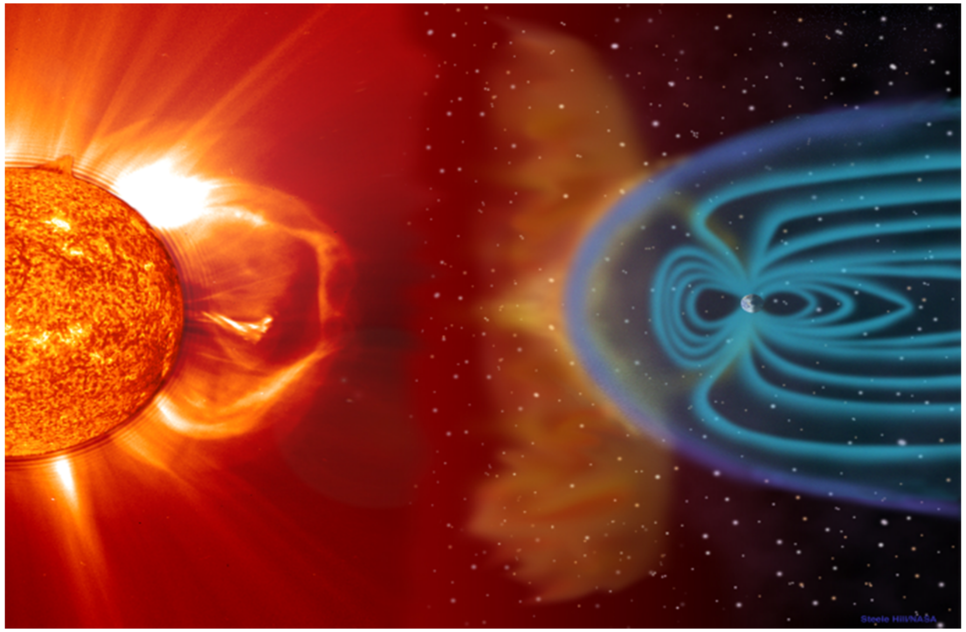
Micrometeoroids

Atomic Oxygen
- Earth Observation Missions
- ISS , Shuttle (US)

(Manned Volumes)

Technology Needs – Mercury Mission

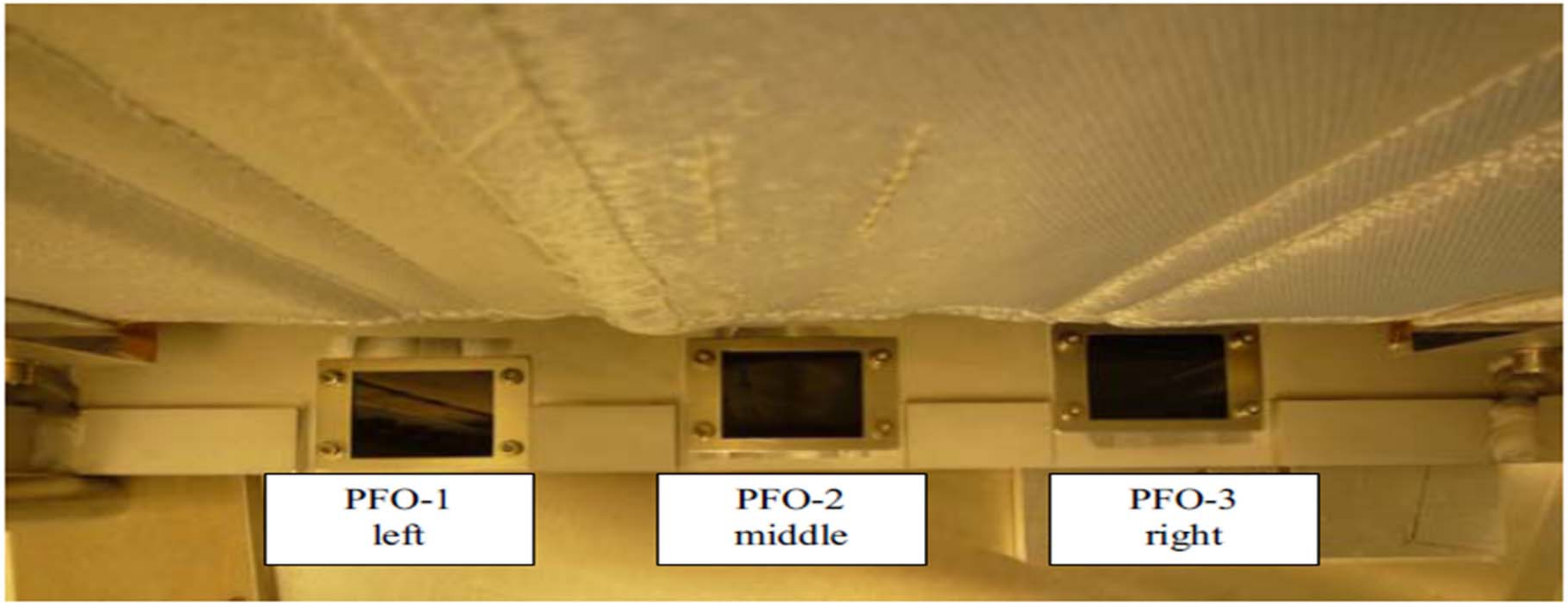


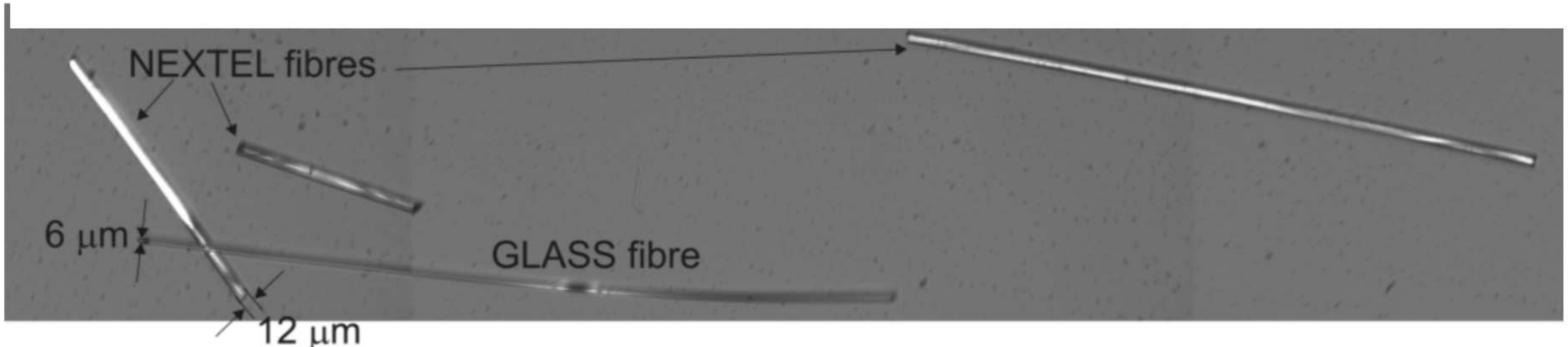


Mission to Mercury is called Bepi Colombo and is an ESA Cornerstone
Development activities started in 2001, envisioned launch date is 2016

Surface Temperature will reach 500C
S/C will be baked from both sides
Mercury and sun when transmitting to Earth

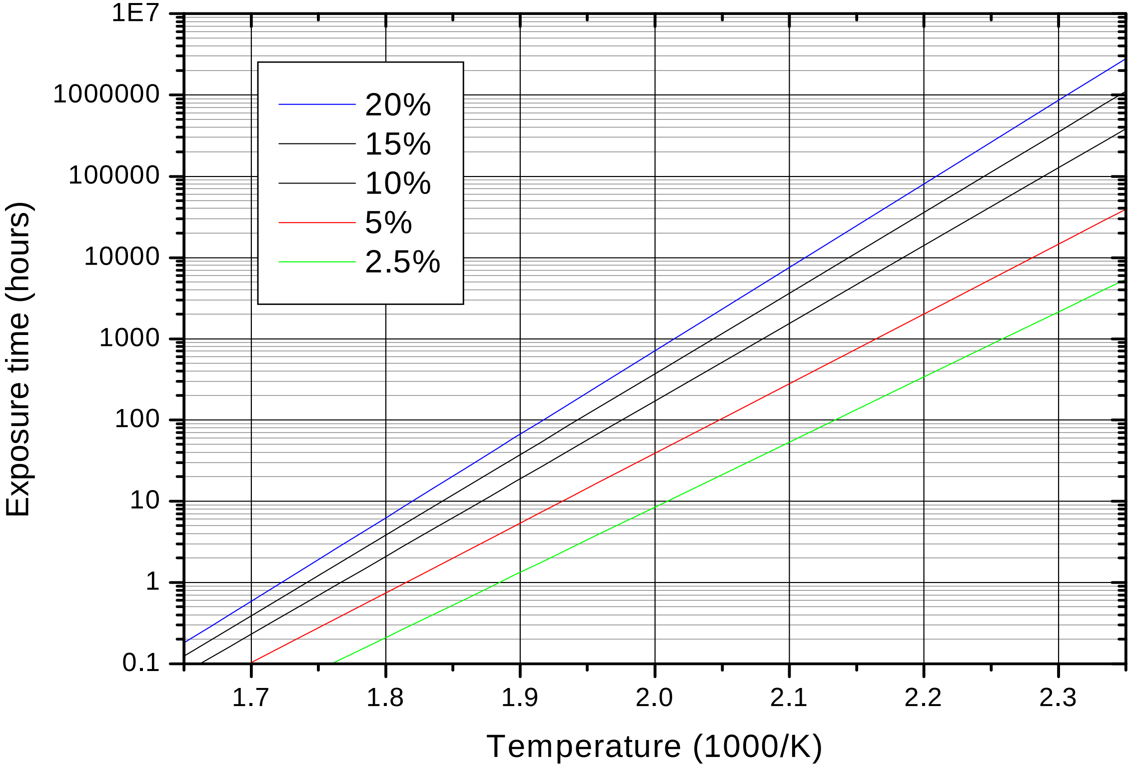
Development of new HT MLI



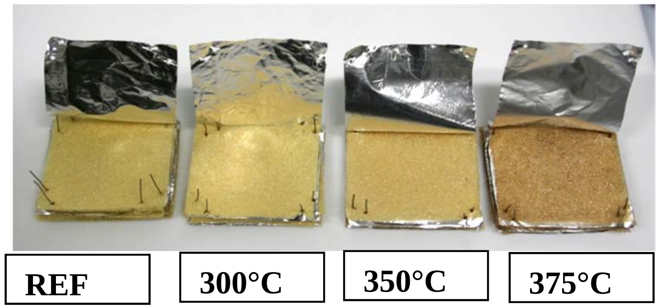


MLI Solutions of earth orbiting s/c does not work – change of materials
Particle shedding was a big challenge

ESA internal lifetime modelling approach
Novel way to pre-select materials



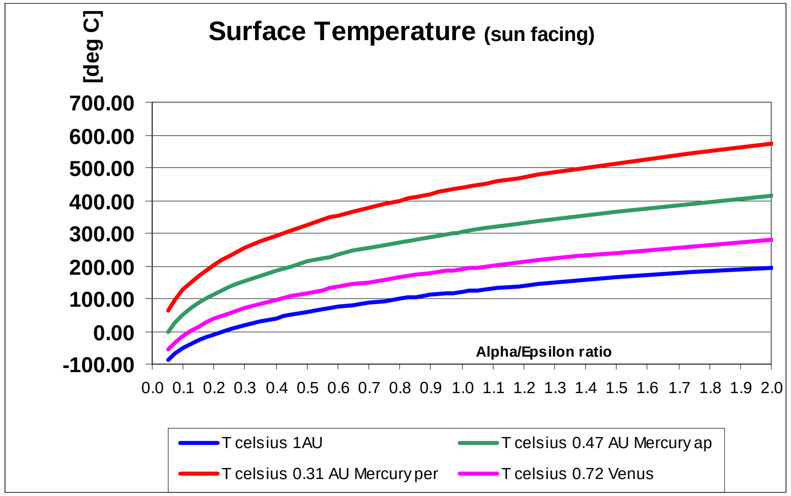
Example 1:
HT Epoxy , Manufacturer quotes use temperature of 315C, At 315C (0.0017 1/T) lifetime of less than 1 hr given for 20% mass loss.

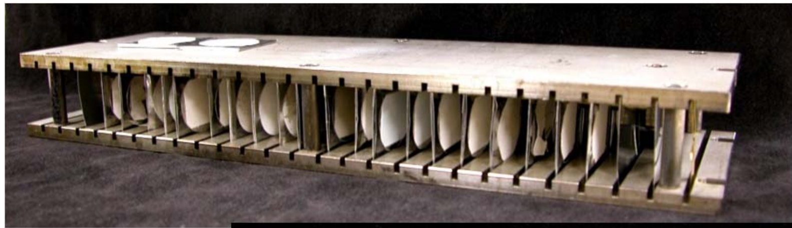


217 hrs of testing

We have used that to select polymeric for continuous use temperature of 350C! Foams are foreseen to be used at the same temperature with a weight of 5 g/m2.

Development of white thermal control surfaces





AZ2000

YB71

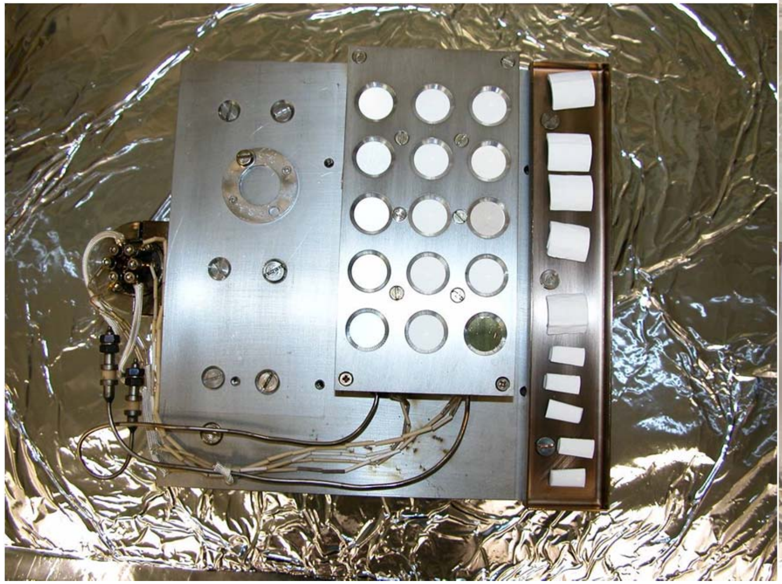
AZ93

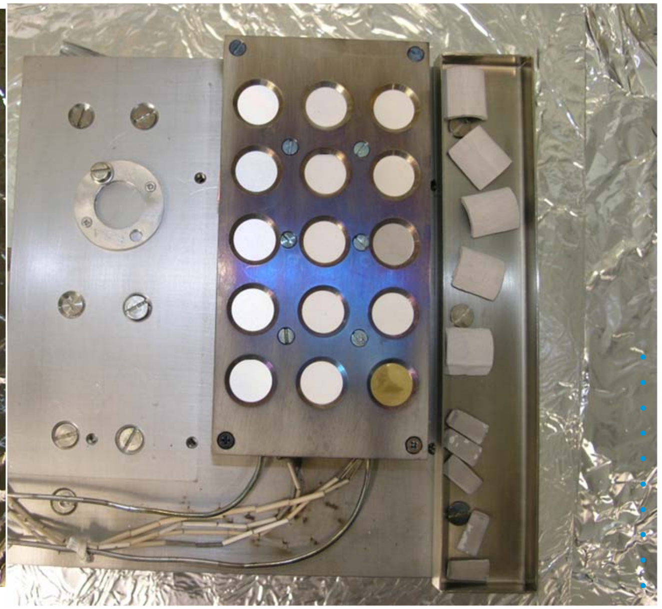
AZ2100

1. 13 commonly used white paints have been assessed in a HV environment for ca. 500 hrs @ 350 C
2. Results were very concerning
3. Cracking,
    a. severe degradation of solar absorptance,
    b. colour formation

Ref: 10th ISMSE S. Heltzel et.al.

Challenges on HGA for BC Verification testing (2)



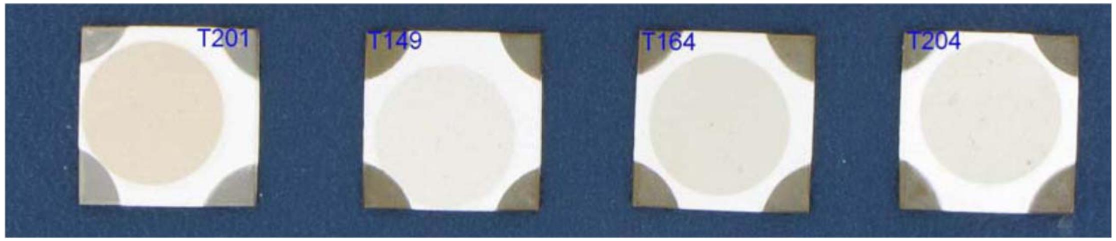


25 000 esh UV/VUV + (above 10 SC) p+/e- full particle dose.

In-situ measurements show a saturation after 25000 esh.

#247 Coldshroud		
Hydrocarbon	:	0.3x10-7 g/cm2
Ester	:	<0.2x10-7 g/cm2
Methylsilicone:		<0.2x10-7g/cm2
Total :		0.3x10-7 g/cm2

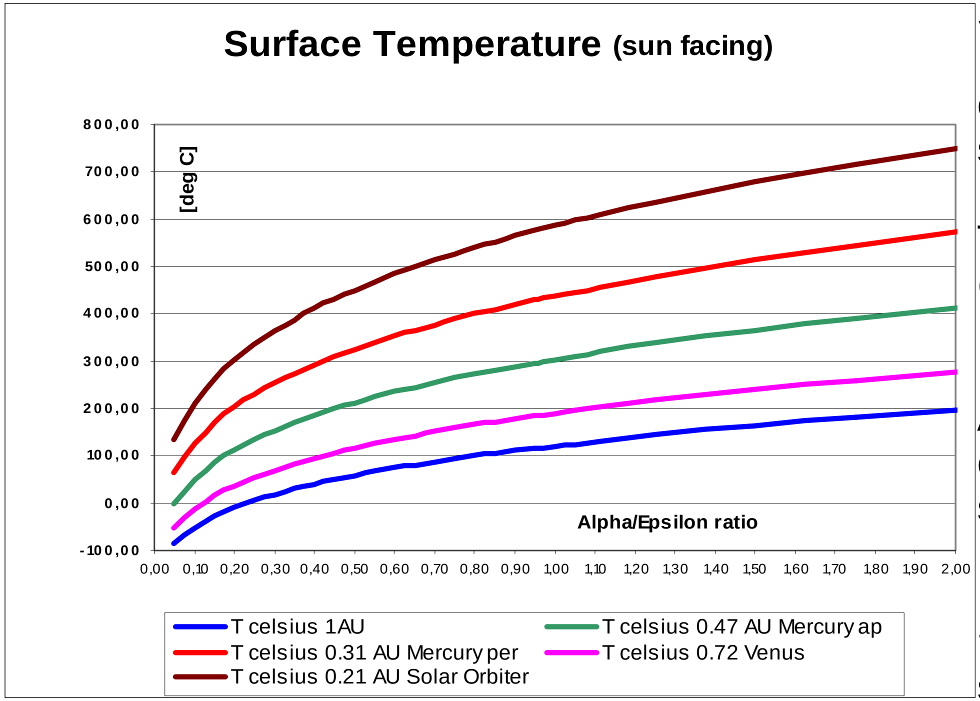
#215 Sample plate, 425°c		
Hydrocarbon	:	0.6x10-7 g/cm2
Ester	:	<0.2x10-7 g/cm2
Methylsilicone:		<0.2x10-7g/cm2
Total :		0.6x10-7 g/cm2



Improvements have been achieved on the HGA

Currently refinements are being tested.

Challenges on Solar Array for BC Introduction



Sketch for flat T equilibrium - IR to be added!

Solar cells became the single most challenging material question. Dramatic degradation in solar cell performance was detected – just one simulated month saw a 20% power loss.

The effect was due to a combination of material degradation due to ultraviolet/light radiation and high temperatures driving down cell efficiency.

A combination of protective coatings and carefully solar array tilting promises a workable solution.

If the solar arrays directly face the Sun then they would heat up and fail. So instead they stay tilted at an optimum angle – their power production stays lower, but so does the temperature.

Note when SA is tilted completely away (90deg SAA) SA has 140-150C equilibrium temperature. One can influence temperature by tilt angle as well as distance from S/C (limit!). MPO does not spin as MMO!

Another Success Story : (Leaving the BC mission example) European Silicone Adhesive

1. In 2006 European Spacecraft Manufactures approached ESA to review possibilities to qualify a European Silicone adhesive

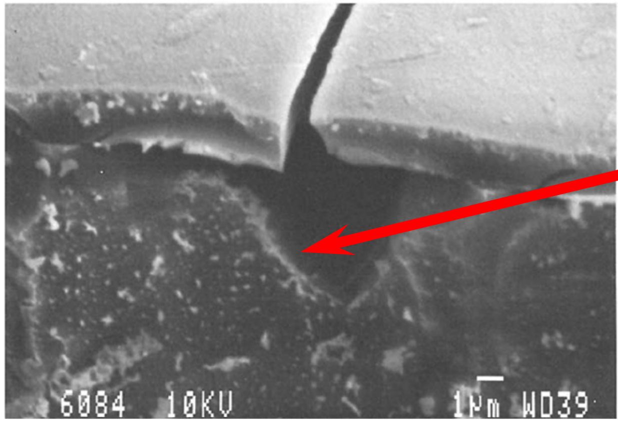
2. Space Applications:
   a. Solar cell coverglass adhesive with EADS Astrium Ottobrunn (D)
   b. High quality pottings & encapsulants with Thales F/D
   c. Optical couplings of detectors/sensors etc.

3. Space grade Silicones are attractive for these applications due to their wide use temperature
   a. low Tg (approx. -110-120C), reasonable thermal endurance (approx 200C)
   b. good processing characteristics, Low outgassing behaviour

4. **Within 18 months ESA qualified a European alternative for those application with acceptable lifetime estimates for a 15 years use in space as required for typical Telecom missions.**

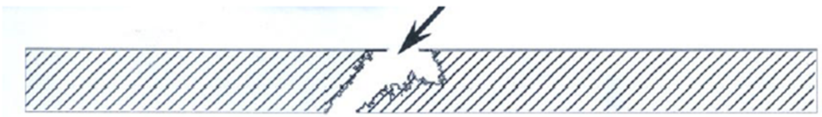
Challenge of Atomic Oxygen in LEO: Protection of PI films

1) SiO2 top-layer



Cracks induced by CTE effects followed by undercutting: increased ATOX erosion

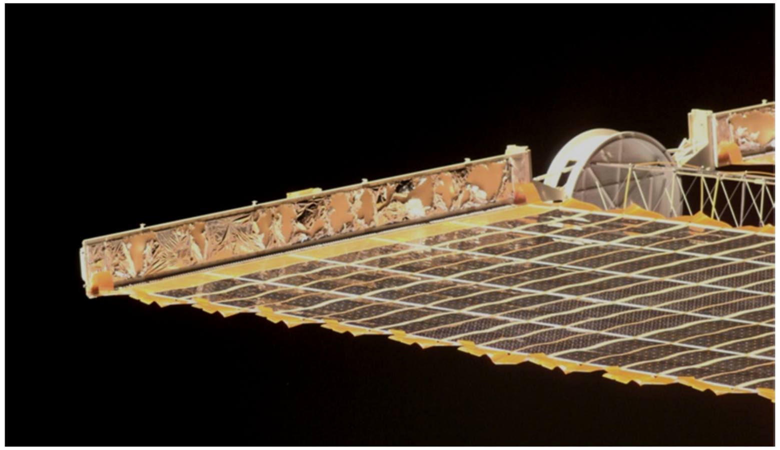
a. Aluminized on both sides



b. Aluminized on exposed side only

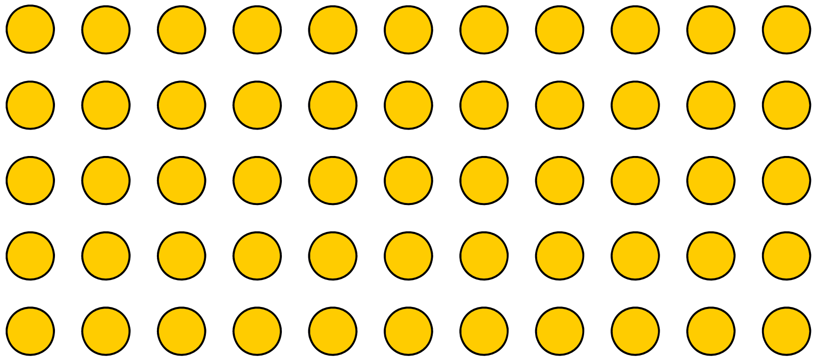
→ not effective solution!

Effects of ATOX erosion on metallised film with pinhole defects: increased ATOX erosion



Deployable solar array on ISS

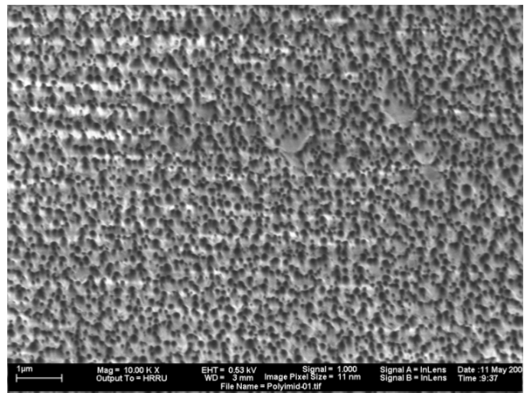
Intrinsic (Surface) SHM



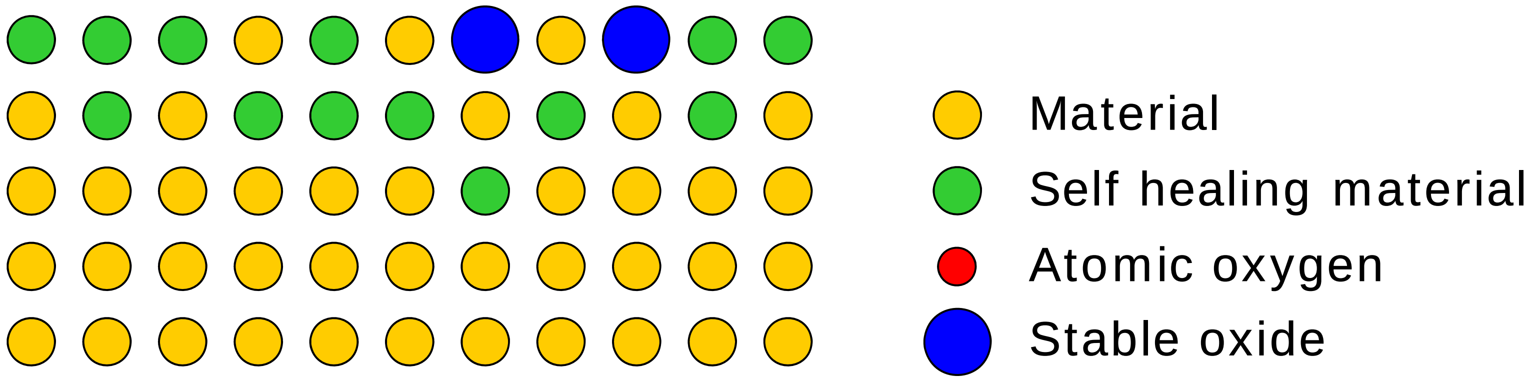
Material

Atomic Oxygen

Erosion of materials by atomic oxygen bombardment



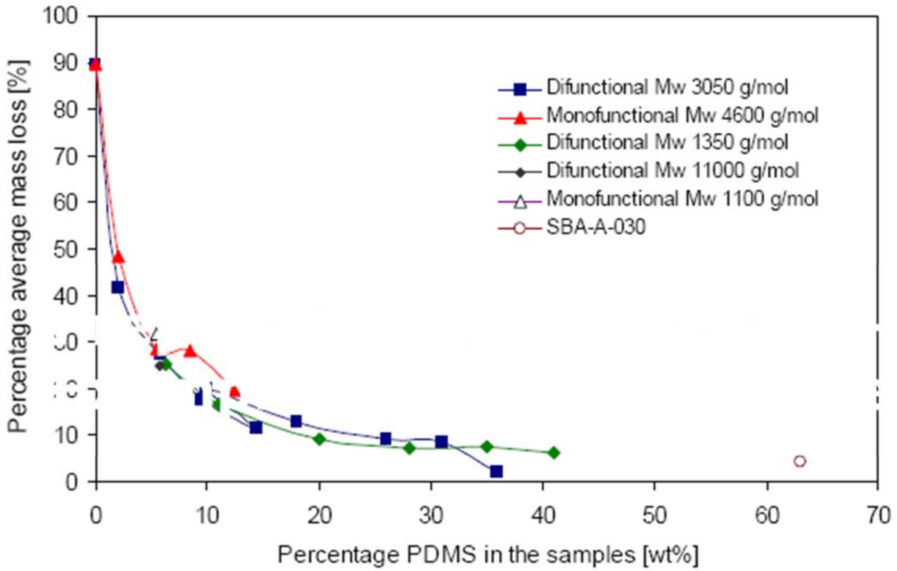
Surface Structure of Kapton after ATOX testing @ ESTEC



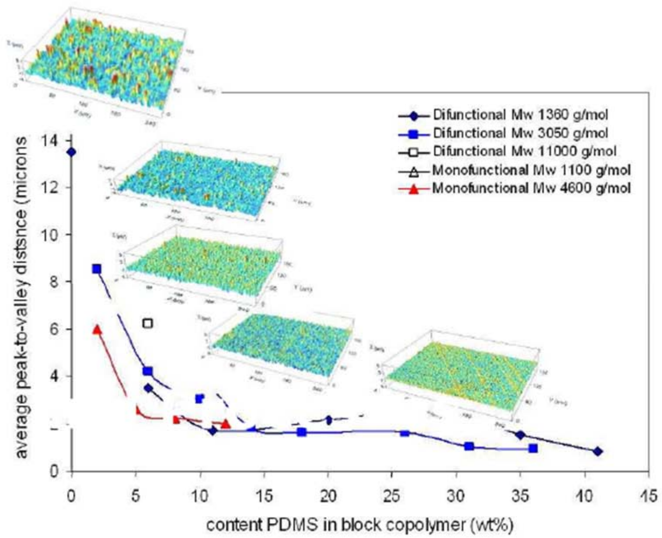
Self-healing (passivation) of materials by atomic oxygen bombardment

Film properties after ATOX test

mass loss as function of wt% PDMS



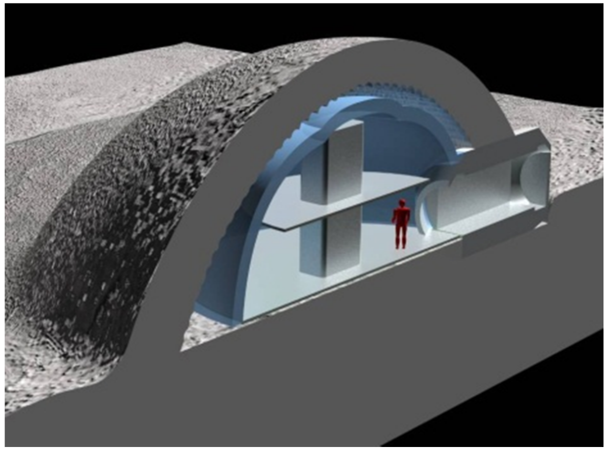
surface roughness as function of wt% PDMS

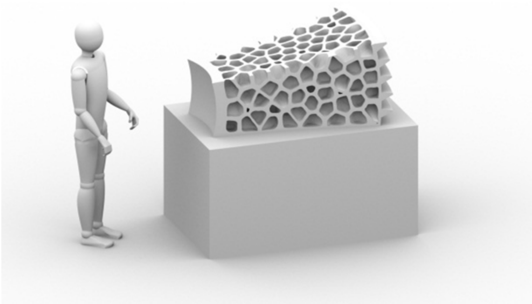


By modifying the chemical structure we could incorporate a self healing capability into a polyimide structure.

Preparing for the future:
ALM - Experience acquired at ESA

- Additive Manufacturing (AM) guarantees significant weight reduction in combination with radical reduction of waste material compared to classical subtractive manufacturing.
- The dramatic decrease in the amount of required and transported raw materials combined with process speed optimization, enables the AM route to decrease energy consumption and reduce CO2 footprint.
- Mass saving by more than 50 % is often obtained, and up to 95% has been possible for one selected part, number of interfaces and associated controls have been reduced, lead time has been shortened by months, number of manufacturing steps in a process chain has been dramatically decreased.





Preparing for the future: Some studies on AM in ESA

1. 2006 – (TAS) Assessment of capabilities offered by Direct Laser Deposition and by EB-Sintering – **EADS IW**
2. 2007 (ARTES) NGA, Manufacturing of OMT using ALM – **Astrium UK**
3. 2008 (GSP) 3D printing blocks using Lunar Soil.
4. 2008 (ARTES) 3D manufacturing of aluminium RF components using ALM
5. **2008 (GSP) Universal fabricator replicator**
6. 2009 (TAS) Technological Demonstrator manufactured by SLM technology"
7. 2009 (ITI) SLM of Propellant Management Device (PMD) – **Astrium Fr**
8. 2009 (TAS) Bipropellant mixing device made by ALM
9. 2011 (TAS) Manufacturing of parts for propulsion by SLM
10. 2011 (TRP) Advanced manufacturing methods
11. 2011 (ARTES) New process for low cost thrusters nozzle manufacturing –**Astrium GmbH**
12. 2012 (ARTES) Direct manufacturing of structure elements for NGP
13. 2012 (FLPP) ALM for launchers
14. 2012 (ITI) SiC by SLS – **Astrium F**
15. 2012-2013 (FP7) AMAZE – **EADS**

Several other activities are considering ALM as technology for improvement within broad scope activities on e.g. structure, propulsion communication or mechanisms

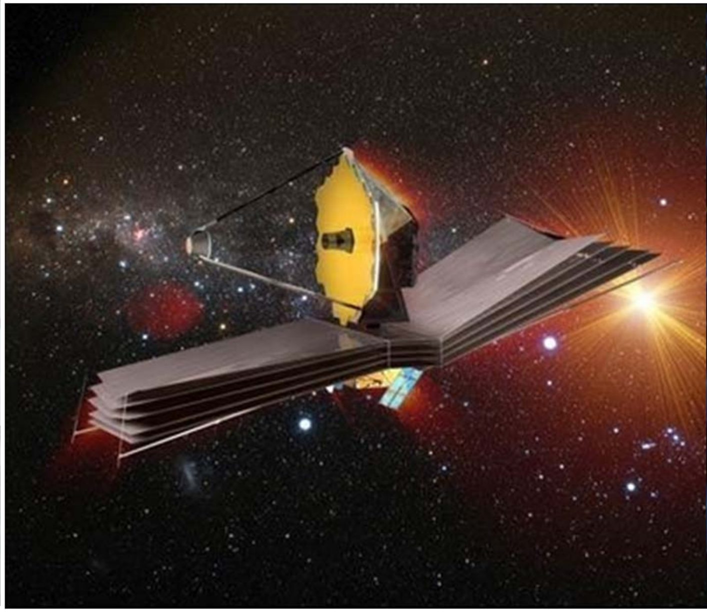
Challenge: Synergism Radiation

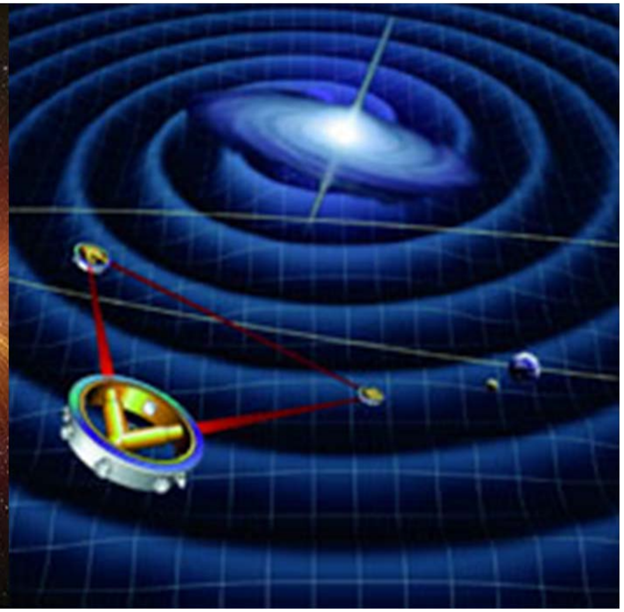
HST in orbit – during servicing mission

Activities on-going on nano-hybrid transparent materials that are both radiation resistant and flexible

Challenge: Temperature

Materials for extreme environments: cryogenic / precision





1. 3.5m Herschel Telescope
2. Operates at 70K
3. Largest Telescope ever built
4. Launched May 2009

In development:
Near Infra-Red Spectrometer for JWST
Operates at 30K

In development:

LISA:

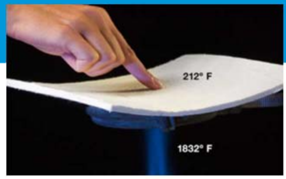
Laser Interferometer Space Antenna

pm range on 5 Mill km!!!

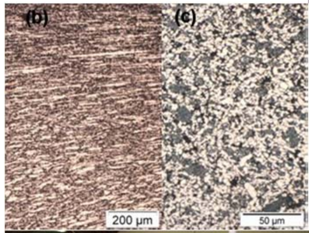
Understanding materials properties at ultra low temperature is important

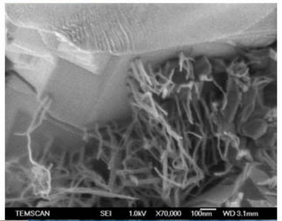
Preparation for the Future –
Examples of Advanced Materials and Processes

- Ultra-light materials like flexible Aerogels
- Radiation resistant Adhesives/Materials
- Flexible Sol/Gel Coatings
- Carbon nano-tube re-inforced materials
- Space stable ceramic coatings & materials incl. anti-static behaviour
- Contamination trapping materials
- Laser damage resistant materials
- Ultra-thin materials (Gossamer/ inflatable etc.)
- Self healing materials/composites
- HT composites / Thermo-plastic composites
- ALM Laser/Electro beam Sintering for 3D parts
- Out of Autoclave Composite Manufacturing
- Gecko mimetic Tape as new joining technology
- CTE variation of thermally stable materials
- Sterilisation / Ultra-Cleaning of Materials/Payloads
- Friction Stir Welding Process
- ITAR free materials supply for Europe
- Green Materials & Processes
- Materials Replacements due to legislation
- Novel Materials for improved lubrication, reduced friction



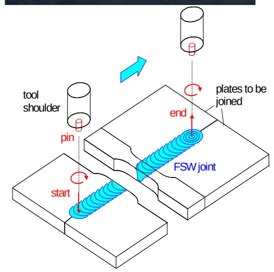


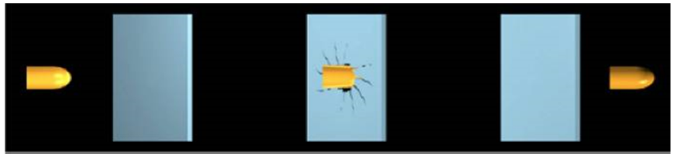













European Space Agency

Conclusions

- The needs of space missions are unique and current and future mission requirements are a continuous source of development needs for materials, surfaces & processing.
- There is no “best material or manufacturing process”.
- Continuous competition between materials and processing technology is stimulating in order to satisfy mission requirements in the most efficient way.
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ESA TTP Who we are

9 ESA Business Incubation Centers

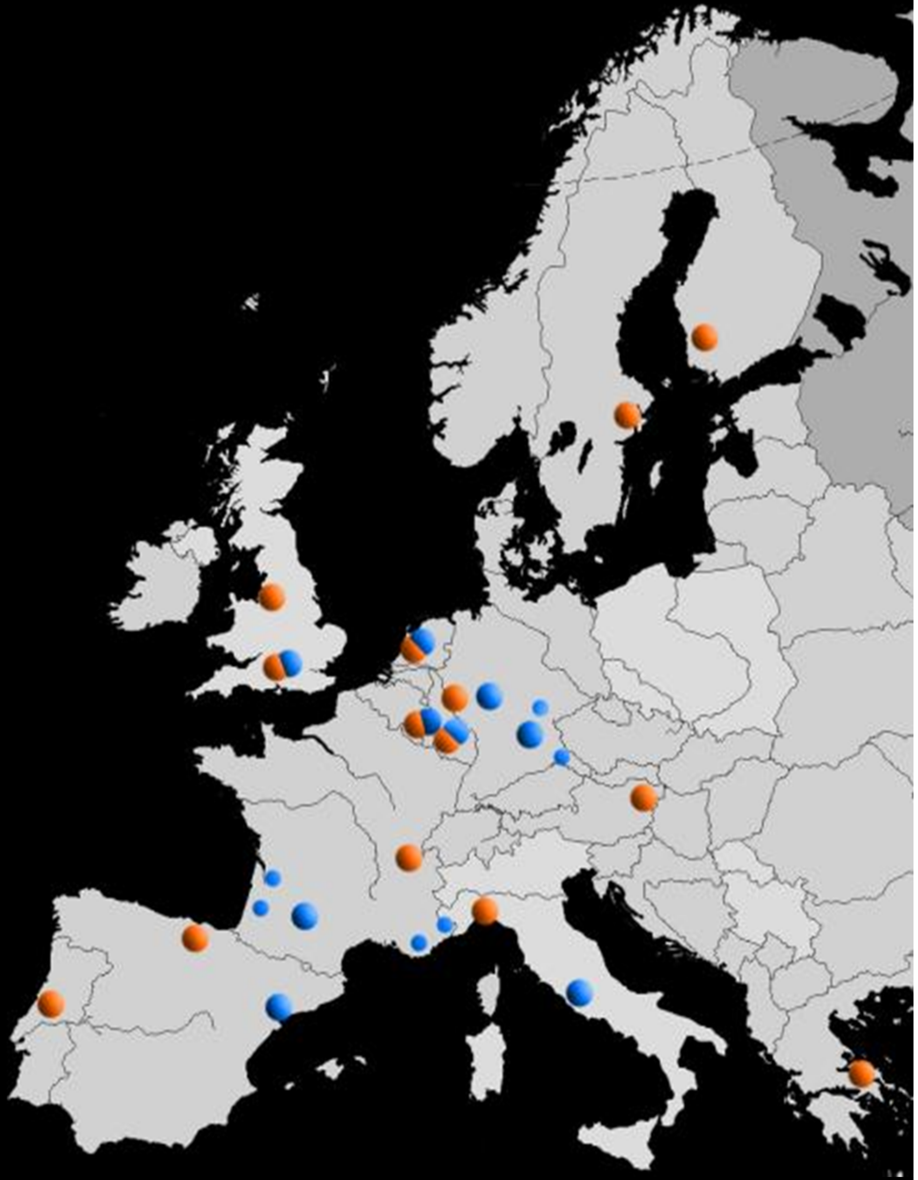
- *9 agencies*
- *11 regions involved*
- *12 research institutes*
- *Over 220 start-up companies*
- *60 per year 2013*
- *80 per year 2014*
- *12 Mio Euro in Seed Investment*
- *Partner of EBN*

Broker Network & EEN

- *14 companies all across Europe*
- *Partner of EEN*

Patents

- *700 patents in ESA portfolio*
- *Access to ESA Space Technology*
- *Over 280 transferred technologies*



ESA Technology Profiles 1

Method and apparatus for testing materials

Methods and means for connecting thin metal layers

Method and apparatus for combinatorial alloy discovery and development using high energy electron beams

Method and system for production and additive manufacturing of metals and alloys

New antistatic paints providing antistatic protection and radio-transparency

POLYMET - Advanced materials

Friction reduction by DICRONITE (R) Dry Lubrication Technique

Contact Callum.Norrie@esa.int Available for Business to Business Meetings

ESA Technology Profiles 2

Elastomers to protect devices from pyrotechnical shocks

Super plastic forming (SPF) combined with diffusion bonding

Hall effect plasma sources for edging and coating

Advanced materials & ceramic matrix composites

CESIC: Carbon-fibre reinforced silicon carbide - Light-weight mirror technology

Ascertaining surface hygiene: fast and easy

Silicon carbide (SiC) deposition by PECVD technique

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ESA Technology Profiles 3

SL-MMS: Self lubricating metal matrix composite for bearings and electrical slip-rings

Radiation shielding using micro cavities filled with highly pressurized gas

Nanotechnology and resin transfer molding (RTM)

Silica-based aerogel

High performing and cost-effective insulation material

Superinsulation - Multilayer insulation for vacuum applications

Ultra low friction films of MoS2

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Latest News:

FUTTA – Fusion Technology Transfer Action

Sponsored by EC/EURATOM

ESA/TTPO contracted to undertake 2 year programme of technology transfer for Fusion