SMARTEES, an European collaborative research for advanced ceramic structures in atmospheric thermal protection from space: Project overview

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INTERNATIONAL CONFERENCE ON MECHANICS OF NANO, MICRO AND MACRO COMPOSITE STRUCTURES

Mechanics of Nano, Micro and Macro Composite Structures

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OUTLINE

- MOTIVATION OF THE WORK
- CONSORTIUM
- CONCEPT OF THE PROJECT
- OBJECTIVES
- WORKPACKAGES
- SUMMARY/CONCLUSIONS

MOTIVATION OF THE WORK

- Future European access and return from space request Thermal Protection Systems (TPS) Technology heritage, which demands **critical technology** for the Future Launchers (FLPP), Human Exploration (THEP) and Re-entry probes.

- On the one hand, ESA's TPS technology are based on existing materials high TRL and mission oriented. On the other hand, **EC space programmes** allows the development of **critical/disruptive technologies** for **advanced materials** on TPS. On this context SMARTEES proposes innovative TPS concepts for ISS return systems and future launchers. Space tourism are potential candidate uses as well.

- **Future space transportation**, equipped with re-usable components will greatly **reduce the cost of launching a payload into space**. This issue is of great importance, i.e. ESA technology strategy and long term plan.

- From the early 60s, the driving re-usable thermal protection systems (TPS) technology for earth re-entry **was dominated by the US (i.e. Space Shuttle)**. Similar dominating situation for other types of heatshields has been encountered for most of the planetary entry probes, aerocapture, and sample return missions to improve our understanding of the Solar System.

MOTIVATION OF THE WORK

- Interest to create a fully **autonomous space thermal protection technology**, by **reducing the dependence** from the leading technologies from other countries. Ref: 2005 Executive summary “The Future of European Space Exploration”, regarding Securing European.

- Therefore, there is an **urgent need** to assure the **access to any technology** required to implement Europe’s space missions.

  - Other hurdles come from the ITAR restrictions that may create undesirable dependence.

  - The point is to ensure the capabilities to create an **independent supply chain** in the TPS components technology.

CONSORTIUM

- CONSORTIUM MEMBERS LOCATION

The core group of SMARTEES project is composed of **7 public and private organisations** coming from **6 different European countries**: Spain, Italy, Greece, Switzerland, Germany and Austria.

tecnalia

POLITECNICO DI TORINO 1859 1906

Erbicol

ΔΗΜΟΚΡΙΤΟΣ

EADS

University of Applied Sciences and Arts of Southern Switzerland
SUPSI

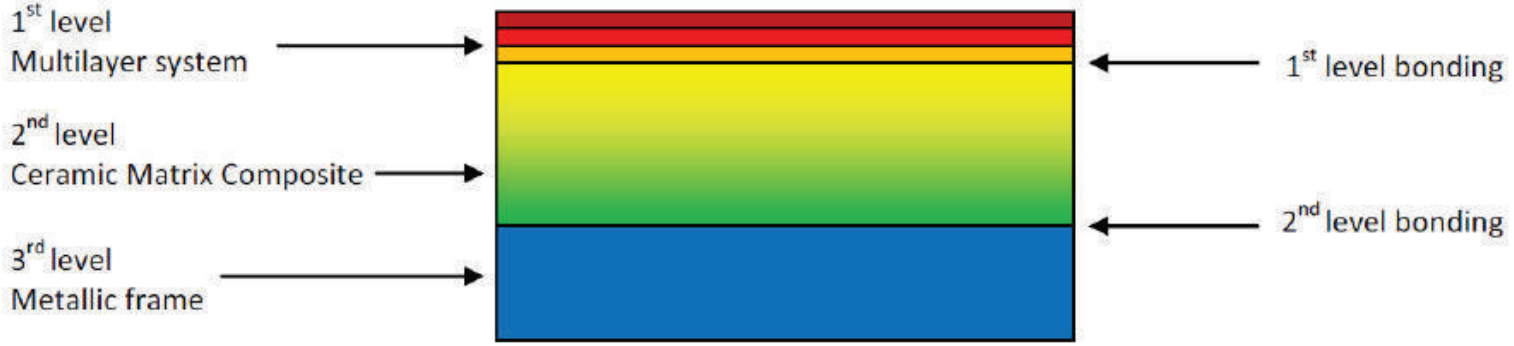
AAC
aerospace & advanced composites

CONCEPT OF THE PROJECT

- SMARTEES addresses the development of advanced ceramic composites structures for reusable thermal protection systems. The solution will be based on a novel reusable TPS architecture which can withstand the extreme environment conditions during earth atmospheric re-entry.

- The concept of the project is based on the **integration of conventional and non conventional parts** to create a **sound TPS protection component** with **multifunctional properties** (oxidation protection, emissivity, insulation,..). The design will incorporate the integration of materials at different levels:

  - Advanced protection layers to withstand high oxidative re-entry conditions
  - Ceramic composites and porous structures with high insulation capabilities (aided by material modelling)
  - Joining technologies to provide a full TPS solution (not only at hot-structure level).



OBJECTIVES

The main objective is to develop a new reusable solution based on multifunctional concept with very high insulation and environmental protection capability during re-entry and the ability to reach a TRL level between 4 and 5 at the end of the project.

- From this premise it is planned to achieve the following technical targets:

  - Develop a concept with the ability to obtain multifunctional properties.
  - Suitable bonding adhesion among the different parts and materials to form the technology sample solutions.
  - Proof-of technology sample concept to satisfy the needs of TPS end users.
  - Validate the technology sample in a ground testing, which simulates and reproduces the space re-entry.
  - Obtain a solution able to survive at least to 10 re-entries with minor repairs.
  - Reduced maintenance and failure probability during the re-entry, due to the minimisation of stand-offs and bolts by bonded joints.
  - Achieve a technology readiness level (TRL) between 4 and 5 after the complete testing of the technology sample.

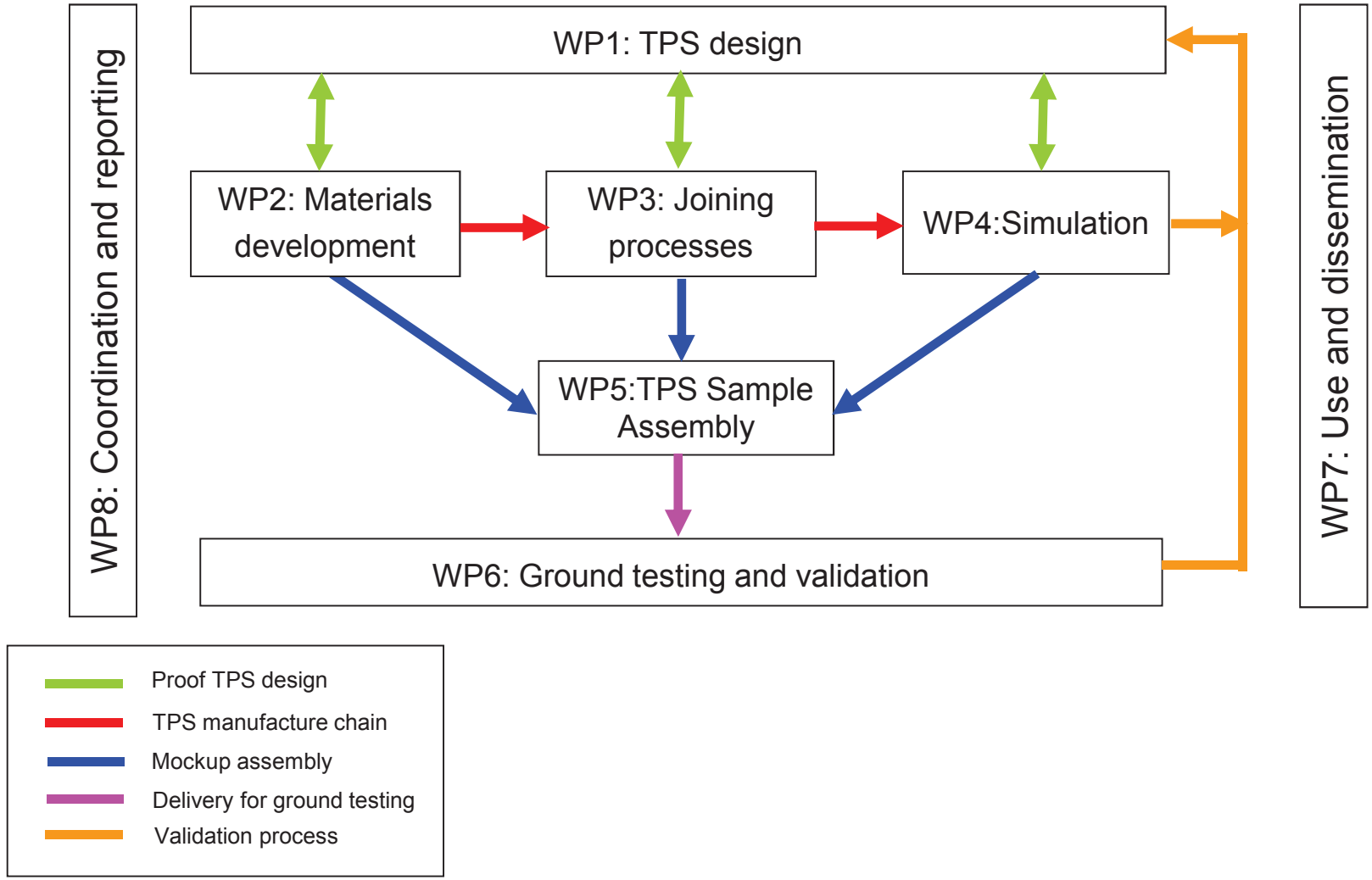
WORKPACKAGES: LIST

The work plan is distributed among a total of 6 technical workpackages and 2 non-technical workpackages:

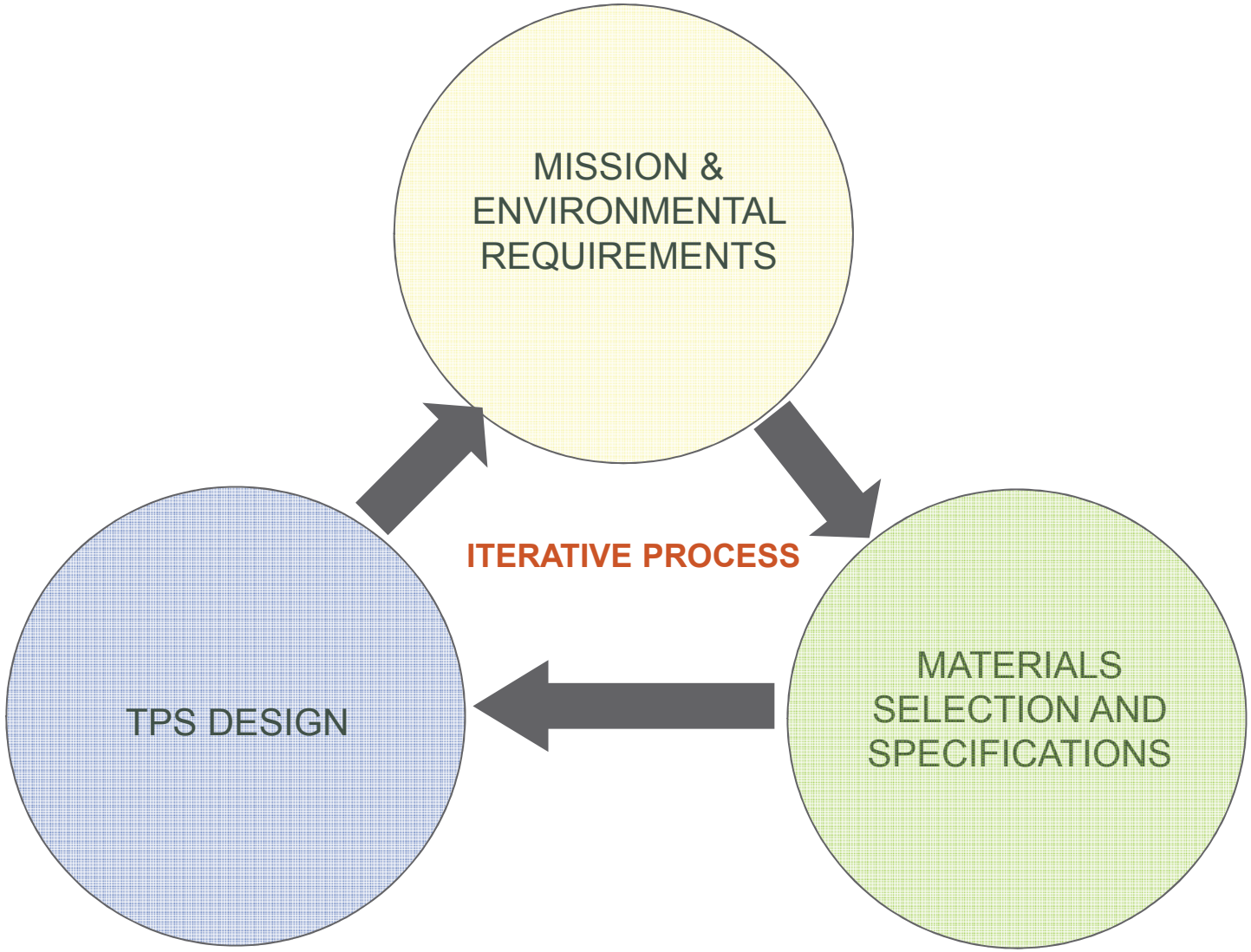
- WP1: Requirements and design.
- WP2: Materials development
- WP3: Joining processes.
- WP4: Simulation.
- WP5: TPS technology sample assembly.
- WP6: Ground testing and validation.

- WP7: Use and dissemination.
- WP8: Coordination and reporting.

WORKPACKAGES: STUDY LOGIC

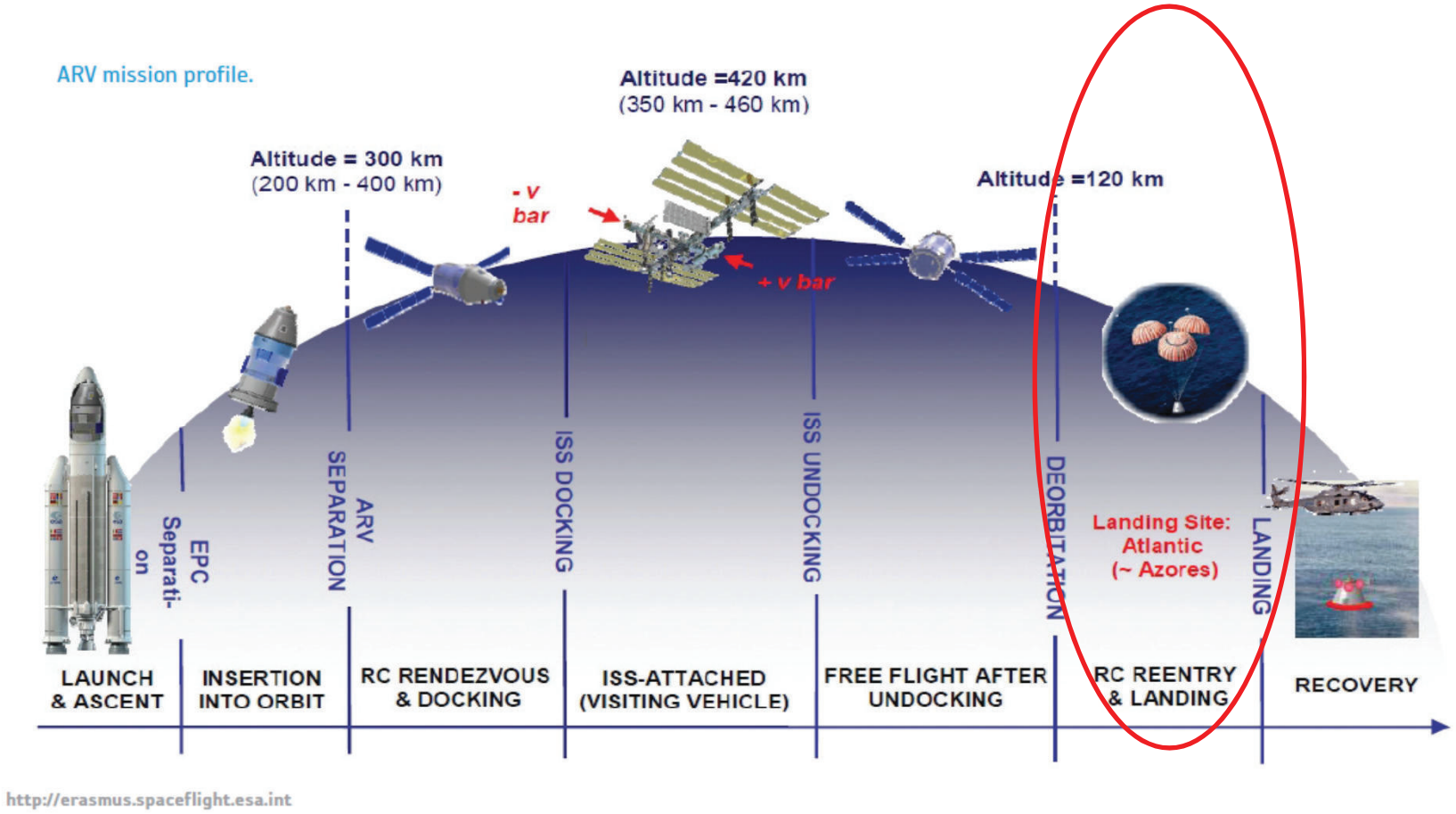


WP1: REQUIREMENTS & TPS DESIGN



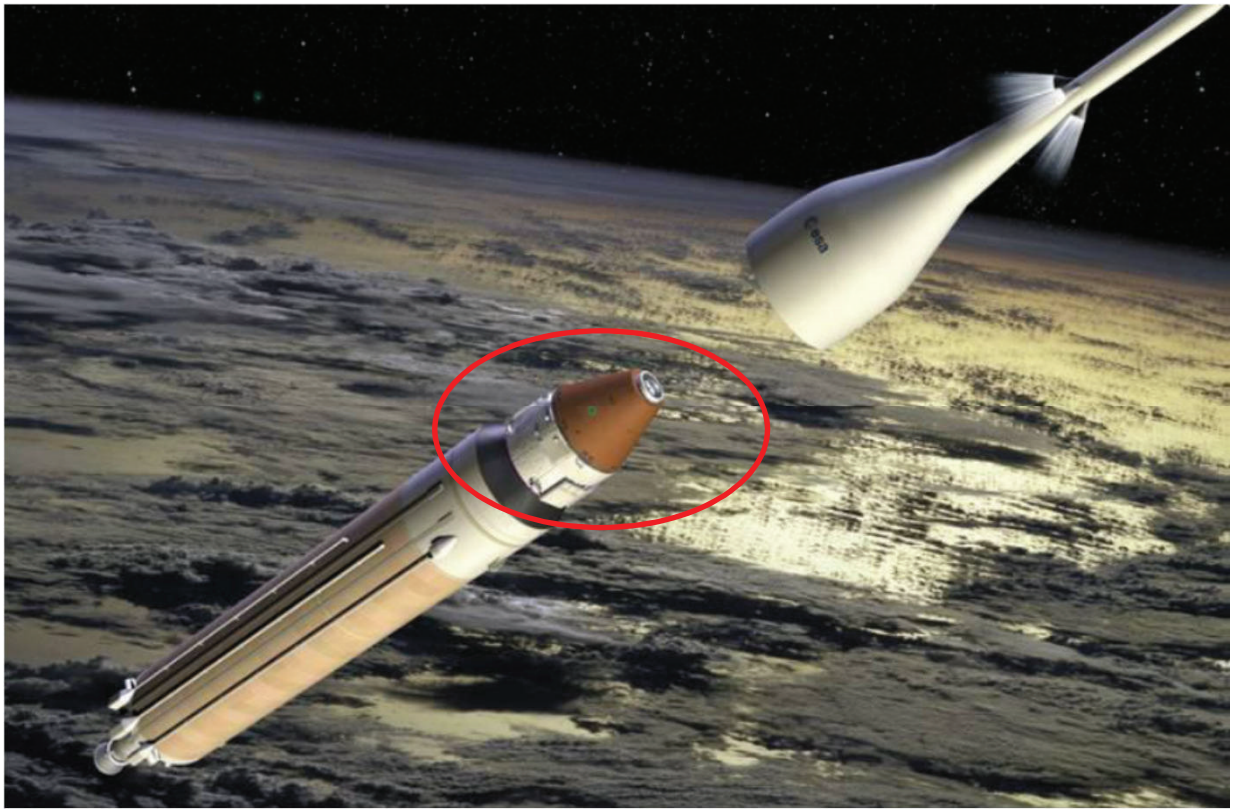
WP1: REQUIREMENTS & TPS DESIGN

- Current Mission is selected based on the Advanced Re-entry Vehicle*



*ARV data have been produced by Astrium GmbH (W. P.P. Fischer) in the frame of a Contract with ESA

WP1: REQUIREMENTS & TPS DESIGN



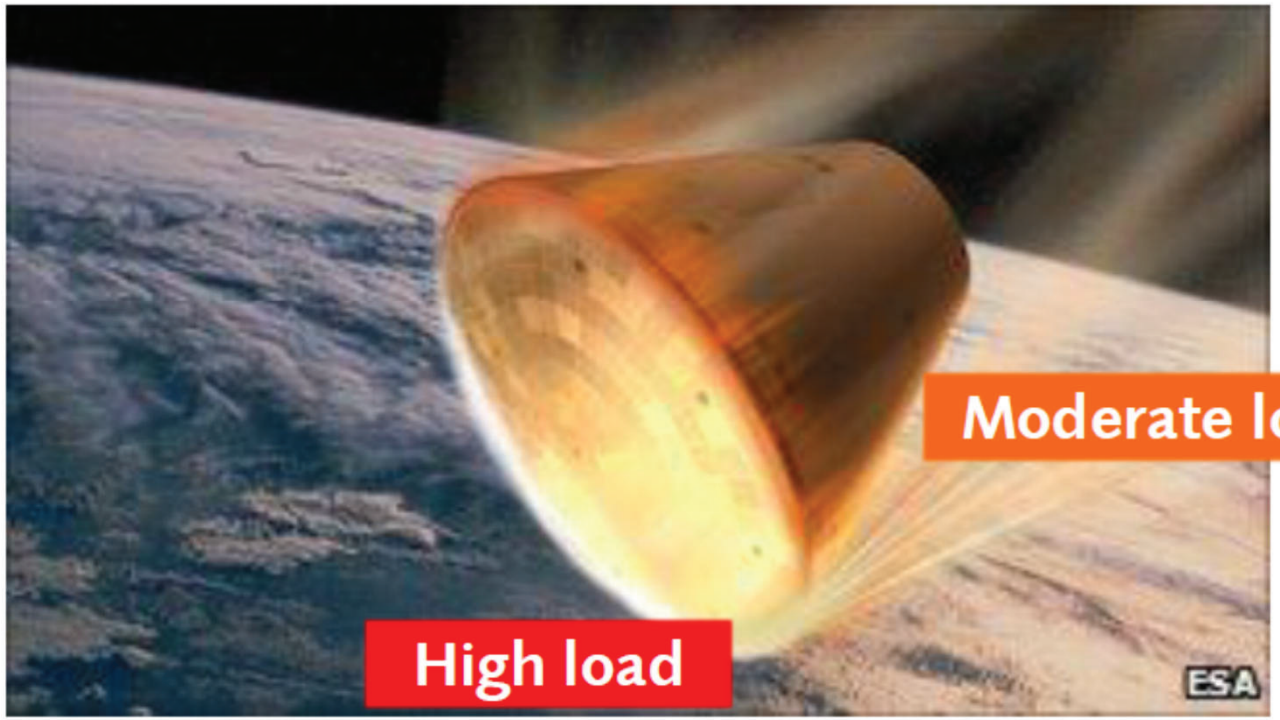
Credit. ESA

- Re-entry module evolved from ATV. It is a real mission owned by ESA and developed by Astrium GmbH, which consist of a capsule-like concept for a service module to the ISS.
- There are two versions for cargo or crew system. The re-entry will be from LEO (500 km). The first flight will be not reusable and currently there is a trade-off of designs (the currently favoured one is similar to Apollo).

For more details go to ARV's webpage: http://www.esa.int/esaMI/ATV/SEMNFZOR4CF_0.html

WP1: REQUIREMENTS & TPS DESIGN

ARV capsule with heat shield locations



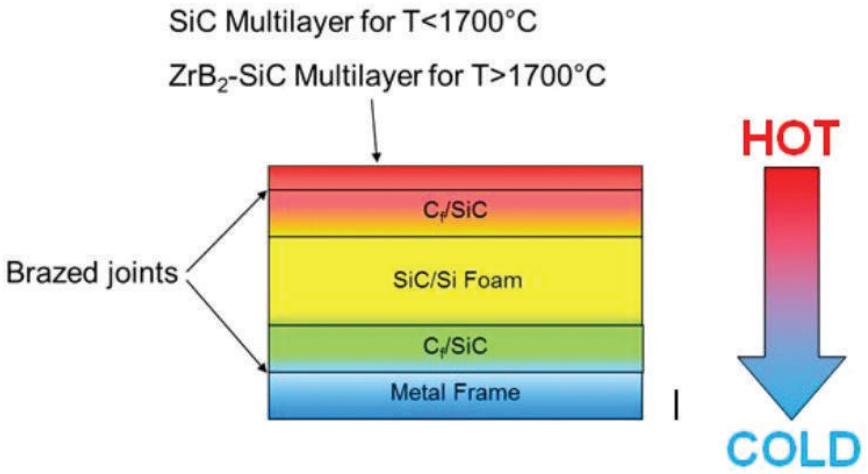
Credit. ESA

- The heat shield for such vehicle shape has been subdivided in to parts, the **front shield** with thermally high loaded areas and the **back shield** which is thermally moderately loaded

WP1: TPS DESIGN

- The following specifications have been collected:
  - Heatfluxes
  - Time (during peak & total)
  - Pressure profile
  - Mechanical load

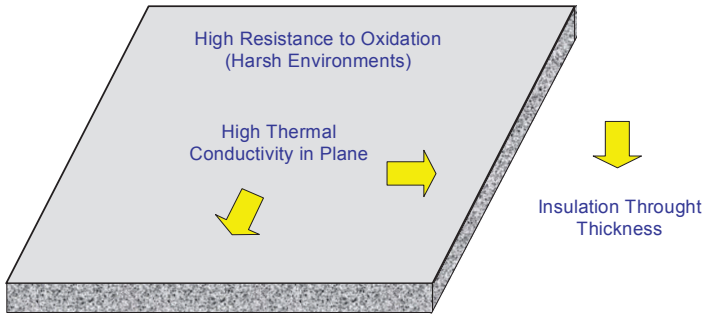
- A preliminary TPS design is ready and detailed design is on-going:
  - Materials & structure levels
  - Aerial mass calculation
  - Shape and thicknesses
  - Joining definition
  - Stand-off attachments



Credit. EADS (C. Wilhelmi)

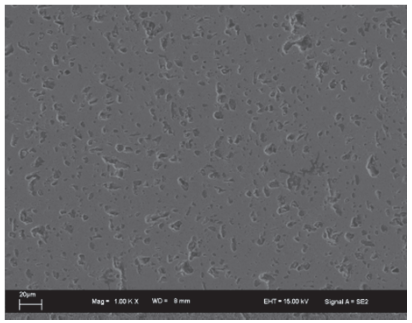
WP2: MATERIALS DEVELOPMENT

- External protective multilayers based on high and ultrahigh temperature ceramics:



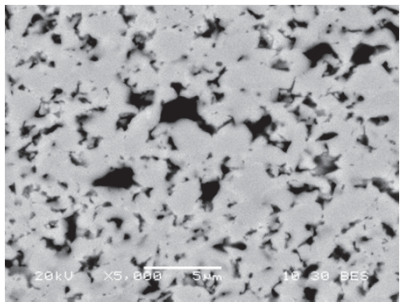
- High temperature (SiC based) suitable for environments leading to a external surface temperature below 1700 ºC.
- Ultrahigh temperature ceramics (ZrB_2 based) suitable for temperatures above 1700 ºC.

POLITO
Presureless sintering



SiC Multilayers (Polito, C. Badini)

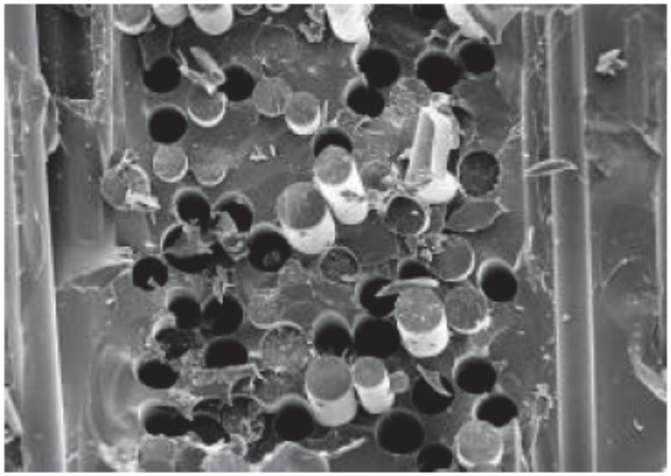
TECNALIA
Spark Plasma Sintering



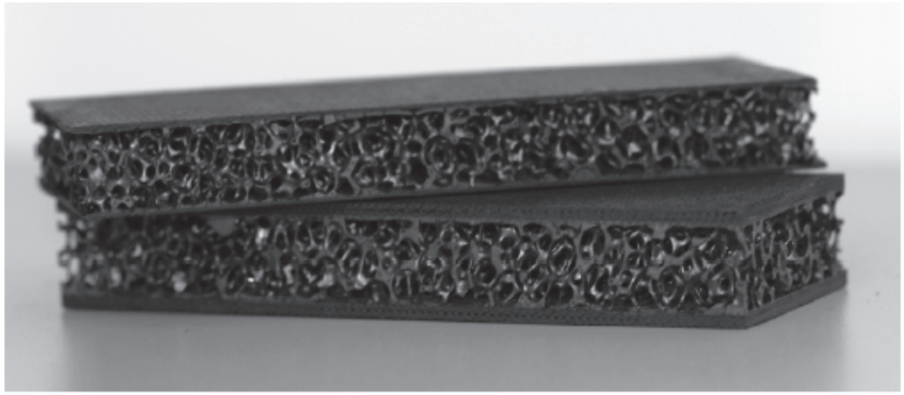
ZrB2 Multilayers (Tecnalia, M. Lagos)

WP2: MATERIALS DEVELOPMENT

- Integration of advanced CMC structures and ceramic foams.



CMC material from EADS: Cf/SiC fabricated via PIP process (EADS, C. Wilhelmi)"

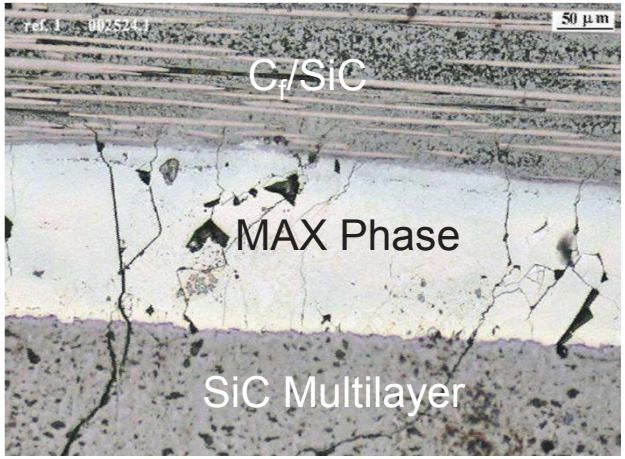


CMC-SiC sandwiches, (SUPSI, A. Ortona) made with ERBISIC ceramic foams (Erbicol S. Gianella)

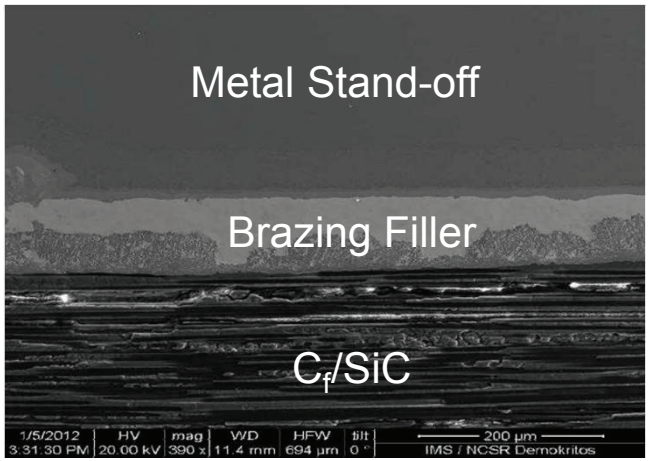
- Definition of metallic materials: stand-offs and vehicle sub-structure

WP3: JOINING PROCESSES

- Definition & selection of the bonding processes.
- Execution of the bonding process
  - External hot-structure to CMC assembly (based on MAX phases)
  - Assembly of stand-offs to the structure (based on metal brazing))
- Thermo-mechanical characterization and high temperature oxidation testing:



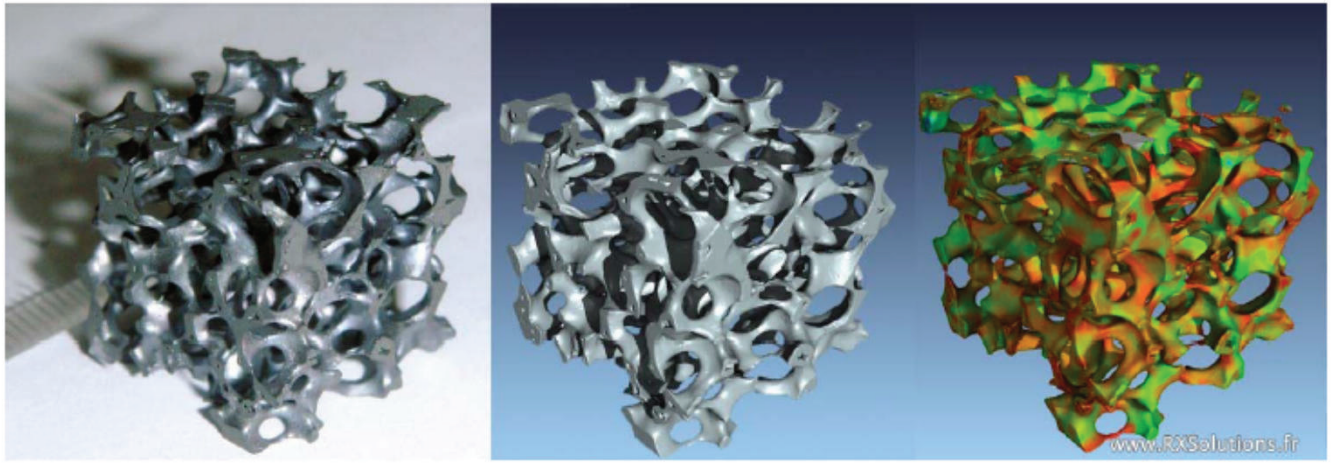
Multilayer/CMC Joining,
Credit:NCRSD/TECNALIA



CMC/Metal Joining,
Credit:NCRSD/TECNALIA

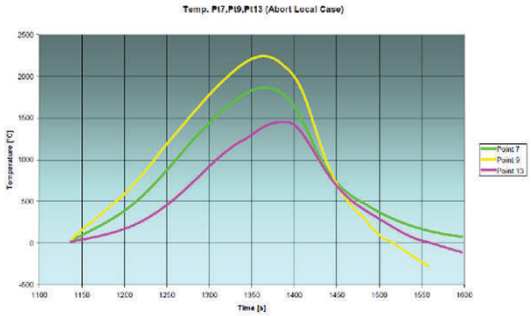
WP4: MODELING & SIMULATION

- Modelling of the different parts of the TPS (aided by computed tomography)

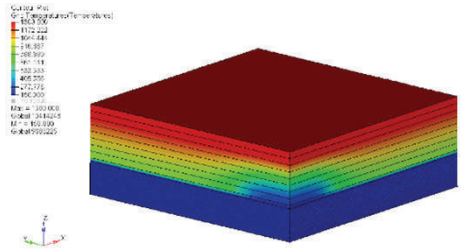


Credit: RX Solutions (France) made with ERBISIC ceramic foams (Erbicol S. Gianella)

- Themo-mechanical analysis
  - Inputs for W1 (specifications), WP2 (materials) and WP3 (processes)
  - Definition of temperature distribution (equilibrium and transient analysis)
  - The output of this work will help to calculate critical design parameters (WP1)



Inputs from ARV Re-entry, Credit:
ESA/Astrium GmbH (W. P.P. Fischer)



Temperatrure distrubution output,
Credit: SUPSI (C. D'Angelo)

WP5: TPS TECHNOLOGY SAMPLE ASSEMBLY

- Scale-up of materials and processes to build-up a technology sample

- This sample is a TPS tile with functional properties.
- Dimensions: 150 x 150 mm.
- Full characterisation of the technological sample: mechanical and thermo-physical.
- Characterisation at the ground test re-entry rig.

WP6: GROUND TESTING AND VALIDATION

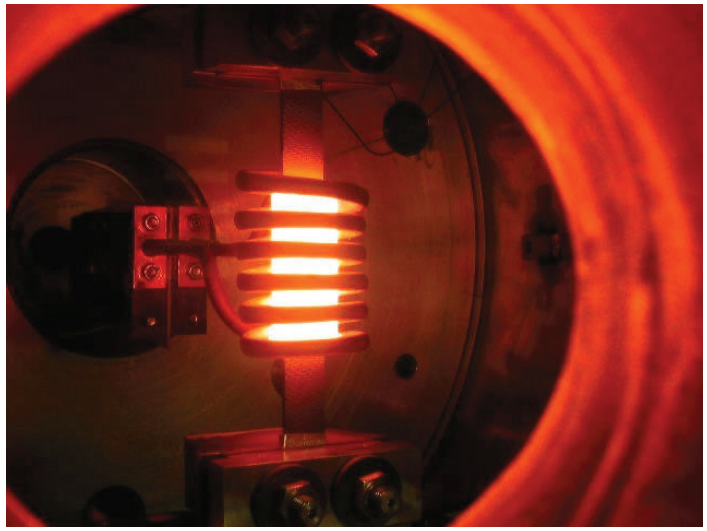
Ground testing for re-entry applications can be performed in different ways:

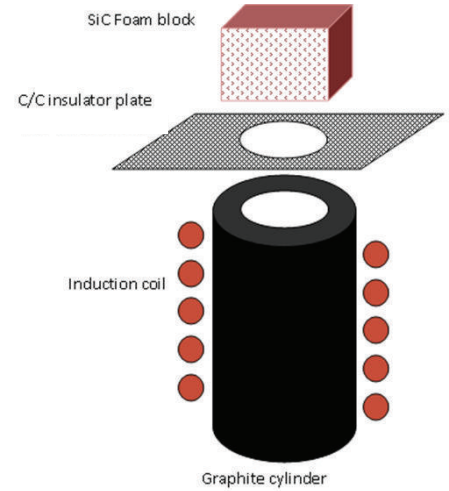
- **Plasma Windtunnels**
  - *Close to reality*
  - *Costly; screening tests hardly justifiable*
- **Standard Test Rigs (e.g. furnaces; mechanical test machines)**
  - *Cheap, fast and easy; good for screening tests*
  - *Not fully representative for re-entry applications*
- **Specific thermo-mechanical test facilities**
  - *Significant cost advantage to plasma windtunnels*
  - *More versatile, e.g. combination of T, F, p*
  - *Plasma-related thermochemical processes cannot be reproduced*
  - *Modern materials‘ durability may exceed the durabilty of test rig components*

WP6: GROUND TESTING AND VALIDATION

- Materials and joints are tested in a relevant ground facility simulating the re-entry conditions -> bottom-up aproach.
- The testing of full TPS will determine the fundamental performance and the degradation mechanisms.
- This final step will give insight into the overall performance of the TPS, identify possible modes of failure, and assess the efficiency of the thermal insulation and the heat fluxes into the sub-structure of a spacecraft.
- The ground testing outputs will be reviewed in comparison with the outputs of TPS requirements and environment specifications.

Re-entry Test Rig Assembly (at AAC)





Credit:V. Liedtke (AAC)

For more details visit the Project webpage: **www.smartees-project.com**

SUMMARY / CONCLUSIONS

- As a result SMARTEES is targeted at obtaining a novel “proof-of reusability” thermal protection system (TPS) concept with multifunctional properties. i.e. insulation and oxidation resistance. The TPS architecture will combine the use of advanced ceramic composites and porous structures.

- Positive effects of European Cooperation:

  - Europe will benefit from the results of SMARTEES by improving its access to space critical technologies. The next generation launcher (NGL) will take advantage of this concept. Another important asset is the contribution to the creation of an independent industrial supply chain and open new doors for collaboration with space fairing nations.

  - Space exploration in general may take advantage of the novel reusable TPS technologies. There is a high potential for its use in cargo and crew space return vehicles. I.e. for a cost effective, safe and reliable return from the international space station (ISS), future launchers, space tourism.

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- Aerospace and Advanced Composites GmbH (V. Liedtke, Austria)
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- Tecnalia Research & Innovation (C. Jimenez, M. Lagos and I. Agote, Spain)

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SEVENTH FRAMEWORK PROGRAMME

END OF PRESENTATION

Many thanks for your attention

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3	Erbicol SA	ERBICOL	Switzerland	S. Gianella	sandro.gianella@erbicol.ch	SME, ceramic component supplier
4	National Center for Scientific Research "Demokritos"	NCSRD	Greece	K. Mergia	kmergia@ipta.demokritos.gr	National Research Centre (largest in Greece)
5	EADS Deutschland GmbH	EADS	Germany	C. Wilhelmi	christian.wilhelmi@eads.net	Industrial partner, space systems manufacturer, end user
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7	Aerospace & Advanced Composites GmbH	AAC	Austria	V. Liedtke	volker.liedtke@aac-research.at	SME, material tester & qualifier