

### Characterisation of the behaviour of typical spacecraft materials exposed to re-entry environment conditions

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### The Problem

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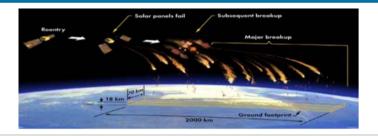
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LEO spacecraft and Launcher upper stages

- Orbital Decay at end of operating Life
- Uncontrolled re-entry in Earth Atmosphere

Space Debris impacting ground



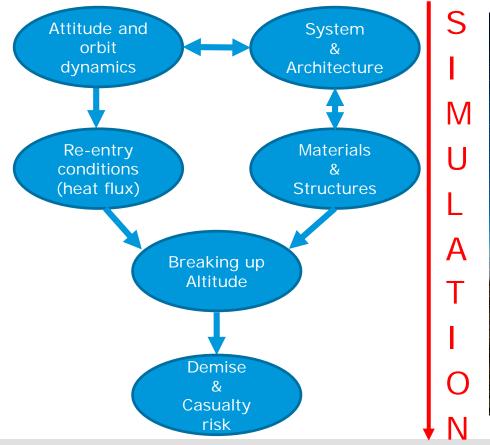








## Demisability: A Multi Disciplinary Field





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European Space Agency

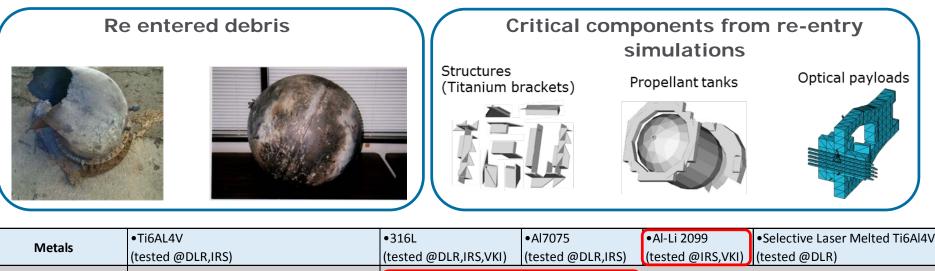
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# ESA initiative for material characterisation esa Two Technology Research Programme (TRP) contracts of 300Keuros each DLR consortium FGE consortium S QinetiQ OGI 🕖 Belstead

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## Common Spacecraft Material selection



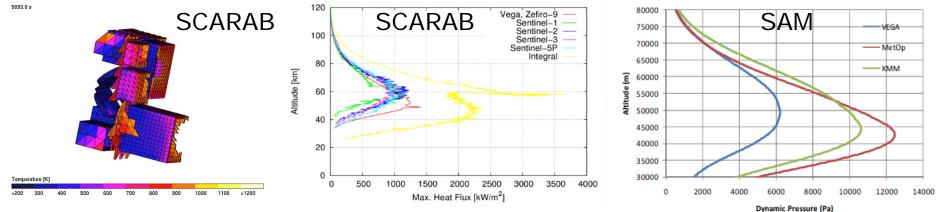


Metals	•Ti6AL4V		•316L	•Al7075	•Al-Li 2099	•Selective Laser Melted Ti6Al4V				
IVIELAIS	(tested @DLR,IR	S)	(tested @DLR,IRS,VKI)	(tested @DLR,IRS)	(tested @IRS,VKI)	(tested @DLR)				
Composites		P Hexcel M55J carbon yanate ester (tested @IRS)	• Monolithic CFRP Hexce /PEEk matrix	IIM7 carbon fibre						
Ceramics	Silicon carbide									
	COPV structure	e : CFRP T1000								
	fibre/UF3325		•Sandwich panel: Hexcel M55J carbon fibre/ TenCate EX-1515 cyanate ester							
Material combinations	epoxy matrix+Ti	6Al4V(liner) (tested @DLR,	and Al honeycomb (teste	ed@DLR)						
Fiber Metal Laminates	• GLARE									

### Test conditions and facilities selection







Facilities selection :



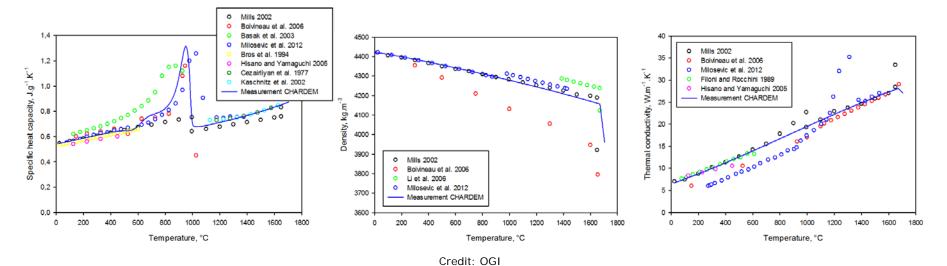
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### **European Space Agency**

### Thermophysical properties characterisation

- Direct inputs for the re-entry simulation software
- Direct inputs for simulating the plasma wind tunnel tests
- Specific heat capacity, specific enthalpy, thermal expansion, density, thermal conductivity were measured or calculated (DSC, Pulse Heating calorimetry, DTA, LFA)



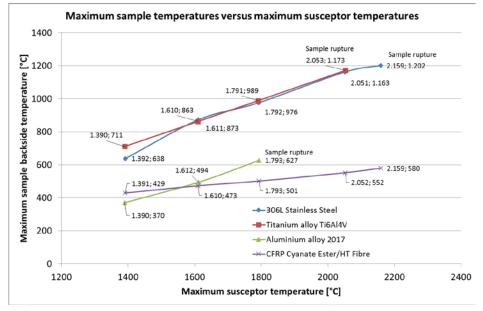


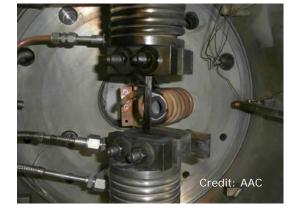


## Mechanical properties characterisation



Direct inputs for the re-entry simulation software





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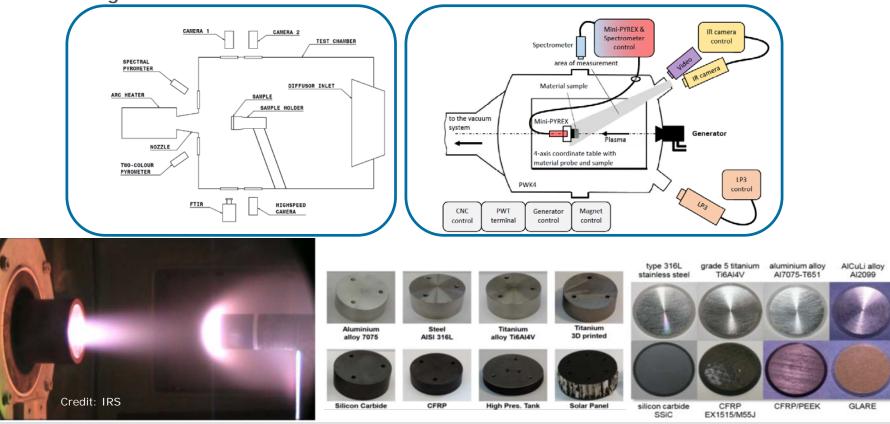
Credit: AAC

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## Plasma Wind Tunnel test campaign



Test configuration



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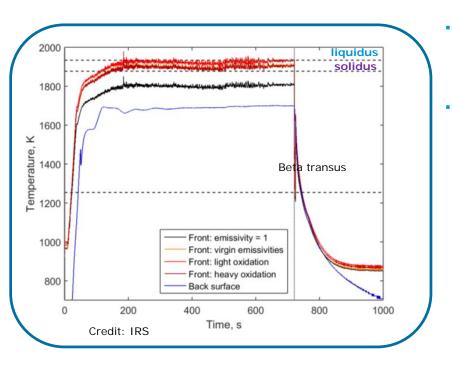
European Space Agency

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## Plasma Wind Tunnel campaign



• Ti6Al4V



- Steady state is reached without melting when testing at heat flux representative of uncontrolled re entry from LEO conditions (1.4MW/m<sup>2</sup>)
- Surface modification (oxides formation)

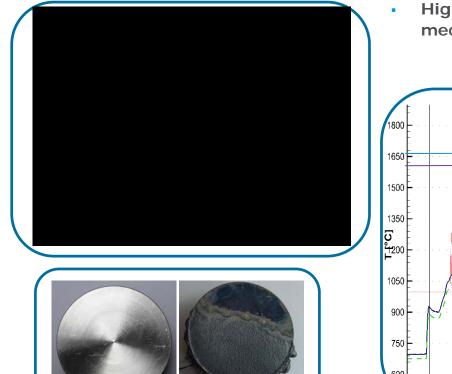


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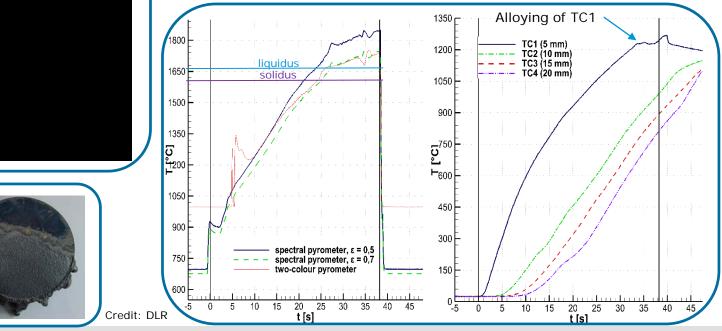
## Plasma Wind Tunnel campaign



Ti6Al4V



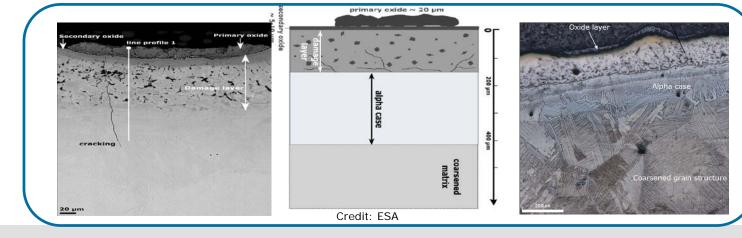
High eccentric re-entry conditions to observe demise mechanisms (2.3MW/m<sup>2</sup>)



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## Post PWT investigation

- Tested sample dimension (mm) and weight (g)
- Photographic evidences of the sample
- Surface analysis of the sample, morphology (LOM and SEM)
- Analysis of the oxide layer (crystalline phase): XRD, Raman spectroscopy
- Microstructure of metals and thickness of the oxides formed (LOM)
- Hardness profile from front surface to back surface



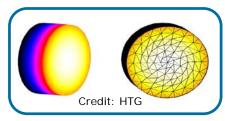


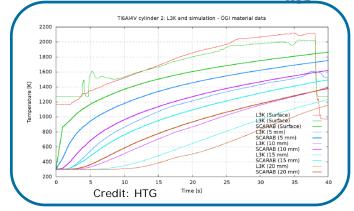


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### Plasma Wind Tunnel Test simulation

- PWT model of SAM and SCARAB used
- Use of thermophysical properties measured





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Material	Status of Modelling Accuracy	TRP Impact on Modelling Accuracy	Open Points
Stainless Steel	GOOD	Improved with catalycity model	Heat-up rate lower than tests
Titanium	GOOD	Improved with catalycity model	Complex material at high temperature
Silicon Carbide	GOOD	Improved with catalycity model	
Aluminium 7075	GOOD	Consolidated specific heats	
Aluminium 2099	GOOD	Established baseline aluminium model is applicable	
CFRP	FAIR	Established baseline model	Thermal conductivity Demise criteria Models for different types
GLARE	FAIR	Established baseline model	Basic data Demise criteria Layer-by-Layer Model

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### Metallic materials:

- Strong surface activity (oxide formation) impacting demise behavior (emissivity and catalicity)
- Ti6Al4V and 316L hardly demisable for LEO uncontrolled re entry conditions

### Composite materials:

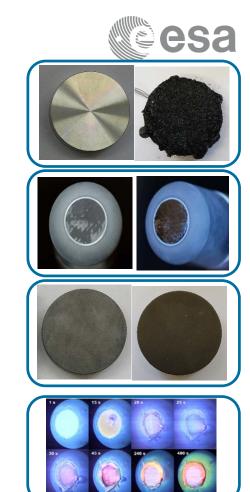
 Demise behavior strongly dependent of the fibers (type, UD, woven etc), matrix, and manufacturing process

### Ceramic materials:

- SiC hardly demisable for LEO uncontrolled re entry conditions
- Uncertainties associated to possible fragmentation of complex ceramic components

### Structures & material combinations:

Difficult to predict the demise mechanism at bigger scale



## **ESTIMATE** database

European Space maTerIal deMisability dATabasE

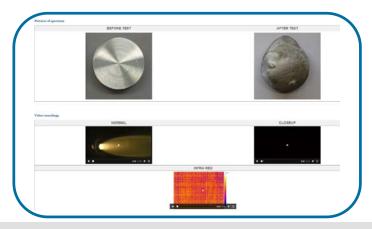
Accessible for European based companies

• Online by end of 2017

• Material thermophysical properties to be used by the codes

- Final reports of the two activities
- Plasma Wind Tunnel Test data (temperature profiles and videos) and test conditions for PWT test rebuild

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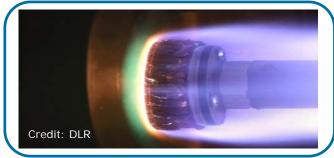


Analysis of re-entered debris

 Additional tests required on composite materials and material combinations

 Additional test required for structural breaking understanding: Activity on demisable joints is ongoing (expected finish end of 2018)





 Observation campaign of controlled re-entry events





# Thank you for your attention



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