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Introduction to H2020 project C3HARME: Next generation ceramic composites for combustion harsh environments and space

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INTRODUCTION TO H2020 EU PROJECT C3HARME

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NEXT GENERATION CERAMIC COMPOSITES FOR COMBUSTION HARSH ENVIRONMENTS AND SPACE

Launched in June 2016

Call	**H2020-NMP-2015-two-stage**
Topic	**NMP-19-2015** Materials for severe operating conditions, including added-value functionalities
Duration	48 months
Budget	€ 8,033,034.97

STATISTICS

First stage: 94 proposals – 14 passed
Second stage: 2 funded project/14
2/94= 2% chance

www.c3harme.eu

HIGHLIGHTS

istec

Objective

Create a new class of **out-performing materials:**
Ultra High Temperature Ceramic Matrix Composites (UHTCMCs) based on C or SiC fibres/preforms enriched with ultra-high temperature ceramics (UHTCs) capable of overcoming limits of current materials

Applications

Aersopace > 2000°C, near-zero erosion nozzles inserts and **near–zero ablation tiles** for launch and re-entry

Expected Impact

Significant improvement in the performance of the existing materials in terms of **increased capability to withstand severe environments**, achieving also efficiency, reliability, cost-effectiveness and scalability

TRL

Capability to manufacture and test in relevant environment reaching TRL 5-6

CONSORTIUM -12 partners

Countries	**Germany, Italy, Spain, UK, Ireland and Portugal**
Type	**6 research institutions, 3 large end-users, 3 SMEs**
Expertise	World class manufacturers: **AVIO** (propulsion systems) and **AIRBUS-SL** (space and defence solutions) Design and modelling of aeronautic/space systems: **DLR**, **TCD**, **AVIO**, **HPS**, **AIRBUS-SL** and **AGI** Advanced ceramic components providers**: DLR, NANOKER** and **AGI** Material and manufacturing process designers: **CNR-ISTEC, UoB**, **TECNALIA**, and **DLR** Advanced Characterization**: UNINA, DLR, AVIO, UoB**

CONSORTIUM

Large COMPANIES

Leading company in space propulsion
Solid- and liquid-propellant propulsion systems

End user
Prototype demonstration in ground simulated environment

- ✓ A global leader in aeronautics, space and related services
- ✓ Around 136,600* employees
- ✓ Suppliers from more than 100 countries
- ✓ 2015 revenues of € 64.5 bn
- ✓ Headquartered in Toulouse

A global company located in
Around 180 sites
Across 35 countries

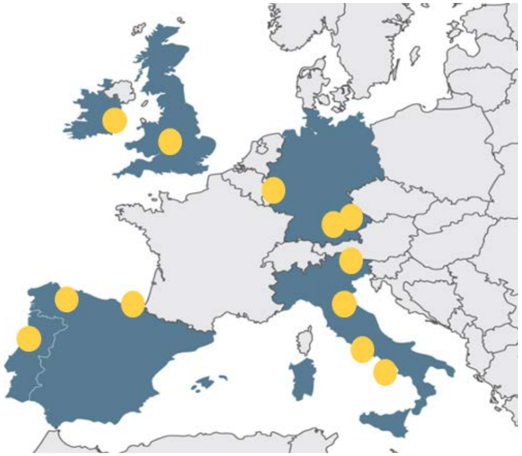
Robust and diverse order backlog
23% Europe
77% Non-Europe

International sales
31% Europe
69% Non-Europe

End user

Material development

CMCs for Harsh environments in Aerospace Sector



SMEs

Manufactruting and commercialization of Advanced technical ceramics

Advanced Technologies & Products for space Applications – Lightweigth Composite Structures

Dissemination and Comunication, project office

CONSORTIUM

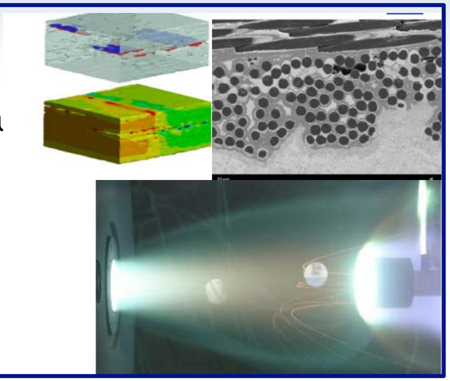
istec

RESEARCH CENTRES

DLR

GERMAN AEROSPACE CENTER
Institute of Structures and Design, Stuttgart
Damage tolerant high performance material for complex structures in high temperatu
and severe environments
Institute of Aerodynamics and Flow Technology, Cologne
With its five wind tunnels is one of the key European institutions in the field of hypersonic and supersonic technologies

8000 employees, 33 institutes and facilities at 16 sites.

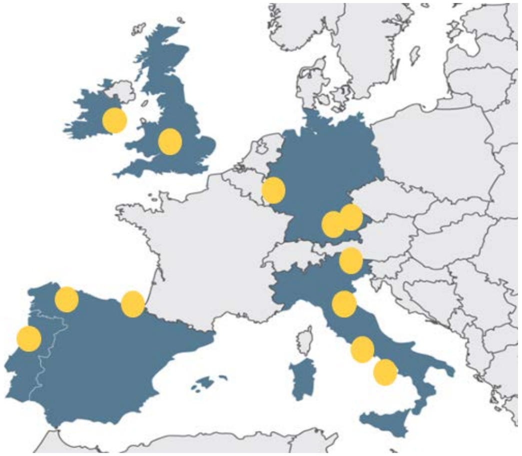


tecnalia

TECNALIA is the first applied research centre in Spain and one of the most important in Europe with around 1.500 people on staff, 122€ millions turnover and more than 4.000 clients.

Research and Development Technological Center

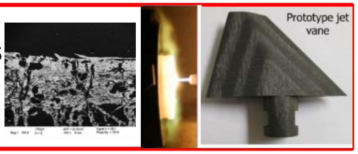
Positioning **between** Fundamental Research (University) and Industrial Application (Company)



UNIVERSITIES

UNIVERSITY OF BIRMINGHAM

Advanced ceramics and composites
UHTC and UHTCMCs

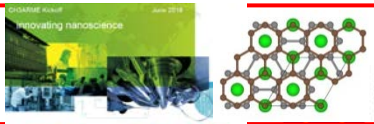


Università degli Studi di Napoli FEDERICO II

Advanced characterization of TPS in plasma wind tunnel - Theoretical and numerical research in hypersonic aerodynamics -

TRINITY COLLEGE DUBLIN

Modelling: DFT and molecular dynamic

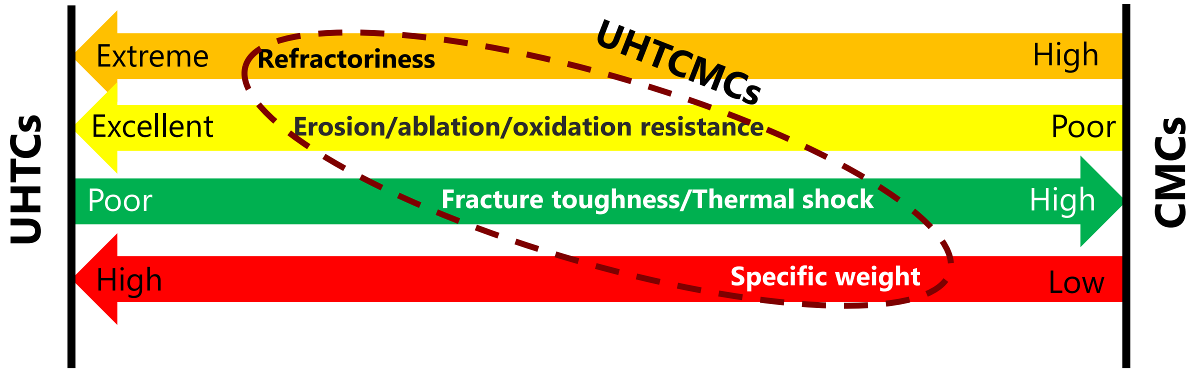


C3HARME

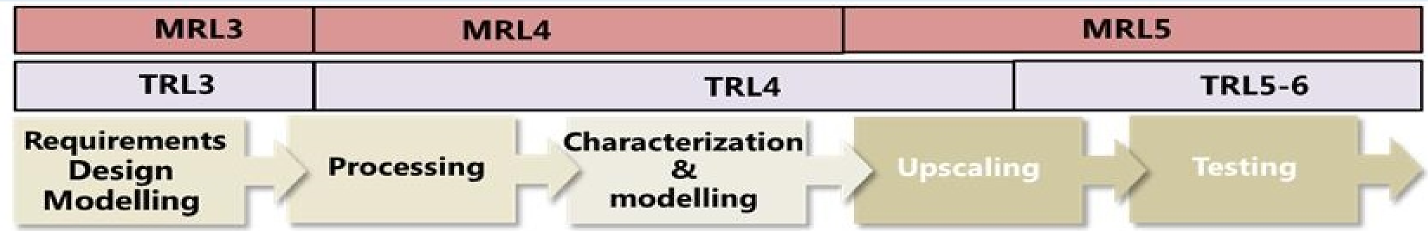
Concept

The combination of extreme temperature, chemically aggressive environments and rapid heating / cooling is beyond the capabilities of current engineering materials (C/C, C/SiC, UHTCs)

to overcome present technological limits,
novel materials must be conceived, combining the best features of CMCs with those of UHTCs.



Methodology



Material Requirements & Design

END-USERS give a list of technical, economic and exploitation indicators and requirements to be met. On this basis, a collection of materials' specifications

Multiscale modelling

Aim: to orient the material development from the early stages, including characterisation and upscaling, with the aim of improving the cost/performance ratio.

- **Parameter-free density functional theory** for understanding interfaces between materials, their performances under extreme conditions and their aging.
- **Micro-models** for chopped and continuous-fibre material with idealized microstructures where relevant properties are estimated from analytical or numerical (finite element) methods.
- **Numerical and analytical macro-models** to predict the structural integrity of components during expositions and fluid-dynamic calculations to understand the aerothermal behaviour and predict the gas/surface reactivity.

Processing

Several technologies are available in C3HARME (sintering and non sintering) , combination of conventional and novel processing methods.Selection of the resulting best processing routes dictated by the need for fast processing/cost effectiveness and performance.

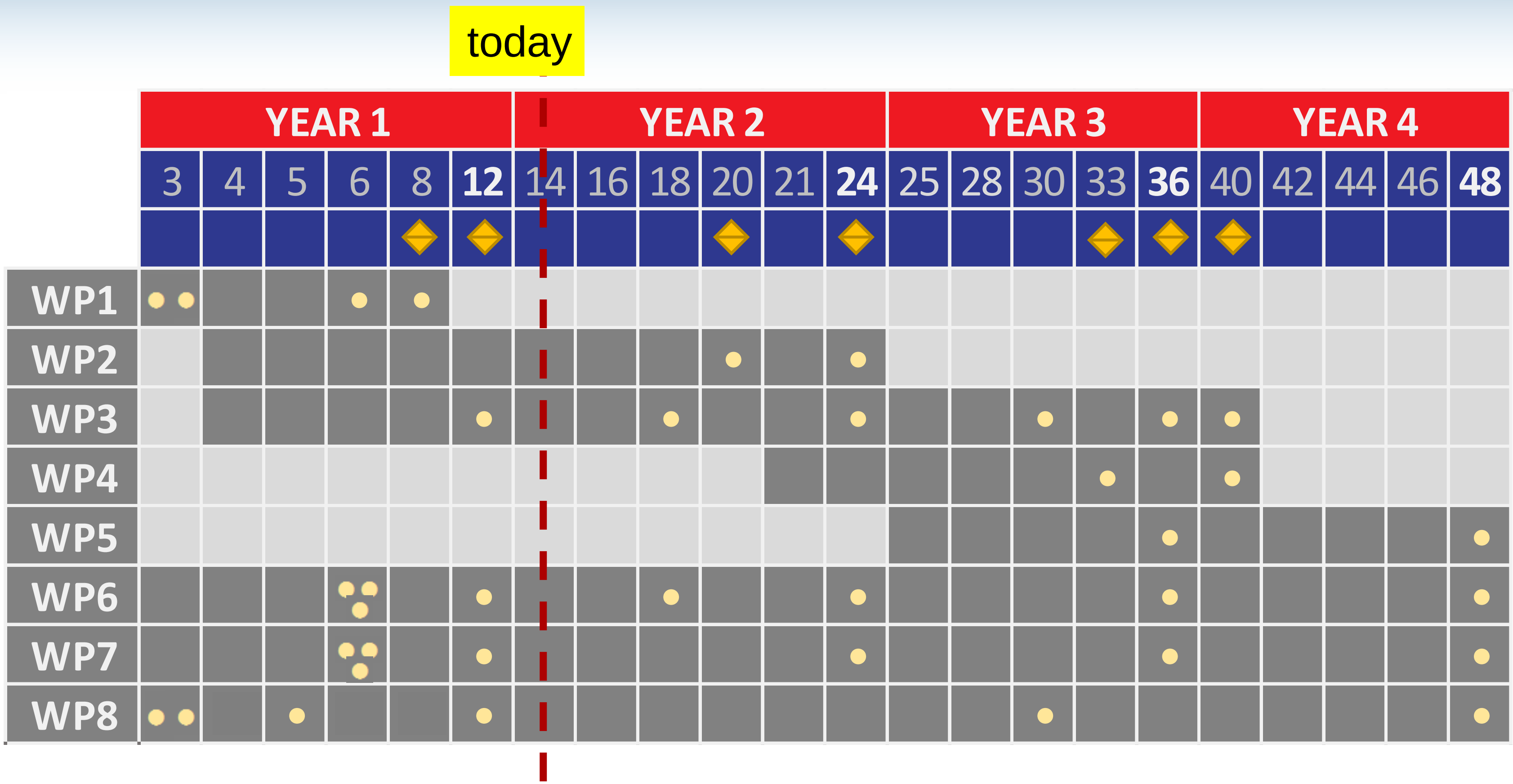
Characterization assessment of the **fundamental relationships properties / microstructure / process** and validation in lab- level

Scale up and testing of components aerothermal and mechanical conditions similar to those found in industry, coupled to a relevant size of the component to be tested.

Work packages

WP	WP Title
WP1	Technical requirement definition & design of prototypes
WP2	Processing of UHTCMCs
WP3	Thermo-chemical/mechanical characterization of UHTCMCs in TRL 3,4 and modelling
WP4	Prototype manufacturing & Up-scaling of UHTCMCs
WP5	Prototype testing & validation (Propulsion and TPS)
WP6	Dissemination & Exploitation
WP7	Project Management
WP8	Ethical issues

GANNT Chart



Deliverables
Milestones

Definition of the best technologies

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S

- **Several technologies are available (sintering and non sintering) , combination of conventional and novel processing methods**
- **Selection of the resulting best processing routes**

OWN & CROSS PROCESSING

	with ISTEC	with TEC	with UoB	with DLR	with AGI
ISTEC does	Short fiber: milled (µm) and chopped (mm) Continuous fibers: UD, -0/90, 2D **Hot pressing**	Prepares fibers/powders mixtures and infiltrated preforms for SPS	Slurry impregnation of 2.5 D preforms received from UoB for: - Sintering (ISTEC) - RFCVI (UoB)		Prepares slurries for filament winding to test in AIRBUS
TEC does	SPS of ISTEC chopped fiber mixtures and infiltrated preforms	Short fibers: MAX phases as matrix with milled fibers (µm) **SPS**			SPS of the porous C/SiC material after first pyrolsis.
UoB does	Torch screening of ISTEC materials with SH phases (in progress)		RF-CVI on 2.5D, 3D preforms	C coating onto C fibers to protect during RMI	-Slurry Impregnation of 3D Cf preforms received from AGI and ZrB2 CVI densification -Torch tests of UHTC coated C/SiC
DLR does				**RMI** of preforms	
AGI does	Filament winding or textile combined with ISTEC slurries	Prepare & provide porous C/SiC material (after first pyrolysis) for SPS	AGI carbon fiber preforms (e.g. 2.5D, 3D) combined with UoB matrix infiltration / processing		**PIP**

Self healing capability

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Definition

Self-healing materials are able to partially or completely repair a damage inflicted on them, restoring/regenerating the original functionality

Application	Identify the functionality	Identify a damage	Envision a repairing mechanism	Determine the restored functionality
TPS	Load-bearing	Crack propagation	Close cracks	Above 90% retained max. load
Nozzle	Zero-erosion	Ablation/Oxidation	Form non-ablative stable, preferably solid, external oxide scales	R_M and R_L below a certain limit

R_M: mass ablation rate, R_L: linear ablation rate

Preliminary screening of different SH phases
Find a way to measure the SH functionality

Characterization of thermo-mechanical properties

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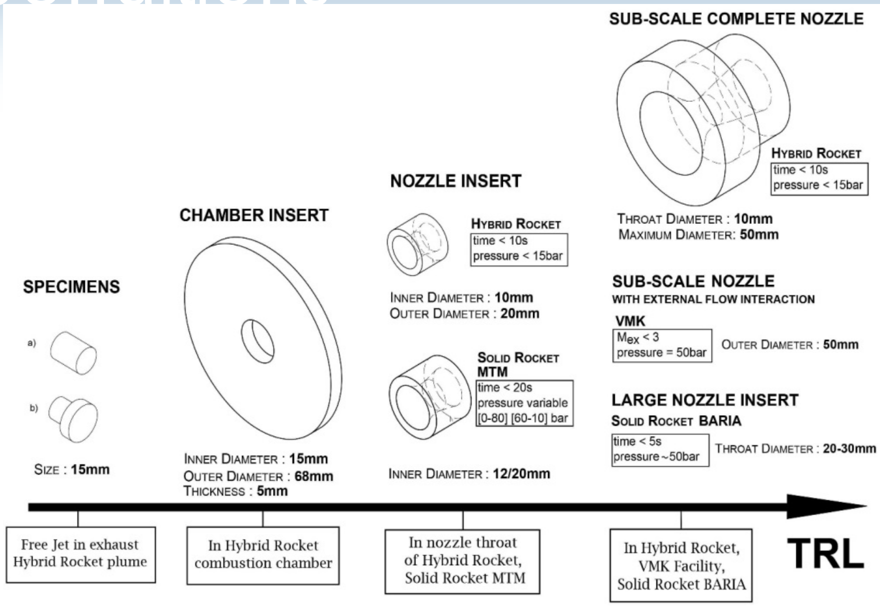
- **Characterization at T >1500°C or higher difficult to find**
- **NEW Standards needed for these new materials**

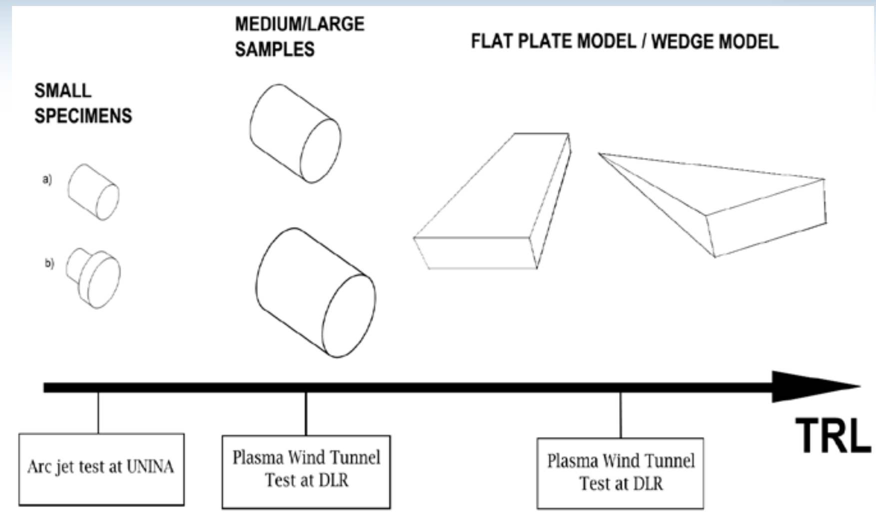
Agreed standards and procedures

Continuous Fibers								
Property	Temperature	Who	Facility	Test type	Standard	Sample Shape	Dimensions	Atm.
HV	RT	ISTEC	Zwick indenter		EN 843-4:2005	plate, bar	flexible	air
E	RT	DLR	Zwick		EN 658-1:1999 ISO 15733:2015	bar	10x2.5x60	air
σ-bending	RT	DLR	Zwick	semi-artic.-steel 4-pt. bend	EN 658-3:2002 ISO 17138:2014	bar	10x2.5x60 (5x1.25x30)	air
σ-bending	HT @1600° C	DLR/ISTEC	INDUTHERM/ MTS	C/C-SiC 4-pt. bend	EN 658-3:2002 (RT) EN 12788:2005	bar	2.5x2x25 10x2.5x60	vacuum, Ar, air
σ-compr	RT	DLR	Zwick		EN 658-2:2003 ISO 20504:2016	cylinder, block	4x4x8 Ø4.5x8	air
σ-compr	HT @1600° C	DLR	INDUTHERM/ MTS		EN 658-2:2003 (RT) ISO 14544:2013	cylinder, block	4x4x8 Ø4.5x8	vacuum, Ar, air
		DLR	Zwick		EN 658-1:1999 ISO 15733:2015	flat strip	(5-10)x3x100 (6x2x70)	air
σ-tension	HT @1600° C	DLR	INDUTHERM/ MTS		ISO 14574:2013	flat strip	(5-10)x3x140	vacuum, Ar, air
σ-interlaminar shear	RT	DLR	Zwick	3-pt. bending DNC	EN 658-5:2003 ISO 20505:2005	bar	(5-10)x3x25	air
K_{Ic}	RT	DLR	Zwick	CNB 4-pt.bend SEPB	EN 14425-3 ISO 15732:2003 (m)	bar	4x3x45	air
K_{Ic}	HT @1600° C	DLR	INDUTHERM/ MTS	CNB 4-pt. bend SEPB	EN 14425-3 (RT) ISO 15732:2003 (m, RT)	bar	2.5x2x25 4x3x45	vacuum, Ar, air
ΔTc (Thermal Shock)	HT	DLR	Zwick	Water quench	EN 820-3:2004	plate, bar	2.5x2x25	vacuum, Ar, air
K_{TH}	up to 1300° C	ISTEC (ext.)		Laser Flasch	ASTM E1461-11	cylinder	Ø5x1	Argon
CTE	up to 1550° C	DLR			ISO 17562:2016	bar	2.5x2x25	Argon

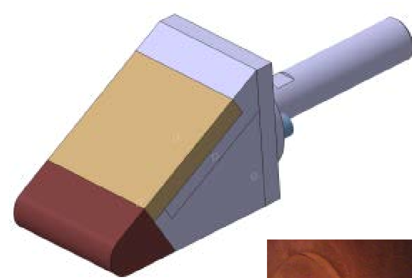
Definition of prototypes and relevant testing conditions

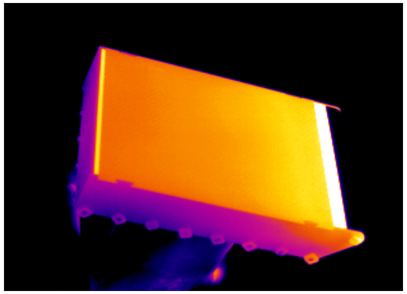
CHALLENGES

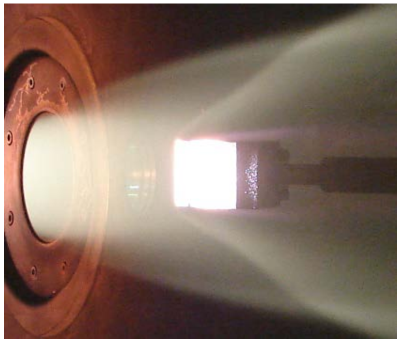




- Incremental approach for the final testing, starting form simple shaped prototypes
- Two applications and 4 different techonologies (potentially)



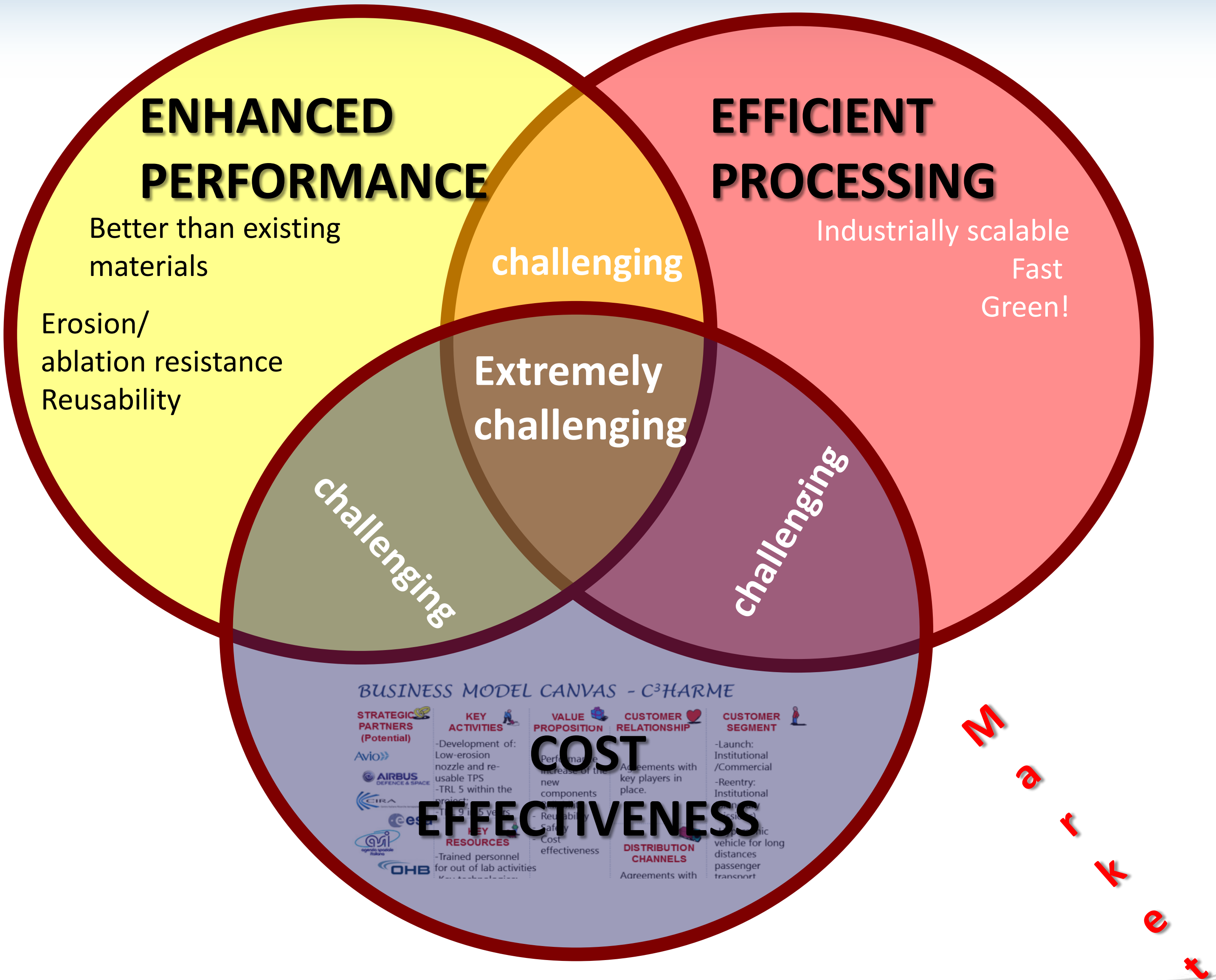




Ambition

LEIT H2020: Leadership in Enabling and Industrial Technologies

Research and innovation to strengthen Europe's industrial capacities and business perspectives, including SMEs



C3HARME

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