PROJECT ACRONYM: C³HARME

PROJECT TITLE: Next generation ceramic composites for combustion harsh environments and space

Deliverable 7.9

Catalogue of innovation risks

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Table of Revisions

REVISION NUMBER	DATE	WORK PERFORMED	CONTRIBUTORS
1	30/04/2018	Production of the first draft	Ana Martín, María Parco
2	03/05/2018	Template sent to main partners involved in each result for updating	Ana Martín, Richard Seddon
3	11/05/2018	Deadline for contributions	All main partners involved in development of exploitable results
4	04/06/2018	Production of the final version of the deliverable	Ana Martín. Sent for revision
5	05/06/2018	Revision	Diletta Sciti
6	06/06/2018	Formatting	Michela Candotti

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1. Executive summary

The main objective of D7.8 is to elaborate an assessment of the innovation risks posed in the C^{3}HARME project and follow a correct and efficient management procedure. This deliverable is the **second release of the catalogue of innovation risks** and builds on the *D7.3 Risk Assessment Plan – initial*, considered as the project's initial Risk Assessment Plan (RAP). The mentioned deliverable presents the procedures to be adopted during the implementation of C^{3}HARME to regularly assess potential risks. It describes the risk management processes: risk identification, qualitative risk analysis and risk response planning. The approach has been adapted to the C^{3}HARME project in order to manage all the different types of risks, the innovation risks for each Key Exploitable Result identified so far.

This second version updates the risks identified in month 12 according to the technical work that have been done since then and the requirements from the end users. Besides, it takes into consideration the evolution of the market during this period.

As explained in each chapter and in the **section dedicated to the conclusions, the higher risks identified during the last year are related with the achievement of the specification requirements** namely properties, TRL and costs. Other risks are the dependency on other technologies, the lack of manufacturer for the exploitable results and the fact that the result aims at replacing existing and well entrenched technologies. In any case, proper mitigation measures have been identified and/or applied to reduce the risks.

2. Introduction

2.1. C³HARME Project in a nutshell

The main purpose of the C³HARME project is the design, development, manufacturing and testing of a new class of Ultra High Temperature Ceramic Matrix Composites (UHTCMCs) based on C or SiC fibre preforms combined with ultra-refractory ceramics (UHTC) suitable for application in severe aerospace environments.

The project will bring the Proof-of-Concept of these new materials into two main applications:

- Application 1: Near **ZERO - Erosion nozzle inserts** that can maintain dimensional stability during firing in combustion chambers of high performance rockets.
- Application 2: Near **ZERO - Ablation thermal protection systems (tiles)** able to resist the very high heat fluxes in strongly reactive gases and thermo-mechanical stresses found at launch and re-entry into Earth's atmosphere.

The **goal of C³HARME** is to introduce a 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. The C³HARME project will reach this goal by introducing innovative material solutions whilst adapting existing and well-established processing techniques. In this sense, the project represents a well-balanced mixture of innovative and consolidated technology for new and very demanding applications, mitigating the level of risk intrinsic in top-quality research and innovative development.

Figure 1 a) Vega launcher and b) sketch of the various stages of launch, indicating the position of nozzles for civil aerospace rockets c) SHEFEX I re-entry experiment (courtesy of DLR) d) CMCs tiles for thermal protection systems

The project will start from a TRL of 3-4 and then focus on TRL 6 thanks to a strong industrial partnership that includes RTOs, SMEs and large companies as end users.

To reach TRL 6, rocket nozzles and TPS tiles with realistic dimensions and shape must be fabricated, assembled into a suitable system and tested in a relevant environment (environment centred testing).

Twelve consortium partners from different industries, countries and company sizes will work collaboratively ensuring an innovative approach and result of the project: 6 research institutions, 3 large end-users, 3 SMEs.

- **World class manufacturers: AVIO** (solid- and liquid-propellant propulsion systems) and **AIRBUS-SL** (space and defence solutions and services)
- **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**, **UNINA** and **DLR**

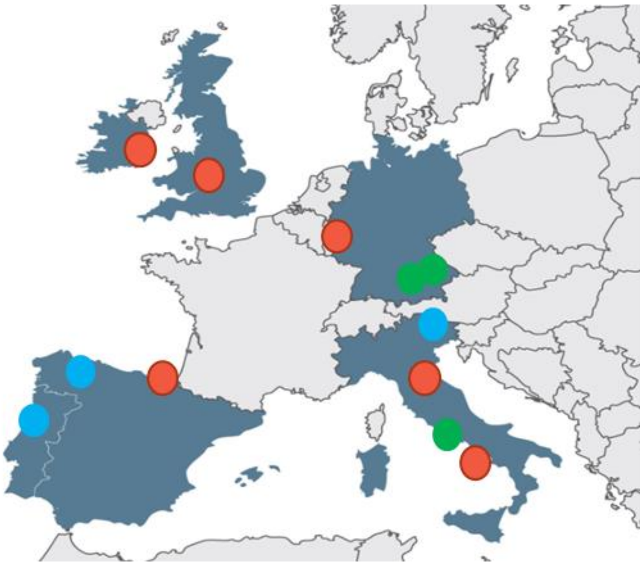


Figure 2 Consortium map

2.2. Main objectives and scope of this deliverable

This project report is the second release of the four deliverables regarding the innovation risks of C^{3}HARME project. The first one was submitted at month 12 of the project. Two subsequent versions of the document shall be further elaborated, updated and released at month 36 (May 2019) and at the end of the Project, at month 48 (May 2020).

All versions are based on the methodological process for risk management described in the deliverable *D7.3 Risk Assessment Plan* submitted in M6.

Besides this executive summary, the deliverable is structured in nine chapters:

The introduction, **Chapter 2**, summarizes the C^{3}HARME project and the approach and main objectives of the deliverable.

Chapter 3 contains the main points of the risk management process coming from D7.3 Risk Assessment Plan which describes it in a precise manner.

Chapter 4 includes a summary of roles and responsibilities.

Chapter 5 presents the identification, assessment and mapping of the innovation risks categorized per Key Exploitable Result.

Chapter 6 is dedicated to the conclusions and **Chapter 7** to collect deviations and/or comments review.

3. Key points of the risk management process

D7.3 Risk Assessment Plan describes in a precise manner the risk management process that is being performed in C^{3}HARME project. C^{3}HARME consortium has followed the mentioned methodology to elaborate the catalogue of innovation risks presented in this project report. The most relevant issues of such methodology are reported below for a better understanding of the present deliverable.

The risk management steps are:

1. **Risk identification:** identification of risk items using a structured and consistent approach to ensure that all areas are addressed;
2. **Qualitative risk analysis:** qualitative assessment of the risk and ranking of items to establish those of most concern;
3. **Risk response planning:** to ensure that the risks identified are properly addressed, contingency plans are planned to reduce threats to project objectives;
4. **Risk monitoring and control:** consists of keeping track of the identified risks, monitoring residual risks and identifying new risks, ensuring the execution of risk plans, and evaluating their effectiveness in reducing risks.

3.1. Risk identification

Identify risks is the process of determining which risks may affect the project and of documenting their characteristics. The key benefit of this process is the documentation of existing risks and the knowledge and ability it provides the Consortium to anticipate events. The risk identification also take into account the objectives and commitments made in the Description of the Action (DoA) of C^{3}HARME. The interactions between different risks will also be considered, as well as the risks resulting from the introduction of new technologies and tools. Identified risks with significant impact will be documented in the **Catalogue of Innovation Risks** and the WP leaders will be assigned with the responsibility, authority and resources for managing those risks.

Key questions that may assist the identification of risks include:

- For us to achieve our goals, when, where, why, and how are risks likely to occur?
- What are the risks associated with achieving each of our priorities?
- What are the risks of not achieving these priorities?
- Who might be involved (for example, suppliers, contractors, stakeholders)?

3.2. Qualitative risk analysis

Qualitative Risk Analysis is the process of analysing and evaluating identified risks to the project processes and deliverables. The risks are prioritized according to their potential effect on project objectives, through the Failure Mode and Effects Analysis (FMEA). FMEA is used to evaluate risk management priorities for mitigating known threat-vulnerabilities. It helps to select mitigation actions that reduce cumulative impacts of life-cycle consequences (risks) from a systems or process failure. In C^{3}HARME, the basic process of risk assessment is adapted to evaluate the different tasks and processes in the project to generate the Risk Priority Number (RPN) via the following **four parameters: criticality, importance, probability and impact.**

Table 1 Summary table of values and indicators of the RPN parameters. *Source: D7.3*

	Indicators			
Value	**Criticality**	**Importance**	**Probability**	**Impact**
1	**Very low:** no modification to existing concepts targeted in the project.	**Not very important** is defined as: the project could satisfactorily deliver even if this risk occurs.	**Low**: very unlikely, but not impossible.	**WP-Specific**: risk relating to a specific WP.
2	**Low:** minor modifications to existing concepts.	**Important** is defined as: the project could deliver even if the risk occurs, however would lose some value.	**Low-Medium**: unlikely to occur.	**Project level**: risk, which is generated at project level and implicates different WPs of the project (but not the relationship between WP's).
3	**Moderate:** well-understood changes to existing concepts.	**Very Important** is defined as: the project could deliver even if the risk occurs, however would lose significant value.	**Medium**: Quite possible.	**Cross-WP**: risk raised within a specific WP that may affect the project success or require actions to be taken in another project WP.
4	**High:** significant modifications to already know.	**Fundamental** is defined as: the project could deliver even if the risk occurs, however would lose much of its value.	**High**: more likely to happen than not.	
5	**Very high:** new concepts, which include a unique approach and no alternatives.	**Very Fundamental** is defined as: the project could not deliver if this risk occurs.	**Very High**: very likely to happen.	

There are several formula that could be used to rank and group the risks. *See further explanations in D7.3 Risk Assessment Plan.* The more generic one is:

RPN=Criticality x Importance x Probability x Impact

Other indicators that could be used are:

CIP=Criticality x Importance x Probability

And the simplest and most commonly used one would be:

IP=Importance x Probability

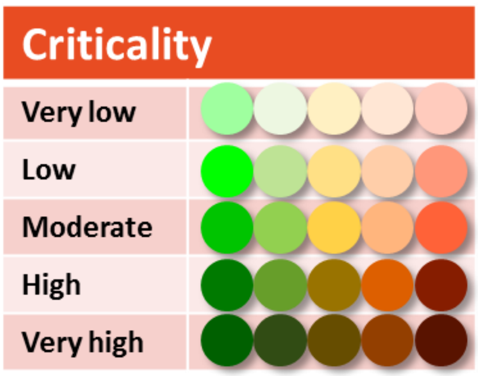
The risks have been mapped according to the above-mentioned criteria. Only the factor "Impact" has been excluded: the fact that a risk has an impact on one or more Work Packages is information that is relevant for the identification and application of mitigation measures, but might be less significant in relation to the project general objectives.

The following risk matrix has been used to generate a visual map of the technological and exploitation risks affecting the project.

Figure 3 Risk mapping matrix

Importance / Probab	**Not very important**	**Important**	**Very important**	**Fundamental**	**Very fundamental**
Very High	Low Med	Medium	Med Hi	High	High
High	Low	Low Med	Medium	Med Hi	High
Medium	Low	Low Med	Medium	Med Hi	Med Hi
Low-Medium	Low	Low Med	Low Med	Medium	Med Hi
Low	Low	Low	Low Med	Medium	Medium

The colour coding used to represent the criticality is the following:



3.3. Risk response planning

Once the list of risks and the associated values for the indicators have been generated, steps and actions to avoid their occurrence are defined.

Accepted risks will be identified and recorded in the RR. In order to ensure that the risks identified will be properly addressed, **contingency plans** will be developed, which will be appropriate to the severity of the risk, to be cost effective in meeting the challenge, as well as timely, successful and realistic within the project context. After a solution to an identified risk is proposed, verification will take place to identify that no undesirable effects or new risks introduced by its implementation, and that the resulting residual risk is addressed

The responsibility for the development and implementation of a **mitigation plan** as needed to reduce the risk to an acceptable level lies with the associated WP leader. Risk mitigation plans will address the following issues: development of alternative courses of action; workarounds; fallback positions; performance measures on the risk-handling activities, and recommended course of action.

Risk response strategies

There are **three risk response strategies** that have been identified to deal with the risks that, if occurred, may have a negative impact on the project objectives: **avoidance, mitigation and acceptance**. Each strategy has a unique influence on the risk condition, and will be chosen to match the risk's probability and impact on the project's overall objectives. (see deliverable D7.3 for further explanations about the three strategies)

Problem resolution

When a risk occurs and **problems** related to it are identified, they may be satisfactorily resolved adopting the **resolution process**. (see deliverable *D7.3 Risk Assessment Plan*, for further explanations about the steps)

3.4. Risk monitoring and control

Risk monitoring and control is the process of implementing risk response plans, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating risk process effectiveness throughout the project.

4. Roles and responsibilities

The main partners involved in each Key Exploitable Result (KER) are responsible for identifying and evaluating new risks and communicating them to the other partners. Based upon **impact level**, **risk management** will be carried out within the KER level when risks concern specific project results, and at project level when risk affect the ethical issues.

The main owners of each KER will collaborate with the partners involved in their KERs and coordinate the completion of the tables. Project coordinator and project management leader will coordinate the identification of the ethical risks.

TECNALIA as leader of the *D7.4 Catalogue of Innovation Risks* will coordinate the process of gathering the information from the partners of the innovation risks for each Key Exploitable Result.

5. Innovation risks related to each KER of the C3HARME project

C^{3}HARME project contains many new ideas which include a high element of risk. Risks are uncertain events or conditions that, if occurs, have a positive or negative impact on, at least, one project objective, such as scope, cost, time or quality. Therefore, risk management is integrating part of this project.

The C^{3}HARME innovation risks have been managed by analysing the different risks factors affecting the Key Exploitable Results identified so far. The project consortium has identified the KERs at this stage of the project and the main partners involved have provided the information concerning the characterization of the result, IPR management issues and first identification of risks.

The following tables have been used to gather the information related to the identification and assessment of the risks in each Exploitable Result. In each of the KERs, the innovation risks are categorized in the following risk factors: partnership, technological, market, IPR/Legal, financial/management and environmental/regulatory.

Besides, proposed risk-mitigating measures have been identified for each risk. The tables will be updated by the main partners involved in the results during the project time.

5.1. Innovation risks related to KER 4 Manufacturing of UHTCMCs via SPS

Description of KER 4: A new standardized process for the reliable and controlled fabrication of high-quality UHTCMC materials. The process route includes the preparation of the raw materials and the material composites. Field assisted sintering technology enabling ultrafast thermal consolidation of UHTCMCs (single step process) and the cost-competitive post-processing of pre-sintered CMCs (multi-step process).

The **main partner** involved is NANOKER. **Other partners** are ISTEC and TECNALIA.

The following table summarizes the main innovation risks identified by the main partners involved so far.

Table 2: Identification of Innovation Risks – KER 4 Manufacturing of UHTCMCs via SPS

Risk code and description	Criticality	Importance	Probability	Mitigation action	Did you apply risk mitigation measures	Did your risk materialise	Comments
Partnership Risk Factors							
R1: Disagreement on ownership rules	Moderate	Very important	Low-medium	Legal mediation of ownership disputes and patent review. IPR management during the project	YES	NO	IPR issues will be discussed in every project meeting.
R2: Disagreement on further investments: some partners may leave.	High	Fundamental	Low-medium	The Steering Committee mediate to find a solution. Assessment of the alternative solutions.	NO	NO	C3HARME consortium seems to be solid and capable of carrying out all the described work. The strong interest of all the partners in project results assures that any of the partners will leave the consortium by other reasons.
Technological Risk Factors							
R3: Better technology emerges	High	Fundamental	Low	Re-evaluation of technology and further optimisation to	YES	NO	Different materials and processes are being

				match/outperform new benchmark			tested to get the best results.
R4: Significant dependency on other technologies	High	Fundamental	Medium	Analyse the state of those technologies. If this occur, try to find different paths to avoid the use of such technologies	YES	NO	No comments
R5: Result aiming at replacing existing and well entrenched technologies	High	Important	Low-Medium	Correctly assess existing market technologies and assess performance and ability to penetrate market through replacement in existing applications	YES	NO	No comments
R5*: Limitation of SPS technology for the manufacturing of long products (i.e. nozzle prototype)	**High**	**Fundamental**	**Medium**	**Think alternative approaches to consolidate the material before sintering**	**YES**	**No**	**Waiting for prototype manufacturing for the final decision**
Market Risk Factor							
R6: Worthless result: performance lower than market needs.	Very high	Very fundamental	Low	Additional market studies, customer surveys and assessment of product shortfalls	NO	NO	No comments
IPR / Legal Risk Factors							
-							No relevant risks identified so far
Financial/Management Risk Factors							
-							No relevant risks identified so far
Environmental/Regulatory Risk Factors							
-							No relevant risks identified so far

Figure 4: Technological Risk Map – – KER 4 Manufacturing of UHTCMCs via SPS

Importance / Probab	Not very important	Important	Very important	Fundamental	Very fundamental
Very High					
High					
Medium				R4	
Low-Medium		R5	R1	R2	
Low				R5* R3	R6

Nanoker has identified a new risk related with the limitation of SPS technology for the manufacturing of long products (i.e. nozzle prototype). The importance is fundamental; however, the probability is still considered low. To mitigate that risk, partners using this technology will think alternative approaches to consolidate the material before sintering. At this stage of the project, the most relevant risk to be manage is still the significant dependency on other technologies. To mitigate the risk, the partners analyse the state of those technologies. If this occur, they will try to find different paths to avoid the use of such technologies

5.2. Innovation risks related to KER 5 Manufacturing of UHTCMCs via non-sintering technologies (RM-PP-MCVI).

Description of KER 5: A new standardized process for the reliable and controlled fabrication of high-quality UHTCMC materials via reactive melt infiltration. The proposed technology is a fast manufacturing route to produce dense composites, similar to liquid silicon infiltration for CMCs.

Reactive Melt Infiltration (RMI) is a versatile technique that enables the manufacturing of dense UHTCMCs composites with dimensions up to 500 mm diameter/square and 20 mm in thickness.

UHTCMC's densified by RF/MW-CVI offer excellent control over the porosity, matrix structure and degree of bonding with the fibres, thus enabling optimum fracture toughness values and protection from oxidation and ultra-high temperatures.

With the polymer Infiltration Pyrolysis (PIP) process, the envisaged material gradient and EBC system shall allow the use of an existing C/SiC CMC quality at ultra-high temperatures well beyond 1600°C.

The **main partners** involved are: University of Birmingham for RF / MW CVI technology, AGI for PP technology and DLR for RMI technology.

The following table summarizes the main innovation risks identified by the main partners involved so far.

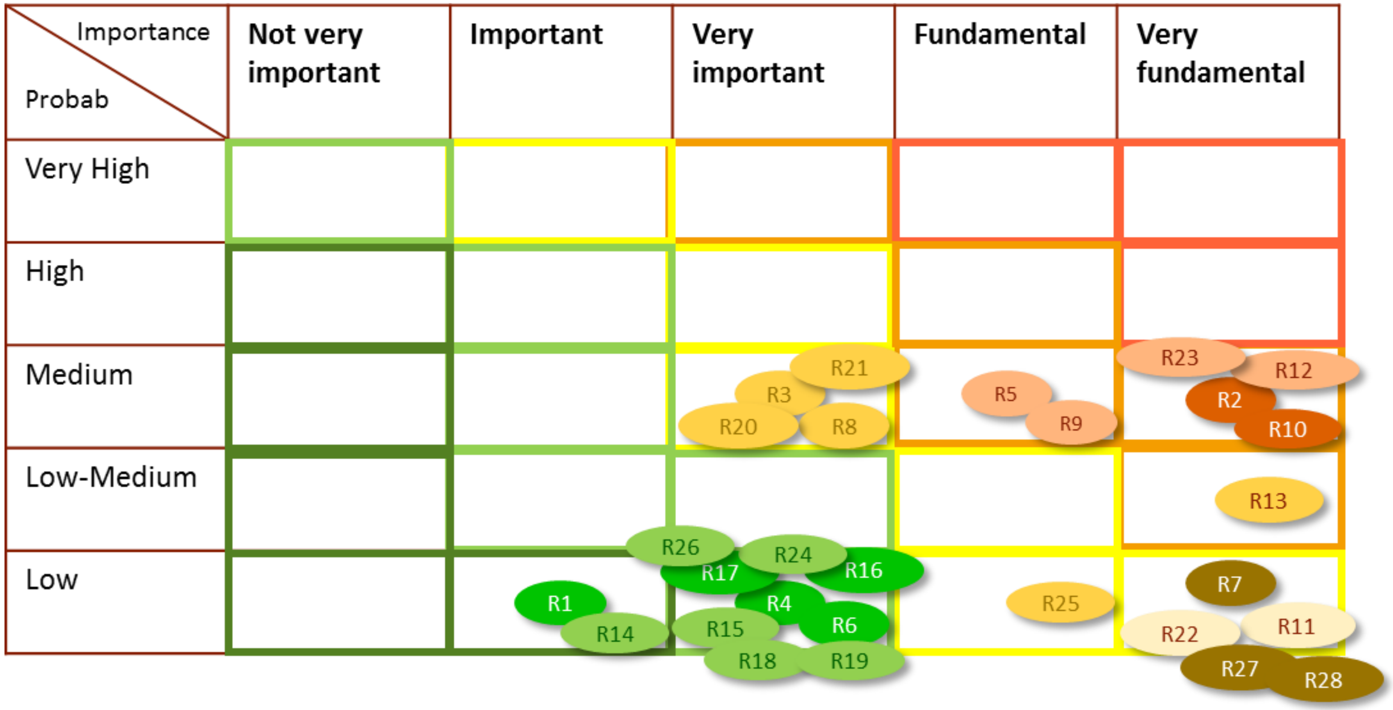
Table 3: Identification of Innovation Risks – KER 5 Manufacturing of UHTCMCs via non-sintering technologies (RIM-PIP-MCVI).

Risk code and description	Criticality	Importance	Probability	Mitigation action	Did you apply risk mitigation measures	Did your risk materialise	Comments
Partnership Risk Factors							
R1: Disagreement on further investments: some partners may leave.	Low	Important	Low	Find replacement or continue without	NO	NO	No comments
R2: Industrialization at risk: no manufacturer for the exploitable result.	Moderate	Very fundamental	Medium	Own making;	NO	NO	No comments
R3: Industrialization at risk: a business partner leaves the market.	Moderate	Very important	Medium	Look for new partners, applications, spin-offs	NO	NO	No comments
R4: Industrialization at risk: a partner declares bankruptcy.	Moderate	Very important	Low	Keep external capital investments low	NO	NO	No comments
R5: Disagreement on ownership rules	Moderate	Fundamental	Medium	Well prepared contracts and documentation	NO	NO	No comments
Technological Risk Factors							
R6: Worthless result: earlier patent exists.	High	Very important	Low	Cooperation or licences	NO	NO	No comments
R7: Worthless result: better technology/methodology exists.	High	Very fundamental	Low	Further development	NO	NO	No comments
R8: Significant dependency on other technologies.	High	Very important	Medium	Cooperation and further development	NO	NO	No comments
R9: The life cycle of the new	High	Fundamental	Medium	Further development	NO	NO	No comments

technology is too short.							
R10: Result aiming at replacing existing and well entrenched technologies	High	Very fundamental	Medium	Start with niche application to show potential	NO	NO	No comments
Market Risk Factors							
R11: Nobody buys the product. The project hits against a monopoly.	Low	Very fundamental	None	-	NO	NO	No monopoly existing
R12: Nobody buys the product. Problems at the time of the first sales.	Medium	Very fundamental	Medium	Careful development phase, no short-term industrialisation	NO	NO	No comments
R13: Nobody buys the product. Rejected by end-users.	Medium	Very fundamental	Low-Medium	Start with niche application to show potential	NO	NO	No comments
R14: Nobody buys the product. Our licensee is not exploiting his exclusive license.	Medium	Important	Low	Careful selection of licensee	NO	NO	No comments
R15: Nobody buys the product. Standards to make it compulsory don't yet exist.	Medium	Very important	Low	Start with niche application to show potential	NO	NO	No comments
IPR / Legal Risk Factors							
R16: Legal problems: proceeding against us.	High	Very important	Low	Check from beginning of development	YES	NO	No comments
R17: Legal problems: we are sued for patent infringement.	High	Very important	low	Check from beginning of development; cooperation or licenses	YES	NO	No comments
R18: Know- how risks: it is easy to counterfeit the patent.	Medium	Very important	None	-	NO	NO	Procedure too complex to copy

R19: Know- how risks: a counterfeit cannot be proved.	Medium	Very important	None	-	NO	NO	Procedure too complex to copy
R20: Know- how risks: the patent application is rejected.	Medium	Very important	Medium	Publication instead of patent	NO	NO	No comments
Financial / Management Risk Factors							
R21: Know- how risks: there are leaks of confidential information.	Medium	Very important	Medium	-	NO	NO	Procedure too complex to copy
R22: Multiple changes to original objectives.	High	Very fundamental	None	-	NO	NO	Objectives clear
R23: Lack of endorsement from top management	Medium	Very fundamental	Medium	Organize pull from end users	NO	NO	No comments
R24: Weak exploitation: Inadequate business plan	Medium	Very important	Low	Organize pull from end users	NO	NO	No comments
R25: No resources (human and/or financial) secured to make the next step toward exploitation	Medium	Very fundamental	Low	Organize pull from end users	NO	NO	No comments
Environmental/Regulatory Risk Factors							
R26: Product/service does not comply with the standards.		Very important	Low	Check from beginning of development	YES	NO	No comments
R27: Research is socially or ethically unacceptable.	Very High	Very fundamental	None	-	YES	NO	No socially or ethical issues w.r.t. Space re-entry technologies. WP 8 dedicated to avoid ethical problems
R28: Influence of laws and regulations.	Very High	Very fundamental	None	-	YES	NO	Check from beginning of development

Figure 5 Technological Risk Map – KER 5 Manufacturing of UHTCMCs via non-sintering technologies (RMI-PIP-MCVI).



The main partners involved, UoB, AGI and DRL, did not modify the risks assessed last year. The main risks to be managed remain those related to the industrialization (no manufacturer for the exploitable results), and the fact that the result aims at replacing existing and well entrenched technologies.

5.3. Innovation risks related to ER7 Knowledge on design and assembling of UHTCMC components in spacecraft structural systems

Description of KER 7: System aspects and design knowledge for systems made with UHTCMC components / New structural material for TPS application at T>2000°C, self-healing properties and improved structural performance compared to CMCs..

The **main partner** involved is: AIRBUS. **Other partners** that might be involved are: TECNALIA, ISTEC, University of Birmingham, DLR, Nanoker, HPS, AGI.

The following table summarizes the main innovation risks identified by the main partners involved so far.

Table 4: Identification of Innovation Risks – ER7 Knowledge on design and assembling of UHTCMC components in spacecraft structural systems

Risk code and description	Criticality	Importance	Probability	Mitigation action	Did you apply risk mitigation measures	Did your risk materialise	Comments
Partnership risk factors							
R1: Disagreement on ownership rules	Moderate	Very important	Low-medium	Legal mediation of ownership disputes and patent review. IPR management during the project.	YES	NO	IPR issues will be discussed in every project meeting.
Technological Risk Factors							
R2: One or more compositions do not have adequate microstructural features/mechanical properties	Moderate	Not very important	Medium	Not a critical risk as long as at least one of the compositions/each application is capable of achieving the required properties	YES	NO	No comments
R3: Unavailable test methodology for tests over 1500°C (in particular for strength)	High	Very important	High	Find alternative validation tests relevant for two applications by M18. Alternatively, involve Missouri Science and Technology (USA) as external service provider to perform tests	YES	NO	No comments

R4: All four routes are not capable of producing a demonstrator	Very high	Very fundamental	Low	As long as one or more of the routes appears capable, resource may need to be moved to where success is most likely.	YES	NO	Equipment failures could mean that progress is slow. Risk mitigation: Will look after equipment as much as possible.
R5: Worthless result: performance lower than market needs.	Very High	Very fundamental	Low	Correctly assess existing market technologies and assess performance and ability to penetrate market through replacement in existing applications	NO	NO	The project assesses different materials that can be produced with innovative processes in order to have different alternatives for market needs.
R6: Result aiming at replacing existing and well entrenched technologies	High	Very important	Low-Medium	Correctly assess existing market technologies and assess performance and ability to penetrate market through replacement in existing applications	NO	NO	No comments
R7: Inability to produce shapes more complex than flat plates for TPS application	**High**	**Very important**	**Medium**	**Communicate the need for such components for competitive**	**NO**	**NO**	**This is the question of TRL; potentially such components are not mandatory to reach TRL 5, however they would be critically important for the actual applications**
R8: Reusability can't be achieved through lack of self-healing and/or non-zero erosion at re-entry conditions	**Very High**	**Fundamental**	**High**	**Ensure that this requirement is communicated to partners involved in material development. Requirement comunicated and discussed during the meeting in Naples.**	**YES**	**NO**	**Will make the usage of this material for frontshield TPS unjustified from cost point of view.**
R9: TPS cost too high	**Very**	**Very**	**Very**	**Ensure that reusability is achievable. Importance of that**	**YES**	**NO**	**Related to reusability requirement. In case it**

	High	**Important**	**High**	**communicated to partners.**			**can't be ensured, the non-recurring costs of manufacturing and integration of such TPS will certainly exceed the cost of e.g. ablative TP solutions.**
Supply chain risk factors							
R10: Material unavailability and lack of alternative suppliers	**High**	**Very Fundamental**	**Low-medium**	**Ensure that partners are aware of the issues and have alternative suppliers of critical materials available.**	**YES**	**NO**	

Figure 6 Innovation Risk Map – ER7 Knowledge on design and assembling of UHTCMC components in spacecraft structural systems

Importance / Probab	Not very important	Important	Very important	Fundamental	Very fundamental
Very High			R9		
High			R3	R8	
Medium	R2		R7		
Low-Medium			R1 R6		R10
Low					R4 R5

New important risks affecting the exploitation of the UHTCMC components have been identified by AIRBUS. The main ones are related to the development of the technology and the achievements of the requirements expected by AIRBUS: achievements of more complex shapes than flat plates for TPS application, reusability and too high costs. Another risk related to the supply chain is the material unavailability and lack of alternative suppliers. However, the probability that such risk occurs been assessed to be low-medium.

5.4. Innovation risks related to ER8 Knowledge on design and assembling of UHTCMC components in propulsion systems / ER11 Advanced rocket nozzles and combustion chamber parts with extreme erosion and thermo-chemical resistance

Description of KER 8: Design improvement of throat components and optimization of design and assembly process of critical parts of solid rocket motors such as the throat insert of nozzles. KER 10: Near zero - erosion materials for nozzles will allow to greatly reduce main losses on rocket motor: those induced by increase of throat diameter (and therefore a decrease of expansion ratio) due to thermo-chemical and mechanical erosion.

The **main partner** involved is: AVIO. **Other partners** that might be involved are: DLR, AGI, NANOKER, ISTEC, UoB, TECNALIA, HPS, and AIRBUS.

The following table summarizes the main innovation risks identified by the main partners involved so far.

Table 5: Identification of Innovation Risks – ER8 Knowledge on design and assembling of UHTCMC components in propulsion systems / ER11 Advanced rocket nozzles and combustion chamber parts with extreme erosion and thermo-chemical resistance

Risk code and description	Criticality	Importance	Probability	Mitigation action	Did you apply risk mitigation measures	Did your risk materialise	Comments
Partnership risk factors							
R1: Disagreement on ownership rules	Very High	Fundamental	Low-medium	Legal mediation of ownership disputes and patent review. IPR management during the project.	YES	NO	IPR issues will be discussed in every project meeting.
Technological Risk Factors							
R2: Significant dependency on other technologies.	High	Fundamental	Medium	Re-evaluation of technology and further optimisation to match/outperform new benchmark	NO	NO	No comments
R3: Result aiming at replacing existing and well entrenched technologies	High	Fundamental	Low-Medium	Correctly assess existing market technologies and assess performance and ability to penetrate market through replacement in existing applications	NO	NO	No comments

R4: Results do not respect the specification requirements	**High**	**Very fundamental**	**High**	**Analysis of technological key-parameters and implementation of improvement actions in order to fit as much as possible the specification requirements**	**NO**	**NO**	**No comments**
IPR/Legal Risk Factors							
-							
Financial/Management Risk Factors							
R5: Know- how risks: there are leaks of confidential information.	High	Fundamental	Medium	Multiple non-disclosure agreements on some specific critical know how to be signed between interested partners	YES	NO	
Environmental/Regulatory Risk Factors							
R6: Product/service does not comply with the standards.	High	Important	Low-Medium	Adapt manufacturing process to environmental regulations, use raw materials not coming from "black list" countries	YES	NO	
R7: Influence of laws and regulations.	High	Fundamental	Low-Medium	Use of not-ITAR raw materials, civil application end-user	YES	NO	

Figure 7 Innovation Risk Map – ER8 Knowledge on design and assembling of UHTCMC components in propulsion systems / ER11 Advanced rocket nozzles and combustion chamber parts with extreme erosion and thermo-chemical resistance

Importance / Probab	Not very important	Important	Very important	Fundamental	Very fundamental
Very High					
High					R4
Medium				R2, R5	
Low-Medium		R6		R1, R7, R3	
Low					

The most important risk identified at this stage of the project by AVIO is that the results from the project do not respect the specification requirements. The mitigation action defined by AVIO is the analysis of technological key parameters and implementation of improvements actions to fit as much as possible the specification requirements. Other risks to be managed are related to the significant dependency on other technologies and leaks of confidential information.

6. Conclusions

This deliverable comprises the second mapping of the innovation risks that the C3HARME project may face during its development. The first version was developed in month 12 of the project. Both releases have been prepared following the procedures described in the *D7.3 Risk Assessment Plan-initial*. All partners involved in the main exploitable results have provided information on the main risks within the scope of the activities developed in *Task 6.3 Assessment and management of the exploitation of project results*. The mentioned task includes and activity dedicated to the characterization of the main exploitable results, IPR management and identification of risks related to the potential exploitation of each key result derived from the project. Besides, the Project Coordinator and the Exploitation manager have coordinated the development of this deliverable and have contributed to the identification and assessment of the risks.

The **main insights** of this updated mapping of the innovation risks **from the point of view of components manufacturers for aerospace applications** are:

- There is one risk is assessed as high: **Results do not respect the specification requirements.** AVIO considers that the importance is very fundamental and the probability that his might occur is high.
- Although the probability that this might happen has been considered lower, AIRBUS also identifies **three risks related to the fulfilment of the specification requirements**. The first one is related to the **achievement of the expected TRL**: the inability to produce shapes more complex than flat plates for TPS application. **Other two risks are associated with the cost**: if the reusability can´t be achieved through lack of self-healing and/or non-zero erosion at re-entry conditions, the usage of the material for frontshield TPS will be unjustified from the cost point of view. As the new material will exceed the cost of current solutions (e.g. Ablative TP solutions), **the reusability requirement must be ensured to justify the higher costs.**
- In all cases, **proper mitigation measures** have been identified and/or applied to reduce the risks impact. AVIO proposes to analyse the technological key-parameters and implementation of improvement actions to fit as much as possible the specification requirements. AIRBUS has stressed the importance to **ensure that reusability is achievable** and this has been communicated to the partners involved in the development of the materials.

The conclusions on the risks affecting the development of the processing routes are:

- **Manufacturing of UHTCMC via SPS:** the higher risk is related to the significant dependency on other technologies. Other important risk identified during the last year is the limitation of SPS technology for the manufacturing of long products (i.e. nozzle prototype)
- The **mitigation measures** to avoid the impact on dependency on other technologies, is to keep on analysing the state of those technology and find different paths to avoid the use of such technologies. To manufacture long products, the main partner involved are approaching alternatives to consolidate the material before sintering
- **Manufacturing of UHTCMC via non-sintering technologies (RIM-PIP-MCVI): t**he main risks to be managed remain those related to the industrialization (no manufacturer for the exploitable results), and the fact that the result aims at replacing existing and well entrenched technologies.
- **The mitigation actions** are linked to the search of niche applications to show potential. Other option could be to find other applications out of the space sector.

An updated version of this "Catalogue of Risks" will be released at M36 (May 2019) and at the end of the Project, at M48 (May 2020). The innovation risks might vary following the evolution in the definition of the KER during the project.

COOPERATION BETWEEN PARTICIPANTS
• TECNALIA coordinated the preparation of the deliverable, organizing the structure of contents and providing the templates to the main partners involved. Besides, TECNALIA developed the document and conclusions collecting contributions from all partners. • ALL PARTNERS provided information on the risk assessment related to the project results in which they are involved. • The COORDINATOR provided the final revision and approval.