Information and Communication Technologies (ICT) Programme

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D2.6: CERBERO Technical Requirements (Ver. 1)

Lead Beneficiary: IBM

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Abstract:

This document is meant to describe the preliminary set of technical requirements that have been elicited, according to the project goals and the scenario needs, for the CERBERO framework including methodology to elicit these requirements.

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25/05/2017	v0.1	UNISS	Contribution to Section 3 (Verification Technologies)
25/05/2017	V0.1	TNO	Included requirements for use case Smart Travelling Included complementary information on the DynAA tool Included suggestions for use of DynAA in several use cases
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29/05/2017	V0.3	IBM	Initial ideas based on use cases
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12/06/2017	V0.6	IBM	With updated by TNO Smart Travelling use case
20/06/2017	V0.7	IBM	With updated by TASE Self-Healing System for Planetary Exploration Use Case
03/07/2017	V0.8	AS	Updated Ocean Monitoring use case, included requirements methodology parts
31/07/2017	V0.9	IBM	New structure
17/09/2017	v1.0	IBM, TNO, UNISS	New structure and methodology
08/10/2017	V2.0	IBM, TNO, UNISS	Improved structure
10/10/207	V3.0	IBM, AI, USI	Final version

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1. Executive Summary

This document defines requirements for tools and technologies developed in CERBERO. Currently there is no standard methodology for elicitation of requirements in research projects. Therefore, we first developed requirements elicitation methodology for large research projects such as CERBERO. The methodology suggests starting requirements elicitation process by consolidation of use case requirements and merging them with project operational objectives. Afterwards, the they are enriched with needs of other stakeholders. As a result, 26 CERBERO user requirements have been identified. Finally, these user requirements lead to 18 CERBERO technical requirements that, as we verified, cover all identified user requirements.

1.1. Structure of Document

In Section 2 we define methodology for elicitation of technical requirements in large research projects. Then, we implement the methodology to CERBERO, consolidating the use case requirements in Section 3, listing CERBERO stakeholder needs in Section 4, and finally, defining technical requirements in Section 5. In Appendixes A-C we provide summary of use case demonstrations per each use case defined in deliverable D2.3 with potential mapping to CERBERO tools.

1.2. Related Documents

CERBERO_D1 1_KoMprogress_UniSS_FF1_20170512.docx

CERBERO_D1.6_Open_Data_Management_Plan_TNO_FF1_20171009.docx

CERBERO_D2.3_ScenariosDescription_TASE_FF1_20171009.docx

CERBERO_D7.5_DisseminationPlan_USI_FF1_20171009

CERBERO_D8.3_InnovationStandardisationExploitationPlan_AI_FF1_20171009

2. CERBERO Methodology for Elicitation of Technical Requirements in Large Research Projects

Methodology for Technical Requirements in research projects is not matured as methodology of product technical requirements. In this section we propose a methodology that is based on the best practice for product development but adjusted to research needs.

Technical Requirements should express needs of all stakeholders. In large research projects, such as CERBERO, identification of all stakeholders and their roles is not trivial and sometimes counterintuitive to standard requirements analysis of products and services. For example, the main purpose of use cases providers is not to develop the use case product or service but evaluate and provide valuable feedback to the research technical, dissemination and exploitation activities. Technical Requirements provide focus in research development and ensure its proper evaluation. In this section we propose a generic process for elicitation of technical requirements. The process is applied to CERBERO in the following sections.

We start by identifying main stakeholders in typical large research projects. Their needs will be merged into User Requirements, traced to the derived Technical Requirements with an appropriate Test for validation. The Technical Requirements will be later used by other project work packages for their implementation with appropriate verification tests.

The following stakeholders have been identified for large research projects:

1. Research sponsor
2. Project reviewer
    a. Technical reviewer
    b. Financial reviewer
3. Use case provider
    a. Technical staff, usually engineers from the provider's organization
    b. User
    c. Manager
4. Research community
5. Industry community
6. Standardization body

Research sponsor's needs and use case user's needs vary a lot from call to call and from use case to use case. Needs of other stakeholders are pretty common for most research projects and may require only slight adjustment/extension for a specific project. In the following paragraphs we propose methodology for elicitation of research sponsor's and use case user's needs and provide an initial list of other stakeholders needs that will be extended / updated in the following versions of the document.

Research sponsor's needs are represented by call's expected impact. Project proposal usually translates the expected impact into Project Operational Objectives adjusting them to the proposed research. We propose using Project Operational Objectives as a part of User Requirements instead of call's expected impact. Some Project Operational Objectives are addressed by project use cases. These objectives will be traced to different use case needs with use case demonstrations as their validation tests.

The case of use case users is more complex. Each use case could have very diverse users and each use case provider could have different methodology for use case implementation. We propose a two step process: first, use case providers define their use case requirements based on use case users' needs, then these requirements will be abstracted and harmonized between use cases to meet project's level of abstraction and focus. While the use case providers are encouraged to apply the best practices for use case requirements elicitation, it could be constrained by provider's company policies and practices.

In the following table we provide an initial list of needs of other stakeholders. These needs look to apply to most large research projects.

Table 1. Common stakeholders needs

Stakeholder	Need	Rationale
Technical reviewer (TR)	TR1. View collaborative executable plan TR2. View intermediate results TR3. View technical risks	Poor collaboration between partners is very common in large research projects. Intermediate results and evaluation of technical risks provide valuable feedback for project direction and required mitigation activities.
Financial reviewer (FR)	FR1. View plan vs actual effort FR2. View financial risks	Financial analysis provides important evidence of project status.
Use case technical staff (UCS)	UCS1. Quality of technical results UCS2. Usability of tools UCS3. Technical education UCS4. Technical support	Use case technical staff should apply developed technologies for their product or service instead of current / state-of-the-art technologies.
Use case manager (UCM)	UCM1. Technology cost UCM2. Technology value (improved product quality, staff productivity, reduced time to market, etc.) UCM3. Technology maintainability	Evaluation of business aspects of the new technology.
Research community (RC)	RC1. Timely research publications RC2. Open access to as much tools and data as possible	Repeatability, cross-verification, and reuse of technical results.

Industry community (IC)	IC1. Dissemination of results in all relevant industry communities IC2. Technical education	Dissemination and exploitation of technical results.
Standardization body (SB)	SB1. Contribution to relevant standards	Interoperability of technical results.

Figure 1 describes the proposed process for elicitation of Technical Requirements. The process starts with elicitation of Use Case Requirements for all project use cases based on use case scenarios and demonstrations. Next, the requirements from all use cases should be abstracted and harmonized according to project focus and required level of abstraction. Then, Project Operational Objectives should be merged with use case requirements providing core project specific User Requirements. Project Operational Objectives should be either traced to the Use Case Requirements or added to User Requirements list. Other stakeholders' needs then should be merged to provide complete list of User Requirements for the project. Based on them, Technical Requirements are defined with appropriate validation tests tracing between User and Technical Requirements.

Even with well-defined methodology for elicitation of technical requirements in product development, defining good requirements considered by many as an art. Therefore, the proposed process does not guarantee generation of good requirements, but increase its probability by taking into account needs of all project stakeholders and providing appropriate validation tests.

In the following sections we apply this methodology to CERBERO. CERBERO implementation is based on an iterative approach: Technical Requirements will be updated along the project timeframe on M14, M20, and M26. Therefore, the described process that embodies the activities of WP2 will be repeated along the time and updated in the next versions of the report.

At M9 all the different requirements coming from all project stakeholders have been identified with different levels of maturity but the process of traceability of each requirement back to Needs and the consolidation of Core user requirement is still under development and it will be fixed in the next released of this deliverable.

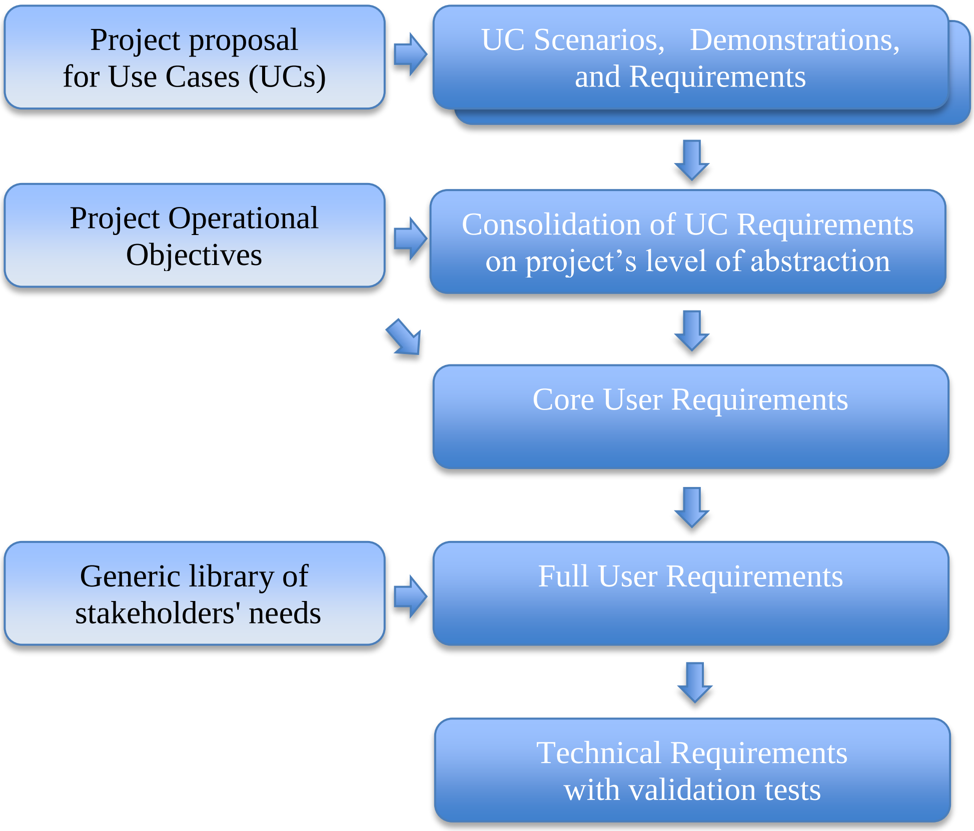

Figure 1. Technical Requirements elicitation process

3. Consolidation of CERBERO Use Case Requirements

In order to focus CERBERO effort and evaluate the proposed framework and developed tools CERBERO defined three use cases targeting development of CPS in very different levels of abstraction.

- The Space Exploration Use Case provides self-monitoring and self-healing capabilities by means of high performance sensor reconfiguring processing techniques to overcome the failures caused by the radiation or the harsh environmental conditions. In this use case CERBERO framework should open a new opportunity for hardware / software co-design of robotic arm by using commercial of-the-shelf (COTS) reconfigurable platform to address all space requirements instead of expensive specialized platforms currently used.
- The use case Smart Travelling focuses on the assistance an electric vehicle can give to the driver, when confronted with the task of driving the car from a given origin place A to a given destination B. This assistance must also assure that sufficient battery capacity is available to complete the route. Smart Travelling Use Case challenges system level design of universal simulation for complete driver experience where CERBERO framework should provide a reconfigurable solution for driver support interface for different car types, driving scenarios, drivers profile and changing physical context of both the environment and car itself integrating with existing complex simulation environment.
- The Ocean Monitoring use case comprises smart video-sensing unmanned vehicles with immersive environmental monitoring capabilities. They serve as “marine eyeballs” that can capture live videos and images of the local on-sea and subsea surroundings. Ocean Monitoring Use Case combines system and hardware / software co-design levels for development of underwater ocean monitoring robots working both in guided modes from the shore and autonomously for a large variety of monitoring and navigating tasks in changing environmental conditions.

Use cases description and the definition of Use Case Requirements took place at the project start. In the CERBERO case, it was part of T2.1 activities, reported in [D2.3]. We expect to evolve that deliverable, as well as the current one, during the prosecution of the project. The use cases have been defined based on CERBERO proposal and a preliminary version of CERBERO toolchain derived during the CERBERO Kickoff meeting [D1.1]. Based on the use cases, teams of tools and technology providers, together with use case owners, have defined specific demonstrations to evaluate the proposed technology. The next step is to consolidate detailed Use Case Requirements to categories to meet the level of abstraction of CERBERO project.

Based on the analysis of detailed requirement in [D2.3] the following Aggregated Use Case Requirements and Demonstrations have been identified.

Table 2. CERBERO Use Case Requiremenets

Use Case	Requirement	Validation demonstration
Self-Healing System for Planetary Exploration (PE)	PE1. Enable Dependable Hardware / Software (HW/SW) co-design for Rad-Hard control of robotic arm for planetary exploration. **Rationale**: reduction of energy consumption and costs, increase reuse in other projects, while keeping or improving safety level and maintenance costs.	Multi-objective Architecture design of arm and motor control unit using COTS HW and considering life-cycle costs, energy efficiency, weight, reliability, etc. Trajectory generation, motor control and status monitoring applications. Self-healing and run time adaptation features.
	PE2. Develop integrated "open" toolchain environment for development of robotic arms for space missions with focus on multi-viewpoint system-in-the-loop virtual environment. **Rationale**: multi-objective design and multi-view analysis for space mission, reduce development time by increasing the level of abstraction, increase reuse, quality and verification level.	Software and System in-the-loop simulation based on high-level applications abstractions. Interoperability between HW/SW co-design tools on different levels of abstraction
Smart Travelling for Electric Vehicles (ST)	ST1. Develop reconfigurable extendable modular simulation environment for smart travelling driver interfaces. **Rationale**: reduction of costs, increase of reuse in different simulation scenarios	Modular communication protocols and time synchronization. Logging application. Building Battery and Motor modules from generic components. Modular and extendable Driver support module. Safe, Secure, and Private Adaptive routing module with energy and cost efficiency and sensitive to drivers needs and environmental status.
	ST2. Develop integrated "open" toolchain environment for development of simulation modules and their integration with focus on modular integration with existing virtual environment. **Rationale**: reduce development, verification, and integration time and costs by a library of reusable components and metrics integrated by com-	Software in-the-loop simulation. Interoperability of System Level Design tools.

	mon framework in different levels of abstraction.	
Ocean Monitoring robot (OM)	OM1. Provide complete design cycle from system level design to HW/SW co-design and implementation of Ocean Monitoring robot using adaptable COTS HW. **Rationale**: reduction of energy consumption and costs, increase reuse in other projects, while keeping or improving safety and security level and maintenance costs.	Development of Adaptive Camera drivers and accelerators with focus on affordability, reliability reconfigurable. Multi-objective navigation and motor control modules with run time adaptation for Autopilot. Data storage according to mission needs On demand task dependent Data Fusion . Secure communication. Building Battery and Motor modules from generic components.
	OM2. Develop integrated "open" toolchain environment for development of Ocean Monitoring robots with focus on fast prototyping. **Rationale**: facilitate development cycles, reduce time to market, and increase reuse, quality and verification level by fast prototyping from high level of abstraction directly to working real time applications.	Rapid prototyping of Adaptive Camera components from high level models.

4. CERBERO User Requirements

4.1. CERBERO Challenges and Operational Objectives

CERBERO intends to propose methodologies and tools to manage the entire CPSoS lifecycle, from requirement specification to runtime management. In particular, dependable, heterogeneous, and potentially highly networked energy efficient CPSoSs are targeted. Their potential applications are extremely wide, from wearable user interfaces to satellite SoSs, connected home and surveillance systems, as well as, from augmented reality to smart robots and autonomous vehicles. Addressing such a large number of application domains by means of a common development environment is possible. Indeed, at the network level, they present similar challenges with respect to dependability and trusted data exchange; while, at the node level, systems are dominated by interconnected Multiprocessor System on Chip (MPSoC)-based processing nodes that are required to present different degrees of flexibility.

CERBERO intends to demonstrate, that it is possible to serve different scenarios leveraging on the same holistic model-based cross-optimization approach, by enabling different scenario-driven optimization objectives. In this way CERBERO addresses the three expected impacts defined by European Committee:

1. Extension of, and/or performance improvement in the supply of CPS methods and tools targeting specific industrial markets
2. Demonstrable advances in CPS engineering to reduce significantly development time and cost of ownership
3. Contributions to interoperability activities, e.g. repositories of models, interface specifications or reference architectures/platforms/patterns

Here follows the analysis of the different challenges CERBERO intends to address.

CHALLENGE 1 [CH1]: *To drastically reduce **energy consumption** and improve **safety**, **security** and system **performance**, while guaranteeing both **functional** and **non-functional requirements** by a holistic model-based and cross-layer engineering approach.* CH1 addresses extension of and performance improvement in the supply of CPS methods and tools targeting specific industrial markets.

Decisions taken at a high-level of abstraction have a great influence on the other abstraction levels, as they alter the complete system design. For example, deciding to embed a hardware (HW) implementation of an algorithm may improve the execution performance and reduce the power consumption related to this algorithm, but it also reduces the implementation flexibility if additional measures are not taken (e.g. leveraging on dynamic partial reconfiguration). In highly interconnected systems, the processing complexity of a sub-system depends also on the others it is connected to. Larger sets of functionalities may be implemented; increasing users' satisfactions, at the price of a more critical data protection and secured data exchanges. Consequently, a holistic approach, with multi-objective optimization capabilities, is required to meet all the functional and non-functional requirements and to design reliable highly interconnected CPS.

CERBERO intend to provide

- a holistic cross-layer design environment based on a ***model-based*** *development approach for CPS,* where all the functional and non-functional requirements are considered early in the design space by means of appropriate abstraction levels.

- verified library of system properties, methods, processes, and relevant environments to build CERBERO use cases systems.

The *CERBERO* ***continuous design and operational framework*** defines **interfaces** and ensures holistic design space exploration (DSE) and **cross-layer optimizations** to account for the dependences between the different CPS layers, the involved sub-systems and hybrid environment.

CHALLENGE 2 [CH2]: *To reduce* ***time-to-market****,* ***development efforts*** *and, in turn the* ***cost of ownership****, of CPS and CPSoS.* CH2 addresses Expected Impact 2 (Demonstrable advances in CPS engineering to reduce significantly development time and cost of ownership) of the call.

The continuous growth in the number of processing units in embedded processors has brought a fast increase in system processing capacity. This evolution has come at the price of an increasingly complexity of system programming. The widening "software (SW) productivity gap" between productivity and complexity reveals the need for new cross-layer design methods and tools for designing complex systems, to keep pace with the market highly evolvable needs.

The *CERBERO continuous design and operational framework* intendeds to reduce both design effort and time to market providing methods and tools for fast

- **multi-view requirements analysis**,
- **DSE for system optimization and customization**,
- **rapid prototyping**,
- **system in the loop simulation and continuous deployment**.

Exploration and optimization are performed at different levels of abstraction and we intend to convert the typical V model design approach into a Ladder model, as depicted in Figure 2, shortening design and verification efforts and offering a complete HW/SW co-design framework. The main idea is to provide a **multi-objective** and **correct-by-construction optimization of reconfigurable systems in uncertain hybrid environment**, where functional versus non-functional requirements are taken into consideration and more detailed models are generated from libraries and optimization at a higher level of abstraction.

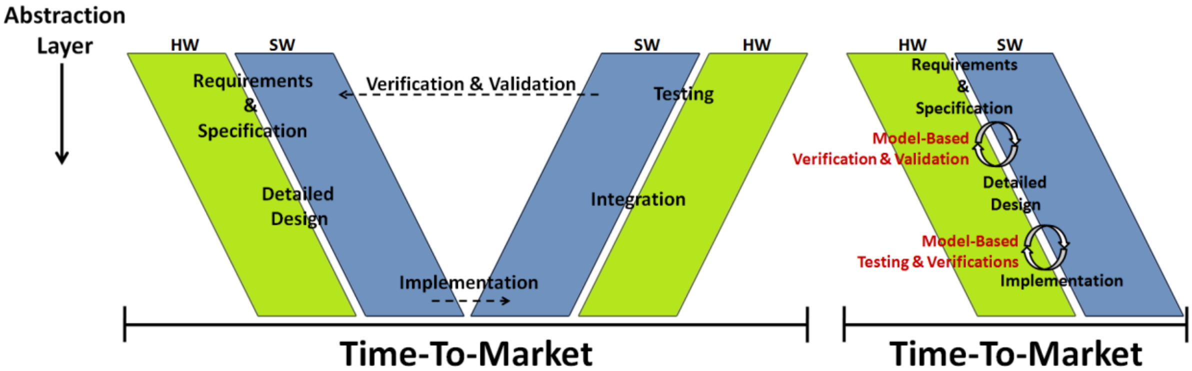

Figure 2 - CERBERO Cross-Layer Model-Based Approach to CPS and CPSoS Design

Cross-layer co-design methodologies lead directly to holistic optimized solutions considering all requirements and constraints and pruning away non-adequate solutions early in the design flow, preventing from optimizing at a low level configurations that, by construction, are not well suited to the scenario needs, cutting down unnecessary extra design effort/cost.

CHALLENGE 3 [CH3]: *To proactively contribute to* ***standardization*** *activities and* ***open-innovation*** *initiatives and to influence specific industrial standards.* CH3 is meant to address

Expected Impact 3 (Contributions to interoperability activities, e.g. repositories of models, interface specifications or reference architectures/platforms/patterns) of the call.

Standards and open-innovation activities are of paramount importance for the success and commercial exploitation of the project.

To maximize impact and acceptance of CERBERO technologies in the CPS scenario, several framework components are going to be released open source.

CERBERO challenges are mapped in the objectives reported in Table 3, extracted directly from the proposal. CEBERO success will be assessed and measured according to the strategies described in the following table that are meant to be verified on the project prototypes.

Table 3 - CERBERO Operational Objectives

	Objective	Indicator	Assessment Strategy
CH1.1	Provide reusable Libraries of Key Performance Indicators (KPIs), Cross-Layer Models and Adaptivity support.	Building use cases specific system KPIs from the generic library including non-functional KPIs, such as security and reliability.	The project is implementing a two phase development approach. Two check points for library deployment are envisioned: MS2 (Phase I deployment) and MS5 (Phase II deployment), plus related deliverables.
		Building use cases specific systems and environments from the given reusable libraries.	
CH1.2	Provide a comprehensive framework, customizable upon the UC needs, extending and making interoperable a large set of tools.	Building and assessing the CERBERO demonstrators adopting the proposed modelling, design and verification environment. Highly different scenarios have been chosen to prove the portability of the CERBERO infrastructure.	Two check points for framework delivery and evaluation are envisioned: MS3 (Phase I evaluation) and MS6 (Phase II evaluation), plus the corresponding deliverables. Framework assessment is provided mainly by WP5 deliverables; while, demonstrators performances in WP6 ones.
CH1.3	Reduce by 30% the energy consumed by a fully CERBERO compliant CPS or CPSoS, while maintaining its performance.	Building up and assessing demonstrators, by means of the CERBERO framework. Energy reduction of at least 30% should be experienced due to CERBERO model-based design methods, in at least two of the three use cases.	Prototypes will be characterized in terms of energy consumption before and after applying CERBERO cross-optimization process. Moreover, with respect to DSE a comparison between the CERBERO approach and simulation based ones is provided.
CH2.1	Reduce DSE by an order of magnitude.	Defining a valuable set of examples based on CERBERO use cases and agile implementation of required methods	Design costs will be observed and measured with and without applying the CERBERO approach. Long term maintenance costs will be estimated by accessing the benefits of incremental design and

CH2.2	Reduce by 50% the design efforts required to build a CPS of a given performance.	Building up and assessing demonstrators, by means of the CERBERO framework including libraries, building refined models from DSE in higher abstraction level and correct-by-construction design.	system in the loop simulation.
CH2.3	Reduce by 50% cost of maintenance.	Building up and assessing demonstrators, by means of the CERBERO framework. Costs of maintenance are expected to be halved, in at least two of the three use cases, due to incremental design and supported CPS adaptivity.	
CH2.4	Plan CERBERO results in at least 3 industrial products.	Definition of a concrete path to market in the CERBERO exploitation plan.	A concrete path to market for CERBERO technologies will be envisioned. The Innovation, Standardization and Exploitation plan (D8.1) and the Dissemination and Communication plan (D7.2), which preliminary version are provided in Section 2, will be updated during the entire project lifecycle. Moreover, a deliverable of WP6 (D6.6) is meant to provide the CERBERO roadmap to market.
CH3.1	Provide a fully marketable version of the CERBERO modelling and design environment.		
CH3.2	Foster Interoperability	Open source distribution of part of the CERBERO framework components.	CERBERO framework components includes the commitment of the project partners for their open source distribution.
		Proactive participation to standardization activities.	CERBERO members already participate to several standardization committees (see Section 2.1.4) and in the work plan a dedicated task, T8.3, is intended to carry out proactive standardization actions, which are part of the Innovation, Standardization and Exploitation plan (D8.1).

4.2. Mapping of CERBERO Operational Objectives to Use Case Requirements and Demonstrations

In this section we map most of CERBERO Operational Objectives to Use Case Requirements and add the rest to the core User Requirements.

Table 4 – Mapping of CERBERO Operational Objectives to Use Case Requirements

	Objective	UC Requirement Categories	Validation demonstration
CH1.1	Provide reusable Libraries of Key Performance Indicators (KPIs), Cross-Layer Models and Adaptivity support.	PE1, ST1, OM1	PE: Architecture, Run time adaptation, motor control, trajectory generation, self-healing, reliability, and dependability ST: Modular simulation with timing, energy, reliability, safety and security related KPIs OM: Energy, cost, reliability, safety and security related KPIs
		PE1, ST1, OM1	PE: Architecture, Run time adaptation, motor control, trajectory generation, self-healing ST: system-in-the-loop, battery and motor models including non-functional concerns, reliable, safe and secure driver support module OM: Components library, adaptive camera systems, secure wireless communication, and marine navigation
CH1.2	Provide a comprehensive framework, customizable upon the UC needs, extending and making interoperable a large set of tools.	PE2, ST2, OM2	PE: All ST: All OM: All

CH1.3	Reduce by 30% the energy consumed by a fully CERBERO compliant CPS or CPSoS, while maintaining its performance.	PE1, ST1, OM1	PE: Architecture, Run time adaptation, trajectory generation, motor control ST: Driver Support module, battery module, motor module, system in the loop functionality OM: Adaptive Camera systems, marine navigation, propulsion/motor control
CH2.1	Reduce DSE by an order of magnitude.	PE1, ST1, OM1 PE2, ST2, OM2	PE: Self-healing, Scalability, Architecture ST: system-in-the loop functionality, driver support OM: fast prototyping
CH2.2	Reduce by 50% the design efforts required to build a CPS of a given performance.	PE2, ST2, OM2	PE: Run time adaptation ST: All OM: sub-optimal hull, propulsion, or battery solution can lead to a deer design. For example an engine can cost \$10,000 to \$30,000, battery solution between \$3,000 to \$15,000 to gain speed and range.
CH2.3	Reduce by 50% cost of maintenance.	PE1, ST1, OM1	PE: Self-monitoring, Self-healing, Scalability ST: System in the loop, driver support OM: multi-objective design, reduced number of controllers, COTS heterogeneous multi-core HW

4.3. Full List of CERBERO User Requirements

In this section we combine unmapped Operational Objectives, Use Case Requirements and the needs of other stakeholders defined in Table 1.

1. OO1. Plan CERBERO results in at least 3 industrial products.
2. OO2. Provide a fully marketable version of the CERBERO modelling and design environment.
3. OO3. Foster Interoperability.
4. PE1. Enable Hardware / Software (HW/SW) co-design for Rad-Hard control of robotic arm for planetary exploration.

5. PE2. Develop integrated “open” toolchain environment for development of robotic arms for space missions with focus on multi-viewpoint system-in-the-loop virtual environment.
6. ST1. Develop reconfigurable extendable modular simulation environment for smart travelling driver interfaces.
7. ST2. Develop integrated “open” toolchain environment for development of simulation modules and their integration with focus on modular integration with existing virtual environment.
8. OM1. Provide complete design cycle from system level design to HW/SW co-design and implementation of Ocean Monitoring robot using adaptable COTS HW.
9. OM2. Develop integrated “open” toolchain environment for development of Ocean Monitoring robots with focus on fast prototyping.
10. TR1. View collaborative executable plan.
11. TR2. View intermediate results.
12. TR3. View technical risks.
13. FR1. View plan vs actual effort.
14. FR2. View financial risks.
15. UCS1. Quality of technical results
16. UCS2. Usability of tools
17. UCS3. Technical education
18. UCS4. Technical support
19. UCM1. Technology cost
20. UCM2. Technology value (improved product quality, staff productivity, reduced time to market, etc.)
21. UCM3. Technology maintainability
22. RC1. Timely research publications
23. RC2. Open access to as much tools and data as possible
24. IC1. Dissemination of results in all relevant industry communities
25. IC2. Technical education
26. SB1. Contribution to relevant standards

5. CERBERO Technical Requirements

5.1. Technical Requirements

In this section we define CERBERO technical requirements and verify their sufficiency in the next section. When the phrases MUST, MUST NOT, REQUIRED, SHALL, SHALL NOT, SHOULD, SHOULD NOT, RECOMMENDED, MAY, or OPTIONAL are being used, these have the following meaning and interpretations:

- MUST, REQUIRED, SHALL - means an absolute requirement for the specification.
- MUST NOT, SHALL NOT - means an absolute prohibition for the specification.
- SHOULD, RECOMMENDED - valid reasons may exist in certain cases to avoid the requirement. However, its full implication must be have been understood and carefully considered before choosing an alternative direction/ option.
- SHOULD NOT, NOT RECOMMENDED - valid reasons may exist when the requirement could be acceptable or even useful. However, its full implications should have been carefully considered understood and prior to implementing anything in breach of this.
- MAY, OPTIONAL - simply means that the requirement is truly optional, nice to have. An implementation that does not fulfil an optional requirement MUST be prepared to function together with another implementation that fulfils/implements this option, and vice versa.

CERBERO-0001. CERBERO framework SHOULD increase the level of abstraction at least by one for HW/SW co-design and for System Level Design. **CERBERO-0002.** CERBERO framework SHOULD provide interoperability between cross-layer tools and semantics at the same level of abstraction. **CERBERO-0003.** CERBERO framework SHOULD provide fast prototyping capabilities for HW/SW co-design. **CERBERO-0004.** CERBERO framework SHOULD provide software and system in-the-loop simulation capabilities for HW/SW co-design and System Level Design. **CERBERO-0005.** CERBERO framework SHOULD provide multi-viewpoint multi-objective correct-by-construction high-level architecture. **CERBERO-0006.** CERBERO framework SHOULD ensure energy efficient and dependable HW/SW co-design using cross-layer run time adaptation of reconfigurable HW. **CERBERO-0007.** CERBERO framework SHALL define methodology and SHOULD provide library of reusable functional and non-functional KPIs. **CERBERO-0008.** CERBERO framework SHALL define methodology and SHOULD provide library of reusable energy related components.
CERBERO-0009. CERBERO SHALL develop integration methodology and framework.
CERBERO-0010. CERBERO SHALL provide Open Data Management Plan
CERBERO-0011. CERBERO SHALL have Dissemination and Exploitation Plans • in relevant industry communities • for technical education

• for standardization effort
CERBERO-0012. CERBERO Exploitation Plan SHALL • consider at least 3 industrial products, • have a business model for the integration methodology and framework.
CERBERO-0013. All CERBERO API and most of CERBERO tools SHALL have open source licence.
CERBERO-0014. CERBERO WP and task leaders SHALL organize scheduled face to face and remote meetings.
CERBERO-0015. CERBERO SHALL provide review reports including • intermediate results, • technical risks evaluation, • plan vs actual effort, • financial risks evaluation.
CERBERO-0016. CERBERO tools SHOULD be tested vs state-of-the-art
CERBERO-0017. CERBERO Use Case providers SHOULD check and provide timely feedback on the usability of CERBERO tools and framework.
CERBERO technology providers SHALL prepare face to face or online tutorials / education for use case engineers.
CERBERO-0018. CERBERO technology providers SHALL coordinate technical support for their tools with use case engineers.

5.2. Validation of User Requirements

The following table validates sufficiency of Technical Requirements described above.

Table 5. Mapping User Requirements to Technical Requirements and Validation Tests

User Requirement	Technical Requirement(s)	Validation Test
OO1. Plan CERBERO results in at least 3 industrial products.	Exploitation Plan MUST consider at least 3 industrial products.	Exploitation Report meets Plan for CERBERO contribution to at least 3 industrial products.
OO2. Provide a fully marketable version of the CERBERO modelling and design environment.	Exploitation Plan SHALL have a business model for the integration methodology and framework.	Exploitation Report meets Plan for the integration methodology and framework.
OO3. Foster Interoperability.	CERBERO SHALL provide all API and most of tools with open source license. CERBERO SHALL develop integration methodology and framework.	Demos with multiple tools, both cross-layer and from different levels of abstraction (All, especially, OM).

PE1. Enable Hardware / Software (HW/SW) co-design for Rad-Hard control of robotic arm for planetary exploration using adaptable COTS HW.	CERBERO framework SHOULD provide multi-viewpoint multi-objective correct-by-construction high-level architecture. CERBERO framework SHOULD ensure energy efficient and dependable HW/SW co-design using cross-layer run time adaptation of reconfigurable HW. CERBERO framework SHALL define methodology and SHOULD provide library of reusable functional and non-functional KPIs. CERBERO framework SHALL define methodology and SHOULD provide library of reusable energy related components.	PE demonstrations
PE2. Develop integrated "open" toolchain environment for development of robotic arms for space missions with focus on multi-viewpoint system-in-the-loop virtual environment.	CERBERO framework SHOULD increase the level of abstraction at least by one for HW/SW co-design and for System Level Design. CERBERO framework SHOULD provide interoperability between cross-layer tools and semantics at the same level of abstraction. CERBERO framework SHOULD provide software and system in-the-loop simulation capabilities for HW/SW co-design.	PE demonstrations
ST1. Develop reconfigurable extendable modular simulation environment for smart travelling driver interfaces.	CERBERO framework SHOULD provide multi-viewpoint multi-objective correct-by-construction high-level architecture. CERBERO framework SHALL define methodology and SHOULD provide library of reusable functional and non-functional KPIs. CERBERO framework SHALL define methodology and SHOULD provide library of reusable energy related components.	ST demonstrations
ST2. Develop integrated "open" toolchain environment for development of simulation modules and their integration with focus on modular integration	CERBERO framework SHOULD provide interoperability between cross-layer tools and semantics at the same level of abstraction. CERBERO framework SHOULD provide software and system in-the-	ST demonstrations

with existing virtual environment.	loop simulation capabilities for System Level Design.	
OM1. Provide complete design cycle from system level design to HW/SW co-design and implementation of Ocean Monitoring robot using adaptable COTS HW.	CERBERO framework SHOULD provide multi-viewpoint multi-objective correct-by-construction high-level architecture. CERBERO framework SHOULD ensure energy efficient and dependable HW/SW co-design using cross-layer run time adaptation of reconfigurable HW.	OM demonstrations
OM2. Develop integrated "open" toolchain environment for development of Ocean Monitoring robots with focus on fast prototyping.	CERBERO framework SHOULD increase the level of abstraction at least by one for HW/SW co-design and for System Level Design. CERBERO framework SHOULD provide interoperability between cross-layer tools and semantics at the same level of abstraction. CERBERO framework SHOULD provide fast prototyping capabilities for HW/SW co-design. CERBERO framework SHALL define methodology and SHOULD provide library of reusable functional and non-functional KPIs. CERBERO framework SHALL define methodology and SHOULD provide library of reusable energy related components.	OM demonstrations
TR1. View collaborative executable plan.	CERBERO WP and task leaders SHALL organize scheduled face to face and remote meetings.	Review reports with scheduled face to face and remote meetings.
TR2. View intermediate results.	CERBERO SHALL provide review reports with intermediate results	Periodic review and demos at GA meetings
TR3. View technical risks.	CERBERO SHALL provide periodic reports with technical risks evaluation	Periodic status meetings / calls with agenda and minutes
FR1. View plan vs actual effort.	CERBERO SHALL provide review reports with plan vs actual effort.	Periodic review
FR2. View financial risks.	CERBERO SHALL provide periodic reports with financial risks evaluation.	Periodic review
UCS1. Quality of technical results	CERBERO tools SHOULD be tested vs state-of-the-art.	Peer reviewed publications
UCS2. Usability of tools	CERBERO Use Case providers SHOULD check and provide timely	Periodic report and questionnaires

	feedback on the usability of CERBERO tools and framework.	
UCS3. Technical education	CERBERO technology providers SHALL prepare face to face or online tutorials / education for use case engineers.	Tool's usage in use case
UCS4. Technical support	CERBERO technology providers SHALL coordinate technical support for their tools with use case engineers.	Tool's usage in use case
UCM1. Technology cost	All CERBERO API and most of CERBERO tools SHALL have open source licence.	All API and at least 80% of tools have open source licence.
UCM2. Technology value (improved product quality, staff productivity, reduced time to market, etc.)	CERBERO framework SHOULD increase the level of abstraction at least by one for HW/SW co-design and for System Level Design. CERBERO framework SHOULD provide interoperability between cross-layer tools and semantics at the same level of abstraction. CERBERO framework SHOULD provide fast prototyping capabilities for HW/SW co-design. CERBERO framework SHOULD provide software and system in-the-loop simulation capabilities for HW/SW co-design and System Level Design. CERBERO framework SHOULD provide multi-viewpoint multi-objective correct-by-construction high-level architecture. CERBERO framework SHOULD ensure energy efficient and dependable HW/SW co-design using cross-layer run time adaptation of reconfigurable HW. CERBERO framework SHALL define methodology and SHOULD provide library of reusable functional and non-functional KPIs. CERBERO framework SHALL define methodology and SHOULD provide library of reusable energy related components.	Business value of all demonstration in all use cases
UCM3. Technology	Exploitation Plan SHALL have a	Exploitation Report

maintainability	business model for the integration methodology and framework.	meets Plan for the integration methodology and framework.
RC1. Timely research publications	Dissemination Plan.	Dissemination Report meets Plan
RC2. Open access to as much tools and data as possible	All CERBERO API and most of CERBERO tools SHALL have open source licence. Open Data Management Plan	All API and at least 80% of tools have open source licence. Open Data storage is established according to the plan.
IC1. Dissemination of results in all relevant industry communities	CERBERO MUST have Dissemination and Exploitation Plans in relevant industry communities	Dissemination and Exploitation Reports meet Plans in relevant industry communities
IC2. Technical education	CERBERO MUST have Dissemination and Exploitation Plans for technical education	Dissemination and Exploitation Reports meet Plans standardization effort
SB1. Contribution to relevant standards	CERBERO MUST have Dissemination and Exploitation Plans for standardization effort	Dissemination and Exploitation Reports meet Plans standardization effort

Based on the technical requirements and demonstrations, tools and technology providers will perform gap analysis and define activities in technical workpackages to fill the gaps of the framework components (which can be enhanced available tools or new components), integration framework itself, and required model transformations between tools.

6. Appendix A. Self-Healing System for Planetary Exploration

6.1. Use Case Demonstrations

Table 2. Traceability from Demonstrations to User Requirements (Table per Use Case)

Self-Healing System for Planetary Exploration			
Demonstration	**User Requirement**	**How**	**Success Criteria**
#1 – Robotic arm	TASE-004,TASE-009, TASE-010	Soft-error-mitigation IP will be used for fault injection	Functional interrupt
	TASE-005	Performance, energy, efficiency, failures scenarios.	Successful adaptation
	TASE-007	A set of trajectories scenarios will be tested.	Trajectory
#2 – Motor control	TASE-014,TASE-018, TASE-019	Soft-error-mitigation IP will be used for fault injection	Functional interrupt
	TASE-015	Performance, energy, efficiency, failures scenarios.	Successful adaptation
	TASE-017	Speed control	Speed regulation

6.2. Potential tools participation

Table 3. Traceability from Demonstrations to Participating Tools/Technologies (Table per Use Case)

Self-Healing System for Planetary Exploration				
Demonstration	**Tool / Technology / Framework**	**Requirements Addressed**	**Coverage**	**How participates in demonstration, including interaction with other tools**

#1 Robotic arm	ARTICo3	TASE-002,TASE-004, TASE-005, TASE-007, TASE-009, TASE-010		Fault tolerance and partial reconfiguration features will be introduced by ARTICo3
	PAPIFY/PAPIFY VIEWER	TASE-003, TASE-005, TASE-009		In order to decide to distribute processing of simulation modules (given the current and required load), the PAPIFY/PAPIFY VIEWER could be used to modify the processing configuration.
	PREESM	TASE-003, TASE-005, TASE-009		Automated mapping of computational tasks (actors) to multiple processing cores
	Spider	TASE-003, TASE-005, TASE-009		Spider performs the mapping of a real-time application at run-time and adaptively depending on application parameters and available cores
	MDC	TASE-003, TASE-005, TASE-009		Automatic deployment of Coarse-Grained Reconfigurable accelerators.
#2 Motor control	ARTICo3	TASE-012,TASE-014, TASE-015, TASE-017, TASE-018, TASE-019		Fault tolerance and partial reconfiguration features will be introduced by ARTICo3
	PAPIFY/PAPIFY VIEWER	TASE-013, TASE-015, TASE-018		In order to decide to distribute processing of simulation modules (given the current and required load), the PAPIFY/PAPIFY VIEWER could be used to modify the processing configuration.
	PREESM	TASE-013, TASE-015, TASE-018		Automated mapping of computational tasks (actors) to multiple processing cores
	Spider	TASE-013, TASE-015, TASE-018		Spider performs the mapping of a real-time application at run-time and adaptively depending

				on application parameters and available cores
	MDC	TASE-013, TASE-015, TASE-018		Automatic deployment of Coarse-Grained Reconfigurable accelerators.

6.3.Toolchain Integration and Framework Specification

The used tools are integrated is such a way that:

- PAPIFY will monitor the behavior of ARTICo3
- External constraints will be introduced in ARTICo3 and/or PAPIFY
- PAPIFY will provide real-time fault statistics
- PREESM, SPIDER & MDC will be integrated in order to provide runtime adaptation and Coarse-Grained Reconfigurable accelerators.
- Logging of the different tools can be integrated in order to perform analysis.

7. Appendix B. Smart Travelling for Electric Vehicles

7.1. Use Case Demonstrations

Table 2. Traceability from Demonstrations to User Requirements (Table per Use Case)

Smart Travelling				
Demonstration	**User Requirement**	**How**	**Success Criteria**	**Comments**
#1 – EV simulation	TNO-001, TNO-011, TNO-012, TNO-017, TNO-018, TNO-019, TNO-023, TNO-DynAA-032, TNO-DynAA-033	New simulation modules (like the EV battery and motor models) are to be integrated in the SCANR based simulation.	EV can be simulated, using EV models provided by TNO.	
	TNO-006, TNO-011, TNO-019	Correct model of the battery will enable precise simulation for battery status.	Able to perform simulations which can possibly be compared to real life sample data.	Complete validation of model is outside the scope of the project.
	TNO-006, TNO-012, TNO-023	Correct model of electric motor will enable a precise calculation for energy consumption.	Able to perform simulations which can possibly be compared to real life sample data.	Complete validation of model is outside the scope of the project.
#2 – Route advice	TNO-006, TNO-011, TNO-019	Correct model of the battery will enable precise calculation for battery status, required to perform a specific	Able to perform simulations which can possibly be compared to real life	Complete validation of model is outside the scope of the project.

		route, to be used for prediction.	sample data.	
	TNO-006, TNO-012, TNO-023	Correct model of electric motor will enable a precise calculation for energy consumption, required to perform a specific route, to be used for prediction.	Able to perform simulations which can possibly be compared to real life sample data.	Complete validation of model is outside the scope of the project.
	TNO-029, TNO-031, TNO-DynAA-034	Calculate and present best advice (optimal route) to driver during trip.	Advice can be presented to driver within acceptable time frame (e.g. few minutes).	It is difficult to fully validate reasoning and complete validation is outside scope of project. Steps should be logged and process can be validated after tests.

7.1.1. Demonstration 1: EV simulation using external modules

In this demonstration the following scenarios will be used:

- Highway route re-planned
- Up-hill trip
- Emergency call
- Unexpected congestion

This demonstration focuses on the simulation and not on possibility to make predictions needed for re-routing. For the predictions the demonstration 2 will be used.

7.1.2. Demonstration 2: Route advice for EV using predictions

In this demonstration the following scenarios will be used:

- Highway route re-planned
- Emergency call
- Unexpected congestion

In this demonstration (which partly shares functionalities of demonstration 1) the focus is on the adaptation of route based on predictions.

7.2.Potential tools participation

Table 3. Traceability from Demonstrations to Participating Tools/Technologies (Table per Use Case)

Smart Travelling				
Demonstration	**Tool / Technology / Framework**	**Requirements Addressed**	**Degree of Coverage**	**How participates in demonstration, including interaction with other tools**
#1 – EV simulation	DynAA	TNO-001, TNO-002, TNO-003, TNO-004, TNO-005, TNO-009, TNO-011, TNO-012, TNO-013, TNO-019, TNO-DynAA-033, TNO-DynAA-034		DynAA is used as system in the loop to support the execution of EV simulation modules.
	SCANR	TNO-013, TNO-011, TNO-019, TNO-012, TNO-023, TNO-028		SCANR is used to simulate the car behavior and the environment, using physical interfaces, simulation modules and DynAA as system in the loop.
#2 – Route advice	DynAA	TNO-011, TNO-019, TNO-012, TNO-023, TNO-027, TNO-030, TNO-031, TNO-032-DynAA, TNO-033-DynAA, TNO-034-DynAA		DynAA (run as system in the loop) will be used to run additional simulation to be used for route related predictions
	SCANR	TNO-013, TNO-011, TNO-019, TNO-012, TNO-023, TNO-028		SCANR is used to simulate the car behavior and the environment, using simulation modules, and the DynAA and the S&T decision support tool as systems in the loop.
	S&T decision support	TNO-028, TNO-031		S&T decision support tool is run as system in the loop with SCANR and DynAA.
	AOW	TNO-028, TNO-029, TNO-030		Calculate optimal routes (based on criteria like time and distance)
	PAPIFY/PAPIFY VIEWER	TNO-001, TNO-006		In order to decide to distribute processing of simulation modules (given the current and required load), the PAPIFY/PAPIFY VIEWER could be used to modify the processing configu-

				ration.

7.3.Toolchain Integration and Framework Specification

The tools used in Demonstration 1 are integrated is such a way that:

- Time is synchronised between the tools and used simulation modules;
- External simulation modules can receive required input from SCANR simulation;
- External simulation modules can provide output towards SCAN simulation;
- Combined simulations provide real time simulation and behavior;
- Logging of the different tools can be integrated in order to perform analysis.

The tools used in Demonstration 2 are integrated is such a way that:

- SCANR simulations can request advice on routes at S&T tool;
- SCANR will provide S&T tool with information on car (e.g. status), position (GPS), route data (maps) and available data on the user/driver;
- S&T tool can request DynAA to calculate impact of alternative routes;
- Prediction modules can receive position, route to calculate and optionally driver information from S&T tool (or directly from SCANR simulator);
- Prediction simulation modules can provide output towards S&T tool;
- The S&T tool can provide advice towards driver in SCANR simulation;
- The S&T tool or DynAA could initiate AOW to perform route calculatiosn;
- Logging of the different tools can be integrated in order to perform analysis.

8. Appendix C. Ocean Monitoring

8.1. Use Case Demonstrations

Table 2. Traceability from Demonstrations to User Requirements (Table per Use Case)

Ocean Monitoring			
Demonstration	**User Requirement**	**How**	**Success Criteria**
#1 – 360 degree video from the subsea prototype camera system	AS-MONITORING-SUBSEA-CAMERA-SYSTEM-04: Underwater camera system	The prototype will comprise of an underwater camera system that cover a wide angle or 360 degrees camera view. The camera system will be used to record videos of the underwater environment.	The user can visually monitor the subsea environment by watching underwater videos recorded by the prototype.
	AS-MONITORING-SUBSEA-RUGGEDIZED-01: Ruggedized, waterproof, and airtight	The underwater prototype must be a ruggedized, waterproof, and airtight part for vehicle capable of withstanding harsh marine conditions including resistance to water pressure to ensure operations.	The prototype isable to withstand harsh marine environmental conditions without leaking water or air.
	AS-MONITORING-SURFACE-SPHERICAL-05: 360 degrees surface camera	The use of the 360 degree camera is will also be used for surface monitoring. The spherical camera provides a natural immersive way of monitoring the surroundings of the marine robot. The 360 degree camera can be also used for easy remote navigation.	The user is presented with 360 degrees view of the environment around the prototype.
#2 – Augmentation of un-	AS-MONITORING-SURFACE-	The camera system may optionally augment the	The recorded videos are augmented with

derwater video with edge enhancement techniques by means of information fusion	AUGMENTED-REALITY-04: Augmented reality	videos by highlighting and tracking moving objects, and enhancing the edges. This can help reduce the information overload for obstacle detection, and focus the user's attention to enhance the ocean monitoring experience.	highlighted moving objects and enhanced edges.
	AS-ADAPTIVE-CAMERA-ADDITIONAL-FEATURES-04: Optional context for the adaptive camera system	The prototype system enhances videos and images by: i) edge detection and ii) edge enhancement. This will enhance user's perception of the surroundings and thus his/her ocean monitoring experience.	The user can turn on/ off edge detection and edge enhancement methods respectively, and see the resulting changes in the videos streams when doing so.
	AS-ADAPTIVE-CAMERA-IMMERSION-05: Adaptive camera system providing immersive experience for the user	The prototype will provide 360 degrees/ panoramic images e.g. by utilizing the camera geometry, or by other means of fusing them together. These videos/ images are best viewed within VR goggles to allow the user to monitor the environment in an immersive way.	The user can inspect the 360 degree videos by using VR goggles for more immersive experience.

8.1.1. Demonstration 1: The 360 degrees video from the subsea prototype camera system

The first prototype of the subsea camera system will allow us to record a 360 degrees underwater spherical video that can be optionally watched in the virtual reality googles for enhanced immersive experience. The following requirements will be addressed by this demo:

- AS-MONITORING-SUBSEA-CAMERA-SYSTEM-04: Underwater camera system

- AS-MONITORING-SUBSEA-RUGGEDIZED-01: Ruggedized, water-proof, and airtight
- AS-MONITORING-SURFACE-SPHERICAL-05: 360 degrees surface camera

The requirements are presented below to indicate and contextualise the demo:

Req ID:	AS-MONITORING-SUBSEA-CAMERA-SYSTEM-04
Short name:	Underwater camera system
Aspect:	Composability
Category:	Sensors, actuators
Priority:	1
Use case / scenario:	Ocean monitoring – subsea
Description:	The underwater robot must comprise an underwater camera system that optionally may have multiple lenses to cover a wide angle or 360 degrees camera view. The camera system will be used for real-time subsea monitoring and will also take pictures and record videos of the underwater environment.
Verification:	The user can visually monitor the subsea environment and the camera system can take underwater pictures and record videos
Conflicts:	N/A
Additional info:	360 degrees underwater cameras: http://www.threesixtycameras.com/waterproof-360-cameras/ Underwater camera robot for farming and fishing: https://www.alibaba.com/product-detail/underwater-rov-robot-camera-for-sea_60599969080.html Deep Trekker with 330 degree field of view: https://www.deeptrekker.com/dtg2/

Version:	1.0

Req ID:	AS-MONITORING-SUBSEA-RUGGEDIZED-01
Short name:	Ruggedized, waterproof, and airtight
Aspect:	Composability
Category:	Mechanical/ physical design
Priority:	1
Use case / scenario:	Ocean monitoring - subsea
Description:	The underwater robot must be a ruggedized, waterproof, and airtight vehicle capable of withstanding harsh marine conditions including resistance to water pressure to ensure operations, and may optionally be able to propel itself.
Verification:	The robot is able to withstand harsh marine environmental conditions
Conflicts:	N/A
Additional info:	Ruggedized waterproof cameras: https://www.ephotozine.com/article/top-10-best-waterproof-tough-cameras-2017-17302
Version:	1.0

Req ID:	AS-MONITORING-SURFACE-SPHERICAL-05
Short name:	360 degrees surface camera
Aspect:	Composability
Category:	Actuators, Sensors

Priority:	1
Use case / scenario:	Ocean monitoring - surface
Description:	The use of the 360 degrees camera is recommended for the surface monitoring and navigation. The spherical camera provides a natural immersive way of ocean environment monitoring around the marine robot. The 360 degrees camera can be also used for easy remote navigation.
Verification:	The user is presented with 360 degrees view of the surface environment around the marine robot
Conflicts:	N/A
Additional info:	Best 360 degrees cameras: http://www.pocket-lint.com/news/137301-best-360-cameras-the-best-vr-and-360-video-cameras-no-matter-your-budget The navy and 360 degrees cameras: http://www.militaryaerospace.com/articles/2014/06/shipboard-persistent-surveillance.html
Version:	1.0

8.1.2. Demonstration 2: Augmentation of underwater video with edge enhancement techniques by means of information fusion

The underwater video recorded by the first subsea 360 degree camera prototype will be fused with the video consisting of edges detected by our fast and effective edge detector. The result of this fusion will be the augmentation of edges in the original video. This augmentation will enhance the perceptual capabilities of the marine robot's operator. The augmented underwater video can be optionally watched in the virtual reality googles for enhanced immersive experience.

The following requirements will be addressed by this demo:

- AS-MONITORING-SURFACE-AUGMENTED-REALITY-04
- AS-ADAPTIVE-CAMERA-ADDITIONAL-FEATURES-04
- AS-ADAPTIVE-CAMERA-IMMERSION-05

The requirements are presented below to indicate and contextualise the demo:

Req ID:	AS-MONITORING-SURFACE-AUGMENTED-REALITY-04
Short name:	Augmented reality
Aspect:	Functional
Category:	Computation
Priority:	1
Use case / scenario:	Ocean monitoring - surface
Description:	The camera system may optionally augment the videos by highlighting and tracking moving objects, and enhancing the edges. This can help reduce the information overload and focus the user's attention to enhance the ocean monitoring experience.
Verification:	The real-time video is augmented with highlighted moving objects and enhanced edges
Conflicts:	N/A
Additional info:	Image data preparation for intelligent security systems - edge enhancement for improved object tracking: http://ieeexplore.ieee.org/document/4736687/ Real time edge detection based motion tracking: http://www.comm.utoronto.ca/~dkundur/course_info/real-time-DSP/implementation/Demo_Vid_Edge_Motion_Track.pdf Real time object tracking and edge detection for augmented reality: https://ai2-s2-pdfs.s3.amazonaws.com/07d5/c7a69e91c6fad4b8f6d82b8275fd21946fe3.pdf
Version:	1.0

Req ID:	AS-ADAPTIVE-CAMERA-ADDITIONAL-FEATURES-04
Short name:	Optional context for the adaptive camera system
Aspect:	Functional
Category:	System task
Priority:	2, 3
Use case / scenario:	Adaptive camera system
Description:	It is recommended for the adaptive camera system to be able to adjust and enhance the videos and images from multiple cameras or lenses by: ● Real-time edge detection and edge enhancement ● Object detection and tracking ● Foreground and background detection ● Foreground enhancement ● Depth perception ● Image stabilisation All the aforementioned tasks can significantly benefit from the multi-lense/multi-camera system design. Moreover, the additional functionalities can greatly enhance user's perception of the surroundings and his/her ocean monitoring experience.
Verification:	The additional optional context can be requested by the user
Conflicts:	N/A
Additional info:	3D reconstruction from multi-camera: http://www-hagen.cs.uni-kl.de/wp-content/uploads/publication/791.pdf Multi-camera tracking: http://imagelab.ing.unimore.it/imagelab2015/pubblicazioni/avss2005_calderara.pdf Multi-camera system for depth estimation: https://www.osapublishing.org/abstract.cfm?uri=isa-2015-IT3A.2

Version:	1.0

Req ID:	AS-ADAPTIVE-CAMERA-IMMERSION-05
Short name:	Adaptive camera system providing immersive experience for the user
Aspect:	User
Category:	Human Factors; Look and Feel
Priority:	2, 3
Use case / scenario:	Adaptive camera system
Description:	It is recommended for the adaptive camera system to be able to provide immersive videos and images to the user by means of: ● Stereoscopic images ● 360 degrees spherical/ panoramic images and videos ● Virtual reality (VR) goggles The 360 degrees/panoramic images can be produced from the images taken by the multi-camera/multi-lense system by fusing them together, or utilizing the camera geometry. In the case of 360 degrees images, the additional immersion and enhanced ocean monitoring capabilities can be provided by the use of Virtual Reality (VR) goggles. The VR goggles will allow the user to monitor the ocean environment in a natural way in real time as well as view the previously taken images/videos in VR.
Verification:	The camera system creates the 360/wide angle images and videos and the user may optionally use VR goggles for even more immersive experience
Conflicts:	N/A
Additional info:	Camera array for wide angle pictures: http://www.isprs.org/proceedings/XXXV/congress/comm1/papers/90.pdf

	Using VR glasses with a drone: http://www.dreamflights.pro/how.html
Version:	1.0

8.2. Potential tools participation

Table 3. Traceability from Demonstrations to Participating Tools/Technologies (Table per Use Case)

Ocean Monitoring					
Demonstration	**Tool / Technology / Framework**	**Requirements Addressed**	**Degree of Coverage**	**How participates in demonstration, including interaction with other tools**	**Comments**
#1 – 360 degree video from the sub-sea prototype camera system	ARTOCo3	▶ AS-ADAPTIVE-CAMERA-02: Adaptive camera ▶ AS-ADAPTIVE-CAMERA-ADAPTIVITY-03: Adaptivity of the camera system ▶ AS-ADAPTIVE-CAMERA-ADDITIONAL-FEATURES-04: Optional context for the adaptive camera system		ARTICo[3] can provide different levels of computing performance and energy consumption for hardware-based implementations of computer-vision algorithms. For instance, in-node processing can provide a desired video quality at the same time as extending battery life.	If an array of cameras is used

#2 – Augmentation of underwater video with edge enhancement techniques by means of information fusion	PREESM	▶ AS-ADAPTIVE-CAMERA-IMMERSION-05: Adaptive camera system providing immersive experience for the user ▶ AS-ADAPTIVE-CAMERA-IMAGE-TRANSMISSION-06: Transmission of images and videos from the camera system		Can be used to model and prototype video compression quality with respect to an array of HD cameras in use at the same time. Output: System Simulation, predicted values for optimization of an adaptive camera system.	If an array of cameras is used
	PAPIFY	▶ AS-STORAGE-FACILITY-01: Storage facility for marine robot ▶ AS-STORAGE-MULTI-CORE-02: Multi-core processors for parallel data transfer ▶ AS-STORAGE-TOPOLOGY-03: Data		Can help decide the desired video compression settings of an adaptive camera system, given it’s available processing and energy capabilities. Output: System performance monitoring.	Porting may be needed.

		communica-tion topologies			

Multitude of requirements of the ocean monitoring use case on battery and motor needs that can be addressed and researched by means of simulation and optimisation. These requirements seem also related to the smart travel use case. Thus, the creation of joint simulations and optimisation models within both the DYNAA and AOW tools would be able to address common aspects and concerns for both use cases, on the following topics:

- **Motor capabilities** – to model and predict the driving range of the vehicles or vessels depending on the energy available. For instance, the electrical engine's Rotation Per Minutes (RPM), e.g. high vs. low, and using a gearbox versus a single direct drive, does affect the overall driving range. The ideal objective would be to analyse, given a small set of motor models, which RPM levels that will gain maximum driving range.
- **Battery capabilities** – to model the battery capabilities of a chosen set of battery cells, without having to purchase several full-sized battery solutions to evaluate and find out. Research on obtaining flexible, reconfigurable battery topologies with DYNAA and AOW would also be beneficial to allow for electric motors to be upgraded/ replaced without having to purchase or rewire new battery solutions.
- **Routing/ navigation aspects** – to calculate and optimise paths for navigation, e.g. for autopilot or driver assistance.

9. References

[CERBERO 2017]	http://www.cerbero-h2020.eu
[D1.1]	CERBERO_D1 1_KoMprogress_UniSS_FF1_20170512.docx
[D1.6]	CERBERO_D1.6_Open_Data_Management_Plan_TNO_FF1_20171009.docx
[D2.3]	CERBERO_D2.3_ScenariosDescription_TASE_FF1_20171009.docx
[D7.7]	CERBERO_D7.5_DisseminationPlan_USI_FF1_20171009
[D8.3]	CERBERO_D8.3_InnovationStandardisationExploitationPlan_AI_FF1_20171009
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