marinerg-i

Marine Renewable Energy Infrastructure

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Preliminary Science Plan

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Abbreviations

DRI	Distributed Research Infrastructure

ORE	Offshore Renewable Energy
TRL	Technology readiness Level

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1. Introduction

The objective of MARINERG-i is to become the leading internationally Distributed Research Infrastructure (DRI) in the Offshore Renewable Energy (ORE) sector. Its integrated nature and coordinated approach will accelerate the research development and deployment of wave, tidal, offshore wind and combined energy technologies and help maintain Europe as a global leader in this emerging and constantly evolving industry. In addition, MARINERG-i will strengthen European, scientific and engineering excellence and expertise as its combined facilities represent an indispensable tool to foster innovation across a large variety of ORE technologies and systems and through all key stages of Technology Readiness Levels (TRL's 1-9).

The purpose of this Science Plan is to support the 2019 MARINERG-i bid to be placed on the ESFRI roadmap in 2020. The content provides the rationale for a Pan-European DRI that is best suited to support the development of ORE at European and global levels, responding to the present and future requirements of the users and developers.

The Science Plan also aims at providing a prioritized research agenda, aligned to long-term strategy documents such as the SET-Plan and the Ocean Energy (OE) Roadmap. It considers fundamental science in key research disciplines with the objective of reducing uncertainties and improving the reliability and survivability of ORE systems. It also addresses applied science and engineering testing, responding to the requirements of the industry involved in ORE development.

The Science Plan proposes a forward-moving approach considering all TRLs and benefitting from the experience of Research Infrastructures (RIs) to identify challenges and gaps as well as developing new ideas. This experience also provides a good support for the identification and selection of the most relevant and most promising projects.

As illustrated in Figure 1, the preliminary Science Plan reflects the outcome from the initial development phase of the project which, through subsequent iterations, will become one of the main elements of the MARINERG-i ESFRI proposal. This preliminary version presents an outline of the main elements to be addressed through the iterative process described in section 2. These elements include the definition of the research community potentially involved in the scientific activity; the selection of the testing facilities constituting the DRI; the definition of the fundamental and applied science programs; the objectives and methodologies to be implemented so as to develop common standards and best practices for testing; the procedures to be developed for selecting and accompanying the projects; and finally the organisation of the data management structure.

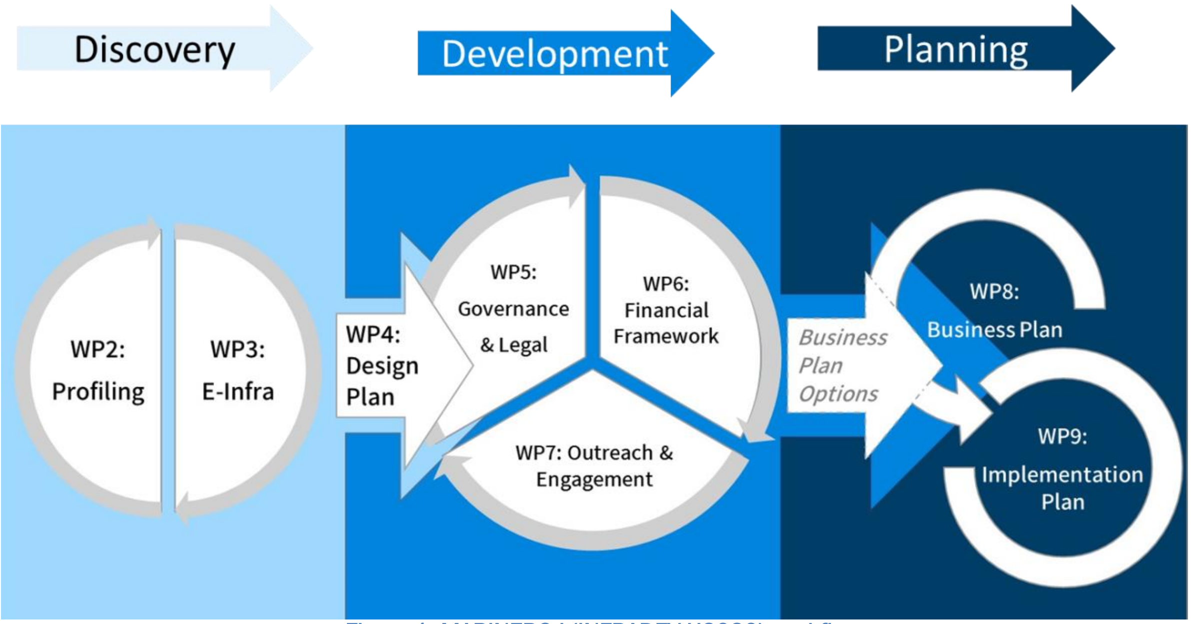

Figure 1: MARINERG-i (INFRADEV H2020) workflow

2. Methodology

The methodology developed for elaborating the MARINERG-i science plan is based on an iterative, collaborative and consensual approach. This aims to balance the interests, requirements and priorities at the national level in each of the partner's country with the necessity to adjust to the actual demand from both the industry and the research community.

This preliminary science plan builds on the evidence and cross-analysis produced by other Work Packages (WP) and elaborated during the discovery phase. This includes the end-users' requirements and RI and e-Infrastructures profiling conducted as part of WP2 and WP3 [1], [2], [3], [4]. It also considers the stakeholders' identification (WP7) [5] and elements taken from the elaboration of the legal and financial frameworks (WP5 and WP6).

A cross-analysis of these various elements is then conducted so as to elaborate a preliminary Science Plan defining:

- the general scientific objectives, considering both fundamental and applied research,
- the methods for identifying common standards and testing guidelines to be applied throughout the whole development process of a system,
- the methodologies for selecting and accompanying the projects having the highest potential for increasing the socio-economic impact of research in ORE,
- data management procedures aiming at optimizing the use of the datasets created through the research and testing programs so as to contribute to reduce the time to deployment of ORE devices.

The preliminary Science Plan is the reference document which provides a common basis for discussion at national level in the various partner countries. This discussion will lead to adjustments where necessary to meet various Member States national requirements. This adjustment process also involves the selection of the most relevant facilities to be included in the DRI, on the basis of the initial profiling conducted as part of WP2. This will be conducted in an iterative and collaborative approach so as to allow the elaboration of a scientific and technical offer in line with the actual demand from the ORE industry.

The Science Plan supports and feeds into the development of the Design Study [6], which provides an implementation model for the MARINERG-i DRI. The preliminary Science Plan and the preliminary Design Study draw [6] on the outcomes of the Workshop "WP4 Science Plan and Design Study" which took place in Brest (IFREMER) on the 7th and 8th of June 2018. The iterative process is to be conducted over a nine-month period so as to deliver the final science and design plan by May 2019.

3. The research community

A clearly established objective of MARINERG-i is to conduct research activities aiming at answering its end-users' requirements and effectively responding to industry demands so as to help accelerate the deployment of ORE technologies.

If the main research activity is to be primarily conducted by the MARINERG-i consortium members, a strong collaboration with other stakeholders will also be necessary. Among the identified stakeholders, the most likely prone to contribute to the research activity are most-likely the end-users [5]:

The end-users are by definition the users of infrastructure services (current or past), in addition to users with potential future interest.
End-users are the direct recipients of the services, directly aware of its characteristics and with a specific interest in its results.
They will be considered as the stakeholders with a primary interest in the infrastructure, with capacity, knowledge and interest to establish a dialogue with the infrastructure and also capable of providing feedback on how to improve services, what new services are demanded and under what conditions to offer them.

Interaction with end-users should be the main driver to the forward moving approach, contributing to the identification of challenges and gaps and yielding the development of new ideas, concepts, and possibly new theories.

However, among the other identified stakeholders (Figure 2), contribution to the research activity is also expected from academia, who should provide an efficient contribution to the fundamental research programs while "other testing facilities" would focus on the development of applied science and engineering and testing programs. Finally, Private Investors as well as Industry and Supply Chain representatives could also be involved in the research activity. They could provide adapted datasets relevant for the studies on technologies validation and improvement as well as for the development of methodologies aiming at optimizing marine operations and maintenance for instance.

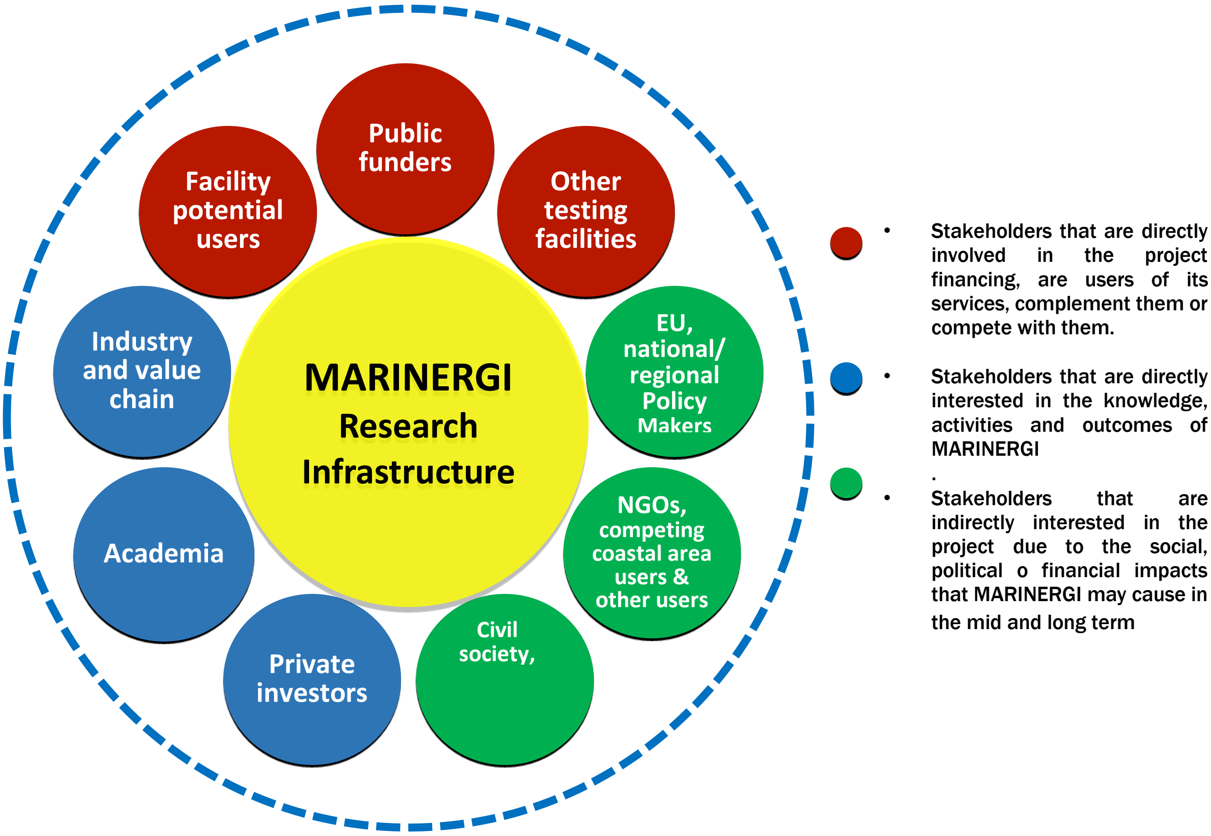

Figure 2: MARINERG-i Stakeholders (after ([5])

4. Testing facilities

The objective of MARINERG-i is to help accelerate the development and deployment of ORE technologies through research and scale testing. This will only be achievable if the Pan-European DRI is properly established and equipped to meet the requirements of the users and developers, considering all technologies and their relative competitiveness at all TRLs. Hence the MARINERG-i DRI must be composed of a sufficiently large number of facilities, providing capacity for the testing of ORE systems in any of the three major considered fields: **wave, tidal** and **offshore wind** plus two additional technological domains: **electrical and grid connection** and **cross-cutting.** They also must accommodate all stages of development from "proof of concept" typically requiring small laboratories, to full scale commercial devices requiring testing in a realistic environment i.e. at a Large Scale Test site [2].

The preliminary infrastructures profiling study conducted in WP 2 allowed the elaboration of a comprehensive listing of facilities composed of 118 entries selected according to a set of predefined criteria, both technical and strategic.

In order to build the most efficient DRI, a more detailed screening of these facilities will be conducted taking into account technical and scientific aspects:

- The capacity to answer the end-users' requirements in any of the five identified focus groups, mostly through the contribution to the research activity

- The capacity to provide support for testing at all stages of development
- The necessity to offer sufficient redundancy to respond to the demand of the industry at all times

As well as more strategic criteria such as:

- A scientific background relevant to the development of the identified fundamental and applied research programs
- National priorities in terms of support to the ORE industry and development of research programs and infrastructures
- Legal and financial requirements for operating the facilities

As a preliminary investigation of these criteria has been completed as part of the profiling activity conducted during the discovery phase, the main drivers to the adjustment of the set of research facilities to be selected as part of the DRI are now the national priorities and the ability of the MARINERG-i DRI to respond the end-users' requirements. Hence, the adjustment of the final listing of facilities will be conducted through the iterative collaborative approach described in section 2 of the report.

It should also be noted that, as MARINERG-i is addressing an emerging and constantly evolving industry the adjustment process will also take into account the longer term evolution of the demand as well as the development of future research facilities identified during the discovery phase.

5. MARINERG-i Scientific Objectives

The MARINERG-i strategic research agenda aims to respond to end-user requirements in terms of scientific development and improving methodologies for testing. The fundamental objective is de-risking different technologies, reducing uncertainties and improving reliability and survivability, optimizing the efficiency of ORE converters and of marine operations and maintenance. This will ultimately contribute to the reduction of LCOE and help accelerate the commercial deployment of devices.

This agenda is elaborated on the basis of the identified end-users' requirements [1] as well as inputs from ongoing EU coordination/ roadmap initiatives (Ocean energy Roadmap, Set Plan/TP Ocean/SI Ocean, EERA joint programs, ETIP wind report, etc.). It includes and benefits from both fundamental science and applied science research activities.

A series of general topics have been identified already which require both fundamental science and applied science research programs and engineering activity:

- Characterisation of the resource and environmental loading
- Environmental loading replication at reduced scale
- Fluid-Power capture interface performance characterisation
- Power-Take-Off and electrical testing
- Cross-cutting and material testing
- Control methods for optimisation of devices operation and survivability
- Approaches coupling numerical modelling and physical testing
- Development of future facilities and new testing methods

5.1. Fundamental Science

Some of the topics there above identified require acquisition of new knowledge or better understanding of basic phenomena, hence the necessity for the development of fundamental science research programs. It is considered that this activity will be conducted by the members of the DRI only through collaboration.

5.1.1. Resource and environmental loading

A capacity to more accurately characterise the environmental loading at the scale of a test site or a production site would help reducing uncertainties and thereby improve the reliability of systems. New monitoring and measuring equipment as well as processing methods are to be developed to tackle complex issues, which cannot be resolved with existing tools. For instance, a phenomenon such as the development of the turbulence of the flow at energetic tidal sites, especially in the presence of waves, is not properly described. Acquisition of the information necessary for understanding this phenomenon and to validate its replication at reduced scale in tanks requires the development of new measurement technologies and processing methods.

5.1.2. Environmental loading replication at reduced scale

Improving the capacity to realistically reproduce the environment at reduced scale in small and large laboratories is key to reducing uncertainties at low TRLs. Innovating theories and methods are to be developed especially considering the scalability and application of similitude laws of physics when considering joint environmental forcing (wave + wind for instance).

5.1.3. Fluid- power capture interface performance characterisation

Developing a fundamental understanding of the fluid mechanics at the power capture interface, especially responding to dynamic fluid flows, from the testing and power capture characterisation of technologies will inform the much-needed innovation and development of power capture and transfer systems. This will enable capital cost reductions and improve system operational durability, reducing operational and maintenance costs.

5.1.4. Power-Take-Off and electrical testing

Methods allowing testing of Power-Take-Off (PTO) systems at all scales are necessary to improve efficiency and develop integrated approaches considering the joint study of the devices dynamics and the energy conversion mechanisms.

5.1.5. Material testing

The increased use of new lower cost materials such as composites or polymers, is a promising alternative being investigated so as to reduce LCOE and optimise device weight and performance. However; long-term performance, durability and the ageing of such materials in the marine environment need to be proven. These key elements for the reliability of the devices and their sub-components still represent major unknowns and require specific research.

5.1.6. Control methods for optimisation of devices operation and survivability

Specific control methods are developed aiming at optimising the power extraction capacity of a device, while raising its survivability threshold and reducing the frequency of maintenance interactions. Control methods are also requested for the optimisation of large arrays of devices. Scaling of such control methods is an important issue for replication at lab scale and new methods and theories are to be developed.

5.2. Applied Science Engineering and Testing

Applied science research programs will be conducted to tackle a broad range of technical or scientific issues, either directly addressing specific technologies or offering solutions to help the developers bringing concepts, prototype devices and components through the TRL stages.

Applied science can involve external groups, from academia, the industry, as well as other research facilities, interacting with the staff of the DRI to develop the best solutions that can then be disseminated through the MARINERG-i network.

5.2.1. Resource and environmental loading

Existing monitoring procedures and available environmental databases, such as those provided by EMODnet, are not necessarily adapted to the needs of the ORE industry requiring joint and standardized measurement of wind, wave and current and considering higher sampling frequency as well as specific parameters. Therefore, new observations programs are to be developed at the scale and size of the testing sites associated with specialised processing and analysis procedures. This approach should be conducted in close collaboration with existing observational programmes and data providers. Methods adapted to real time environmental characterisation are also required by several control methods to be developed for optimisation of production and survivability of ORE systems.

5.2.2. Environmental loading replication at reduced scale

Development of new testing methods to better represent the real environment at scale would help reduce uncertainties at the early stages of concept development and yield more reliable and valuable prototype testing at sea.

The development of methods for an accurate replication of site turbulence characteristics in a laboratory, based on the fundamental research conducted on turbulence characterisation. This will help to better quantify the loading characteristics on marine structures, improving reliability and, for tidal turbines, the power and thrust coefficients so as to reduce uncertainty on efficiency.

Linked to this problem, understanding the influence of the methods of combining waves and currents on technology performance in laboratory tanks is an important area of study. A number of infrastructures offer this capability but there is little validation that site conditions can be properly replicated and how variations can impact performance and loadings.

New or advanced methodologies are to be developed (particularly hardware in the loop and software in the loop systems) to replicate complicated aerodynamic and hydrodynamic loading as well as simulating the behaviour of Power Take Off (PTO) systems. This would also include investigating more standardised methods for considering mooring systems and umbilical cables.

5.2.3. Power-Take-Off and electrical testing

PTO testing and development is an important area of study particularly for the wave and tidal sectors. Linked to this are the electrical systems and power electronics that need to be developed and tested. The wind industry has developed large turbine testing rigs but wave and tidal have not developed to the same level as yet. For wave energy, how the PTO is represented at model scale and the separation between the tank testing and the PTO testing on test rigs are to be addressed. Similarly, for tidal energy the scaling of the PTO systems has not been the subject of much attention and would require some standardisation and better general understanding. This activity will require the development of new measurement techniques and possibly new instrumentation and methods to enable more advanced understanding of technology behaviour.

5.2.4. Cross-cutting and material testing

Cross-cutting encompasses a broad range of activities requiring specific research activity to address topics such as the use of new materials, blade performance and durability, mooring lines etc.

In addition to specific research programs, this activity will require the development of new measurement techniques and possibly new instrumentation and methods for enabling more advanced understanding of technologies behaviour.

5.2.5. Control methods for optimisation of devices operation and survivability

The development and testing of control methods are critical for the efficient operation and survivability of ORE technologies. The MARINERG-i network can facilitate the development of passive and active controllers which, depending on the type, can increase power production, regulate and decrease loading, reduce fatigue or improve survivability.

5.2.6. Approaches coupling numerical modelling and physical testing

Combining the numerical and experimental approaches is a common and necessary methodology for the development and design of marine structures and ORE systems. The MARINERG-i network can facilitate advancement of numerical modelling approaches through better integration with empirical data derived from purposeful physical testing.

Numerical approaches are becoming very sophisticated and powerful with combined aero/hydro/servo/elastic modelling now being used. It is important to develop methods so that physical model testing approaches are in tune with these advanced numerical models. This will ensure proper validation of the models and maximise the understanding of technology behaviour, particularly at lower TRLs before significant development funding is required for larger scale open sea testing.

5.2.7. Development of future facilities and new testing methods

There should be a consolidated approach in terms of examining what resources the ORE industry and Europe needs in order to remain a world leader in the ORE sector. For example, tank testing undertaken during the FP7 MaRINET project showed that blockage ratios as low as 5% can affect the performance of small scale tidal turbine prototypes. Although techniques to apply blockage correction can be developed there may be a requirement for a new controllable infrastructure for testing tidal current technologies at a larger scale.

Specific research programs involving for instance benchmarking between different facilities will be developed with the aim of characterising possible improvements for both facilities and testing methodologies. It is envisioned that this will yield to the development of new kinds of specific testing facilities.

It is also expected that the demand for offshore test sites and larger test tanks increases with the evolution of projects towards higher TRL's. Hence specific attention should be given to the development of such facilities as well as to the adaptation of the methods requested to adequately operate them.

It should be noted that this research activity, whether considering fundamental or applied science, is also to be considered in an integrated approach as many of these topics are closely related. Scalability problems address environmental loading and PTO modelling for instance and control methods are closely related to the environmental observation.

6. Common standards and Best Practices

Establishing common standards and best practices for testing is necessary to ensure the consistency and comparability of results between facilities of the DRI, while ensuring the quality of the service offered by the member facilities throughout the development process.

Best practices and standards for testing, where they exist, are very light and limited and there is a strong demand for common procedure allowing consistent evaluation of ORE systems.

A common code of practice will be elaborated, adapted from existing protocols (Equimar, MaRINET and MaRINET2, MET-Certified etc.) and standards (ITTC, IEC etc.) to provide harmonized procedures and testing methods.

Mechanisms for a standardized continuous evaluation procedure of ORE devices along the whole development process (TRL 1-9) will be developed and assessed through common research projects involving testing of generic systems or subsystems at facilities from different size classes. Outcomes of these projects will be implemented at each facility so as to provide a standardised service to end-users.

7. Projects selection

MARINERG-i aims at providing access to ORE testing facilities across Europe for national and trans-national users so as to support them throughout the whole development of their projects. However; considering the objective of helping to accelerate the development of the ORE industry, it is also important to identify the projects with most potential to progress. This would also help increase the socio-economic impact of research in ORE.

This can be done by identifying a range of selection criteria to assess for instance the capacity of the applicant to provide a realistic development plan from TRL 1 to TRL 5. However, it can also be more valuable to engage directly with the developers, especially in the early stages, to help capitalize on the outcomes from their testing, provide guidance at each stage to facilitate and accelerate progression using the best suited testing facilities from the small Lab all the way to the large scale test site. Therefore, a comprehensive development protocol is needed, as part of the code of practice shared by the MARINERG-i certified centers.

8. Data Management

The MARINERG-i e-Infrastructure will provide an efficient data archiving and management system and will be of primary importance in the development of the research projects conducted by the partners of the DRI.

Attention will especially be given to the development of common standards (compliant with international standards (RDA, SeaDataNet) and knowledge sharing tools to facilitate exchanges between partner institutions and with the other stakeholders. These will consider the specificities of the various forms of information generated to allow combined use of laboratory testing data, in-situ monitoring data and numerical model outputs.

A virtual Research Environment (VRE) workplace will be developed and based on common national and European e-Infrastructures (SeaDataCloud) to support data access. It is foreseen that the MARINERG-i e-Infrastructure will be based on the tools and services developed as part of the MaRINET2 e-Infrastructure development program, especially aspects related to management of ORE technologies testing data sets. Curation of other datasets with a broader range of applications will be developed in collaboration with other European networks such as Emodnet, which should for instance facilitate access to in-situ monitoring data.

9. Conclusions

This document constitutes the preliminary Science Plan elaborated to initiate the development phase of the project, which will build main elements constituting the MARINERG-i proposal.

This science plan provides a prioritized research agenda and includes the main fundamental science topics to be addressed by the MARINERG-i members, together with the necessary applied research activity to be conducted in collaboration with the other stakeholders. It also takes into account the requirements for the development of standard methods and codes of practice as well as the elaboration of a plan for selecting and accompanying projects with a real potential and the development of a data management plan elaborated around a dedicated e-infrastructure.

These elements will be developed and detailed through an iterative procedure involving all the project partners to establish a final scientific agenda in line with both the priorities of the ORE industry and research development plans at the national level as well as the identified end-user requirements.

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