SCIENCE AND TECHNOLOGY AS KEY FACTORS FOR IORA COUNTRIES ROLE AT WORLDWIDE LEVEL

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ABSTRACT

This article presents a methodological approach for policy decision makers in science and technology looking at their interactions and it offers a model for their implementation. This methodology is useful both ex-ante for planning and ex-post for evaluating investments in science and technology, in such a way to optimize the impact of R&D and Innovation activities onto the economy of a given country. A case study of the application of this method is highlighted in the results section by presenting an Italian R&D and Innovation project named TecBIA (Technologies with low environmental impact for the production of energy on ships), specifically dealing with the maritime and marine domain. The main outcome of the TecBIA project is ZEUS (Zero Emission Ultimate Ship), a 25 meter ship that integrates cutting edge technologies for sustainability, by using green hydrogen as propeller for a fuel cell technology engine. The ZEUS ship is multi-purpose, and it can therefore constitutes a model to beused by individual countries according to their priority needs in term of target uses.

Keywords: science and technology model and policy, R&D and Innovation, key enabling technologies, interoperability, standardization, Indian ocean, IORA.

1. INTRODUCTION

While increasing the human knowledge, research and development (R&D) efforts play a vital role in sectors such as financial growth and job creation, business competitiveness, national security, energy, agriculture, transportation, public health, environmental protection. Global spending on R&D has reached a record high of almost US $ 1.7 trillion (UNESCO, How much does your country invest in R&D, s.d.). The top fifteen countries for R&D spending by billions (US dollar) or by percentage of their Gross Domestic Product (GDP) include only three IORA current members: France, Australia and Singapore (UNESCO, How much does your country invest in R$D UNESCO UIS., s.d.). Several IORA dialogue partners are part of the top fifteen. Recently, innovation has been added to the classic R&D efforts, creating research and development and innovation (R&D&I) efforts where the final products and/or services are not only the results of strong research background and cutting-edge industrial know-how but also have a disruptive nature. Nowadays, the R&D&I efforts are highly dependent from the interaction between science and technology.

In this paper, the role of science and technology for IORA countries will be discussed as a key issue to promote their continuous development stemmed out from the IORA mission and vision as represented in the IORA original documents of 25 years ago. The analysis of such a role will put into evidence how science and technology, thanks to their quite fast and disruptive evolution in the two last decades, at affordable cost, offers an unexpected occasion not only for carrying out the original IORA vision and mission limited to the interest of their participant countries, but also for allowing a reinforced place for IORA worldwide. Such an analysis will be conducted by looking at the interplay between science and technology, offering a model to their future structuring and conducting. This model can be eventually shared among IORA countries, starting from their main demands as arising at social, economic and industrial level, looking at their geographical condition of facing the Indian ocean as a sort of liquid glue to yield a proactive union of the large number of the various IORA cultural heritages, reach of values to be made available not only to IORA dialoguing partners, but worldwide.

2. METHODS

From a methodological point of view, the model to be considered as useful for science and technology in order to provide a measurable driving force with impact on IORA countries is the one currently shared at international level (Cristina, Laura, Mioara, & Ciprian Ionel, 2018), i.e. the OECD circular model versus the linear one. As matter of fact, it is quite evident to anyone the limitations which are inherent to the old original linear model for science and technology. Such linear model envisages a series of linear steps starting from the inventor idea, through the various phases of prototyping at laboratory level, then the testing phase at preliminary verification trials level, followed by a quite long and costly structured phase defined as validation over many different centers with many cases in each center, to lead at the difficult technology transfer phase to industries, ending with the even more risky issue of finding interested investors. It is quite clear how these steps require a long time from the original idea and how the rate of failure is unacceptably high.

Since at least the end of the ’80, in the OECD context, it became quite clear the advantages as offered by the circular model for science and technology, aimed at shortening time, costs and maximizing impact of results. Such a model starts from the premise of involving since the very beginning in the scientific adventure on a given matter the entrepreneur, intended in its double face role of demand carrier and active idea promoter in a jointly manner with scientific actors. Therefore, the first advantage is the jointly presence at the same table of demand and offer, which allows the scientific actors to match their offer considering the culture of the industrial partner, in order to optimize the impact of the results over the short and the long term (Satish, 2017).

More specifically, given by granted the principle of starting the scientific roadmap from demand in order to design, developing and verifying the correspondent offer in technological terms of products and processes and not viceversa, two kinds of research activities have to be carried out in parallel, i.e. the first one, commonly named industrial research devoted to lead impact for the industrial entrepreneur in the short-mid term (time being determined basically from the quality and the disruptive level of the originally conceived idea), and the second one, which can be named strategic mission oriented basic research on the very same issue, aiming at pursuing and maintaining in the long range the impact as achieved in the short term by the line of industrial research. Of course, industrial research acts as relevant feedback onto the strategic mission oriented basic research, modulating/re-adjusting the original idea according to the measured impact versus time: here is where the role of the loop is coming in (from which the naming of circular model). Circular cooperation of industrial research and of strategic mission oriented basic research will hopefully ensure impact persistence and, in the end, a competitive advantage for the entrepreneur with respect to his market of reference.

A more general view of the aforementioned circular model can be represented by three words:

RESEARCH, KNOWLEDGE and VALUE**.**

This means that an effective scientific research policy has to consider that RESEARCH is devoted - but not limited to - KNOWLEDGE production, since this last one needs to have a VALUE, i.e. of being not only curiosity KNOWLEDGE but, possibly, performative KNOWLEDGE. Such a sentence may be better understood if stated backwards: if a need which as a certain VALUE in a given area of a society arises, i.e., healthcare, transport, etc., that means that something is still unknown and therefore it calls for KNOWLEDGE production and the professional activity for such a purpose is to conduct scientific RESEARCH, not a generic one, but as merged and inspired by the culture as expressed by that target use calling for that societal or economic needs of that VALUE. Again, it is quite clear the circularity nature of such an approach, eventually leading to effective and efficient impacts.

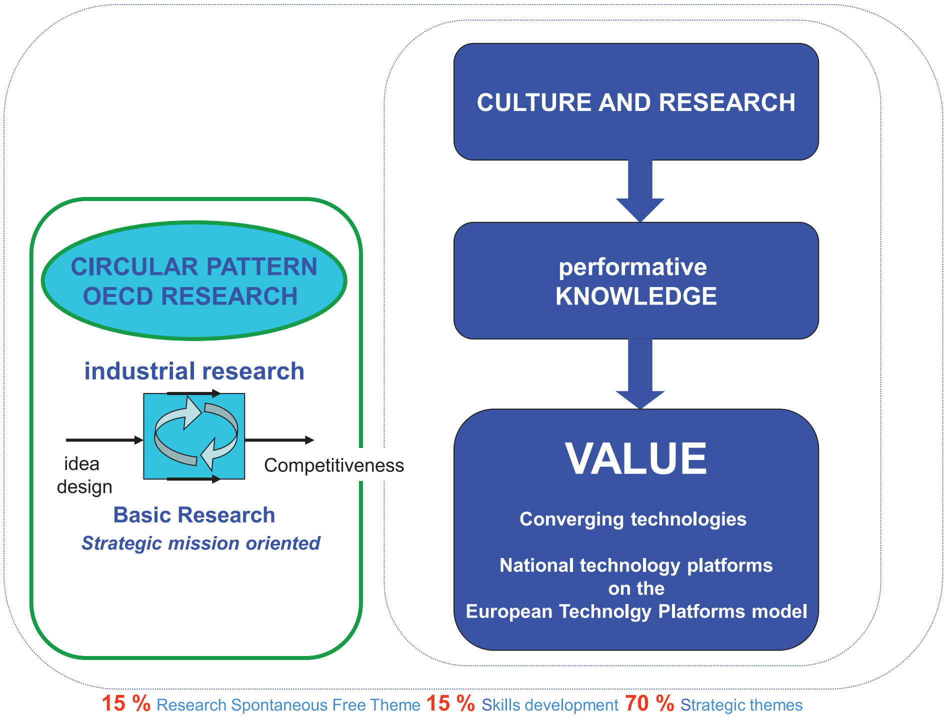

Figure 1 - R&D circular model.

Furthermore, what above stated should not be read as a suggestion to disregard the power of research driven by free curiosity as normally conducted in academic and research institutions, with specific reference to the IORA basin. On the contrary, RESEARCH, KNOWLEDGE and VALUE need to be properly nurtured and protected, because most of the time they act as necessary inspiration input for the previously described approach.

The important factor for science and technology policy decision makers, in the IORA context, would be to propose, define and share an appropriate model for research resources distribution weighted according to the different described kinds of research activities. The European Union, in recent decades, has allocated the funding as follows: 15% for curiosity driven research projects (i.e. ERC), 15% for human and material infrastructures and 70% for industrial research. IORA will have to consider its own peculiarities to choose the appropriate focuses and percentage allocations.

Another important issue to be taken into account is the difference between R&D activities, as above represented to be conducted (see Figure 1), from innovation activity, particularly the difference between innovative research and innovation. Innovation per se is a completely separated sphere of action, much larger that the sphere of R&D. It needs to be associated with specific attributes such as technological innovation, economic innovation, social innovation and so on. The sphere of innovation is located between the sphere of R&D and the sphere of industrial policies. It is quite evident its role, for example, in transferring from one to another target use R&D results which may be quite assessed in one area (i.e, automotive sector) into another one (i.e. maritime sector). Moreover, under the pervasive diffused adoption of Internet and ICT in general intended as key enabling technology (KET), the definition and way of action of innovation itself have been changing in time, particularly since the first decade of year 2000, at international level, as clearly indicated by OECD, specifically from the DSTI (Department of Science Technology and Innovation), as depicted in the following Figure 2:

INNOVATION

OECD INNOVATION STRATEGY, as reported in the "*Harnessing the power of innovation framework for the strategy* - 21 Feb. 2008", "*Scoping document* - 7 Oct. 2008", "*Annex to the scoping document* – 17 Oct. 2008".

Cited documents continue to indicate clearly a different way of defining innovation than ever before, as stated below:

"***Thirty years ago the focus was mainly on technological change, on finished products and their supply chain, today's innovators draw on knowledge across networks, systems using open innovation are part of communities affected by the mode of operation, Innovation is made locally but with global reach***".

Figure 2 - OECD Innovation Strategy.

Such a new definition carries quite important consequences onto the interaction between the innovation sphere and the industrial policies sphere, therefore giving even much more importance and impact to science and technology achievements obtained through R&D activities. The most important of them being the possibility to offer an integrated and systemic vision from outside to the productive system of a given country, empowering its attractively for potential investors.

For evaluating the social and economic impact of both R&D and Innovation results as deliverables of resources investment decisions in a given country, it is important to have available an integrated visualization, for example in the form of a 3D graph as depicted in Figure 3, of at least the main three concurrent instances: Innovative Technology Platforms (axis y), Infrastructures (axis x) and, overall, Target Uses (axis z). Innovative Technology Platforms is mainly related to the novelty and disruptive degree of the R&D activities dimension, Infrastructures is linked to the availability of feasible support for them as a necessary condition deriving from the Innovation dimension existing or easily deployable at a given time in a given country, while Target Uses represents the measurements of the features of the potential end users of the R&D products and processes and its properly conducted estimation as volume and variety: perhaps it is the crucial element to decide the identification of R&D and Innovation investment priorities. An example may be of help in better understanding the relevance of such a 3D representation and corresponding qualitative and quantitative evaluation to optimize the return of the R&D and Innovation investments, or the benefit to cost ratio.

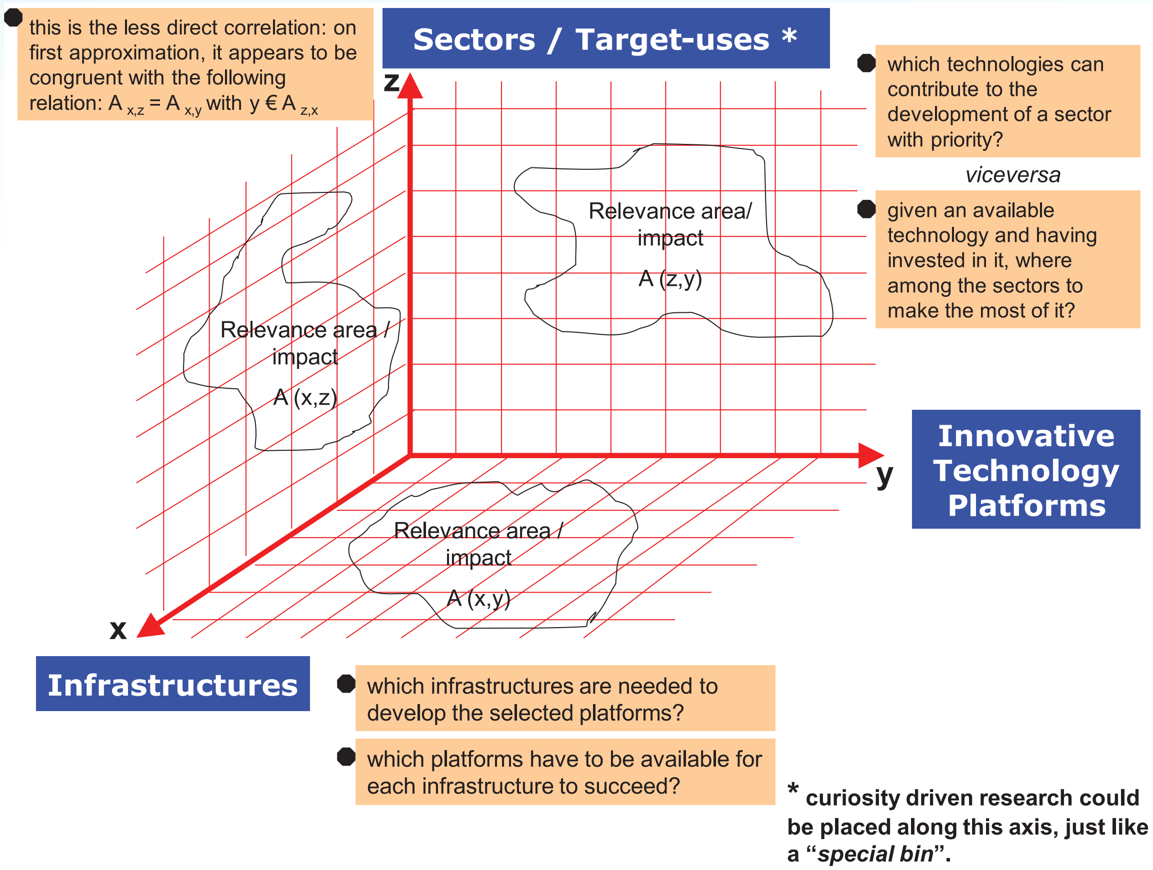

Figure 1 - 3D graphic representation of the relationships among innovative technological platforms, infrastructures and target uses to evaluate R&D and Innovation policies relevance

Let's suppose the Innovative Technological Platform be the ship of the future, in view of a zero emission system. In this case, the necessary Infrastructure for the use of such a ship will be the availability of properly equipped ports, for example with adequate electrical power lines and also able to carry onto the ship the green fuel (i.e. hydrogen). Target uses will first be marine and maritime research people, progressively evolving to the passenger category (i.e. cruise ships), for example oriented to green tourism and other scenarios.

From a methodological point of view, jointly with the graph of Figure 3, is the question of interoperability (for example, among different IORA countries), which leads to the issue of providing shared guidelines and standardization in view of further certification which in turns acts as positive factor for market competitivity worldwide. The result section will present a real example of the aforementioned methodology.

3. RESULTS

Information and Communication Technologies (ICT) are a central pillar for the world, as the world is now labeled as "digital" and "global village". The usefulness of ICT transcends all sectors including the marine and maritime sector (A.B., 2018). Innovative and sustainable ICT technological solutions are fundamental for the production of clean energy, for an increasingly less polluted environment and for an increasingly safer sea (Zacharoula, 2012). Paying particular attention to the maritime research activity and analyzing what is above the sea and what is below the sea, we have an integrated circular vision, in which what is present on land can also be included.

The experience of the research project TecBIA (Technologies with low environmental impact for the production of energy on ships), co-financed by the Italian Ministry of Economic Development, led by FINCANTIERI, intends to verify the sustainable technology of fuel cells propelled with green hydrogen for naval applications by creating of a vessel prototype, named ZEUS (Zero Emission Ultimate Ship) with hybrid propulsion. The project started on 31 October 2018, and is expected to end on 30 October 2022, with a contribution of 5.077.000 euros. (Fincantieri, 2014/2020). The hull is 26 meters long and weights approximately 170 tons. ZEUS is also equipped with a hybrid apparatus to be used as a conventional propulsion system (2 Diesel generators and 2 electric motors). To this apparatus are added a fuel system (130 kW), powered by about 50 kg of hydrogen contained in 8 metal hydride cylinders, and a lithium battery system. The ship will thus have an autonomy of approximately 8 hours of zero emission navigation at a speed of approximately 7.5 knots.

The common reference scenario of the research concerns the improvement of the level of environmental sustainability of merchant and cruise ships, through the reduction of emissions of greenhouse gases, nitrogen oxides, sulfur oxides and particulate matter.

The naval prototype ZEUS was designed and developed following a well-defined approach that combined innovative technological solutions with appropriate and available know-how and industrial infrastructures. Since the beginning of the TecBIA project, this approach kept under consideration the needs of the target uses of ZEUS. Only an integrated approach, like the one used for ZEUS, can help IORA countries identifying which research efforts should be prioritized and eventually funded. Figure 3 shows a three-dimensional representation of the recommended approach The innovative technological solutions and the infrastructure are the foundations to identify an innovative product or service that, with an appropriate funded research effort, can been built or offered in a well-defined short time frame (less than 5 years). It is important to highlight that only by identifying and engaging with the target uses, the results have the possibility to positively impact the life of the target uses.

The main activity of ENR (The National Institution of Italy for Standardization Research and Promotion), in the TecBIA project, has focused on the proposal of a set of regulations for the use of hydrogen as a fuel on board ships. In accordance with internationally established procedures, on the basis of the experience gained and the assessments made in the project, guidelines have been drawn up for the use of hydrogen as a fuel on board ships. The drafting of appropriate safety regulations, with the requirements that these types of ships must possess to ensure safe navigation for the environment and for the crew, will represent a fundamental element in promoting the spread of hydrogen as a fuel. ENR, will present the TecBIA project and the ZEUS naval prototype, technically launched on 31 January 2022 in the Castellammare di Stabia FINCANTIERI shipyard, at the EXPO 2020 in Dubai. The ZEUS prototype ship produced by Italian industrial and research excellence has as its main objective to propose the vision of a possible environment for future generations around the world. This theme recalls the need to respect marine ecosystems using internationally shared standardization processes that do not yet exist or that are in an initial state of conceptualization

Figure 4 - ZEUS technical launch in Castellammare di Stabia on January 31, 2022 (Stabianews, 2022).

The concept of the prototype follows the chemical / physical and acoustic balance of the environment and it is oriented towards marine-maritime sustainability, according to the principles of the circular blue economy. Green hydrogen and fuel cells generate 100% clean energy (DNV-GL, 2019) and the ZEUS ship is multipurpose for fishing, recovery and energy reuse of plastic marine litter, research in marine protected areas, silent transport of goods and people, underwater robotics missions such as sustainable deep sea mining.

The ZEUS ship is an opportunity for dialogue between countries belonging to geographic basins of ancient and rich different cultures that share, for their activities, communicating seas. In particular, the above described circular model can be applied within the large IORA basin where very different cultures are facing but all sharing a common purpose. The cultural difference of the various IORA countries must be intended as a value to focus on and not as a barrier. For each country, for example, a matrix of priority needs that could be met by other countries could be created, representing real needs that must be highlighted. This approach can be shared in a scientific and technological context, through the Suez Canal for the Mediterranean basin and the IORA basin. The Mediterranean basin, in turn, has an opening onto the Atlantic ocean through the Strait of Gibraltar and onto the Pacific ocean through the Panama canal.

The goal is to combine the issue of environmental sustainability and the issue of technological innovation (Janusz, et al., 2018). The latter has as a fundamental requirement the increase of the safety of those

who work a sea, of those who live at sea and of the entire supply chain connected to this sector. In particular green hydrogen is the potential proactive technological witness of this dialogue, due to its nature as a sustainable fuel produced from electrolysis powered by electricity from renewable sources available in large quantities, as in the case of photovoltaic, in countries overlooking the southern shores of the Mediterranean and the Indian ocean, benefiting from better solar radiation (SNAM, 2019).

4. DISCUSSION

An interesting aspect to consider is the role of technology in facilitating international co-governance of a complex matter as the exploitation and preservation of a shared resource, the sea, is.

Observation and mapping of coastal and marine biodiversity are key tools to manage and share the "ocean commons" in a fair and responsible way under the present global challenges and rapid environmental changes. They also help ensure that the benefits derived from the exploitation of ocean resources can be sustainably managed and equitably shared. The distribution of these "ocean commons" is changing. The melting polar ice caps, stagnation in wild seafood provisioning opportunities, emergence of harmful pathogens and parasites, and previously inaccessible ocean spaces (i.e. the deep sea) now increasingly within human reach, are challenges that need to be addressed by responsible ocean governance to reduce the potential for conflicts at all levels and ensure human well-being. Current knowledge on how to relate and govern marine natural resources and associated societal changes is fragmented, and observations of resource distribution, use, state and dynamics are scant and insufficiently accessible. We need to advance observations to support modelling of the complex links between marine ecosystems and societal developments to forecast, manage and mitigate these changes.

Examples of modern technologies and their possible applications for monitoring biodiversity in view of better governance are (PJStephenson, 2020):

- use of satellite and drone images (earth observation) to assess pressures on freshwater, coastal and marine ecosystems (fragmentation, hydromorphological changes, etc.); - innovative bioinformatic protocols complementing established biological indicators to monitor ecological status i.e. of sea waters; - ICT platforms for storage and integration of a variety of sensors in situ, autonomous unmanned vehicles, acoustic monitoring, satellite applications, holistic approaches (i.e.., systems biology, meta-omics, and ecosystem approaches) in an integrated framework to inform decision making, particularly in inherently dynamic coastal ecosystems.

The related amount of data is enormous and growing constantly: without doubt the “big data” paradigm applies to marine biodiversity (Isabelle, et al., 2021). This means that, even more than in the past, it is necessary to create links with existing relevant information and data storage systems such as, for example, the ones of the Group on Earth Observations (GEO) and the Global Earth Observation System of Systems (GEOSS) and, in an EU perspective, the ones of the EC-ESA Joint Earth system science initiative.

Creating links and enabling immediate, safe and controlled upload, download and use of data and information distributed on a variety of different data spaces and platforms: this is all what interoperability of ICT system is about. Without entering into technical details, it requires the use common data exchange protocols and agreed semantics, in other words, a good deal of collaboration which, at the end of the day, is one of the scopes of IORA: establish a permanent collaboration among its members to enable a shared and sustainable exploitation of the Indian ocean.

Apparently, there is nothing new: technology (in this case ICT) changes the way to operate it but not the final aim and result. However, in this case, there is something new and really important: preservation of marine biodiversity and sustainable exploitation of oceans is a global issue and it also should be dealt with at global level by establishing synergies and focused inter-ocean cooperation i.e. Indian ocean and Mediterranean. Interoperability between ICT systems would enable it, already today.

In the definition of interoperability there is an implicit concept that needs to be made explicit: standardization (Sergio, 2020). In fact, by making the various ICT systems interoperable (i.e. ships, ports, electrification of ports, transport, goods) they can be standardized and consequently are able to offer the best margins of competitiveness for product manufacturers, processes and services themselves.

5. CONCLUSION

The role of science and technology at international level has been discussed in this paper. In order to encourage development in these sectors, a methodology has been introduced and it can be used to promote investments, in order to optimize impacts according to the priorities of various countries, obviously of potential interest in the wide international context of IORA member states. From a methodological point of view, the model to be used for science and technology is the circular stemming from OECD, that sees the active involvement of the entrepreneur during scientific activity. In particular, carrying out two research activities in parallel: industrial research and strategic mission oriented basic research.

The application of this method made it possible to create a quite intelligent real object, i.e, the ZEUS (Zero Emission Ultimate Ship).ship. The common reference scenario of the research concerns the improvement of the level of environmental sustainability of merchant and cruise ships, through the reduction of emissions of greenhouse gases, nitrogen oxides, sulfur oxides and particulate matter. Within the research project TecBIA, the sustainable technology of fuel cells for naval applications was verified through the development of the ZEUS naval prototype.

The ZEUS naval prototype was designed and built according to the chemical / physical and acoustic balance of the environment and is oriented towards marine-maritime sustainability, following the principles of the circular blue economy. The ZEUS ship is multipurpose and can be used by individual countries according to the priority needs of the target uses (i.e. for fishing, recovery and energy reuse of plastic marine litter, research in marine protected areas, silent transport of goods and people, underwater robotics missions such as the sustainable deep sea mining).

An R&D&I project such as ZEUS is not considered concluded at the end of the product realization, but as the product is innovative, it is itself subject to a new cycle of R&D&I projects. Innovative ships such as ZEUS will in turn require, for example, ports with innovative infrastructures, which do not yet exist and are capable of supporting them.

The goal is to combine the theme of environmental sustainability with the theme of technological innovation and the ZEUS ship is a quite important real opportunity to foster dialogue between the countries belonging to the large IORA basin

LIST OF ACRONYMS

ERC European Research Council

GEO Group on Earth Observations

GEOSS Global Earth Observation System of Systems

ICT Information and Communication Technologies

OECD Organization for Economic Co-operation and Development

ZEUS Zero Emission Ultimate Ship.

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