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A strategy for meeting the needs for marine-based research in the Arctic

Deliverable 2.3. Report on potential science - industry priorities in research and observations

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1. Introduction

In the context of the global climate change, where the Arctic sea ice has been shrinking with accelerating losses in the last two decades starting to make commercially viable sea routes through the Arctic, the ARICE project aims at establishing an international cooperation strategy to better coordinate the existing polar research fleet, to offer transnational access to a set of international High Arctic research icebreakers, and to collaborate with maritime industry in a "programme of ships and platforms of opportunity". The achievement of these goals represents a fundamental step to provide information on the state of the Arctic Ocean that is urgently needed due to the fast increase of the Arctic marine traffic. Safe navigation and voyage planning in Arctic waters as well as sustainability in operations, in particular concerning environmental aspects related to shipwrecks, oil spill risk, shipping impacts, underwater noise, invasive species, require improved weather and sea ice forecast, that has to be supported by investments in hydrographic, meteorological and oceanographic data. In particular, safe navigation requires additional hydrographic surveys to improve Arctic navigation charts, and systems to support realtime acquisition, analysis and transfer of meteorological, oceanographic, sea ice and iceberg information.

Results in this direction can be achieved only through international cooperation not limited to the scientific community but extended to industry involved in Arctic exploitation and services or in some way impacted by Arctic climate changes. With the awareness that "science-stakeholder connection follows an iterative process: iteration ensures better adjustment of the research priorities to the society expectations"[1], the ARICE project, starting from previous activities carried out by the International Arctic Science Committee (IASC) and EU-PolarNet project, promoted a path of interactions between the scientific community and industrial stakeholders in the Arctic which allowed to identify in a first phase common themes of research, innovation and technological development, and specific industrial research interests in a second phase. Furthermore, the discussion highlighted the absence of instruments capable of carrying out automatic measurements in the field of physic-chemical quantities of significant scientific interest, opening the way for the development of new products by high-tech companies.

This activity was mainly supported by the organization of a research-industry session at Arctic Circle Assembly 2019 in cooperation with EU polar cluster members and a side event Workshop at the Sustainable Ocean Summit 2019.

This report is organized as it follows. Previous activities aiming at connecting science and industrial stakeholders are summarized and discussed in section 2. Section 3 reports ARICE workshop activities and contributions with an overall discussion of their results identifying potential science-industry priorities in research and observation. Major cooperation, industrial and science needs are reported. Concluding remarks will summarise open issues and possible future steps.

[1] N. Biebow. Implementing Science for Society – Next Steps. Connecting Arctic science with society: lessons learned and progress, Arctic Circle 2019

2. Previous activities

2.1 International Arctic Science Committee sessions at Arctic Circle Assembly

During the Arctic Circle Assembly 2017 and 2018, the International Arctic Science Committee (IASC), a non-governmental, international scientific organization with the mission of encouraging and facilitating cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic region, organized a couple of sessions to discuss Arctic science and business/industry cooperation. Discussion, summarized in [2] and [3], pointed out the emergence of awareness of how research can reduce the risks associated with investments in new frontiers and how the development of new technologies for remote and extreme environments can allow private companies to invest in sectors previously considered too risky.

Cleaner technologies, operational datasets, communication technologies are seen as key sectors where research can help industry to reduce the risk that is inherent in working in the Arctic. However, the emphasis on aspects such as requirements with regard to publishing, intellectual property, and timelines, as well as the need of good chemistry between collaborators show as the process of science and business/industry cooperation is still ongoing and likely requires a holistic approach including social science and governance issues.

2.2. EU-PolarNet industrial stakeholder engagement

Within its clear mandate to co-design an integrated European Polar Research Programme involving different stakeholders from the beginning of the creation process, the project EU-PolarNet identified stakeholders related to the polar regions to reinforcing interactions and promoting their participation in different surveys and events.

In particular, EU-PolarNet D4.5 A stakeholder map, released in May 2016, starting from [4] identifies key industry and economic opportunities in the Arctic region related to:

- the exploitation of fossil fuels and mineral resources (oil and gas, including onshore and offshore projects in shallow and deep water; land-based mining / mineral resources, thanks to improved shipping out from Arctic ports)
- the growth of fisheries and aquaculture, thanks to the increased access to ice free waters
- the development of shipping routes with reduced costs due to shorter distances for transit and of the related maritime infrastructures (including ports), logistics and services

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[2] https://iasc.info/communications/news-archive/372-action-group-update-arctic-science-and-business-industry-cooperation

[3] https://iasc.info/communications/news-archive/475-meeting-report-the-cooperation-of-arctic-science-with-business-and-industry

[4] Lára Jóhannsdóttir & David Cook (2015). *AN INSURANCE PERSPECTIVE ON ARCTIC OPPORTUNITIES AND RISKS: Hydrocarbon exploration & shipping.* Reykjavik: Institute of International Affairs / The Centre for Arctic Policy Studies

- the growth of the tourist sector with higher frequency of cruises in remote areas
- the deployment of the first ever transarctic submarine cable, decreasing latency in Asia-Europe telecommunications

Moreover, the specific interests of stakeholder groups for a list of preliminary research topics were identified as summarized in the following table. Research on polar climate systems has a direct impact on oils and gas, fisheries, shipping and ports, and tourism and involves specific economic interest of insurance and reinsurance companies.

Economic interest by different key industry stakeholder groups is also demonstrated for research on solid earth and its interaction, palaeoclimate and palaeo environment, ecosystem services and sustainable management of resources, new technologies, and polar ecosystems and biodiversity.

Key Research topics	Key industry stakeholder groups	Reasoning (position, influence, impacts etc.)
Polar climate systems	Oils and gas, Shipping, Fisheries, Tourism, Ports	Directly impacted
	Insurance and reinsurance companies	Economic interest
Solid earth and its interactions	Mining, Oil and gas; Ports and infrastructure	Economic interest
Palaeoclimate and Palaeo Environment	Oil and gas	Economic interest
Ecosystem Services and Sustainable management of resources	Fishery industry and aquaculture	Economic interest in resource use; Potential impacts
	Living resources industry	Economic interest
	Mining, oil and gas and tourism	Economic interest
New technologies	Industry	Economic interest
	Engineering	Economic interest
Polar ecosystems and biodiversity	Fishery industry	Economic interest in resource use
	Oil and gas, shipping, tourism	Potential impacts
	Tourist industry	Nature interest
Cryosphere	Oils and gas, Shipping, Fisheries, Tourism, Science and research	Changing ice conditions; Data collection and analysis opportunities
Human impacts	Industry operating outside the region	Distant pollution
	Oil and gas, shipping, tourism	Local pollutions sources and potential pollution emergencies
People, Societies and Cultures	All industries	Concerns about impacts local and indigenous people

A starting point for stakeholder mapping has been revised in EU-PolarNet D4.15 White paper on status of stakeholder engagement in polar research, released in September 2019, where business and industry sectors focus on fisheries; port, harbours, shipping and logistics; tourism; insurance and re-insurance companies; development of new technologies for oil and gas industry and renewable resources. It is worth noting the mention of specific organizations such as the Association of Arctic Expedition Cruise Operators (AECO) and International Maritime Organization (IMO) with the International Code for Ships Operating in Polar Waters (Polar Code).

3. ARICE: identification of potential science-industry cooperation and priorities

3.1 Session at Arctic Circle assembly 2019 organized by EU Polar Cluster members

On October 11, 2019, in the framework of the Arctic Circle assembly in Reykjavik, Iceland, the EU Polar Cluster members ARICE, KEPLER, ARCSAR, with ExtremeEarth, organized the session “Breaking the ice: cooperation for safe and responsible exploitation of Arctic sea routes”. The breakout session in addition to an overview of the ARICE, KEPLER, ARCSAR and ExtremeEarth projects, included presentations on industry priorities to support safe, responsible, and effective industry operations in the Arctic Ocean, provided from the sectors of expedition cruise industry and ship construction. The session ended with a panel discussion on the needs of the industry to operate safely in the Arctic, and on ways of industry-science cooperation.

Presentations and discussion pointed out two main general needs (both from science and industry and strictly related to safety in operations) with related opportunities of technological innovation:

- affordable high bandwidth communications
- true (meter scale) high resolution information products in all services.

Indeed, Arctic operators need short term (tactical) situation awareness, basically answering the question “how do I stay safe in what I'm doing today?”. This points out a clear gap between what model-based forecast systems can deliver and what polar (marine) end-user need (in particular, in terms of spatial resolution), i.e. near-real-time climate and weather forecasting exploiting continuous satellite observations and making more use of existing routine observations (in situ and field, also from research groups). Accurate and routine sea ice information products are required, with specific interest in ice strength, able to provide high quality, timely and reliable about sea ice and iceberg conditions. This paves the way to research on automatic extraction of information from satellite data in near-real-time by applying scalable deep learning algorithms for sea ice classification, including the developing of new techniques for distributed training.

Immediate opportunities of cooperation between science and industry have been identified in the tourism sector, where expedition cruise industry can provide vessels of opportunity hosting onboard scientists and scientific equipment and promoting citizens science involving passengers in activities related to improve their awareness of the need of environmental sustainability.

Moreover the expedition cruise industry is generally open to share position (vessel tracking) and sea-floor information to increase safety, although hydrographic offices do not accept crowdsourcing.

The opening of Arctic ship routes poses new issues in maritime safety: shipping activities increase faster than Arctic search and rescue capabilities and an insufficient number of icebreakers to provide expanded escort services is available. Research and innovation in the field of on-board emergency response and lifesaving equipment, that, being the essential first line of defense, must be appropriate, is required. In this context appropriate formation of the personnel plays a key role: not only inexperienced crews may not recognize hazards, but also inexperienced operators may under-specify ships and this, combined with limited experience of many ship designers, could be quite unsafe. From this point of view Polar Code can be a game changer for the design methodologies of polar ships, a sector where climate change and environmental protection pose main challenges such as: i) the effect of disappearance of multi-year ice in much of the Arctic, where Polar Class design points are based on multi-year ice strength and thickness; ii) the design and construction of decarbonized high-powered ice-capable ships with the corresponding development of infrastructures for transition (LNG) and future (hydrogen, etc) fuels; iii) the reduction of ship underwater radiated noise, that is now affecting many areas/ seasons for the first time; iv) the effects of change in ecosystems and invasion species on ship coating.

Environmental sustainability of increasing tourist cruise, shipping, and offshore activities requires the transfer of existing technologies for waste management over ships as well as the development of technology for dealing with oil spills and pollution such as autonomous vehicles for operating in extreme conditions, under ice oil detection and recovery systems, satellite data analysis and enhanced pollution monitoring sensors.

In particular, further discussion with representatives of the shipping sector led to the following table summarizing possible common science and industry fields of interest in ship design and navigation

TOPIC	**INDUSTRY INTEREST**	**ACTIVITIES TO DEVELOP**	
		OBSERVATIONS / TECHNOLOGY	**STUDIES/MODELLING**
change in ecosystems/invasion species	shipping coating	mapping status along navigation routes	assess seasonal behaviour develop simple parametric models
ice physical properties and characteristics	risk assessment/tools ship design route planning optimal use of infrastructures/shipping resources	perform dedicated field campaigns acquire ship and ice data at the same time recover old data sets and perform integrated analysis	lab-experiments improve ice physics knowledge in polar conditions develop parametric models
ice conditions (coverage, thickness)	route planning long-term (monthly, seasonal) navigation services planning	improve use of satellite data NRT mapping	improve risk assessment tools (both for input and risk evaluation algorithms - cfr. above)

pollution	respond to POLAR CODE test new technologies in real conditions	perform extensive campaigns improve automatic measurements establish a baseline for spring and summer	
waste management	prevent new POLAR CODE regulations support tourism industry interests (cfr.)	transfer existing technologies over ships	
survival equipments	reduce risks support ship design	perform tests in real conditions	carry out research on existing and new materials
materials in cold environments (in particular ice growth)	ship design respond to POLAR CODE	perform tests and collect data in real conditions	lab-experiments to improve knowledge and explore new materials and coatings
standards	respond to POLAR CODE work to improve/ameliorate POLAR CODE	work to develop new standards: possible interesting areas, ice radars, steels (thanks to work above on materials) for this point see also EU project CAPARDUS when registered on CORDIS	

3.2 Side Workshop at Sustainable Ocean Summit 2019

On November 20, 2019, in Paris, ARICE project organized a side workshop to the Sustainable Ocean Summit on the topic "Industry-Science Cooperation for Safe and Sustainable Arctic Operations".

Presentations by significant members of the energy and tourism sectors pointed out how industry is already carrying out internal research projects, developing tools and acquiring instrumentation and infrastructures in key areas of interests such as: i) ship design to guarantee performance in ice and environmental sustainability, ii) safe and sustainable navigation in ice; iii) fleet sizing; iv) port management; v) safety equipment and tools. Anyway efforts carried out by a single company are not sufficient to tackle open issues in this area, and cooperative research and innovation is needed.

As already pointed out during the science-industry meeting at Arctic Circle assembly, in the context of a general interest in improved coverage and accuracy of meteo-ocean and ice data for model verification and indicators of climate change as well as for understanding of the specific local conditions and attributes, the leak of quantitative and qualitative information on sea ice is a fundamental issue. Ice thickness is quite important for the initialization of forecast systems as well as the development of reliable dynamics models of ice thickness and drift. Although valuable data on ice concentration and thickness are already acquired along industrial/commercial routes, the coverage of the examined area has to be extended with the development of remote observation systems and improved with new sea ice thickness sensors. Moreover specific data acquisition on deformed ice, ridges, brash ice, rubble ice, ice compression, and ice drift is required also through the development of suitable instrumentation. In particular, the development of advanced image processing systems can support the extraction from satellite images of information on floe size and concentration as well as on iceberg properties and detection. Moreover, the design and development of devices for monitoring of ice-air boundary layer dynamics is fundamental to improve modeling towards the automation of forecast optimized in domain, resolution, output, and time step.

It is worth noting that monitoring and modeling of brash ice, with the development of brash ice growth models and dedicated in-situ measurement systems, could improve the management of port infrastructures, since this phenomenon is very acute in areas where temperature is low and the ship traffic is frequent.

The availability of an ice information system, integrated with shipboard information, will strongly support efficient operations, greatly improving strategic decision making, with a relevant impact not only on safe navigation but also on economics and environmental sustainability due to optimization of fuel consumption enabled by ice routing.

Moreover the integration of ice information with ship performance models can lead to the design of more efficient and safe ships, accounting for variability of ice conditions in design, and to optimize fleet sizing and performance in ice. The assessment of mapping of ice conditions vs. ice class ship can support the assessment of ship rotations during different ice conditions, the ship size and number required for the given transport demand, and the need of icebreakers.

Environment characterization and sustainability plays a key role in the planning of polar activities and design of the new generation of polar ships: i) understanding of environmental conditions, e.g. wild-life migration patterns and alien species, have direct impact on energy industry and the development of ecological coatings; ii) last generation cruise ships are already equipped with systems for waste recycling and advanced wastewater treatment as well as with sustainable propulsion systems reducing SOx, NOx, CO2 and fine particulate emissions through the use of LNG, reducing fuel consumption through the use of digital navigation assistance and energy optimization techniques, and navigating at zero emissions and very low noise in hybrid electric mode.

In this framework both cruise and energy industry declared their availability to assist, support and cooperate with science being involved and participating in observation/measurement campaigns. In particular, tourist cruise industry not only raises awareness among passengers and crew about responsible behavior aboard ship and when on shore but also makes its vessels into ships of opportunity for the scientific community, offering the chance to use its ships and its destinations for logistics purposes, i.e. depositing material or people at specific sites, welcoming aboard the ship researchers and their scientific material in dedicated laboratories, allowing teams to disseminate their knowledge and the latest developments in science to a very receptive audience, often ambassadors of the region being visited.

The idea of recruiting ships of opportunity for data collection can be extended to other sectors such as fishing vessels, covering large areas with respect to fix commercial and limited touristic routes. On the other hand, fisheries can strongly benefit of improved marine environment forecasts and simulation of migration patterns.
Anyway, the perspective of a huge fleet of ships of opportunity for data collection has to deal with a basic technical issue: since ship systems are diverse for instrumentation, configurations and onboard topologies (also changing over time), the integration against ship systems would require tailoring by each "app" for data acquisition. This approach is not technically sustainable on a large scale. A possible solution is suggested by what happened for computers: making the integration against vessel

systems vessel-independent through a kind of hardware abstraction. The main idea of defining standard ship interfaces based on DDS requires, of course, a global discussion and path towards standardization since it could/should be extended to any ship of opportunity, also outside Arctic regions.
Moreover, data collection through ships of opportunity has to be supported by automatic instruments. State-of-the-art technology provides automatic devices for measuring essential climate and ocean variables, with the exception of cloud properties and, partially, of aerosols, but does not present suitable instrumentation for the automatic measurement of essential sea ice and snow variables, i.e. sea ice extent/ice edge, sea ice thickness, sea ice concentration, floe size, snow thickness, Albedo, and ice ridge frequency, that, as discussed before, are fundamental for the development of useful new generation forecast systems.
In conclusion, the Arctic operators confirmed a strong interest in the development and monitoring performance of emergency and lifesaving equipment and systems as well as in the design and development of vehicles able to move on scattered ice both for recreation and safe evacuation purposes.

3.3 Identified potential science-industry priorities in research and observation

Since it undergoes globally the strongest warming and the changes in the ice cover are substantial, the Arctic Ocean has an especially high interest in the study and monitoring of changing climate. This motivates the need of a comprehensive monitoring, in spite of dramatic limitations in environmental data collection due to the difficult access, in order to develop a deeper understanding of the numerous processes related to changes in the Arctic climate, sea ice and ocean. This will allow the design and development of improved forecasting models, and an increased safety and sustainability of all operations in the Arctic Ocean. In such a context, where the need to better understand, model, and monitor the Arctic in support of responsible economic use, conservation, and management has never been greater, government and scientific institutions have fewer resources to collect data. On the other hand, shipping, oil and gas, mining, fisheries and other Arctic industries operate infrastructure with tremendous potential for cost effectively collecting data, often in areas important to filling science gaps. Hence the idea of filling the lack of observations through co-operation outside of science community by recruiting ships and platforms of opportunity.
In the vision proposed by the ARICE project, the involvement of industry in collection of oceanic and atmospheric data enables the scientific community to have a deeper understanding of phenomena thanks to long time series and repeated acquisition routes. On the other hand, the improved weather forecasts, also in targeted operational areas, as well as predictability of extreme events affecting ships and platforms would benefit industry with safe operations, better planning, reduced risk, and savings from ship routing.
On the basis of these considerations, together safety needs related to harsh remote environment, as well as the need of environmental sustainability and fast and efficient intervention in case of any incident, Arctic in-field industrial operators, e.g. expedition cruise and energy, demonstrated their availability to share data and make available their logistic infrastructure to cooperate with science.
The iterative discussion between science and industry communities did not just lay the foundations, at least in principle, for a "programme of ships and platforms of opportunity", but it led to identify key technologies to overcome the bottlenecks that prevent an efficient and effective large-scale improvement of ship-based and autonomous measurements in ice-covered seas. In this way, specific technological standards and tools that require research and innovation for their development with short-medium term transfer time to market have been identified.

Indeed, the implementation of a large heterogeneous fleet of ships and platforms of opportunity, involving expedition cruise, energy, fishery and other sectors, requires the design and development of standard ship interfaces based on DDS, opening new markets, not only in the Arctic area, for major system architecture and software companies as well as for SMEs developing apps for instrument and data management. Moreover, the acquisition of sea ice and snow variables of interest by ships and platforms of opportunity requires the development of automatic instruments, not yet available, paving the way RD&I activities with interesting short-mid term market opportunities.
In order to support the definition of more accurate models and simulations for near real-time high resolution forecasts the big amount of data acquired have to be transferred to storage, analysis and management systems requiring the development of high bandwidth communications in the Arctic area as well as of cloud-based services. A specific bottleneck has been identified in the design, implementation and validation of AI-based methodologies for automatic classification of ice properties from satellite images: further basic research is required in particular for the definition of distributed training methodologies for deep learning systems.
Better knowledge of the environment (ice coverage, ice properties, presence of alien species, etc.), combined with information on effects on ship behaviors, will lead to improve the design of new Arctic ships for safe navigation in ice and environmental sustainability and will support optimal planning of routes, fleet sizing and characterization, thus reducing costs and environmental impacts for industrial operators.
To conclude, it should be stressed how research on new materials and equipment for individual protection survival, even of weak people, in a polar environment, as well as vehicles for transport and evacuation in harsh conditions, e.g. scattered ice, is always a topic of interest for industrial operators.

4. Conclusions

The previous sections show how iterative interactions between science and industry communities led to interesting perspectives of cooperation related to a common programme of ships/platforms of opportunity for data collection, paving the way to RD&I activities on key technological topics.

Anyway common interest and willing, in order to get effective, should be supported by high level political agreements fostering data sharing and cooperation for a sustainable use of Arctic resources and efficient answers to accidents with potential dramatic environmental impacts.

In addition, in view of potential technological development and market opportunities related to science-industry Arctic cooperative operations, it is worth noting that this report focuses only on the aspects more related to a “ships of opportunity” program, leaving open space to discuss technology required to monitor the ice-covered areas.