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Oceans and the law of the sea

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Report of the Secretary-General**

Summary

In paragraph 378 of its resolution 77/248, the General Assembly decided that the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea would focus its discussions at its twenty-third meeting on the theme "New maritime technologies: challenges and opportunities". The present report has been prepared pursuant to paragraph 389 of the resolution, with a view to facilitating discussions on the topic of focus. It is being submitted to the Assembly for consideration at its seventy-eighth session and to the States parties to the United Nations Convention on the Law of the Sea, pursuant to article 319 of the Convention.

* A/78/50.

** Owing to word limits for reports mandated by the General Assembly, references for the material contained in the present report are to be found in the advance, unedited version, which includes comprehensive footnotes and is available on the website of the Division for Ocean Affairs and the Law of the Sea at https://www.un.org/depts/los/consultative_process/icp23/ICP2023AdvanceUneditedReportingMaterial.pdf.

I. Introduction

1. Technology is recognized, in particular through Sustainable Development Goal 17 of the 2030 Agenda for Sustainable Development, as one of the major pillars of the means of implementation of the 2030 Agenda and of the United Nations Conference on Sustainable Development follow-up processes. Innovations in marine technology and improved access to and exchange of ocean technologies are part of what is needed to improve the management of human uses of the ocean to ensure sustainability. All maritime industries are highly reliant on technology to operate efficiently, safely and without damaging the marine environment.

2. The importance of maritime technologies to sustainable development, including of the ocean, as well as challenges linked to the development of new technologies, is underlined by the decision of the General Assembly in its resolution 77/248, paragraph 378, that the twenty-third meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea would focus its discussions on the theme "New maritime technologies: challenges and opportunities".

3. To facilitate discussions at the twenty-third meeting of the Informal Consultative Process, the present report provides an overview of maritime technologies on a sectoral basis, with a focus on new technologies, as well as outlining challenges in each sector and opportunities. Also covered are technologies that are cross-sectoral or that are not inherently maritime technologies, but that enable or enhance the sustainable development of the ocean. The report draws on the contributions submitted by States and relevant organizations and bodies,[1] as well as on other reports and studies related to the theme.

II. New maritime technologies

A. Marine science technologies

4. Marine science, which is underpinned by ocean observations, is important for eradicating poverty, contributing to food security, conserving the marine environment and resources, helping to understand, predict and respond to natural events, and promoting the sustainable development of oceans and seas. New maritime technologies for ocean observation, such as next-generation sensors, novel analytical tools and uncrewed systems, dramatically enhance our ability to explore and observe the ocean at unprecedented temporal and spatial scales. They have the potential for transformative advancements in the quality and timeliness of maritime products and services, provide more comprehensive knowledge about the ocean, inform sustainable management and improve environmental intelligence for decision-making and developing the blue economy. These technologies span all other sectors covered in the present report.

5. Advances in sensor development, from lab-on-a-chip technology to acoustic sensing, enable cost-effective low-carbon measurements of an increasing range of essential ocean variables and other physical, chemical, biological and anthropogenic impact parameters with greater accuracy. Innovative methods in marine biotechnology, also known as omics technologies, such as the analysis of environmental DNA and RNA in seawater or sediment samples, have the potential to revolutionize the monitoring and understanding of marine biological communities,

[1] The full text of the contributions is available from the website of the Division for Ocean Affairs and the Law of the Sea at https://www.un.org/depts/los/consultative_process/icp23/ICP2023AdvanceUneditedReportingMaterial.pdf.

including fish stocks. They can be faster, cheaper and less invasive and provide more information than traditional methods. Enhancing traditional platforms, including ships of opportunity, with those new sensors is key but has not yet been sufficiently realized.

6. Uncrewed systems, including remotely operated, autonomous or hybrid aerial, surface and underwater vehicles and platforms, such as floats, gliders, drones and smart buoys, as well as animal-borne sensors and tags, have dramatically expanded the collection and use, often in real time, of critical, high accuracy and time-sensitive data. They have proven to be particularly effective at facilitating missions in remote, data-sparse locations and harsh or inaccessible environments and for sampling efforts of long duration. Such systems are becoming increasingly important for bathymetric mapping, habitat characterization, shipwreck localization, real-time monitoring of harmful algal blooms, detection and tracking of oil seeps and spills, monitoring of marine plastics, weather predictions and traffic monitoring, as well as hydrographic, oceanographic, atmospheric, meteorological, biodiversity, fishery, ecosystem and geographical surveys, augmenting more expensive and environmentally burdensome conventional methods that use crewed systems. Among the newest technologies are modular and customizable suites of automated systems that provide an “end-to-end” approach, from monitoring design to data collection, analysis and reporting, and translate field data into comprehensive information.

7. New autonomous underwater vehicles have advanced navigational and obstacle avoidance sensors and artificial intelligence capabilities, allowing them to complete georeferenced and repeatable surveys and to detect and follow contours and slopes automatically. Sail drones, powered by wind and solar energy, can transmit oceanic and atmospheric data in real time, while hybrid versions can also operate underwater. Solar-powered smart buoys provide customized monitoring of multiple parameters from permanent locations, with a view to obtaining high-definition time series. Autonomous systems carrying hydrophones have provided new opportunities for the passive acoustic monitoring of vocalizing marine mammals, facilitating the avoidance of ship collisions. In this context, equipping Argo floats with acoustic sensors could represent a major opportunity for enhancing global passive ocean observation and improving ocean acoustic models.

8. The integration of environmental sensors into undersea telecommunications cables, known as Science Monitoring and Reliable Telecommunications (SMART) cables, is expected to boost ocean monitoring and tsunami and earthquake early warning for disaster risk reduction. A pilot SMART cable system is expected to become operational off the coast of Portugal in 2025.

9. Advanced seabed mapping instrumentation enables the faster collection of large quantities of high-quality data to be collected in 3D at any depth. Uncrewed vehicles can complement the work of crewed research vessels equipped with echo sounders, side-scan sonar and other mapping technologies, furthering efforts to produce a complete map of the world’s ocean floor by 2030.

10. Improved ocean and coastal observation requires a sustained, persistent and affordable presence in the ocean, with a densified global observation network, both at sea and from space. To achieve these ambitious goals, it will be necessary to enhance existing infrastructure to meet the analytical demands of emerging technologies, and to overcome the engineering challenges associated with novel technologies, including by decreasing the weight and size of instrumentation, lowering costs in terms of deployment, acquisition and maintenance, increasing resistance to corrosion and biofouling and finding innovative solutions regarding energy supply and data transfer, for example, by subsea acoustical, optical and electromagnetic networks (see para. 63). In this context, dedicated facilities to test

and evaluate new maritime technologies safely offer an opportunity for verifying that they are fit for purpose, safe to operate and environmentally compliant. Fostering the operationalization of successfully tested emerging technologies, strengthening research, expanding partnerships, integrating artificial intelligence and other computing tools (see para. 64) and increasing workforce proficiency in the operation and use of new technologies are also important. The integration of new technologies into long-term data sets that inform policy decisions has been identified as a challenge that needs to be addressed.

11. The Ocean of Things is a programme that seeks to enable persistent maritime situational awareness over large ocean areas by deploying thousands of small, low-cost floats that form a distributed sensor network. Cutting-edge technologies under development include the adaptive collaboration of networked multiple uncrewed systems, which will require improved interoperability and international cooperation, addressing the legal challenges of autonomous navigation and implementing formal command and control architectures with advanced tools for distributed mission and motion planning, navigation and real-time decision-making, the combination of which is still in its infancy.

12. Marine genetic resources are at the cutting edge of marine science and the focus of an expanding range of applications, including in the pharmaceutical, nutraceutical, antifouling and cosmetic industries, with significant methodological innovations, including sampling, screening and analytical techniques. The decreasing costs of sequencing and advances in the biotechnology sector have led to an increased reliance on public databases of genetic sequence data, rather than physical samples. Developments in molecular technologies, such as DNA sequencing, are enabling new scientific discoveries, while developments in omics approaches, including high-throughput DNA sequencing and bioinformatics analyses, could be used in diverse applications, including the discovery of natural products that may have medical or commercial value.

13. Methodological challenges include difficulties in obtaining high-quality near-complete genomes from uncultured microorganisms, with further advances needed to improve their completeness. Significant knowledge gaps remain regarding the extent of genetic diversity in the ocean. With most research in this field being carried out by a small number of countries, many States, in particular developing States, face the challenges of limited capacity and financial resources to conduct such research. In addition to the challenges inherent to deep-sea sample collection, downstream processing and analysis require specialized expertise and tools, which are often limited in developing countries. Capacity-building initiatives, including the transfer of marine technology, are key to addressing such challenges.

14. Systemic barriers and lack of representation in leadership roles have contributed to an underrepresentation of women in ocean science. To fully utilize the significant contributions and potential of women to the development of new technologies, as well as the protection and preservation of the marine environment, this underrepresentation needs to be addressed and gender balance achieved.

B. Technologies to mitigate climate change

15. As the ocean continues to absorb most of the excess heat caused by increasing concentrations of greenhouse gases, as well as a significant proportion of anthropogenic carbon dioxide emissions, it is warming, rising and becoming more deoxygenated and acidified. New maritime technologies can play a crucial role in monitoring, better understanding, preventing and potentially reversing those negative

impacts, and global and regional initiatives make use of related innovations (see para. 70).

16. The United Nations Framework Convention on Climate Change (UNFCCC) has identified the need to further strengthen sustained systematic observations of the ocean and address gaps by developing or employing new ocean observation techniques to monitor the ocean and better understand climate change impacts. An example of a tool used to that end is ReefCloud, a cloud-based, open-source technology powered by artificial intelligence to facilitate the management, analysis and reporting of coral reef monitoring data. Satellite imagery and independent autonomous underwater gliders can assist with forecasting and understanding ocean acidification by monitoring the behaviour of phytoplankton.

17. Ocean-based options for climate change mitigation, including ocean-based renewable energy (see paras. 32–39), the decarbonization of ocean industries and ocean-based carbon capture and storage, would help States to achieve the goals of the Paris Agreement. Advancements in modelling are also helping in this regard (see para. 65). Investments in the development of new technologies to lower greenhouse gas emissions from shipping and fishing vessels are ongoing and need to be scaled up. Regional fisheries management organizations or arrangements could facilitate the identification and testing of technologies aimed at decarbonizing the fishing sector. The Global Centre for Maritime Decarbonisation has been conducting research on technologies to decarbonize the maritime sector more generally. Research continues on the development of new technologies for the sequestration of those maritime emissions that cannot be avoided and on potential carbon dioxide removal in coastal and marine settings.

18. Emerging technologies for carbon capture and sequestration in subseabed formations, as well as geoengineering, are being addressed within the International Maritime Organization (IMO). Four geoengineering techniques have been identified for priority evaluation. The need to apply the precautionary approach and utmost caution in the consideration of those techniques has been underscored by the parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and its 1996 Protocol.

19. With regard to adaptation to climate change, UNFCCC reported that one of the 10 key messages from the Ocean and Climate Change Dialogue 2022 was that marine technology and marine and coastal nature-based solutions should be integrated to ensure that action is more robust, comprehensive and cost-effective. A call was made in the dialogue outcome for hybrid approaches, including the restoration of coastal vegetation alongside engineered sea walls to reduce the impacts of storm surges and sea level rise, investments in nature-based infrastructure and new technologies to reduce harmful fishing practices. It also noted that offshore renewable technologies could be paired with adaptation strategies, for example, mangrove protection with wave energy, to create synergies to protect coastal and marine communities at risk. Lastly, the outcome highlighted the need to build cross-sectoral partnerships, including with the private sector, to, inter alia, develop innovative technologies and bolster the business case for integrated adaptation solutions.

20. The lack of financing and capacity-building continues to present challenges for the development and implementation of new maritime technologies to address climate change. Despite the pressing adaptation needs of coastal and island communities, knowledge, capacity and financing gaps prevent the widespread implementation of integrated solutions, including those incorporating new technologies. “Funding for ocean-climate action needs to increase and access to funding must be supported” was another key message of the 2022 dialogue. Perceived risks in investments in marine technologies continue to be a challenge. However, advances in ocean observation and

knowledge could ameliorate those risks. States could identify and promote innovative financing and risk reduction mechanisms, including through capital investment support and revenue support mechanisms. The rolling workplan of the UNFCCC an Technology Executive Committee for 2023–2027 includes an activity on “Innovative ocean climate solutions” that continues to enhance action on technology development and transfer in support of mitigation of and adaptation to climate change.

C. Technology to mitigate the impacts of anthropogenic activities

21. Land-based sources are the biggest contributors to marine pollution. A wide variety of pollutants enter the marine environment from land-based sources, including nutrient run-off, hazardous substances, such as heavy metals, solid waste, such as plastics, and sewage sludge and organic and inorganic waste.

22. Innovative sensor technology allows for better monitoring of human impact variables, such as marine plastics. Satellites are also playing an increasingly important role in monitoring, and modelling can be used to identify and predict the impact of anthropogenic pollution. New technologies may also play a role in managing the full life cycle of plastics, including in removing plastic pollution from the ocean.

23. Introduced anthropogenic noise may interfere with many functions of marine species, and it may also cause physical damage to marine mammals, fish and invertebrates. Solutions for shipping noise include new propellor and hull design, improving hull insulation and damping and better maintenance of those parts. New quieting technologies and low-noise concepts have been developed for pile-driving, including surrounding pile-driving with bubble curtains and using vibratory hammers and dampening systems. New technologies are also assisting in the conduct of research to fill knowledge and data gaps on ocean noise and its impacts.

24. Beyond the decarbonization of the shipping sector (see paras. 40–42), new technologies are being developed to address other impacts of the sector caused by the discharge of ballast water, biofouling and marine plastic litter. The GloFouling Partnerships Project promotes new technologies to prevent and manage marine biofouling, including in-water cleaning systems, new anti-fouling components and the use of robotics for monitoring and inspecting surfaces. The GloLitter Partnerships Project addresses marine plastic litter from ships, including by targeting waste management in ports. Follow-up activities delivered as technology demonstration and capacity-building are also planned to minimize the transfer of invasive aquatic species.

25. Capacity-building is needed to reduce the input of pollutants into the ocean, in particular through the introduction of cleaner production, quieter technologies and cheaper and readily deployable wastewater-processing technologies. Demonstration pilots to reduce biofouling and related emissions from shipping will assist developing countries with building their knowledge on the control and management of biofouling, including to prevent the transfer of invasive aquatic species.

D. Technology for the sustainable exploration for and exploitation of non-living resources

26. New technologies to enable the sustainable exploration for and exploitation of non-living resources are constantly emerging or planned, including for regional

identification, local confirmation and characterization, and the assessment of prospective areas, as well as for deep-sea mining.

27. In terms of exploration technologies, recent innovations include high-resolution remote sensing techniques, ranging from photographic surveys to geophysical measurements, as well as combined autonomous underwater vehicle photographic surveys, automated object-based image analysis and multibeam backscatter recording, with the potential to increase the density of observational data in the exploration for marine polymetallic nodules.

28. As regards exploitation, new machinery has been developed for the seafloor extraction of marine polymetallic sulphides, including cutting and collector machines and subsea slurry lift pumps for transport to the surface. Exploitation technologies have also been successfully tested to retrieve polymetallic nodules from significant depths; however, additional field testing and further improvements in terms of scalability are needed. New technologies are currently under development to selectively harvest polymetallic nodules individually using image sensing and employing robotic technology to minimize plumes, preserving nodule fauna and avoiding impacts to sediment structure or fauna. Low-energy and selective techniques currently under development also include bioprocessing using microbes and reusable eutectic liquid solvents. Relevant mining technologies are still at an early stage of development for marine cobalt-rich ferromanganese crusts. Research is being conducted to look into the extraction of uranium from seawater, though it is not yet near practical application.

29. Technology development and innovation supported a series of International Seabed Authority activities, including the conduct of unique training activities by exploration contractors, the development of research and publications and the engagement of expert groups to inform future policy dialogue.

30. This technological progress notwithstanding, many challenges remain in connection with deep-sea mining or have newly emerged, including the limited knowledge of the impacts of deep-sea mining on the marine environment and gaps in overall knowledge of the deep-sea environment, including deep-sea ecosystems. Specific concerns have been raised over the known effects of deep-sea mining, including the disturbance of sediment and seafloor ecosystems during extraction and processing, the energy intensity of certain extraction methods and the potential environmental impacts of chemical leaching agents during processing. While the need to balance environmental protection with economic progress has been underscored, a moratorium, or precautionary pause, before deep-sea mining exploration progresses, or a deferment or extension of the deadline for the adoption of regulations on exploitation by the International Seabed Authority has been put forward.

31. The extraction of many mineral resources requires advanced technology and is thus largely limited to those that have access to such technology. Other challenges concern the limited capacity of developing countries and their access to tools for carrying out downstream steps in sample processing, taxonomic or functional description, data analysis and ecosystem characterization, which hamper their contributions to deep-sea assessments. Acquiring the infrastructure and knowledge required to assess the potential for exploration for and sustainable exploitation of deep-sea mineral resources, while ensuring marine environmental protection, remains a challenge, in particular for small island developing States. Identifying key priorities for scientific research and technology development, as well as mobilizing resources for internationalized sciences, is also a critical challenge for developing States.

E. Energy production technologies

32. By 2050, the electricity sector will account for two thirds of energy use. Unlocking the potential of offshore renewable energy sources is necessary to meet that demand, as those would also support the decarbonization of the power sector. Clean and renewable energy can be generated from the ocean to provide electricity and contribute to emissions reductions from the energy sector. The development of offshore renewable energy sources could open the potential of other sectors of the blue economy.

33. Offshore wind turbine installations and operations have moved further offshore into deeper waters to obtain the best potential wind resources. The most mature wind farm technology uses fixed foundations as the base structure, with floating wind farms installed in waters more than 60 metres in depth. A number of European Union member States have announced large commercial floating wind energy projects. Some States have a legal framework in place, based on the ecosystem approach, to address the potential negative impacts of offshore renewables on marine life and seabirds. Spatial modelling has also been used within the United States of America to determine offshore wind installation sites in order to limit the impact on fisheries and endangered species, while also resulting in stronger stakeholder support. Another form of offshore wind energy that is currently at an early stage of development is airborne wind energy systems, which produce electricity through propeller turbines and generators mounted on a flying wing operating at 200 to 450 metres of altitude. The expansion of offshore wind also supports the development of green hydrogen with commercial-scale offshore wind parks coupled with battery storage or hydrogen production envisaged in the near future.

34. Ocean energy is currently largely unrealized, despite its significant potential. Global ocean energy is projected to contain an annual energy potential that is more than enough to meet current global electricity demand. Ocean energy technologies, such as for tidal and wave energy, are the most advanced, with about 75 per cent of global capacity located in European waters. Singapore has commenced work on the MAKO Tidal Energy Site through a two-year project involving academia, industry and government agencies to harness tidal energy. Ocean thermal energy conversion only has a few existing demonstration plants in operation, and salinity gradient technology had only one operational project in 2020. Projects are often decommissioned after successfully completing the testing phase.

35. Placing solar photovoltaic panels on a floating platform has become a viable alternative, in particular for islands or densely populated countries with limited land area. Floating nuclear power plants are being explored in several countries, with research being done to design reactors that can accommodate the highly variable movement of the vessel on which the reactor would be situated.

36. The development of offshore renewables is projected to bring socioeconomic benefits and enhance the livelihoods of developing States, in particular small island developing States and least developed countries, through the creation of jobs, local value chains and synergies among various actors in the blue economy.

37. Clear and long-term policy frameworks are needed to enhance the adoption of most offshore renewable technologies into a nation’s energy mix, including in energy road maps or nationally determined contributions. Global and regional initiatives also assist in this regard (see para. 70).

38. Offshore renewables are often located far from demand centres, requiring long-distance grid infrastructure. Another challenge for clean energy technologies such as offshore renewables, in particular in developing countries, is the high cost of upfront

capital. In this regard, participants in the Ocean and Climate Change Dialogue 2022 called upon parties to promote innovative financing and de-risking mechanisms. Bringing the cost of capital down, in particular in developing economies, could help to provide clean and affordable energy as a way to ensure public support for offshore renewables projects.

39. More investment is needed to reach the level at which clean energy technologies can replace fossil fuels. The European Union has a number of frameworks to help to mobilize the necessary funds, such as the InvestEU programme, the Connecting Europe Facility or the Innovation Fund. However, there are also challenges in that, except for offshore wind, most ocean-based renewable sources are not at a commercial stage, and more research, development and demonstration are required to bring those technologies to maturity.

F. Shipping technologies

40. International shipping is an integral part of the global economy, carrying over 80 per cent of world trade and providing the most economic and environmentally sustainable way of transporting cargo; however, it is heavily reliant on fossil fuel. The decarbonization of the maritime sector, in line with the Paris Agreement temperature goal, thus remains a significant challenge. In support of a greener transition, the IMO world maritime theme for 2022 was “New technologies for greener shipping”. The revision of the Initial IMO Strategy on Greenhouse Gas Emissions from Ships, due to be conducted in July 2023, is an important opportunity for increasing sectoral ambition and aligning the decarbonization pathway of the industry with a 1.5 degree Celsius trajectory. It will be important for decarbonization targets to be supported by agreement on a set of midterm measures that encourage an equitable transition, including technical standards and market-based incentives that support the maritime workforce. While innovation in the global blue economy will help to reduce overall greenhouse gas emissions from shipping, technological innovation in the maritime industry is also critical to realize that potential. Significant investment on the part of Governments and industry, including in the form of subsidies and loans, will help to promote the technological innovation needed to facilitate the sector’s rapid decarbonization.

41. Investment in research and innovation is planned in the European Union to achieve zero emissions in waterborne transport by 2050. In this regard, technological advances have been made to reduce greenhouse gas emissions in shipping through the use of alternative or renewable energies to power vessels, and trials with biofuel-powered shipping and preparations for operating container ships that run on carbon-neutral “green” methanol and ferries that run on hydrogen are under way. Engines that use novel fuels are also being developed. Research and development on technologies related to hull design, power, propulsion and energy efficiency, as well as operational, coordination and support measures to decrease the impact of waterborne transport greenhouse gas emissions, is also ongoing.

42. Green shipping corridors to spur the early and rapid adoption of fuels and technologies that deliver low or zero emissions across the maritime sector in order to put it on a pathway to full decarbonization have been underscored by UNFCCC. Signatories to the Clydebank Declaration for Green Shipping Corridors recognized that fully decarbonized fuels or propulsion technologies should have the capability to not add additional greenhouse gases to the global system through their life cycle, including during production, transport and consumption. In the year following the launch of the Clydebank Declaration, the number of global green corridor initiatives grew to more than 20.

43. In addition to mitigating sources of other ship-based pollution, such as invasive species and biofouling (see para. 24–25), new maritime technologies can help to address other challenges facing the maritime industry, including risks to navigation and the safety of life at sea.

44. Artificial intelligence has been introduced on smart ships with the aim of limiting human error and avoiding collisions, saving fuel by optimizing routes and limiting waiting times, distributing goods efficiently in ports and optimizing cargo distribution by avoiding unused cargo space. Trends towards more efficient and autonomous systems in shipping, including by employing energy harvesting and advanced battery technologies, are emerging.

45. More broadly, cloud computing has increased the exchange of real-time data with operational and forecast services, and big data analytics have increased navigational efficiency by factoring weather trends into navigational decision-making. Blockchain technology has the potential to limit paperwork and processing time, and smart contracts may enable the tracking of shipments through the value chain. Improvements in sensor technology have reduced the need for examining equipment aboard ships and increased the automation of alerts for necessary maintenance. 3D printing technology can contribute to the availability of spare parts on vessels, and aerial drones can help to supply goods to ships or assist with route inspections, as well as other aspects of security and surveillance. In addition to contributing to security, maintenance and inspection operations, industrial robots can also assist with delivery and firefighting.

46. Efforts to enhance the collection and availability of data to improve the safety of navigation are ongoing. In this regard, Australia has made bathymetric data freely available, and the European Union has made global navigation satellite system (GNSS) data available to commercial shipping, including for use in search and rescue beacons and high-accuracy navigation. Real-time data to improve congestion in ports, including to reduce vessel waiting times, improve environmental monitoring and identify sources of pollution, was also called for by one State.

47. Singapore has been working with like-minded countries, as well as research and industry stakeholders, to develop green and digital shipping corridors as valuable test beds to trial new technologies and fuels in a controlled environment, gain operational and safety experience and optimize route planning. Tools and approaches to support safe navigation, including aerial drone technology to fill data gaps in nearshore coastal seafloor mapping and technology to process voluminous data produced by modern sonar systems, have also been developed.

48. In terms of future challenges, the availability and affordability of innovative technologies represent a cross-cutting challenge and require balancing the potential benefits of efficiencies against safety and security concerns, as well as environmental and trade impacts, costs to the maritime industry and effects on workers, both on board and ashore. It has also been suggested that new technologies be developed that would assist seafarers in their work instead of replacing them.

49. New innovations will be needed in the maritime industry to facilitate the scalability, affordability and availability of low-emission propulsion technology and fuel, increase integration and interconnectedness of new technologies, including for data collection and evaluation, and improve observation capabilities to monitor and address the consequences of climate change. Enhanced coordination and cooperation, as well as capacity-building, will also be needed to harness technological progress at the regional and global levels. In this regard, IMO has stressed the need to promote inclusive innovation, especially in the context of developing countries, and in particular small island developing States and least developed countries.

G. Technologies for sustainable fisheries and aquaculture

50. The lack of sufficient scientific knowledge regarding fish stocks and the ecosystems that they are part of, as well as associated data gaps, hamper fisheries management based on the best available scientific information. New marine technologies are being developed to address some of those challenges, including through the remote or automated monitoring of environmental conditions, the automated collection of data on fish and advanced modelling.

51. Earth observation data help both the fisheries industry by using satellite imagery, coupled with ocean modelling techniques, to provide information services, such as ocean forecasts and zooplankton observations for fish stock detection, and aquaculture businesses for farm siting and production. Satellites, aerial and underwater surveys from ships and autonomous platforms, including smart buoys, as well as tagging, are being used to assess the abundance of marine mammal and fish populations. Emerging genetic technology promises to inform fisheries management through a range of advances, including “Fit-Chips”, which, through the collection of non-invasive samples, provide information on the physiological condition of a fish, the presence of pathogens and environmental conditions that are affecting it.

52. New technologies can also contribute to making fishing activities more sustainable, for example, electronic gear tagging can help to reduce illegal, unreported and unregulated fishing and track lost gear, thereby diminishing pollution and curbing ghost fishing. The incorporation of marine protected area information in vessel monitoring systems could further enhance their capacity to regulate fishing in such areas. The Singapore Food Story R&D programme was launched in 2019 to support the development and use of productive, climate-resilient, innovative and sustainable technologies for aquaculture.

53. Monitoring, control and surveillance are essential to combating illegal, unreported and unregulated fishing but have historically proven labour- and resource-intensive. New marine technologies, such as drones, uncrewed surface vessels and sound traps, as well as improvements to existing monitoring tools, have rendered those activities easier and less expensive, thereby making it possible to expand their scope to small-scale fisheries. The progressive evolution of on-board transponders for fishing vessels, with reduced upfront costs, equipment size and technical requirements and enhanced effectiveness, reliability and functionality, has allowed for improved tracking and control by coastal States and flag States over a greater range of vessels, including small-scale fishing vessels. Technology, including through improvements in cloud computing, has also improved the efficiency and interoperability of vessel monitoring systems and platforms used by States and regional fisheries management organizations or arrangements to track and analyse fishing vessel activities in real time, so as to identify potential illegal, unreported and unregulated fishing.

54. Vessel monitoring systems and electronic monitoring systems can monitor vessel movement and activity, as well as on-board activities. New advanced tools for fisheries control include closed-circuit television; sensor data in real time, automatic species recognition software; artificial intelligence; machine learning; robotics, remotely piloted surveillance platforms; high-resolution satellite imagery; Internet-connected systems and real-time transmission of catch and traceability records; improved systems for data analysis, data cross-checking and data-sharing; radio frequency identification; traceability for labelling, rapid DNA-based assays and open access to shipowner register and flag data enabled by blockchain technology; the digitalization of catch documentation schemes; intelligent supply chains enabling

traceability systems from vessel to market; and handheld vessel positioning and logbook systems suited to small-scale and recreational vessels.

55. To combat the use of tampered or spoofed automatic identification system signals, some monitoring, control and surveillance data providers are already able to combine resulting data with satellite imagery to spot vessels that may have purposefully deactivated or tampered with their vessel monitoring systems and automatic identification system transponders.

56. In the field of fisheries, some of the challenges associated with the introduction of new technologies include: the high cost and technical complexity of new technology, which may exacerbate capacity gaps; the high level of diversity among fisheries and fishers, in particular between commercial and small-scale and artisanal fishers; and the lack of harmonized technical specification frameworks and data-sharing protocols.

H. Technologies in the field of maritime safety and security

57. In the area of maritime safety and security, new technologies, such as marine autonomous surface ships, aerial surveillance, including drones, satellite surveillance, satellite-based search and rescue, underwater communication systems, remote sensors and sensor platforms, can be applied. For example, the Copernicus Maritime Surveillance Service provides earth observation products with operational functions that include maritime safety and security. The development of those technologies presents considerable opportunities but also gives rise to various challenges and concerns.

58. New technologies may present many opportunities to improve maritime domain awareness, including the integration of new satellite-based technologies to create a single common operating picture and supplement automatic identification systems in identifying and tracking so-called “dark shipping”. Such technologies present opportunities for ensuring stability and peace in the maritime domain, including through enhanced and less costly monitoring.

59. The coordination of national efforts in respect of data exchange standards (see para. 67) with larger regional and global initiatives is important. In this regard, initiatives such as the International Hydrographic Organization S-100 data standards and the IMO Global Integrated Shipping Information System, which contains a specific subsection for information-sharing in respect of maritime security, are examples of the integration of maritime security considerations in modern data exchange.

60. Maritime cyberrisk presents a multitude of challenges for information technology and operational technology systems, including for shipping, ports, navigation and monitoring systems, which can be as vulnerable to cyberattacks as other systems, as evidenced by an increase in the number of such attacks across the maritime industry. As early as 2017, IMO took the initiative to raise awareness of how to tackle emerging risks through its maritime cyberrisk management approach.

61. New technologies may facilitate the commission of maritime crimes, including terrorist acts against shipping and maritime installations, drug trafficking by sea and piracy and armed robbery against ships. Various methods can be employed to manipulate automatic identification systems, the so-called “automatic identification system spoofing”, which allows for more sophisticated ways to conceal illegal operations. At the same time, new technologies can also be used for the detection of criminals and prevention of crimes, as well as for maritime law enforcement. In this respect, the United Nations Office on Drugs and Crime Global Maritime Crime

Programme supports the innovative use of technology to counter maritime crime and assist maritime law enforcement. Similarly, artificial intelligence-powered security systems may offer a wide range of opportunities for maritime law enforcement.

I. Associated technologies

Remote sensing

62. Earth observation satellite technologies and GNSSs have fundamentally changed the maritime domain. Remotely sensed data, obtained by satellites or aircraft, are available at increasingly higher resolutions and include a range of essential ocean variables. Satellite imaging and modelling technology, as well as aerial drones, can also assist in mapping the nearshore coastal seafloor and facilitate marine spatial planning, while telecommunication satellites also support the tracking of tagged marine animals. The development of next-generation high-performance micro- or nanosatellites conducting higher-frequency and lower-latency observations is needed to improve applications, such as the monitoring of natural disasters and extreme weather events, fishery protection, search and rescue operations and detailed modelling of ocean phenomena. The Galileo High Accuracy Service GNSS has started to provide free-of-charge decimetre accuracy data globally that can be used for more accurate navigation, positioning and timing applications.

Communications

63. The increase in the volume and density of data collected and transmitted using new maritime technologies requires an enhancement of high-throughput communications hardware and software. Research in and development of multimodal underwater communication networks that combine acoustic, optical and electromagnetic communication channels have been put forward in this regard. This communication framework is known as the Internet of Underwater Things and has the capacity to revolutionize industry, business and scientific research.

Advanced technologies

64. Advanced technologies, such as artificial intelligence, machine learning and cloud computing, have significantly improved data acquisition and the processing of the vast amounts of data generated today, including by making it simpler and cheaper. Although the true potential of artificial intelligence methods has not yet been realized, they have already enabled data correlation and forecasting of unprecedented accuracy and complexity, and are finding increasingly wide applications in such areas as weather, ocean and ice modelling, the operation of uncrewed systems and the reliable and enhanced processing and interpretation of observations. Cloud-based data management services allow for increased data-sharing and integration in near real time, thus facilitating operational and forecasting services, but require strong cloud governance to mitigate risks. The management of critical marine ecosystems has been aided by artificial intelligence-powered machine-learning and automated image analysis, and artificial intelligence-enabled mobile marine protected areas, which adapt their position in real time as endangered species migrate through the ocean, is emerging.

Modelling

65. The European Union Digital Twin of the Ocean initiative will integrate historical and real-time data to create digital interactive high-resolution models of the ocean capable of simulating various interrelationships between human activities and the ocean and its ecosystems, and will thus advance knowledge-based decision-

making about the use and management of ocean resources, help to mitigate the impacts of human activity and natural hazards and support a sustainable blue economy.

Standardized best practices

66. The harmonization and standardization of data acquisition and processing, focused on priority observations, are of particular importance but remain challenging, and projects such as the Observing Air-Sea Interactions Strategy and the Ocean Best Practices System are aimed at addressing this. The benefits of applying standardized best practices in ocean operations include the interoperability, compatibility and reproducibility of ocean data, which allow for data comparison, change detection and improved modelling and forecasting and create opportunities for collaboration. In order to facilitate a more consistent approach in the classification of seabed features, a new glossary of seabed morphology features has been developed, which provided the opportunity for developing new tools to automate portions of the classification workflow.

Data exchange standards

67. Developing and adopting common standards for data and metadata from multiple sources can facilitate data compatibility, interoperability and machine-readability, which is essential to their effective exchange and use. The S-100 Universal Hydrographic Data Model and the suite of marine data product specifications developed under its framework can be applied in a variety of ocean disciplines linked to the protection and sustainable use of the ocean, for example, the S-121 Maritime Limits and Boundaries Product Specification is used to encode digital information related to maritime limits, zones and boundaries. The United Nations Fisheries Language for Universal Exchange is a standard that underpins sustainable fisheries management in line with Sustainable Development Goals 12 and 14, harmonizes the data exchange needs of fisheries and contributes to tracking fisheries activities.

Databases and data management

68. New maritime technologies generate benefits for society through a data value chain, supported by data management that enables unprecedented amounts of data from many validated sources to be discovered, integrated, shared in open databases and used in near real time. Data management and analysis are increasingly moving towards using geographic information systems in interactive online geoportals, with open source and commercial systems available for setting up marine spatial data infrastructures. In order to maximize the value of data, the development of data strategies is helpful to maximize openness and transparency and deliver results while protecting quality, integrity, security, privacy and confidentiality, as well as being flexible and adaptable to external influences and new technologies. Effective data management also relies on data being findable, accessible, interoperable and reusable. Efforts are needed by all relevant stakeholders to enhance the quantity and quality of shared data, as well as the conditions under which access to data is granted, given in particular that data are at the core of opportunities offered by new technologies.

69. The International Seabed Authority DeepData database includes cutting-edge data on deep-sea biodiversity and ecosystems, and the European Marine Observation and Data Network recently launched its fully centralized marine data service, thus supporting new technologies and approaches, such as artificial intelligence. Data

collected during expeditions under the International Year of the Salmon initiative are available through a dedicated data portal.[2]

III. International cooperation and coordination

70. Enhanced cross-sectoral cooperation and coordination at the national, regional and global levels are crucial to ensure the continued development and effective application of new maritime technology and to harness such technologies for the attainment of the 2030 Agenda, in particular Sustainable Development Goal 14.

71. On a global and regional scale, such initiatives as the Global Marine Technologies Cooperation Centres Network, GreenVoyage2050 and the IMO Coordinated Actions to Reduce Emissions from Shipping rely on coordinated actions to accelerate the adoption of new technologies globally and thereby advance energy efficiency in the shipping sector. In the renewable energy sector, coordinated action is carried out through such initiatives as the Collaborative Framework on Ocean Energy/Offshore Renewables of the International Renewable Energy Agency, the Global Alliance for Offshore Wind and the Global Ocean Energy Alliance, with the latter focusing on the needs of small island developing States and least developed countries to gain access to ocean energy technologies. The UNFCCC Technology Executive Committee works with United Nations entities and other organizations on integrating technological innovations for climate adaptation and mitigation.

72. Maritime aerial surveillance, data visualization tools and satellite technology have provided opportunities for working collaboratively to advance the protection of life at sea. Regional fisheries management organizations or arrangements play an important role in promoting cooperation in the use of new monitoring, control and surveillance technologies, essential for fisheries management and for combating illegal, unreported and unregulated fishing. Collaboration between regional fisheries management organizations or arrangements and member States offers an opportunity for identifying regional monitoring, control and surveillance needs, while considering the unique characteristics of national fleets and enabling local technology start-ups to offer customized solutions.

73. In the field of ocean observation, collaborative platforms and partnerships, such as those under the Global Ocean Observing System, are essential for coordinating global action on the development and application of new technologies. The International Seabed Authority coordinates international efforts to develop innovative tools and technologies, best practices for data collection, and scientific capacity with respect to the international seabed area, including through its recently launched Sustainable Seabed Knowledge Initiative.

74. Improved access to technology, finance and expertise is crucial to enable developing countries, especially small island developing States and least developed countries, to fully harness the benefits of new maritime technology, and there are numerous activities and programmes aimed at building capacity in this regard. Needs include the training of personnel, the provision and maintenance of equipment, access to data generated by new technologies, capabilities to manage and process such data and the transfer of technology.

75. Coordination and cooperation among Governments, intergovernmental and regional organizations, the private sector and academia, including though public-private partnerships and industry dialogues, as well as in the context of the United Nations Decade of Ocean Science for Sustainable Development, could stimulate

[2] https://yearofthesalmon.org/.

investment in new maritime technologies by determining shared needs, aggregating demand, reducing market risk and promoting standardization for technology and data. Such collaboration can help with identifying opportunities for the efficient modular and mass production of technical solutions to improve the availability of low-cost, small and easy-to-deploy instruments, making the technology more accessible to developing countries. This can also stimulate their participation in emerging sectors of the blue economy, including marine renewable energy, marine biotechnology and ocean observation.

76. Coordination could also enhance co-design, involving end users to tailor marine technologies to their needs, and align national efforts with regional and global initiatives, in particular in the fields of data and process standardization. Ensuring data protection and privacy is key to overcoming stakeholder resistance in this regard. Improved connections between public institutions, private actors and academia can also help to bridge the divide between ocean science, technology and policy.

77. Developments in miniaturized, affordable and user-friendly systems of robots, sensors and communication devices also provide new opportunities for engaging the general public, enhancing ocean literacy and involving new actors in ocean science, for example, through the Ship of Opportunity Programme and the Global Ocean Observing System Odyssey project, which mobilize commercial and private vessels for ocean observation, and national citizen science initiatives.

IV. Legal and regulatory aspects

78. New maritime technologies have great potential for increasing the safety, efficiency and sustainability of ocean-related activities and facilitating the implementation of existing international legal obligations. For example, it was reported that such technologies constituted basic working tools for fulfilling the mandate of the International Seabed Authority under the United Nations Convention on the Law of the Sea. Furthermore, the use of maritime aerial surveillance assets, including drones, and satellite-based search and rescue distress-alert detection systems can improve the protection of persons at sea. In addition, recent technological advancements relating to fishing are supporting efforts to conserve and sustainably use marine living resources and to decarbonize fishing activities. On the other hand, technological constraints, including the significant costs associated with the use and maintenance of new maritime technologies, can hinder the implementation of a State’s obligations.

79. The international legal regime for the ocean consists of a wide range of global, regional and bilateral legal instruments, as well as national laws and regulations adopted under the overarching legal framework set out in the Convention. Those binding instruments are complemented by non-binding instruments, such as standards and declarations adopted by competent international organizations, at international conferences and in other forums, as appropriate, with regard to activities in the ocean, including, where applicable, activities undertaken with new maritime technologies. Taken together, the Convention and those instruments provide a comprehensive legal and regulatory framework for the effective governance and management of maritime technologies, as well as for their development and transfer.

80. Such technologies as uncrewed vessels and electronic bills of lading have reportedly given rise to legal issues to be addressed in international maritime law. IMO reported that, in order to ensure that its regulatory framework kept pace with technological developments concerning marine autonomous surface ships, it conducted a regulatory scoping exercise to assess how its existing instruments might apply to ships with varying degrees of automation, with further work under way on

the development of a goal-based instrument regulating their operation. One State noted that greater regulation of marine autonomous surface ships would enable higher levels of maritime automation to be introduced safely and sustainably.

81. Other efforts of significant relevance in this regard include the work of the intergovernmental conference on an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. The text of the draft agreement, which was finalized at the resumed fifth session of the conference, held from 20 February to 3 March 2023, addresses a series of issues, in the context of which new maritime technologies will be relevant.

82. While the legal and regulatory framework may respond and adapt to new maritime technologies, it may also drive innovation and technological developments. Such innovations may go towards addressing the "triple planetary crisis" of climate change, biodiversity loss and pollution, which is causing severe and unprecedented damage to our ocean. For example, in the context of climate change mitigation, regulatory initiatives under the respective auspices of IMO and UNFCCC to decarbonize international shipping have been noted to accelerate those efforts. In this regard, it was observed that, in response to priorities expressed by member States, regional fisheries management organizations or arrangements could test innovative decarbonization solutions and their impact on, inter alia, fuel consumption and emissions, towards the achievement of the targets set in the Paris Agreement.

83. With regard to the protection and preservation of the marine environment, IMO regulations and guidelines were reported to drive innovation in the areas of ballast water management, biofouling and marine plastic litter. Noise limits set by some States for the construction of offshore wind farms and pursuant to the Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean led to the development of new quieting technologies to protect sensitive marine species. Also at the regional level, the Mediterranean Sea Emission Control Area for Sulphur Oxides and Particulate Matter, which was adopted in 2022 and is due to come into effect in 2025, will further limit air pollution from ships, pursuant to annex VI to the International Convention for the Prevention of Pollution from Ships, 1973, with contracting parties also encouraged to explore the feasibility of a similar initiative for nitrous oxides.

V. Conclusions

84. Technological innovations increase efficiency, expand markets and enhance economic growth. Future technological advances offer the potential for greater exploitation of ocean resources but also the promise of greater protection. Science, technology and innovation will continue to play a growing role in managing the responsible development of the ocean economy. Economic activity in the ocean is expected to continue to accelerate, growing to $3 trillion by 2030 with activities, including aquaculture, capture fisheries, fish processing, offshore wind and port activities, expected to grow at faster rates than the global economy.

85. However, technological advances carry their allotment of negative impacts, as highlighted in the present report, including with respect to achieving the 2030 Agenda. In particular, access to technologies that can assist in the conservation and sustainable use of marine resources remains uneven. The resulting technological and digital divide against the goal of "No one left behind" particularly affects small island developing States and least developed countries, including their ability to implement international law as reflected in the United Nations Convention on the Law of the Sea. Bringing women and other marginalized groups into technology as a means to

ensure more creative solutions and promote gender equality also needs to be addressed. Increased international cooperation and coordination are necessary to address the various gaps in the development of and access to maritime technologies, including through capacity-building, the transfer of technology and sustainable investments, whether in human resources or institutional frameworks.

86. As to the legal framework, and as recognized by the General Assembly, the Convention sets out the legal framework within which all activities in the oceans and seas must be carried out and, as such, continues to serve as the foundation for the governance and management of new maritime technologies. As a framework instrument, the Convention appears to be of sufficient breadth and flexibility to apply to new and emerging technologies, and this has proven true even through a period of significant technological advancement. Such framework is critical to maximize the benefits offered by new maritime technologies and to minimize any potential adverse impacts that may result from their use, including on marine living resources, biodiversity, maritime safety and security and the protection and preservation of the marine environment. It is also critical that new maritime technologies be used in a manner that respects international law, including human rights and humanitarian law.

87. New maritime technologies can however pose legal and regulatory challenges, as well as with respect to how current instruments may be effectively implemented in relation to new maritime technologies. There is an array of efforts under way to strengthen the legal and regulatory framework, including by clarifying the scope of existing legal instruments. The legal and regulatory framework will therefore need to continuously evolve to respond and adapt to new maritime technologies.