Maritime 2050 Plus

Safe & Secure

Challenges. Synergies. Solutions.

Maritime 2050+

Safe & Secure

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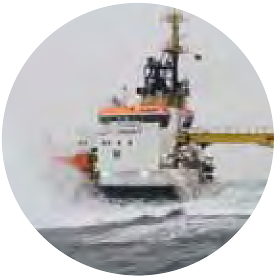

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FOREWORD

Norbert Brackmann, MdB
Federal Government Coordinator
for the Maritime Industry

How will the world and the maritime space look in 2050? This is the question addressed by the "Maritime 2050+" report. Even if we are looking towards far-reaching changes, particularly due to digitalisation, one thing should be clear: the maritime space will continue to play a crucial role for humanity in future. After all, the world's seas cover 70 per cent of our planet's surface.

For an exporting country like Germany, the seas are of great economic significance. Up to 90 per cent of trade in goods is conducted by sea. But the sea is more than just a transport route. Germany's North and Baltic Sea coasts are almost 2,400 km long – that is three times the distance from Hamburg to Munich – and offer recreation, attract tourism, and host ports and an economic zone.

In addition, the world's seas are a deposit and production site for renewable and fossil energy as well as for mineral resources. They are also a source of food. They are sensitive ecosystems, a place for recreation, and areas of high relevance to security policy. They exert a decisive influence on the climate and provide a habitat for rich and largely unresearched biological diversity.

The maritime space will grow in significance in the coming years and decades in terms of mineral resources, the deposits of which are becoming scarcer on land, and as a production site for renewable energy.

Here, the German Government particularly wants to work towards an environmentally acceptable and globally sustainable use of the seas in line with the UN sustainability targets and the German Government's National Sustainability Strategy.

The European Union has anchored these objectives in its "Blue Economy – Blue Growth" initiative. At national level, the blue economy is the economic pillar of the integrated maritime policy and plays a strategic role in the Government's Maritime Agenda 2025. The Maritime Agenda 2025 is underpinned by the Maritime Research Strategy 2025 and the National Maritime Technologies Masterplan. This is because we will need to keep researching and taking a cross-sectoral approach so that our successful companies can continue to set benchmarks for a high-tech, sustainable maritime economy and survive in the face of international competition. Advances in technology can also make a lasting contribution towards necessary improvements in the effective protection given to the marine environment and towards the attainment of the climate targets.

I am glad that we have strong research partners at our side which will support us on our journey to a successful maritime future.

N. Brackmann

Norbert Brackmann

Michael Ozegowski
CEO ATLAS ELEKTRONIK GmbH

ATLAS ELEKTRONIK is a maritime high-technology enterprise with German roots and a global footprint. The know-how and expertise of our skilled workforce in the fields of hydroacoustics, sensor engineering and information technology have made us the preferred supplier to numerous navies and civilian customers worldwide. As specialists for underwater acoustics, we are the market and technology leader in many sectors.

We are a company that is driven by technology. Our structure and organization is oriented towards market requirements and research and development. Our innovative capacity is one of the foundations of our success.

In order to ensure sustainable company development, it is not sufficient merely to respond to the current demands of our customers – it is also vital to consider their future requirements and challenges they may face.

Predicting the trends and demands of tomorrow's world is not an easy task. But these efforts are essential if we are to position our products successfully on the markets in the coming decades.

It is not possible to foresee the future – new technologies and challenges will emerge and predictions are not always fulfilled. Therefore, together with our research partners, the German Aerospace Centre (DLR) and the Fraunhofer Institute for Communication, Information Processing and Ergonomics (FKIE), we have critically reviewed the developments over the two years since the presentation of Maritime 2050 and have made adaptations to take new insights into account.

This Maritime 2050+ study, like previous versions, is not a vision set in stone. Rather the intention is to identify the drivers and technologies of possible future scenarios at an early stage and to prepare the way for future research and development.

In addition to carrying out intensive R&D work, our company also maintains close links with numerous national and international partners. In particular, long-term cooperation agreements with outstanding research institutions such as DLR and FKIE are a guarantee for our success.

It is our pleasure, together with our research partners DLR and FKIE, to present this brochure as a contribution to the discussion on the maritime future.

Michael Ozegowski

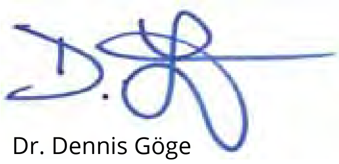
Dr. Dennis Göge
Executive Board Representative
Defence and Security Research, DLR

The geopolitical, economic, and technological developments of the coming decades will have dramatic societal impacts. The coasts and oceans of our planet will also be profoundly affected by these changes. Worldwide production and globalised logistics chains create growing ties between countries and continents. Global communication networks establish links at various societal levels across borders and between systems. International relationships and cooperation agreements lead to interdependencies and promote mutual understanding. However, the intensive exchanges also generate increased competition for resources, transport routes and markets, presenting many new challenges for business and science – and on occasion also leading to new conflicts.

More than two-thirds of the earth's surface is covered by water. The oceans have always been of vital importance for life on earth and for the climate. At the same time they are an important source of raw materials and are essential for the transport of people and goods. In order to maintain this unique ecosphere while at the same time using it as a living space and economic area for a continually growing world population, our highest priority must be protection and security on and beneath the seas, including the directly and indirectly associated infrastructures, some of which are of critical importance. What challenges will we face in the 21st century and how will we respond to these? What steps can we take today to change the world of tomorrow?

What needs to be reconsidered? Who are the actors and partners who will have to work together for a safe and sustainable future of the oceans? Are we indeed at a turning point?

The answers to these questions and the solutions for the global challenges can only be found by means of combined contributions from the fields of politics, commerce, and science. As a way of providing impulses for society, the German Aerospace Centre (DLR) has cooperated in producing the "Maritime 2050+" brochure, showing new trends, technologies and interrelationships. They highlight why it is so important (and also in their own interests) for people to protect the maritime domain. With its interdisciplinary expertise in the fields of aeronautics, astronautics, energy, transport, digitalisation, and security, DLR can and will make important contributions towards tackling these questions, together with its partners in the fields of politics, business, and science.



Dr. Dennis Göge

Prof. Dr. Peter Martini
Head of Institute, FKIE

In Jules Verne's celebrated novel Twenty Thousand Leagues Under the Sea (1870), the ingenious commander of the Nautilus, Captain Nemo, remarks that the sea comprises the three kingdoms of nature: mineral, vegetable, and animal. And what were his means to explore them? Technology in the shape of a futuristic submarine.

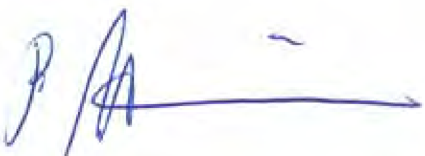
From pre-historic times to the present, societies have striven to exploit the sea for their manifold purposes. The more powerful technology became, the deeper and further we dared; and the more reckless we were.

In order to maintain the balance between various ecological, commercial, and military considerations, the international community has tried to establish a set of common rules, legal regulations and technical standards concerning the safe, secure, and responsible use of maritime resources for the benefit of all parties involved. Germany, as a leading economic power, is strongly involved in this process.

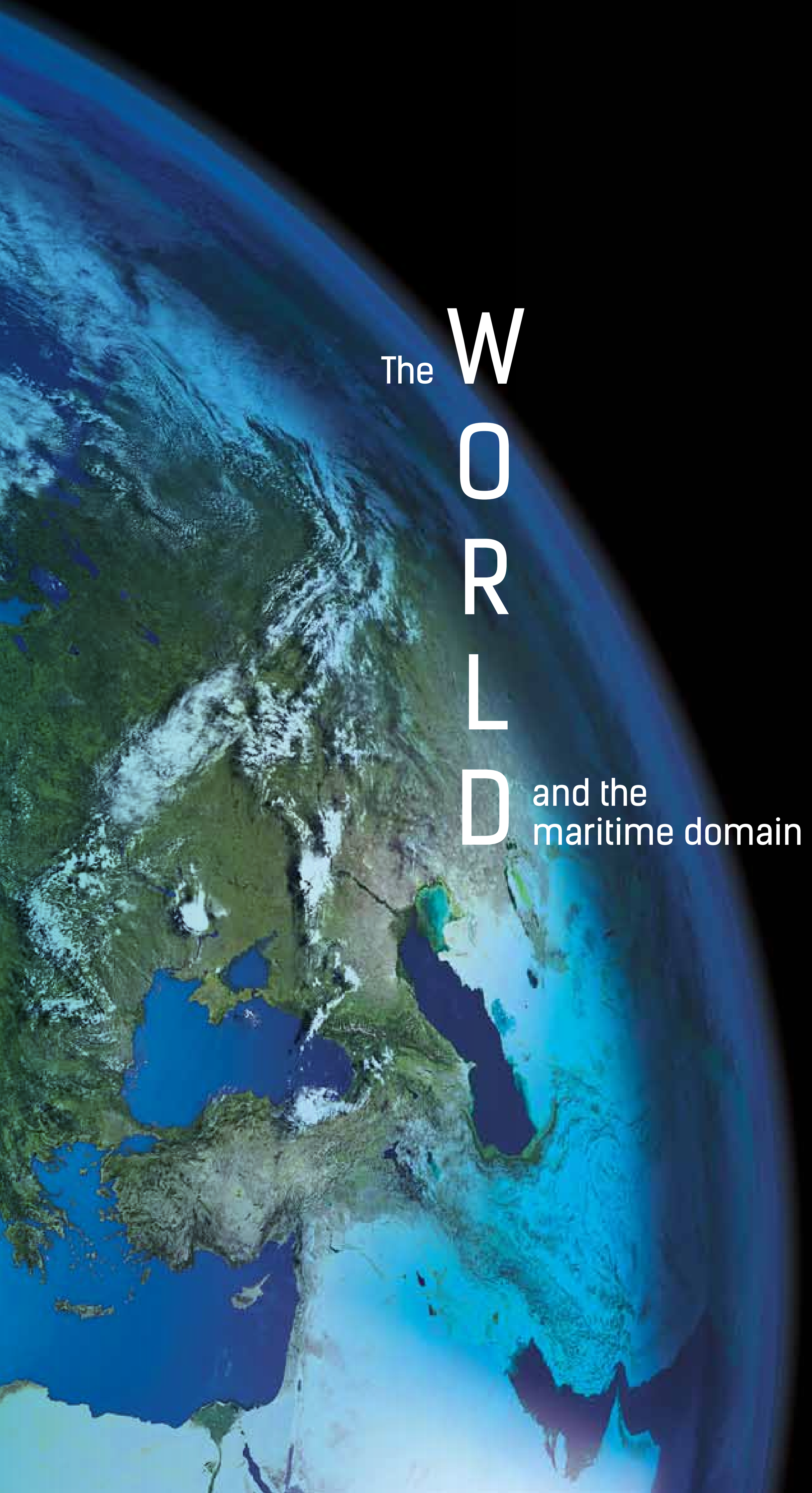
However, mutual agreements on paper are one thing, permanent implementation in real environments is quite another. Moreover, the wheel of innovation keeps turning faster and faster, quickly rendering yesterday's solutions obsolete. There is a constant need for scientific and technological research to develop resilient platforms, to guarantee reliable system interoperability, to provide smart navigation, monitoring, and surveillance solutions, and above all to improve cooperation between the key stakeholders.

At Fraunhofer FKIE we are focussed on the development of advanced information and communications technology to support risk detection, crisis handling and impact mitigation. Our institute can boast an impressive record of maritime-related projects, both civilian and military. Current areas of research address the design and implementation of seamless data and information exchange in heterogeneous operation environments, the responsible integration of AI-algorithms in critical decision making situations, and the development of robust cyber security solutions for maritime platforms, infrastructures and process chains.

We are convinced that the ambitious research agenda outlined below can only be fulfilled if the key players join forces. Government authorities, research institutions, hardware suppliers, infrastructure operators, and service providers need to form co-operation networks on an international scale in order to meet the challenges. Germany should actively promote this development as there is so much at stake: the mineral, the vegetable, and the animal kingdom of the sea.



Prof. Dr. Peter Martini



The WORLD and the maritime domain

The maritime domain is essential for human life. Marine resources feed a growing global population that increasingly lives in coastal areas.

The future maritime domain

By Dr. Heiko Borchert – Owner and Managing Director of Borchert Consulting & Research AG

The maritime domain is essential for human life. Marine resources feed a growing global population that is increasingly concentrated in coastal areas.[1] In addition, maritime transport corridors are the lifelines of globalization.[2] Prosperity and economic globalization build on the unrestricted exchange of resources, goods, capital, information, and the mobility of people. The interactions create strategic flows that connect different locations of production, transit and consumption. In sum, prosperity requires connectivity that depends on transport corridors, infrastructure, and means of transport.[3]

As we approach the third decade of the 21st century it is becoming increasingly evident that flow – the will and the capability of an actor to define the framework and the operational conditions for strategic flows[4] – control will be a key element of the new grand systemic competition that is emerging. Traditional geostrategic rivalries are being exacerbated by an increasingly assertive struggle for access to and influence over key regions. State and non-state actors are eager to influence global connectivity, and by changing strategic flows that provide prosperity they are affecting security and stability. Everyone with an interest in shaping global connectivity tries to portray their own actions as legitimate, while challenging the actions of others. There is thus a new competition about narratives and worldviews. China's Belt and Road Initiative is one example that combines the striving for connectivity with a new, forceful narrative written by a non-Western nation.[5] As a consequence, existing norms, rules, and principles that guide international relations are coming under pressure. Ambitious rising powers comply with existing norms where this suits their strategic interests, but they also show a preference to rewrite these rules or free-ride on the existing international order without engaging in the provision of stability as a public good.

1 *The State of World Fisheries and Acquaculture (Rome: FAO, 2016).; World Urbanization Prospects. 2014 Revision (New York: United Nations 2014); The State of Asian and Pacific Cities (Fukouka: UNHABITAT, 2015).*
2 *Review of Maritime Transport 2017 (Geneva: UNCTAD, 2017).*
3 *Pankaj Ghemawat and Steven A. Altman, DHL Global Connectedness Index 2016. The State of Globalization in an Age of Ambiguity (Bonn: DHL, 2016).*
4 *Heiko Borchert, Flow Control Rewrites Globalization. Implications for Business and Investors (Dubai: HEDGE21/Alcazar Capital, 2019), p. 10, https://www.hedge21.com/app/download/17844943525/190128_Flow%20Control_final.pdf?t=1548765854*
5 *"Mapping the Belt and Road initiative: this is where we stand", Mercator Institute for China Studies, 7 June 2018, https://www.merics.org/en/bri-tracker/mapping-the-belt-and-road-initiative (accessed 3 July 2018)*

Maritime trading is constantly expanding.

Modern container handling is a logistical challenge.

Military conflicts at sea could become a threat.

Ultimately, all of this leads to competing models of prosperity. While capitalism seems undisputed, liberal capitalism differs fundamentally from state capitalism. There is no longer one way to prosperity. Rather, various role models emerge, and countries epitomizing different forms of capitalism are eager to create, protect, and expand their respective spheres of influence.[6]

This new grand systemic competition is changing the nature of the maritime domain. What used to be a common good open to everyone is increasingly under pressure from a variety of actors trying to restrict everyone's access to the maritime domain and thus also its resources and trade routes. The forces of competition might thus replace the forces of cooperation in dealing with maritime issues. In turn, the maritime domain is becoming more unstable:[7]

- Expanding coastal urbanization implies that more and more actors will use the sea for their activities. This makes maritime regions more crowded and congested. National ambitions to control strategic flows at sea by expanding zones of influence are reinforcing this trend. Naval operations, for example, are likely to become riskier because it will be much harder to evade unwanted contact with adversaries. This increases the need for new (unmanned) assets that can be used to take on these risks.
- Congestion of the maritime domain raises the need for joint and interagency situational awareness and situational understanding in order to get a sense of what is going on at sea. Data from undersea sensors and surface sensors will need to be combined with data from airborne and space-based assets as well as information from other sources. This increasingly shifts the focus from single platforms carrying appropriate sensors to federated networks needed to fuse, assess, and disseminate the information that is generated.
- Digital connectivity reinforces the consequences of a congested maritime environment. Connectivity is the key currency for networked assets, but it also creates new vulnerabilities. A lack of connectivity can slow down operations, and the loss or corruption of data can affect everyone involved in global maritime supply chains. There is thus a growing need for all stakeholders in the maritime domain to jointly address digital vulnerabilities and develop adequate capabilities for digital crisis prevention and crisis management.[8]

All of these developments affect the requirements of future maritime and naval systems. The prevalence of sensors will mean that stealth, cyber-security, camouflage, concealment, and deception will gain in importance. An increasing number of free-floating smart sensors and autonomous platforms will need to be integrated into the overall information architecture, which in turn needs to be seamlessly connected with systems operating in adjacent air, space, land, and cyber domains. The growing volume of data also prompts the need to strengthen analytical capabilities and step up investments in data quality assurance. Unless protected in novel ways, power projection at sea by assertive state and non-state actors will heighten the risk for today's high value assets such as multipurpose platforms. Capability distribution between assets becomes increasingly interesting as self-organizing swarms operating at different levels of autonomy become more mature.

Ultimately, however, these and other solutions needed to provide for the stability and security of the future maritime environment will come under pressure from two different trends. First, if economic globalization were to decline it would become more difficult to maintain a global naval posture that has hitherto been justified with reference to the need to protect strategic flows at sea.[9] This coincides with the shift of economic and political power to rising non-Western actors. Historically, ruling nations have used their power to define the rules of global interaction. But in the future, Western nations are very likely to lose the monopoly for making the rules for operating in the maritime domain and setting the standards of the products and systems used. Striking a new balance for co-evolutionary standard definition involving existing and rising maritime powers is thus the ultimate challenge for maritime stability and security in the 21st century. //

6 Oliver Stuenkel, Post-Western World. How Emerging Powers Are Remaking Global Order (Cambridge: Polity, 2016); Henry R. Nau and Deepa M. Ollapally (eds.), Worldview of Aspiring Powers. Domestic Foreign Policy Debates in China, India, Iran, Japan, and Russia (Oxford: Oxford University Press, 2012).
7 Heiko Borchert, Tim Kraemer, and Daniel Mahon, Waiting for Disruption?! Undersea Autonomy and the Challenging Nature of Naval Innovation. RSIS Working Paper 302 (Singapore: RSIS, 2017), pp. 11-13.
8 Nineta Polemi, Port Cybersecurity. Securing Critical Information Infrastructures and the Supply Chains (Amsterdam: Elsevier, 2018); Cyber Security. Assessment and Protection of Ships (Paris: Ministry of Environment, Energy and the Sea, 2016).
9 T.X. Hammes, Will Technological Convergence Reverse Globalization? (Washington, DC: National Defense University 2016); Peter D. Haynes, Toward a New Maritime Strategy. American Naval Thinking in the Post-Cold War Era (Annapolis: Naval Institute Press, 2015).

A new grand systemic competition is changing the nature of the maritime environment in the 21st century.

Melting polar ice is causing sea levels to rise.

The world in 2050+

The maritime domain has often seen profound changes. For example, advances in navigation in the 15th century led to increased global exploration and the discovery of "New Worlds". In our times, the fishing industry and the intensive exploitation of maritime resources are impacting on the marine ecosystem. Meanwhile, the global political situation is also becoming increasingly complicated.

What challenges lie ahead? What new prospects will unfold? The maritime domain of the future will call for new strategies, new technologies, and adapted framework conditions. Key factors for the future development are the environment, population, resources & energy, the political and legal framework, and the influence of new technologies. What will the maritime domain look like in 20 or 30 years' time?

Megacities are increasing in size and numbers.

Conflicts can arise over trading routes.

Plastics are accumulating in the world's oceans.

We need new strategies, technologies and regulations for the maritime environment of the future.

Environment

- The climate has undergone considerable overall change, but the conditions in the individual regions have developed very differently. Some climatically disadvantaged regions are suffering. But there are also climatically favoured areas, especially in the land masses of the northern hemisphere. Extreme weather conditions and natural disasters have become increasingly frequent, with intermittent local droughts and flooding.
- There has been no breakthrough in global climate action and environmental protection. In particular the visible and invisible pollution of the oceans has increased steadily. Micro-plastic in the world's seas and oceans has become a serious problem.
- Sea levels have risen by about 30 cm. In general, dikes have so far been able to restrict changes to the coastlines. Installations for coastal protection will be further extended and adapted to the demands of weather extremes and the rising sea levels.

Population

- By 2050, the world population will have grown to about 9 billion. Both the demand for new living space and the pressure on existing settlement areas have increased enormously. The conurbations have expanded, the megacities have grown and new urban areas have emerged. Wherever possible, the coastal regions and climatically favoured areas are being settled preferentially. Steps have been taken to make increased use of the seas for manufacturing and for housing, in the form of floating settlements and artificial islands.
- Global migration as a result of state and non-state crises and conflicts or due to persecution, resource shortages and economic inequalities has continued and in part has increased. The events triggering the migration occur suddenly and largely without warning.

Resources & energy

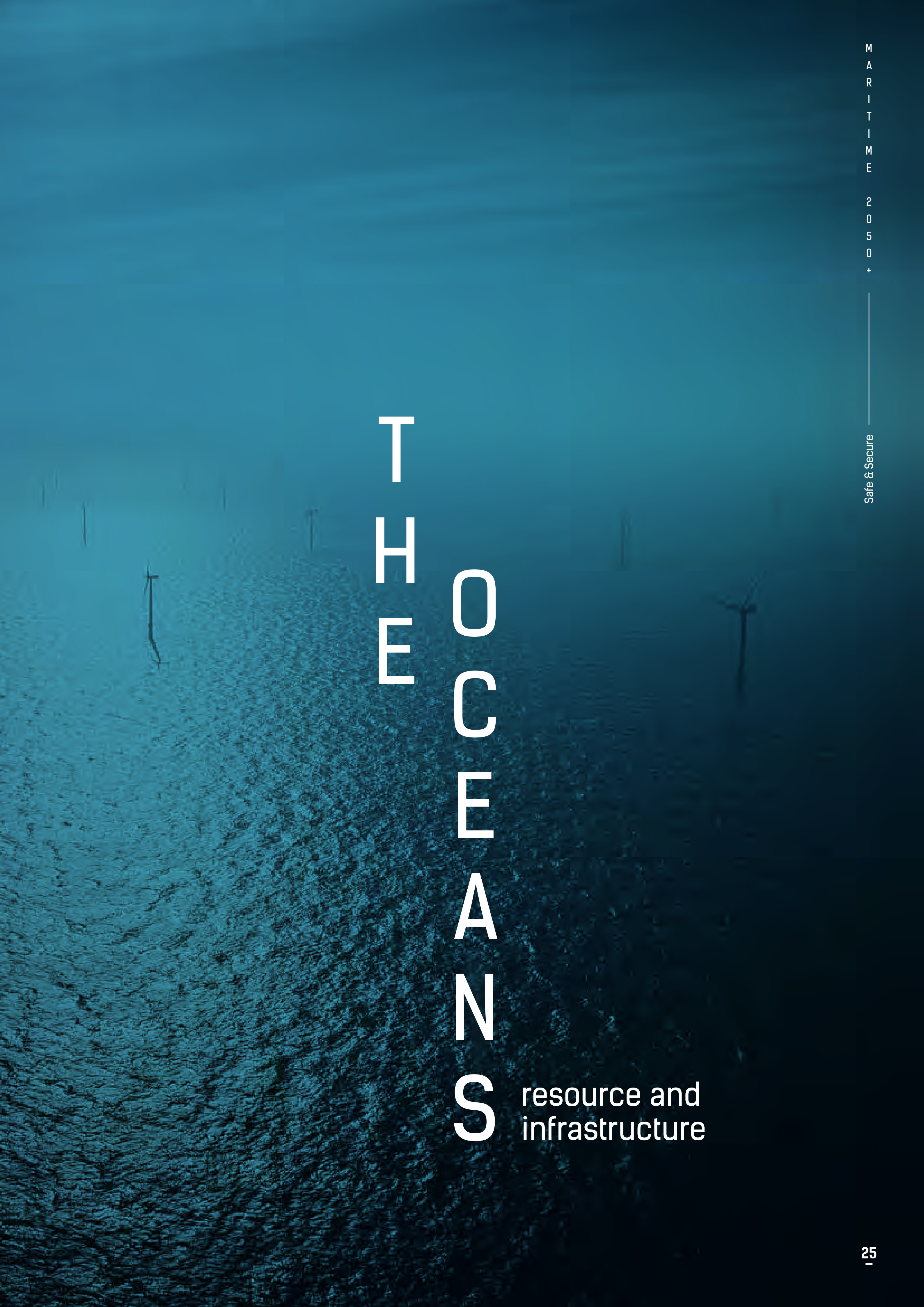
- The exploration of the deep oceans and the coastal regions is being continued systematically and the extraction of valuable marine resources from the deep oceans is in a phase of expansion. This leads to conflicts between individual countries.
- Existing offshore installations have been expanded and further installations are being developed, producing a tight offshore network. The resources extracted from the seabed are refined and processed in floating factories. The energy for these processes is generated on-site, the labour force live in part in floating settlements. All their daily needs are provided for there.
- The global demand for food and drinking water is increasing. In particular, the situation in arid areas is growing worse because of the extremes of climate. There has been a significant increase in the use of the seas as a source of food and water. But sea fish has vanished from the menu.

Political and legal framework

- Large-scale political and legal unions have grown in importance. Worldwide, there are only a small number of such unions, implementing their own political and legal regulations. Exchanges take place on the basis of treaties and laws. The first globally valid regulations and laws exist in order to regulate responsibilities, for example for the use of resources, however they are ignored by individual countries who claim that 'might is right'.
- The conflicts over resources, trading routes, and spheres of influence have grown. This has led to an increase in the demands on the protection of borders, not only on land but also on and under the seas. The relevant areas are secured visibly and invisibly by autonomous systems and by patrol boats.
- There are first developments towards a central certification and standardisation of technical systems for use in the maritime domain. These include requirements for production, as well as for training, sustainability, and support.

Technology

- Technical advances have led to the widespread automation of work. Autonomous and semi-autonomous systems have therefore taken over routine tasks and provide support for human operators. The systems are available round the clock and are widely accepted.
- The exchange of data and information provides an important basis for global trade and for society as a whole. The continuous development of satellite networks with cost-effective microsatellites has enabled global communication and comprehensive remote sensing of all land and sea areas. The exponential growth in the quantities of available data and information has led to increasing demands in the fields of big-data analysis and security.
- Underwater communications and navigation continue to present a challenge. Over short distances, information can be exchanged under water satisfactorily, but the problem of long-distance transmission of large amounts of data through water has not yet been solved.
- Energy storage is not a problem; energy is available everywhere, but is expensive. //



THE OCEANS

resource and infrastructure

The coasts and the oceans have enormous potential for the increased development of alternative sources of energy.

The oceans as resource

In 2050+ the maritime domain will play an increasingly important role as a resource and as a location for vital activities:

- Food production, including the generation of drinking water by desalination
- Power generation, above all from wind power and tidal power
- Extraction and mining of seabed fossil resources and minerals

As a result of dwindling natural fish stocks, there will be a growth in alternative methods of food production, such as aquaculture, or the processing of seaweed, algae, and phytoplankton. This will have grave impacts in the maritime domain. In order to meet the growing demand for drinking water, further desalination plants will be installed, in particular in arid coastal regions.

Despite evident successes in the field of energy management and the increasingly efficient consumption of energy, the demand for energy will increase by more than a third. The use of fossil fuels as a source of energy will be reduced considerably in the medium term due to the negative environmental and economic impacts. This will lead to the increased development of alternative sources of energy. The coasts and the oceans have enormous potential in this respect – with offshore wind power generation and in future also in the form of tidal power and marine current power generation.

Technological developments will soon make it possible to extract oil and gas reserves from deeper and less accessible regions of the oceans. Furthermore, the increasing demand for metals and raw earth elements will lead to a surge in seabed extraction and deep sea mining. And the construction industry will remove billions of tons of sand from the seashores and oceans – with severe consequences for coastal erosion protection. //

Advanced aquaculture can provide food for the future.

Oil and gas reserves are being exploited even in less accessible ocean regions.

Offshore wind-power generation is continuing to expand.

As a result of dwindling natural fish stocks, there will be a growth in alternative methods of food production. This will have grave impacts in the maritime domain.

As a result of the growing population densities in combination with territorial claims, new living spaces will be created – including inhabited islands.

Global flows of goods are increasing – in particular sea freight.

The oceans as infrastructure

Looking forward to the second half of the 21st century, there are three main infrastructure sectors in which the maritime domain will gain in importance, namely:

- Transport
- Living space
- Production installations

The use of maritime transport routes will increase considerably, because further globalisation and the growth of the world population will lead to the increased transfer of goods. Existing waterways will be highly frequented, and new coastal routes will be created. These waterways are in some cases privately owned while others are publicly accessible. This will require better control and optimisation. In addition to traditional ships, there will be very large or important modes of transport on and below water, including numerous cables and pipelines for a variety of purposes. However, the underwater situation cannot be fully registered for all sectors.

As a result of the growing population densities in combination with territorial claims, new living spaces will be created – including inhabited islands. The coastal areas will continue to be very densely populated, which will lead to severe environmental problems. Among other things, new infrastructure will have to be developed for supply and disposal management.

Primary industrial activities in coastal waters will only be possible to a limited extent in view of the environmental impact, and they will be under much stricter controls and monitoring. On the other hand, production plants will be established both on and under water in order to reduce the transport distances for the input materials to be processed. Some of these industrial plants will be in fixed positions, while other will float on the water. Such factories will produce semi-finished and finished products to supply the needs of the population. New materials promise to open up exciting opportunities in the future. //

Utilisation of the world's SEA areas


LIZEI

The German police force also operates at sea.

Safeguarding territorial interests

At sea, all nations must protect their citizens, their waters, and their coastal borders. New key tasks have been added to these basic obligations in recent years. For example, it is necessary to energetically prosecute and where possible prevent the dumping of industrial pollutants, as well as illegal fishing, and the pillaging of marine resources in other ways. Further problems that require action on the part of state authorities, even beyond territorial waters, include piracy, terrorism, drug smuggling, the flow of refugees and migrants, as well as illegal immigration. The comprehensive protection of critical maritime infrastructure and the international trading routes therefore presents a real challenge for the world's major economies.

In future, the protection of the maritime interests of individual countries and groups of countries will become even more important.

The comprehensive protection of critical maritime infrastructure and the international trading routes therefore presents a real challenge for the world's major economies.

Many European countries do not have a unified maritime security agency with sole responsibility for guarding all coastal interests. The duties are distributed across a number of authorities. This means that a variety of state institutions and societal organisations are responsible for security, and they all have to be fully provided with accurate information. This information must be exchanged efficiently between the authorities in an appropriate form for the users.

In future, the protection of the maritime interests of individual countries and groups of countries will become even more important. Regional crises and conflicts can have destabilising effects and must therefore always be considered locally as well as globally. National interests must also be protected and if necessary defended outside the actual territorial waters. In Germany, the "Out-of-Area" ruling of the Federal Constitutional Court has meant that since July 1994 the deployment of the German Armed Forces is permissible outside the borders of the NATO Alliance. A well-known example of the international coordination of forces is the combatting of piracy off the coast of Somalia on the Horn of Africa and in the Gulf of Aden. It is likely that there will be increasing numbers of these sorts of activities.

Emergency services can save lives at sea.

It is important that the actors involved not only exchange information, but also harmonise their plans of action. Operations in a multinational context can help to improve the utilisation of regional resources and make up for gaps in capabilities. The monitoring and surveillance of the oceans and the exchange of maritime data and information in near real-time require observational and communication satellites. These will have to be improved in order to provide continuous and timely coverage of expanses of the world's seas.

As well as knowledge of relevant activities on the oceans, in coming decades the observation of underwater activities will become increasingly important. For example, critical maritime infrastructures such as offshore installations or deep-sea mining plants will have to be permanently maintained, monitored, and protected against destruction. A further challenge is the early detection of illegal or unlicensed exploitation of marine resources. Future application scenarios therefore call for new solutions in the field of autonomous and semi-autonomous systems. //

Maritime trading

Global maritime trading is already the backbone of the global production and supply chain. More than 90 per cent of global trade is realized by shipping. Raw materials and finished goods have to be transported to their destinations safely and efficiently. The high volumes of shipping, the increasing use to the world's seas and the networking of maritime and land-based supply and production chains require these trading flows to be computer controlled if they are to operate reliably round the clock. The much-cited "Freedom of the seas" is therefore a luxury that the next generations will only be able to allow themselves with considerable limitations.

In future, autonomous and semi-autonomous navigation will play a crucial role for the trading and production fleets. Increasingly, large unmanned underwater vehicles will be used for the transport of goods and raw materials between the sea bottom, production sites, and the harbours. They could be supplied with electricity and mission data at underwater garages. Transport routes will be used for product integration and the development of intermediate products. The new floating production plants will be coordinated by satellite, so that the on-going product development processes can be coordinated. Production and deliveries can then be parallelised. The oceans and the sea routes will become a distributed industrial production system.

The coordination of the autonomous and semi-autonomous systems will involve an integrated control system with land-based, aerial and satellite sensors together with a global information system for supervising maritime transport routes.

The role of human operators will be shifted further towards the central control and monitoring of the

Busy shipping lanes off the coast of Singapore.

processes – supported by suitable digital assistance systems. Decisions will be prepared by cognitive agents, and the presentation and the pre-selection of the information will be adapted to meet the current needs and duties of the operators. Similar developments can be observed in the automotive industry.

The security of trade routes will continue to be at the focus of attention. Monitoring and protecting the movements of people and goods will require close cooperation between military and civilian agencies. Predicting future developments and the real-time assessment of critical situations will call for reliable and stable access to an appropriate data and information network.

In the future it will no longer be possible to separate questions of operative safety, efficient and dependable logistics, and security against targeted external interventions in the system and process chains. For the reliable and secure maritime trading of tomorrow, it will be necessary to provide solutions that integrate all modes of transport – by land, sea and air – so that these can be coordinated and combined across domains. //

Autonomous and semi-autonomous navigation will play a crucial role for the trading and production fleets.

An early lead in the technologies for the sustainable exploration of marine minerals will open up considerable opportunities for the future growth and profitability of the economy.

Deep-sea mining for the resources of the future

First attempts were already being made in the 1970s to extract minerals from the deep sea beds. However, falling prices on world markets soon led to a loss of interest in the development of technologies for large-scale exploitation of deep-sea resources. But the current high levels of demand for metals and rare earths – above all for advanced technology applications and ubiquitous electronic devices such as smartphones, in combination with the rise in the prices of metals in recent years, have fundamentally changed this situation. If this trend continues it is therefore to be expected that deep-sea mining will be expanded in the coming decades. Further driving factors are geopolitical interests and the considerations of those countries that have no reserves of metals and rare earths within their borders.

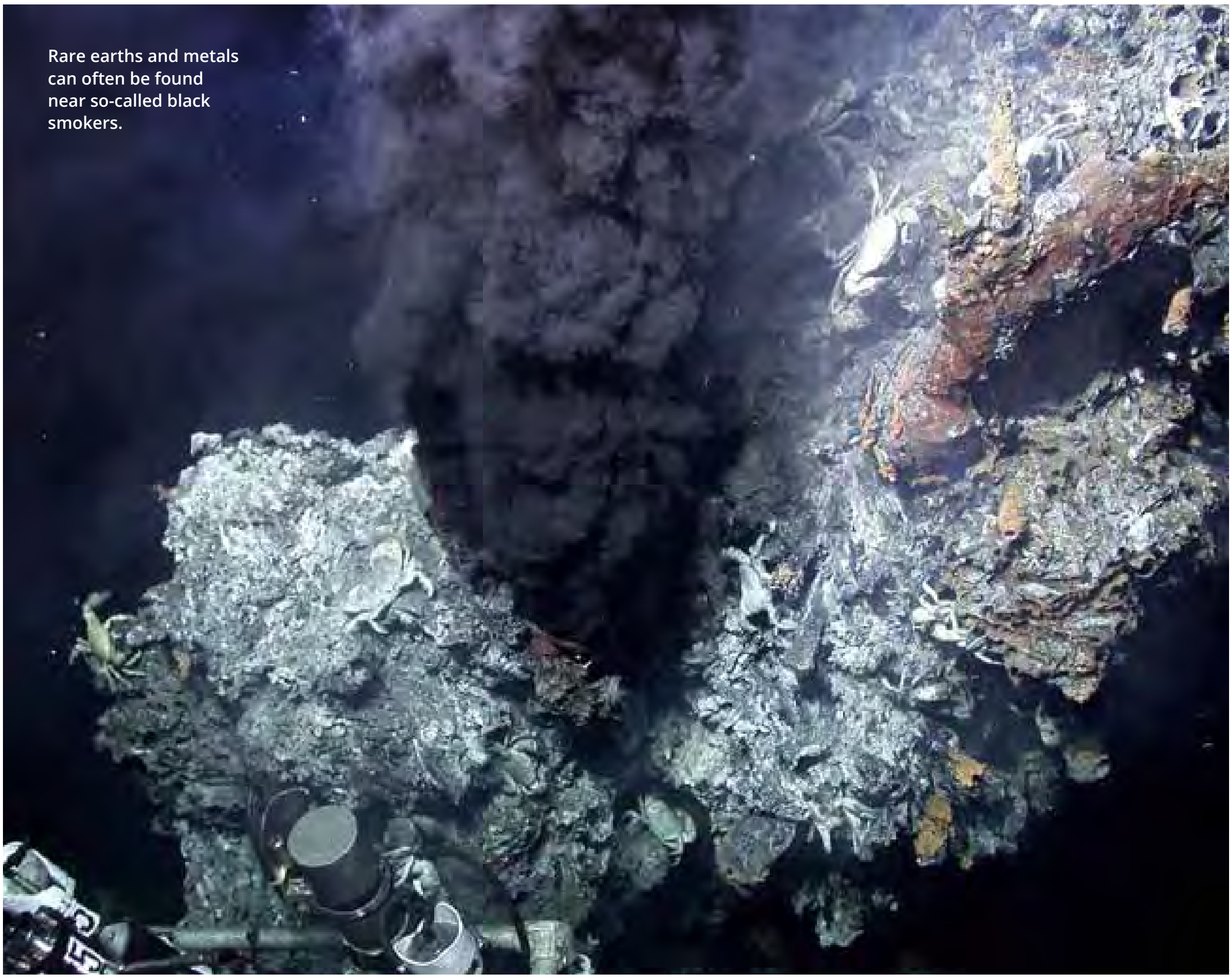
The marine mineral resources in the deep sea include in particular manganese nodules, cobalt-rich ferromanganese crusts, and sulphide deposits. In international waters beyond the exclusive economic zones of individual countries, the International Seabed Authority has reached agreements for the exploration of specific areas with nations and private companies, beginning in 2001. However, these contracts are strictly tied to scientific exploration with permanent environmental monitoring and impact assessments, as well as proof of the technical feasibility of the extraction by the contractors. They are initially valid for a limited period of 15 years with an option for an extension of five years. By then at the latest, work must start on operational extraction.

Because of the widely differing types of materials concerned, the extraction of deep-sea resources will require a variety of methods and equipment. At present there are no suitable machines on the market for such deep-sea exploration. Prototypes and design studies have been presented in some countries, but a series of technical solutions, adaptations and improvements will be required in order to guarantee that extraction is environmentally acceptable, economically viable, and safe. It will involve a large number of technologies that still have to be developed. This applies for a variety of drilling, collecting, cutting, and crushing devices that can be integrated in diving vessels, or remote-controlled and/or autonomous underwater vessels. The equipment will have to be robust enough to operate very reliably under water.

A further challenge, apart from the technology, is the provision of the necessary on-site infrastructure. The production sites must have a permanent energy supply and broad-band communications. If the extracted materials are to be processed at sea, then this requires the construction of suitably equipped large-scale offshore platforms. Transport between the platforms and harbours can be by means of autonomous or semi-autonomous systems.

In all phases of deep-sea mining – planning, operations and renaturation – it will also be necessary to ensure compliance with the highest environmental and safety standards. Irreversible damage to the marine ecosystems must be avoided, and after the mining has ended it must be possible for marine organisms to resettle in the areas. Continuous monitoring and protection of the entire infrastructure and the mining areas in order to prevent illicit activities represent further challenges – and at the same time are necessary conditions if companies are to make major investments in these technologies.

Deep-sea mining not only offers considerable potential for the extraction of urgently needed raw materials for important high-tech developments, but from the perspective of export industries it also offers promising prospects for the future. However, this will require more efforts in research and development. Major advances must be made in the near future, particular with regard to the development of environmentally acceptable and economically viable mining technologies. It is also crucial that solutions are found for an autonomous and sustainable energy supply, as well as for secure transport. Finally, the innovative individual solutions will have to be combined in an overall, system-based process. //


Rare earths and metals can often be found near so-called black smokers.

Tomorrow's TECHnologies

After an attack by the malware NotPetya, the Danish shipping company Maersk had to replace virtually its entire IT infrastructure. (Damages amounted to US$ 250-300 million.)

Cyber security is the key to successful digitalisation in the maritime domain.

Cyber security – the key to a successful future

Digitalisation has affected all sectors, and the maritime domain is no exception. Innovative concepts such as the Maritime Connectivity Platform, the National Single Window, and autonomous shipping are heavily based on the use of digital technologies and tools. The growing importance of digital technology and tools will develop further in future. In addition to the enormous opportunities digitalisation offers, such as new services, more flexible production and more efficient processes, it can also bring with it the risk of possible attacks on the cyber and information space. This means that cyber security is extremely relevant for ensuring that systems can retain their functionality. Digitalisation will only be able to offer sustainable benefits if it is planned and implemented in parallel with effective cyber security solutions.

The severe consequences of IT security breaches for business activities in the maritime domain were demonstrated by the case of the Danish shipping company Maersk. After an attack by the malware NotPetya, the company had to operate for ten days without IT, and had to replace virtually its entire IT infrastructure. The consequences were a significant drop in turnover and damages amounting to US$ 250-300 million. But the NotPetya attack was not targeted specifically at Maersk. In fact, Maersk was only one of a number of companies that were affected by a much wider campaign. It is easy to imagine just how dramatic the effects of IT security breaches could be in the maritime domain of the future, when it will be much more highly dependent on digital technologies.

In order to keep the risks to the cyber and information space at manageable levels, an holistic approach is required, based on Prevention, Detection and Reaction. Prevention involves proactive measures intended to obstruct IT security attacks. The aim is to minimise the attack space for potential attackers. In particular, prevention measures should address the commissioning and hardening of systems and networks. Detection, in this context, is the timely identification of IT security incidents. The aim here is to minimise the likelihood and duration of IT security breaches and their result-

ing impacts. This can be achieved above all by rapid detection. The measures to be implemented here include the efficient monitoring of the status of systems and networks for malfunctions and attacks. Reaction involves the actions to be taken after a security breach has been detected. The aim is to keep the outages for the systems and networks as short as possible. In addition, knowledge should be gained about the approach and the identity of the attackers, so that this can be used to improve prevention and detection. Points to be addressed include incident response, forensic investigations of systems and networks, and the acquisition of knowledge about the perpetrators and their tools.

In addition to these three spheres, it will be eminently important to address cyber security at various levels and at various phases of the lifecycle of systems. Cyber security should be ensured at all stages of a system from the production, delivery and operation through to decommissioning. Different measures are required in the various phases, always considering prevention, detection and reaction. Cyber security has to be ensured at various levels – the individual and networked systems, information networks, and input and sensor data. Only on this basis will it be possible to realise the potential of digitalisation with suitable security provisions and acceptable risks. In this respect, cyber security represents an enabler for the profitable use of cyber and information spaces for the maritime domain.

In summary, the following challenges will have to be faced in the coming decades:

- An holistic approach will be required, based on Prevention, Detection, and Reaction, in order to keep risks in the cyber and information space at manageable levels.
- Cyber security will have to be addressed:
  - In the various phases of the system lifecycle (production, delivery, operation, decommissioning), and
  - At the various levels (individual systems, networked systems, information networks, input and sensor data). //

The vastness of the maritime domain and the increasingly dynamic global political developments call for targeted and timely access to large amounts of data.

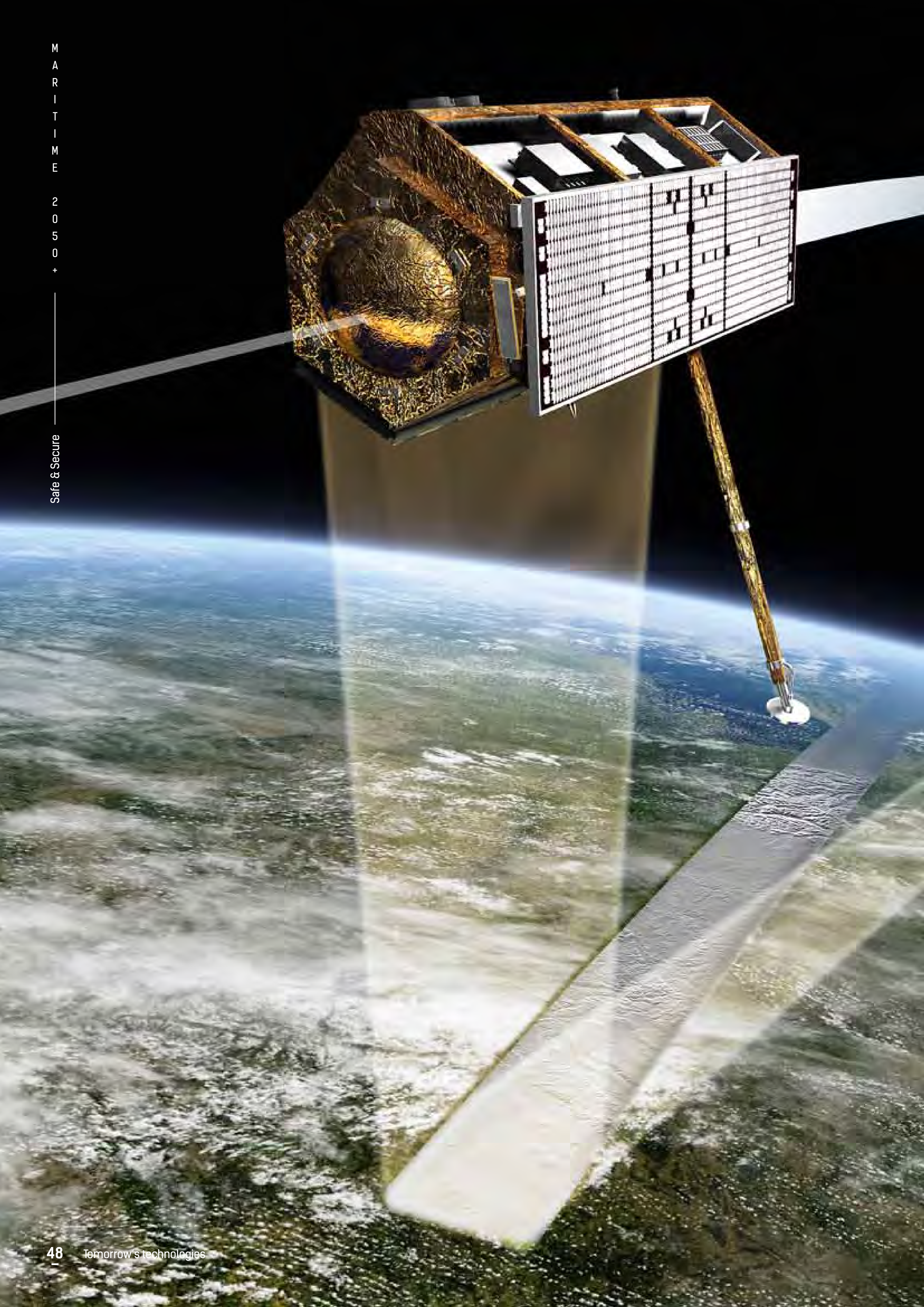
Situational awareness of world's oceans

The immense maritime domain and the dynamic global political developments call for well focused and near real-time access to large amounts of data. The surveillance of the oceans and border security (e.g. EU external borders) are becoming more and more important in view of mass migration, terrorist threats and crime by paramilitary groups, as well as the illegal disposal of hazardous substances at sea. To this end, both military and civil situational awareness centres have been established, merging the information from a range of sources in order to provide representative situational monitoring. Data is obtained from both local and global sensor systems. Local sensor systems are situated along the coast line or coastal areas, or on ships. Well known representatives are radars, which are able to detect objects larger than a certain minimum size on the water surface – in some cases even when these are hundreds of kilometres away. There are also optical instruments and thermal imaging cameras, but their ranges are much shorter and are limited by daytime and atmospheric conditions. Airborne surveillance systems also utilise such sensors, but they are generally used for local applications. Under water, the situation is monitored using passive or active sonar systems. These provide ranges of a few dozen nautical miles. On a global scale, sensor systems for security-related tasks are predominantly mounted on satellites. At present, the limited number of satellites do indeed afford global coverage, but their orbital constraints mean that a specific area will only be covered at intervals of several hours or even days.

For maritime traffic, navigational data are required like position, speed, heading and orientation (PNT data), in combination with meteorological data. Satellite-based navigation systems (e.g. Galileo, GPS) are a primary source for determining locations. Complementary systems are able to ensure that in coastal regions or in harbours the position can be determined with an accuracy of less than a metre. However, multi-sensor approaches are required for the reliable and robust determination of PNT data, in combination with back-up systems. Meteorological data are transmitted to vessels, but the accuracy of the weather forecasts is not as good as on land. The Automatic Identification System (AIS) has been developed for transmission of

Access to the full range of navigational data is important for shipping.

Radar detects object on the sea surface.



For global monitoring of large areas, airborne or satellite-based systems are often more useful than earth-based methods.

PNT data to nearby vessels or to coastal authorities. However, only vessels above a certain size are required to transmit an AIS signal, so that no comprehensive overview of the entire maritime traffic can be obtained. Furthermore, signals may interfere with one another, particularly in heavy traffic areas, leading to partial or total loss of information. Depending on the physical transmission geometry, the range of the AIS system is usually limited by the horizon to some 15-20 nautical miles. In addition, the system can be manipulated or manually disabled. The global mapping of maritime traffic by AIS is only possible using satellites, but in areas with high traffic density the system is frequently affected by the above-mentioned signal interference. Maritime security authorities and environmental agencies not only require weather and traffic data but they also need information about environmental parameters, possible pollution, intrusion in protected areas, and illegal ship traffic. Due to the vast extent of the oceans, regular patrols and compliance checks for regulations are too time-consuming and expensive to be feasible. For global monitoring of large areas, airborne or satellite-based systems are the only viable methods. For future submarine observation, mobile and stationary sonar systems will have to be integrated.

The long-term goal is the provision of data and information for maritime situational awareness on a global scale. The related requirements are:

- Global acquisition of information at open sea and coastal regions by means of suitable sensors, providing adequate frequent updates;
- Extension and refinement of local sensor systems and roll-out of worldwide networking through cooperative agreements;
- Provision of rapidly deployable aircraft or high-altitude sensor platforms (UAS);
- Provision of mobile and stationary sonar systems, including related infrastructure;
- Extensive and simple access to maritime data and information, with protection against misuse. //

An aerial view of the shipping along the Turkish Straits.

Communications is crucial in the maritime domain

Communications is a crucial factor for all applications in the maritime domain, whether by radio or via satellite across the oceans, on-board vessels, or underwater. The technical provisions for powerful communication systems play a key role.

Terrestrial maritime communications is mostly based on conventional analogue technologies. But only very small amounts of data can be transmitted at sea by radio – comparable perhaps with text messaging or analogue voice communications. Geo-stationary satellites currently cover all the ocean surfaces up to the 75th parallel with data connections. However, this is expensive, and does not cover the areas further to the north, such as the Arctic Ocean.

The increasingly complex requirements for communication between port operators, logistics and shipping companies, vessels, and personnel, can no longer be met by existing radio systems, just these are unable to meet the demands in the aeronautic sector. New maritime applications and future land-based administrative tasks also call for increasingly frequent exchanges of large amounts of data. The exchanges take place in coastal areas, in ports, or on the open seas, with and between vessels, and with planes or helicopters. This may involve the transfer of mapping data between vessels for the safe navigation of heavily-frequented waters, or exchanges of prospecting data between ships involved in exploring for new underwater resources. There is also a lack of infrastructure for the airspace above the oceans that would be needed to ensure permanent and reliable communication. This is highlighted by tragic plane disappearances and the time-consuming search for the crashed planes, as for example in the cases of EgyptAir MS804, Malaysia Airlines MH370, or Air France AF447.

In addition, security-relevant communication technologies such as analogue radiotelephony or digital anti-collision systems (AIS) do not have integrated security protection. Everybody can listen in, or can distribute (and also receive) false information.

Although it could make shipping more effective and efficient, there is currently no detailed exchange of situational information between maritime users, and information such as details of routes and freight is not

All means of communication are used to exchange information.

shared. To redress this situation, it has been proposed that relevant information should be made available via a Maritime Connectivity Platform (MCP). However, this would require standardised means of communications on the vessels and on land for the exchange of data.

As a result of the physical properties of water, it is only possible to communicate over very short distances underwater using optical means (less than 150 metres), and though longer distances are possible using sonar, communication rates are still low. But in particular in offshore situations, the maintenance of underwater infrastructure and plants requires effective communication with divers, as well as autonomous maintenance equipment and sensors.

The maritime community is increasingly calling for systems, technologies and standards for reliable communications, including the provision of suitable data transmission networks. This sector offers considerable economic potential, and services that are dependent on data exchange, such as remote maintenance, weather forecasting to reduce storm risks and damage, or route planning, could become more cost-effective and logistics chains could be made more efficient and reliable.

With increased networking, and the ubiquitous implementation of information and communication technologies, maritime actors are becoming more and more aware of the growing threats of abuse or intentional disruption of maritime communications and navigation systems. The development and testing of robust and resilient communication technologies, including solutions should in future help to protect these systems and means of navigation.

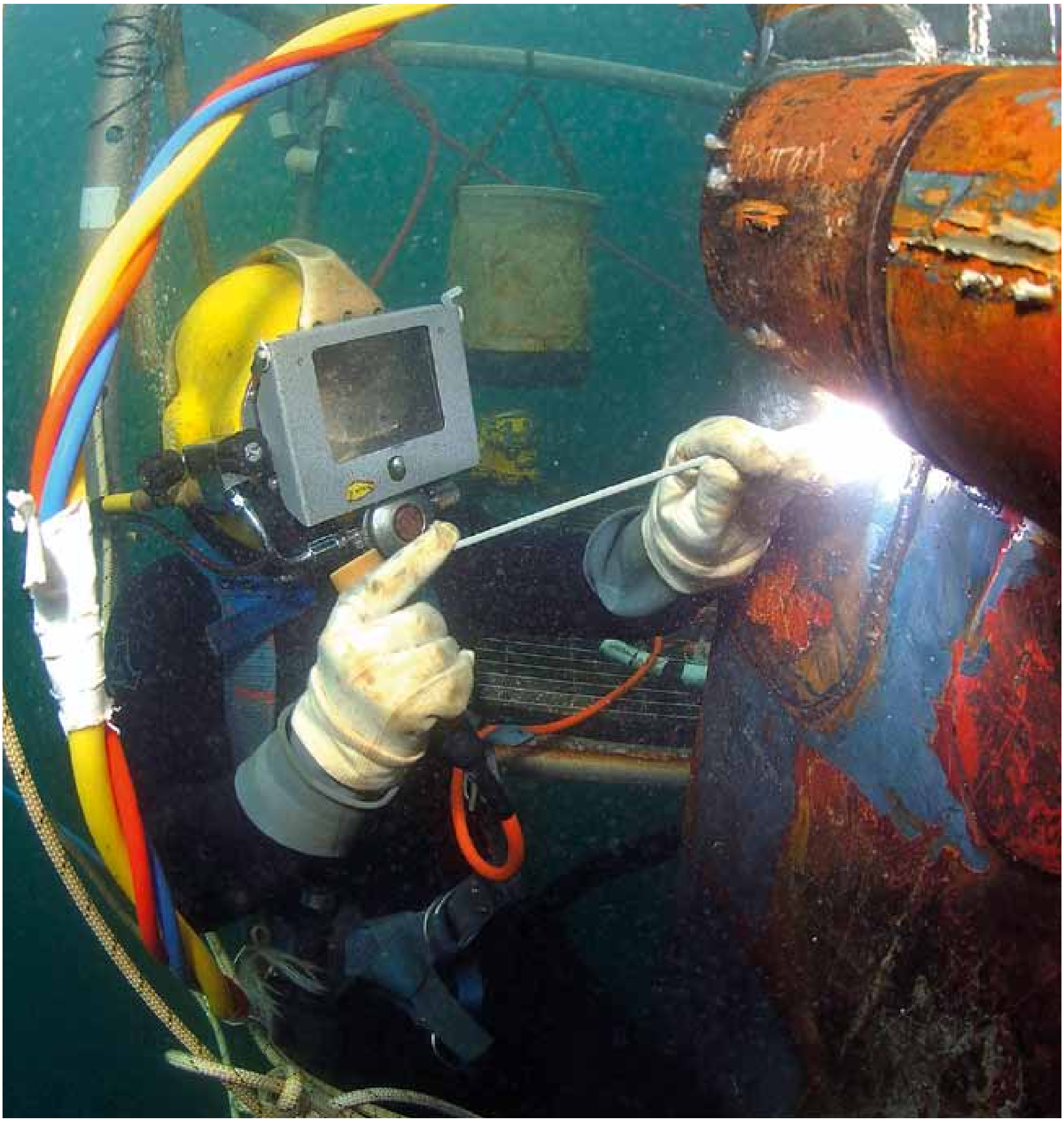
The long-term goal (2050+) is the provision of more secure and more accessible communications in all maritime sectors. This requires:

- A global maritime information management system;
- Global coverage with secure and reliable high-rate data links by means of new terrestrial infrastructures along the coasts, as well as new satellite systems in geo-stationary and low earth orbits, and high-altitude platforms;
- Local networks for high-rate underwater communications for offshore or deep sea operations. //

Lighthouses on the coast can act as communication hubs.

A network of broadband antennae is important for global communications.

Communications is a crucial factor for all applications in the maritime domain.



Humans still work underwater, but soon automated technology will carry out these dangerous tasks.

Intelligent systems on the water and under water

> Intelligent systems will have to be able to adapt and optimise their behaviour and capabilities in real time to meet the current demands.

In future, intelligent autonomous systems will operate under water, on the water and in the air and will be able to carry out complex tasks independently in the fields of logistics, construction, inspection, maintenance and supervision. The missions will be carried out more effectively and more efficiently by the autonomous or semi-autonomous systems, reducing costs and saving time. These intelligent systems will also be deployed in inhospitable surroundings, for example in contaminated areas, or places which are inaccessible or hazardous for humans.

Intelligent systems will be able to adapt and optimise their behaviour and capabilities in real time to meet the current demands. They must have access to knowledge-based structures in order to control and configure independently in new and unfamiliar situations. For individual highly-complex operations, specialised adaptive intelligent systems are required.

Novel methods must be developed in order to improve the interaction between humans and intelligent technical systems. This includes communications with the goal of transmitting assignments and results, as well as the support of cooperation to solve confidential joint tasks. For the cooperation and communication of multiple intelligent systems underwater, on the seas and in the air, comprehensive networking is essential – both with combinations of autonomous and semi-autonomous systems as well as independent of the deployment location by means of real-time data services.

Matters of data security play an important role, both with regard to the exchange of the data and also its central storage. And the integrity and authenticity of the data is also becoming increasingly important. This involves the detection and correction of systematic sensor errors.

Furthermore, uniform communication standards and data exchange formats are required in order to ensure compatibility between producer-specific intelligent systems, and in particular for the deployment of cooperating systems at a global level. This is a precondition if such systems are to be deployed flexibly and easily.

It can be assumed that in the near future there will be new technologies and materials which will reduce the cost of producing systems with considerably improved properties such as resilience, durability, or shape. New computer processors and novel form of artificial intelligence will improve the responses of intelligent systems in unforeseen situations.

One of the major technical challenges is the maintenance of intelligent and autonomous systems. In the past this has required specialised personnel. In future, intelligent systems will be developed which have "resilience by design". They will not only be able to detect and diagnose faults at an early stage, but will also be able to remedy the faults independently or adapt to the situation without threatening the mission. This requires automatic tests before the operation followed by permanent on-going analysis of the behaviour.

The long-term goal of the technological development in the maritime domain is the provision of autonomous intelligent systems with the following characteristics:

- Intelligence: Independent data processing and data evaluation, autonomous analysis and reactions to unforeseeable events.
- Variety: The missions of the future will require a mixture of specialised systems, generally deployable systems, and small, agile systems.
- Cooperation: Completing highly-complex tasks by means of division of labour.
- Networking: Exchange and comparison of situational maps and objectives.
- Resilience: Ability to withstand internal and external disturbances. //

Virtual colleagues for human-machine interactions at sea

The surveillance of the oceans and the introduction of appropriate measures in response to threats or damage are of central importance for maritime safety. Depending on the context, various areas must be taken into account for the operational control: the direct surroundings, areas within visible range, and remoter sea areas. In view of the asymmetric security situation, it is also necessary to take the underwater realm into consideration. If decision-makers are to implement efficient and effective measures, they require comprehensive information. Therefore current systems for operational control focus on integrating all available sources of data. Support is also provided for operators in the form of instructions, guided user interactions, and standardised recommendations. The support systems are based on comprehensive rule systems and heuristics. However, the deployment scenarios are becoming increasingly complex and this presents new challenges for the users.

As the demands on maritime operational systems change, so too do the demands on the operators on land, at sea and in the air. The operative associations become larger, while the numbers of personnel involved decrease. In addition, the duties of civil and military units merge. An example of this is the deployment of military personnel on civilian vessels. The cooperation between actors in a challenging environment calls for comprehensive support by means of operational control. In view of the increasing automation of technical systems, the growing density of data and information, and the complexity of the maritime situation, innovative forms of human-machine interaction are essential.

In response to these demands, future systems will include cognitive agents which act as virtual colleagues to support the human operators. With such assisted operational control, threatening situations can be interpreted, operational centres can be instructed, and a basis can be provided on which decisions can be taken. The virtual colleague can adapt to the expectations of the operators and can take pro-active steps. For example, the virtual colleague can interpret the situation and prepare the technical systems in accordance with the level of expertise of the available operators. The final decision about which measures should be implemented are taken by the human operator, or this is actively assigned to the virtual colleague. The human thus acts as a supervisor. To this end, novel interaction systems will be introduced which assist simple, intuitive human-machine interactions, e.g. natural user interfaces, 3D-presentations, or augmented reality. This allows the operators to make better decisions more quickly and efficiently, to identify and objectively assess hazards sooner, and with this to avoid damage to humans, the environment, and materials.

The long-term goal is the provision of virtual colleagues for assisted operational control in maritime security systems. This requires:

- Virtual agents for the processing of information and the preparation of interactions;
- Global situational mapping for the preparation of maritime information;
- Local and global networks for the continuous exchange of knowledge between local virtual agents;
- Novel interaction systems for human-centred human-machine interaction. //

In view of the increasing automation of technical systems, the growing density of data and information, and the complexity of the maritime situation, innovative forms of human-machine interaction are essential.

High altitude platforms offer new opportunities for existing and future maritime solutions.

Surveillance of the maritime domain

Global sensor systems are predominantly satellite-based. The existing satellites and the physical limits of their orbits allow access to certain areas, but in most cases only intermittently, at intervals of hours or days. However, we are currently experiencing the start of a new era in satellite-supported remote sensing. In Europe, the development is being promoted in particular by the on-going EU Copernicus Programme. In the course of this programme, a series of satellite systems have been started since 2014 for a variety of core services, including the monitoring of the marine environment. For example, the European Maritime Safety Agency (EMSA) drew on more than 8700 satellite images in 2017 alone. The Sentinel earth exploration satellites of the Copernicus Programme mainly provide for the observation of the marine environment, the provision of support for catastrophe and crisis management, and also contribute to various security applications, but international missions are also an important part of the service. Newly developed "satellite-driven bathymetry" has been introduced for the mapping of the ocean floors. However, the depth of vision plays a key role for this technology, so that the potential for applications varies from region to region. Despite this limitation, it can be assumed that the utilisation of remote sensing data will also increase in this field in the coming years.

There has been a considerable growth in the overall numbers of remote sensing satellites. Some thirty per cent of all operational satellite systems are currently deployed for earth observation purposes. The numbers increased from 374 satellites in 2016 to 596 satellites as of August 2017. It is expected that this trend will continue in the coming years, and it will be promoted in particular by new technologies and miniaturisation. Satellites will become less expensive and at the same time smaller and more powerful. In 2017, 88 planet satellites were brought into orbit in a single launch in order to augment the existing constellation of earth exploration satellites. The Finnish satellite ICEYE-X1, launched in January 2018, is the first SAR-satellite (Synthetic Aperture Radar) weighing less than 100 kilograms, and more will follow to form a constellation with more than 18 satellites. However, it is likely that for future missions a few powerful satellites will be deployed together with a larger number of smaller, less performant ones. In order to obtain sufficiently comprehensive data for all parts of the oceans at a

Remote sensing satellite technologies have already established themselves as an integral element of maritime applications.

reasonable revisit rate, there will have to be a considerable increase in the numbers of low orbit earth exploration satellites (up to 1,000 km). Alternatively, geo-stationary satellites (orbiting at some 36,000 km) or satellites with a medium earth orbit (between 1,000 and 36,000 km) could carry out at least some of the tasks, although they do not currently do so.

In addition to established satellite systems, other technologies could also be deployed in future, such as High Altitude Platform Stations (HAPS), which operate autonomously in the stratosphere at an altitude of some 20-30 km for very long periods, powered by solar energy, allowing continuous monitoring. This technology can be deployed when detailed local data is required which is up-dated at short intervals.

The growing numbers of satellites will also increase the availability of data from the various sensor systems, while also shortening the revisit intervals for possible data acquisition. This is already generating enormous amounts of data – totalling several trillion bytes per day, which opens up potential for new forms of data analysis and information retrieval. The challenge of Big Data will thus also offer opportunities for the analysis and intelligent combination of information. Over coming decades, the focus will be on the enrichment of Big Data to generate Smart Data, which will allow for user-specific solutions.

Remote sensing technologies have already established themselves as an integral element of maritime applications. Satellite instruments deliver precise data from which complex, high-quality information products can be derived. Nevertheless, in the coming decades satellite-based marine observation will face a number of challenges. These will include:

- Providing global coverage with the best possible spatial and temporal resolution;
- Synergetic use of satellite systems with appropriate, mission-based compromises concerning coverage, geometric and temporal resolution, and the specific properties of the sensors, e.g. the spectral bandwidth;
- Continuous processing of large amounts of data using a variety of sensors and systems;
- Developing new technologies for networking and the collation of information in order to improve availability at all times. //

Copernicus Program

Sentinel-4

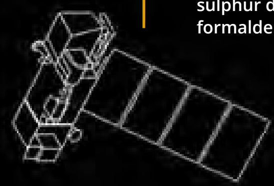
Sentinel-4 will provide data for atmospheric composition monitoring. Its objective is to monitor key air quality trace gases and aerosols over Europe at hight spatial reslution with a fast (hourly) revisit time. It will be a payload embarked on EUMETSAT's Meteosat Third Generation (MTG), which is scheduled to be launched around 2019.

Sentinel-1

Sentinel-1 provides all-weather, day and night radar imagery for land and ocean services. The twin satellites Sentinel-1A and Sentinel-1B were respectively launched on 3 April 2014 and on 25 April 2016.

Sentinel-5

Sentinel-5 will also be dedicated to atmospheric composition monitoring. It will be a payload embarked on a EUMETSAT's Metop Second Generation (Metop-SG) to be launched in 2021 timeframe. It will provide accurate measurements of key atmospheric constituents such as ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide, methane, formaldehyde, and aerosol properties.



Sentinel-2

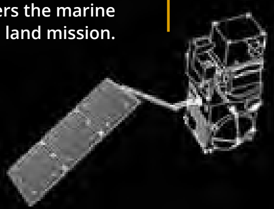
Sentinel-2 provides high-resolution optical imagery for land services. It provides for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 also delivers information for emergency services. The twin satellites Sentinel-2A and Sentinel-2B were respectively launched on 22 June 2015 and on 7 March 2017.

Sentinel-5P

Sentinel-5 Precursor is a satellite mission launched on 13 October 2017. It is a gap filler mission aiming to provide data continuity until the launch of Sentinel-5, the dedicated atmospheric Copernicus mission, scheduled for launch in 2021.

Sentinel-3

Sentinel-3 provides high-accuracy optical, radar and altimetry data for marine and land services. It measures variables such as sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The twin satellites Sentinel-3A and Sentinel-3B were respectively launched on 16 February 2016 and on 25 April 2018. EUMETSAT operates the satellites and delivers the marine mission, while ESA delivers the land mission.



Sentinel-6

Sentinel-6 will provide high accuracy altimetry for measuring global sea-surface height, primarily for operational oceanography and for climate studies. It is a cooperative mission developed in partnership between Europe (EU, ESA and EUMETSAT) and the U.S. (NOAA and NASA). It is planned for launch in 2020.

Cognitive assistance will support the human operator to remain in control in highly complex maritime scenarios.

Responsible decision-making

Despite increasing digitalisation and automation, human operators will continue to play a key role in maritime systems. In the end, they are responsible for their decisions and actions in critical situations. However, they can benefit from smart technological support that enhances their capabilities.

When operators need to remain in control in highly complex maritime scenarios under harsh operating conditions, systems for cognitive assistance help to reduce the workload, making it possible for the operator to concentrate on the essentials. Cognitive assistance is therefore becoming a key maritime technology, drawing on and implementing innovative methods from the rapidly evolving field of artificial intelligence (AI).

At the technological heart of cognitive assistance are multisensor fusion engines. These help to provide high-quality information from a range of sources for comprehensive situational awareness and effective decision making by efficient mass data processing, optimised sensor management, or smart control of critical platform resources. They form the basis for role-specific, independent human actions and decision-making.

Algorithms of sensor data fusion and artificial intelligence enable sensor fusion engines to learn the key elements of the registered environment and adapt to dynamic scenarios. At the same time, these algorithms deliver information for situational maritime awareness. Finally, the algorithms support the selection of suitable combinations of sensors. They thus provide the basis for the optimised management of the sensors and platforms.

Beyond these technological aspects, maritime research also needs to address the ethical and process related questions concerning the use of AI-powered systems that will inevitably arise. What degree of autonomy is appropriate and necessary to achieve safe and effective human-machine cooperation? What level of transparency is required to enable the operator to assess the system's recommendations? How can full data integrity be guaranteed to avoid erroneous judgements? What fall back options are required to avoid total system dependency?

The long-term goal in the maritime domain is the development of cognitive assistance systems for responsible decision-making using AI-technology in which:

- Information and data from fusion engines form the basis for responsible decision-making in maritime multi-sensor systems.
- Maritime multi-sensor systems integrate a variety of sensors that are able to generate information and data redundantly, both independently and in combination.
- The system design of maritime fusion engines is empowered by artificial intelligence software.
- Aspects of data integrity play a crucial role in cognitive assistance.
- Transparency ensures that cognitive technologies are socially acceptable for sustainable commercial uses in the maritime domain. //

Policy recommendations

The need for action

The maritime world offers a huge economic potential in numerous fields such as logistics, tourism, fresh water and food production, or ocean mining. Yet, the most important benefit lies perhaps in the protection of this unique natural environment for our planet. These diverse interests need to be kept in a sustainable balance, addressing both the economic and environmental needs of all main interest groups.

Currently, there is not enough international cooperation, technical integration, and applied research to meet all major challenges. Germany, as a leading economic power, should take the initiative and play an active role in unlocking the future potential of the maritime domain in close cooperation with partner countries. This requires a far-sighted and structured multi-level approach as well as sufficient funding. There are several areas of action that need to be addressed without delay, including conceptual, technical, legal, organisational, and procedural subjects.

Key areas of action

***Developing a common understanding* –** All relevant stakeholders should develop a shared holistic view of the maritime domain that reflects the complexity of this fragile system. Short-sighted exploitation of individual benefits will most likely tilt the balance in a fatal direction. In fact, careless or even criminal behaviour has repeatedly led to serious ecological incidents with dire repercussions. There is a need for rules and strictly enforced limitations that apply to all users.

***International cooperation* –** Based on this common understanding of the maritime world, governments, companies, research institutions, and other key players should seek and support international cooperation. A fragmented approach regarding the exploitation and protection of the sea does not reflect the fact that we all share the biggest part of this natural environment and therefore share the responsibility to look after it. Moreover, active cooperation in value chain networks is much more efficient and effective than uncoordinated isolated initiatives. There needs to be a guiding hand but each government must also contribute its intellectual and budgetary share to support the development of joint solutions.

***Technological research* –** The will to work together towards common goals and structures is the basis for success. Maritime 2050+ proposes pursuing a long-term perspective and there are still many technical challenges to meet on our ambitious road ahead as drafted in the previous chapters. Among them are global surveillance solutions for maritime applications, the development of autonomous vehicles for transport, exploration, and maintenance, the seamless integration of heterogeneous systems, and the fusion of big data streams to exploit the full potential of digitalisation – including many complementary subjects such as communications or power supplies. Moreover, the maritime research community needs to observe indirectly related research disciplines that may contribute to solving pressing problems of the maritime domain. For instance, what if it were possible to provide cheap packaging material that fully degrades in water but maintains all the functional characteristics of plastics in dry conditions? To a certain extent, this might shift our paradigm from avoiding to replacing.

This edition of Maritime 2050+ includes contributions on two new subjects that have an impact on almost all technology-related domains: Artificial intelligence and cyber security. We would therefore like to address them separately in the two following paragraphs although they are, of course, part of the suggested technological research agenda.

Artificial intelligence – In recent years, there has been tremendous progress in the field of artificial intelligence research and there is more to come. This is a game changer of utmost importance for the maritime world. Moreover, AI runs laterally through most other key technologies and therefore deserves special attention.

From our perspective, AI is not an end in itself but rather a very powerful enabler of superior solutions that will fundamentally shift the role that technical systems play in value creation. But although AI will strongly influence the means to utilise and protect the maritime world and should be actively pursued on the research agenda, smart systems cannot fully replace human reasoning in critical situations. Therefore, AI research must also deal with responsible decision making including aspects such as data integrity, causal transparency, or system reliability.

Cyber security – A further crucial technological issue for the entire maritime domain and its stakeholders is cyber security. The authors of Maritime 2050+ would like to emphasise that government authorities need to increase their efforts to develop and implement suitable solutions.

It is apparent that digitalisation goes along with increased cyber security threats. When it comes to critical infrastructures, security experts even talk about cyber bombs that could deliberately be placed and triggered to disrupt the provision of essential services. The maritime domain must not be naive about the fact that it is an attractive and vulnerable target with an increasing demand for digitalisation and a high potential for extensive collateral damage. One reason for its vulnerability is that there are many stakeholders who need to share sensitive data and information across the entire value chain, across systems, and between organisations.

In order to achieve the necessary international cooperation, numerous topics must be tackled, such as common standards, certification, improved system resilience, risk awareness, distributed monitoring. There are also more pragmatic issues like the integration of weakly protected legacy equipment with limited technical performance. A possible way to systematically increase the level of cyber security is to follow the triad of prevention, detection and reaction on various levels (e.g. legal, technical, procedural, organisational) in order to strengthen the maritime domain against cybercrime attacks in their various guises – theft, manipulation, sabotage, and disruption. //

> Germany needs to invest more budgetary, intellectual, and industrial resources to effectively pursue its economic, environmental, and security-related maritime interests.

Practical recommendations

- ***Place a stronger focus on the maritime domain***
  Governmental authorities must dedicate more resources to the development and protection of the maritime domain.
- ***Support cross-organisational cooperation***
  The maritime community in Germany needs structural support aimed at bringing together regulatory bodies, research institutions, industrial suppliers, infrastructure operators, and law enforcement organisations.
- ***Strengthen international networks***
  National activities should be aligned and coordinated with international maritime agendas to avoid solitary solutions (e.g. technical, environmental and legal standards).
- ***Cover the full research-to-product cycle***
  Well-resourced and less bureaucratic funding programmes to cover the full research-to-product cycle are required.
- ***Provide technological test facilities***
  Stakeholders need an independent infrastructure to test the performance, interoperability, and usability of new technology.
- ***Invest in qualification and training***
  Our community would benefit from programmes that support additional training as the speed of technology increases.
- ***Use cross-domain synergies***
  Government bodies concerned with maritime matters should seek to foster and exploit technological synergies with other domains such as aeronautics and space, or telecommunications.

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