General Lighthouse Authorities

The United Kingdom and Ireland

2040: Navigating the Future

The General Lighthouse Authorities Strategy has been undertaken by:-

Irish Lights | Northern Lighthouse Board | Trinity House

Commissioners of IRISH LIGHTS | Navigation and Maritime Services

Northern Lighthouse Board

TRINITY HOUSE

Contents

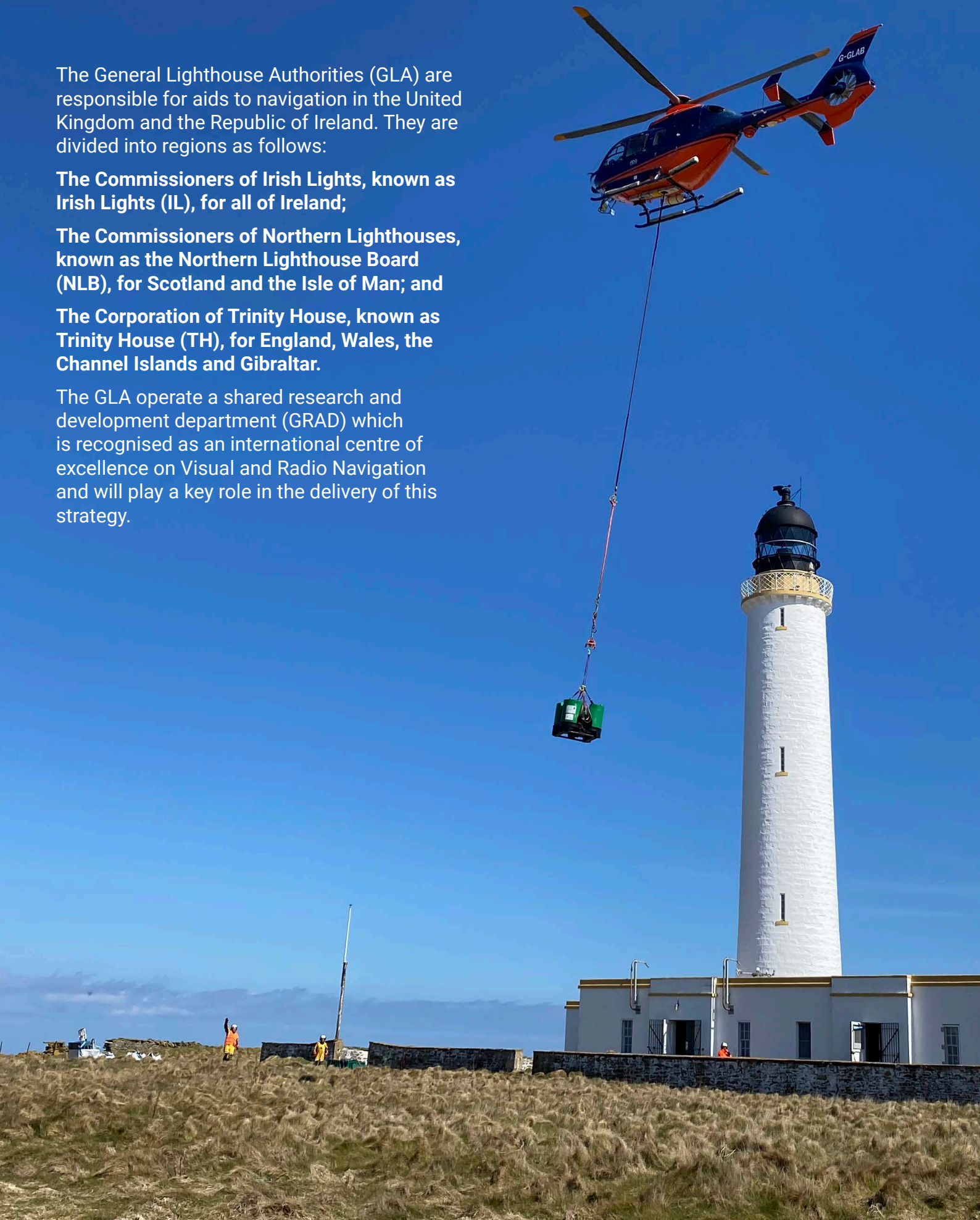
The General Lighthouse Authorities (GLA) are responsible for aids to navigation in the United Kingdom and the Republic of Ireland. They are divided into regions as follows:

The Commissioners of Irish Lights, known as Irish Lights (IL), for all of Ireland;

The Commissioners of Northern Lighthouses, known as the Northern Lighthouse Board (NLB), for Scotland and the Isle of Man; and

The Corporation of Trinity House, known as Trinity House (TH), for England, Wales, the Channel Islands and Gibraltar.

The GLA operate a shared research and development department (GRAD) which is recognised as an international centre of excellence on Visual and Radio Navigation and will play a key role in the delivery of this strategy.



Marine aids to navigation are going to remain an important and strategic resource for the United Kingdom and Ireland

1 Executive Summary

2040 - Navigating the Future is the United Kingdom and Ireland's marine Aids to Navigation (AtoN) strategy. It has been prepared by the General Lighthouse Authorities (GLA) of the United Kingdom (UK) and Ireland for our users, partners, and stakeholders.

The operating environment and navigation context in 2040 is likely to be very different to today, nonetheless the UK and Ireland's prosperity and security will continue to depend, to a significant degree, upon trade by sea. 95% of our trade currently occurs by sea and this is not expected to change significantly over the life of this strategy. The complex nature of marine operations will make demands on the GLA (and other regulators and responsible bodies), that will suggest greater multi-agency cooperation and coordination to maintain safety standards. Planning for the future needs to understand the changing nature of the sea-space, climate change and carbon neutrality.

Operations will need to benefit from increasing big data, artificial intelligence and automation as a new generation of economically and environmentally savvy maritime leaders, who will know what they can have, and will demand more coherent data and services. Enabled by technology, the financials will drive the transformation of a shipping sector with which legislation will need to retain control and relevance.

The challenge for the GLA is to relate these factors (including a degree of uncertainty) to future AtoN requirements and planning. Marine AtoNs will remain strategically important to secure safe passage through our waters, but it is clear that the changing maritime requirements will mean the GLA will have to ensure the mix of aids remains appropriate. The strategic importance of AtoN will see little change, if any. The context will continue to evolve and understanding (and managing) safety in this complex environment will rely heavily on partnership, co-operation and collaboration. The opportunity for the GLA is to use its engagement with the end-user, knowledge of emerging technologies and understanding of operational paradigms to move towards a position of thought leadership and the development of new AtoN in a digital infrastructure, utilising existing physical infrastructure, to fulfil its role in safety at sea.

Whilst recognising the emergence of new technology will enable the GLA to employ and support a new exciting range of digital AtoNs, it is extremely likely that the requirement for physical AtoN will remain. A disparate mix of AtoN is envisaged in order to support the wide range of users and provide security through resilience.

So, Marine AtoN are going to remain an important and strategic resource for the United Kingdom and Ireland. The pace of change in our waters will nonetheless be significant as the number and range of users becomes more diverse, resulting in a wider range of requirements for the GLA to meet. As such, the GLA will need to be innovative and flexible, while continuing to provide an efficient and cost effective service.

In order to ensure the GLA remain optimised to deliver appropriate, effective and efficient marine AtoN, their strategy to 2040 is to:

Leverage trusted agent status, experience and understanding of emerging technology to provide the maritime community with thought leadership.

Influence the development of regulations and policy to support the evolving use of the maritime sea-space and the ever-growing complexity associated with the change in vessel types, operations and the introduction of autonomy.

Grow government and academic support for research into innovative e-Navigation, marine data infrastructure, physical aids, and PNT and Data resilience as part of the GRAD programme.

Hasten the GLA reduction in emissions to support a net zero carbon footprint by 2050 and the adaptation of the AtoN estate in response to the impact of climate change.

Transform AtoN services to ensure they continue to provide reliability, efficiency, cost effectiveness and relevance in an evolving, complex, sea-space.

Highlight the users of AtoN and services in emerging blue-economy roles and seek opportunities to collaborate, in pursuit of government aims and objectives.

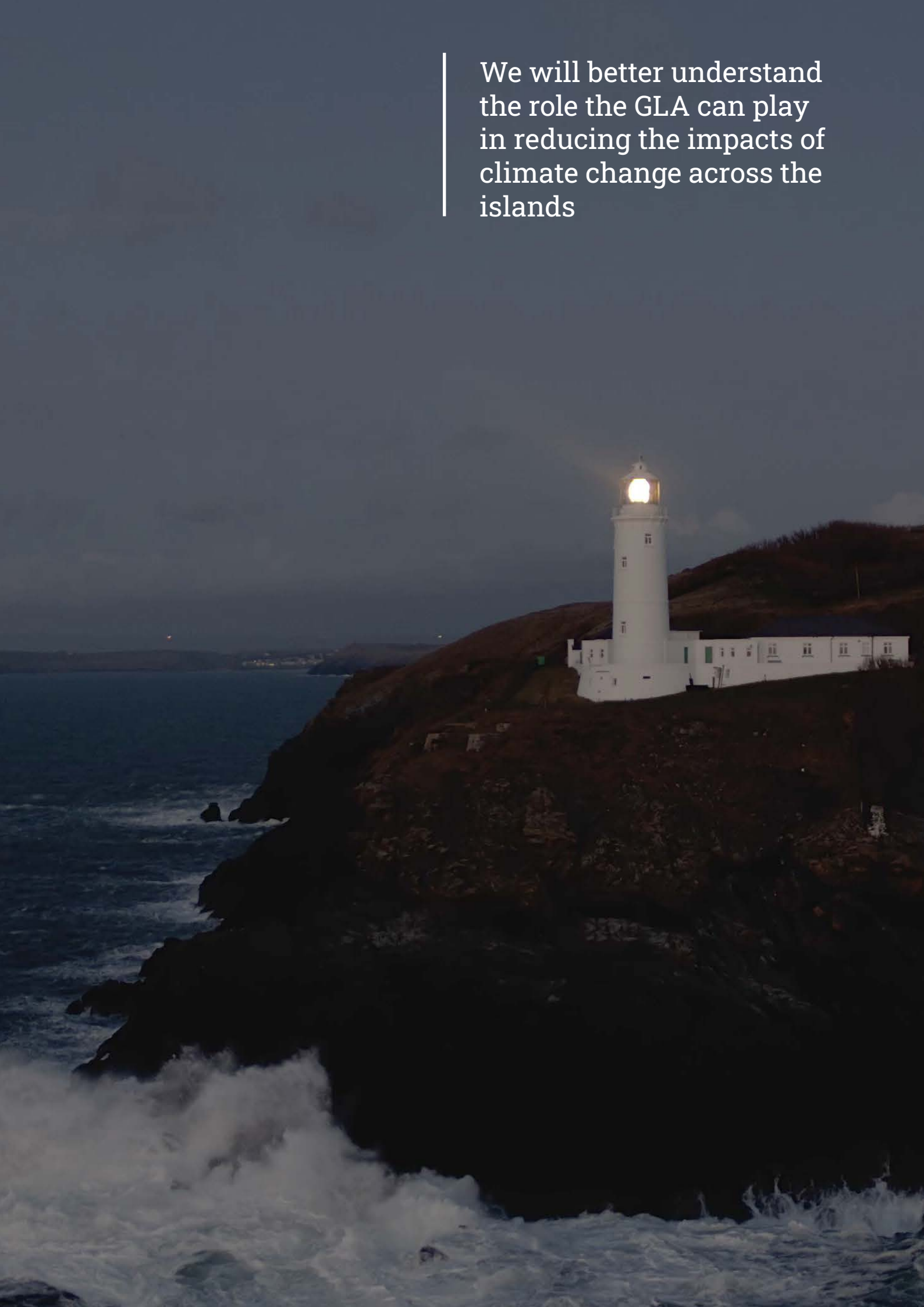
Optimise the GLA physical infrastructure for future data-enabled support of safe navigation and maritime operations.

Understand the role the GLA can play in reducing the impacts of climate change across the islands.

Support mass data connectivity at sea through exploitation of the GLA physical infrastructure.

Ensure government SOLAS responsibilities continue to be met as efficiently as possible.

We will better understand the role the GLA can play in reducing the impacts of climate change across the islands



2 Our commitment

The GLA will:

Deliver navigational services that underpin safety of the mariner, national prosperity, and security;

Offer a safety critical, efficient and cost-effective service, for the benefit of all mariners;

Provide a reliable AtoN service for general navigation, and the superintendence and management of local light authorities to meet international standards, recommendations and guidelines;

Respond to wrecks, new dangers and AtoN failures in a timely fashion to minimise risk to safe navigation;

Use innovation to provide a holistic mix of traditional and novel AtoN, and be prepared and resilient to emerging technology threats and opportunities;

Regularly review our AtoN requirements in consultation with our users , and ensure that the AtoN mix is appropriate for a shared and changing sea space, and the resulting volume of traffic and degree of risk;

Work collaboratively with key stakeholders nationally and internationally to ensure a coordinated and seamless approach to safety of navigation in our areas of responsibility;

Engage with international organisations, governments and other bodies to promote the standardisation of AtoN services;

Conduct activities in a way that minimises impact on the environment, in a response to climate change and requirements for sustainability.

Seek where possible to influence policy and decision making by providing thought leadership, expert advice, and innovation.

When delivered, this strategy will mitigate risk and provide for the safety of navigation, the protection of life, property and the marine environment.

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1 Including the GLA Joint User Consultative Group and local consultation groups.

The GLA will work collaboratively with key stakeholders nationally and internationally to ensure a coordinated and seamless approach to safety of navigation in our areas of responsibility

3 Introduction

3.1 Context

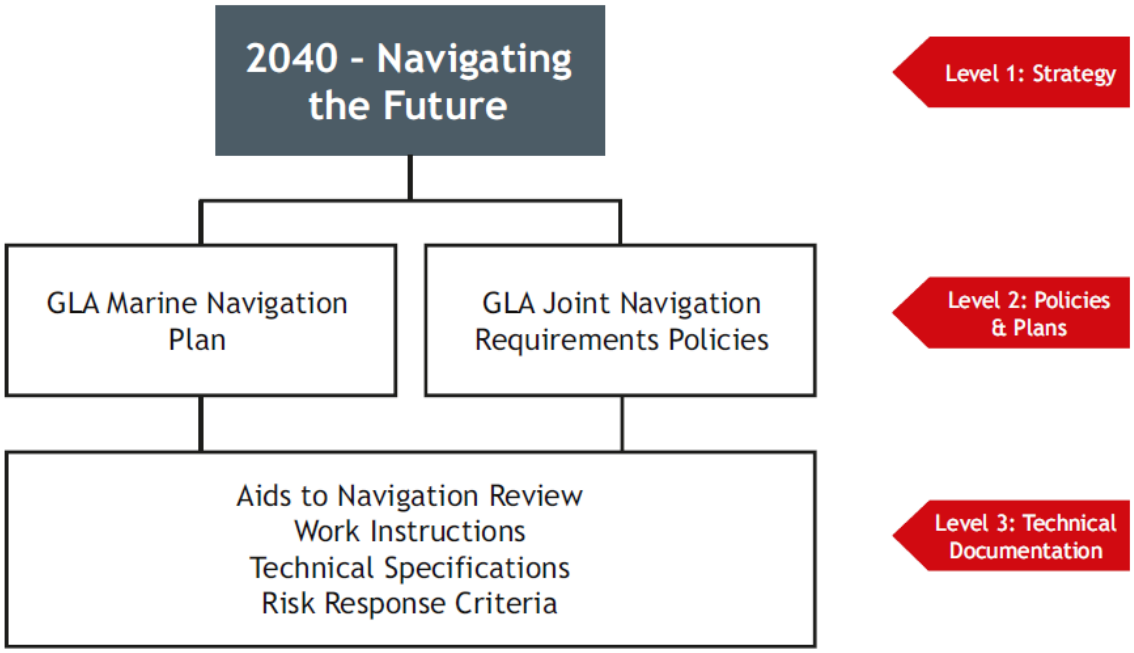
The United Kingdom and Ireland's coastal and offshore regions are supporting increasing levels of human activity including economic, leisure and increasing demand for protection. Climate change and other natural events will also impact significantly on heavily populated and developed coastal regions. Changes deriving from these and other factors will drive legislative and regulatory change that will add further to the physical and legal complexity of the marine space around the UK and Ireland.

The GLA have been empowered by the UK and Irish Governments, through the Merchant Shipping Acts [1] and other legislation, to meet their Aids to Navigation (AtoN) obligations as per the Safety Of Life At Sea (SOLAS) Convention [2] and to carry out other functions in relation to wreck marking. The GLA responsibilities apply equally to all types of mariner from the highly-trained professional navigator through to the amateur leisure user.

The SOLAS Convention advises administrations to adhere to systems and standards developed and managed by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). The GLA participate actively in IALA at Council level and in the committees tasked with the creation and promotion of recommendations and guidelines applied by all AtoN authorities and service providers. These recommendations and guidelines are based on the principle that the mariner receives a consistent AtoN service, irrespective of the provider.

To remain relevant in the ever-evolving landscape in which they operate, the GLA must be proactive in anticipating emerging requirements in the evolving complex sea-space and flexible in adapting to changes derived from technological development. The next 20 years will continue to see very significant change in the science, technology, and the practice of marine navigation, which will reshape the nature of AtoN. Addressing the need for resilience within marine navigation will remain important as will the application of Human Factors science to marine navigational practices, some of which may significantly change how AtoNs are used. The emergence of autonomous and un-crewed vessels is likely to impose different, and possibly more stringent, performance requirements on AtoN services.

All the key indicators considered in the context used for this strategy point towards the waters around the UK and Ireland becoming home to an



To remain relevant in the ever-evolving landscape in which they operate, the GLA must be proactive in anticipating emerging requirements in the evolving complex sea-space

increasing number of users, not least in response to climate change, and that congestion and the complexity and diversity of operations in our waters will grow. As a result, the GLA will have an increasingly important role at the heart of the UK and Ireland's response to its international maritime commitments. The GLA must be ready to provide a robust and sustainable AtoN service with increased reliability as well as a mobile and rapid response to new wrecks and dangers. Beyond this, the GLA are uniquely positioned in terms of their statutory responsibilities, their estate and their level of expertise to influence and provide thought leadership to a wide range of maritime issues that our islands will face.

The need to continuously improve the efficiency and cost effectiveness of GLA operations while still meeting the high standards required of a critical maritime safety service remains paramount. The challenge is to deliver real and tangible benefits to users through the continued delivery of traditional AtoN, where volume of traffic and degree of risk require this, alongside the development and deployment of new, emerging technologies in a measured and cost-effective way and through appropriate international frameworks.

3.2 Policies and Plans

The GLA maintains three levels of documents to align Authority-wide goals across the organisations. "2040 - Navigating the Future" is the highest and broadest level of strategy that defines main purpose and directs all our downstream decision-making. Our Level 2 Policies and Plans are designed to implement the strategy and allows us to weigh the costs and benefits of specific challenges and to support specific resource decisions. Our Level 3 documents provide more detailed technical documentation and work instructions.

4 The changing landscape of 2040 & beyond

The Statutory Framework (see Annex A) outlines the wide ranging responsibility and service provision of the GLA, which will need to be preserved in an ever-changing environment. By 2040 and beyond, there will be significant changes to vessels, mariners, technology, the environment, legislation, and the global political situation, with wide-ranging impact and new challenges for GLA operations. Some examples of these are outlined in the following section.

4.1 A shared and changing sea-space

The current shipping routes will continue to be in high demand, but as we progress to 2040, these routes will need to adapt to potential constriction, sharing the sea space, and changing vessel types. For instance:

a. Restriction of shipping space

The United Kingdom's and Ireland's coastal and offshore regions are supporting increasing levels of human activity involving a substantial proliferation of artificial structures and associated operations [3]. These include oil and gas production, renewable energy generation (including wind, tidal, and wave), and aquaculture, extending into deep waters. These developments, as well as National Marine Spatial Plans [4] and restrictions for marine conservation, will markedly reduce navigable sea-space, restricting free movement of shipping.

b. Changes to vessels

The traffic mix currently comprises vessels of many sizes and performance levels. Going forward, a desire to decrease dependence on long-distance supply chains for environmental concerns, combined with improvements to robotics, automation, and recycling, may shift supply and manufacture closer to home, supporting short sea shipping operations. Traffic is expected to remain a mix of large and small vessels with an increasing range of operational capabilities [5]. The speeds of vessels could also be restricted to reduce emissions, which would result in longer transit times and more crowded shipping routes.

4.2 The future mariner

There is likely to remain a very wide spread of ability, qualification and experience in mariners. Less qualified and less experienced leisure users will go further afield, and current trends suggest lower levels of experience in (and possibly even a shortage of) seafarers, superintendents, surveyors and pilots. There is the possibility of a dangerous combination of lower experience levels coupled with more vessels in busier, more restricted areas around our coasts.

The growing use of technology is set to continue, and will influence day-to- day operations, placing different demands on the mariner and the nature of GLA operations. Mariner expectation of digital service provision will increase, as their home-use of technology extends to their seafaring. This will add further dependence on digital systems for all aspects of seafaring, and increase the importance of human factors concerns such as digital display design.

There is an important human aspect to complexity and risk, part of which lies in training and supporting mariners to work in a digitalising sector. There is increasing concern over the misuse of technology and its potential to lead to an increased number of incidents. The IMO is laying increasing emphasis on the importance of non- technological skills such as Human Factors science as being a critical part of incident prevention. As the blue-economy sector expands a new generation of mariners will be conducting detailed activities at sea, though they may not be navigating in a traditional sense or relying on any particular maritime experience other than that gained online, virtually, or in a classroom.

With the rise of autonomy, future GLA operations will need to consider 'robot' mariners, which may necessitate new forms of AtoN and services designed primarily for interaction with machines [6].

4.3 Global politics and changing legislation

Many aspects of maritime law have been established over centuries, and much of this will remain in place by 2040. However, with a turbulent political space in Europe and beyond, there may well be implications on the maritime sector, which will need to be carefully monitored and managed by the GLA. In particular, the following matters pose particular challenge:

a. International relations

The GLAs operate across domestic and International borders. With the UK leaving the EU, crossing international borders brings new challenges affecting GLA role and such things as procurement and material/equipment transfer. Ongoing inter- GLA operations will need to continually consider legislative changes around the borders. The impact on shared capabilities, especially around navigation tools and systems will need to be carefully understood. The GLAs will continue to engage with European and Scandinavian colleagues on operational AtoN and new danger response matters. To ensure AtoN harmonization and navigational safety at an international level, the GLAs will continue to work with IALA and other such bodies.

b. Political instability

In 2022, decades of peace in Europe came to an end with the Ukraine conflict. This is possibly an indication that globalisation and the greater interdependency we now see between nations will lead to maritime being a political tool in times of tension. As shipping will remain a key element of globalisation and international trade, vessels are increasingly likely to be impacted by political instability. Impacts may include changing traffic patterns as well as intentional disruption to digital/GNSS navigation services through cyber-attacks and jamming/spoofing [7]. Therefore, a responsive and resilient AtoN service will need to be provided; one that can rapidly adapt to changes in routes and traffic behaviours to preserve the integrity of safe shipping around British and Irish waters.

4.4 Climate change

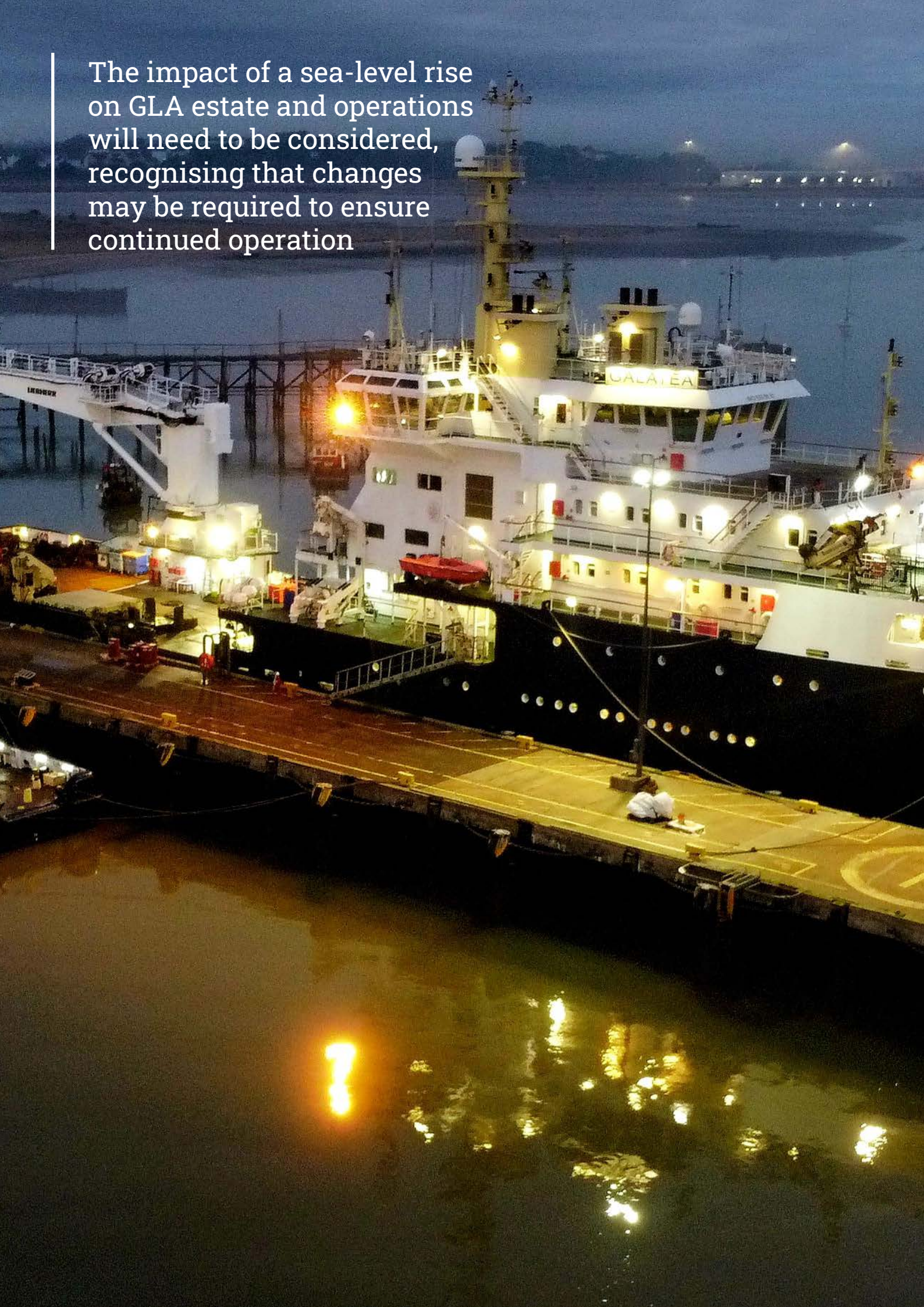
The threat of climate change is widely recognised, and will likely impact across all GLA operations by 2040. Projections indicate that the effects of climate change will be felt strongly in UK and Irish waters, influencing the challenges to and safety of at-sea operations, and potentially causing wide disruption to port operations [8]. With increasing focus from government, significant environmental legislation and targets are being placed on developers and government departments and the GLA will continue to participate in the process of consent for an increasing number of offshore developments, adapting AtoN design and deployment to ensure navigational safety.

Whilst the challenges set by climate change are diverse, the following groups of issues require particular consideration:

a. Net Zero

The drive for carbon net-zero will necessitate significant operational efficiency across the maritime sector, driving demand for carbon efficient routing and logistics, and catalysing new operating models (including fuels, routes, logistics, and supply chains). Whilst the ultimate goal would be carbon neutral vessels, ship operators will be seeking efficiency in every aspect of their operations on their path to net-zero. Key to this will be improved routing and logistics, enabled by maritime digitalisation and traffic management. GLA real estate on land will need to meet new legislation on efficiency targets and reporting requirements, which will require adaption and careful retrofitting of technology such as wind turbines, replacing diesel generators at non mains stations and expanding the already extensive use of off grid solar power. This brings new challenges for buildings especially with older assets that are no longer manned and that may suffer from building degradation. The challenge further extends to vessels which are the biggest GLA CO_2 emitters. A transition to more efficient and ultimately zero emission ships is essential through a replacement and upgrade programme.

The impact of a sea-level rise on GLA estate and operations will need to be considered, recognising that changes may be required to ensure continued operation



b. Offshore energy generation

Offshore wind energy production is growing rapidly [8], and this trend is set to continue in coming decades following commitments by the UK and EU at the COP26 Climate Summit. Other forms of sea-based renewable energy may also feature in coming years, such as wave, tidal, or floating solar farms. The areas designated for energy generation will grow, with knock-on effects to shipping. Additional challenges are presented when navigating in close proximity to wind turbines, as they may interfere with some navigation aids and systems.

c. Sea-level rise

The mean sea-level is expected to continue to rise, as melting of the glacial and polar ice releases freshwater into the seas [9]. The exact figure for the rise varies in estimate, but one recent study suggested that regardless of any action taken, the level will rise by 27cm in the next century from Greenland ice melt alone (and as much as 78cm without intervention). In the longer term, this sea level rise will alter the coastline, creating new hazards around the UK and Ireland as well as open other routes to deeper draught traffic. Without effective defences and mitigations this could render some ports unviable and may change navigable approaches. The impact of a sea-level rise on GLA estate and operations will need to be considered, recognising that changes may be required to ensure continued operation [10].

d. Sea state, currents, and extreme weather events

In the last 35 years there has been a fivefold increase in the number of natural disasters, and a warmer climate around the UK and Ireland would increase the frequency and duration of heat-waves and storms [11].

Due to increasing temperature, there has been more, and larger sized, sea fog events, with fog sitting closer to the ocean level [12]. The release of freshwater combined with increasing temperature gradients is also threatening sea currents, most notably the Gulf Stream [13]. This may have devastating effects, including new ice hazards

forming in winter months, more storms occurring, and fresh challenges to the fishing and aquaculture industries.

In general, worsening conditions would increase the need for maintenance & repair, affect the number of solar panels required on site, require the re- enforcement of both coastal and offshore infrastructure, and make access more challenging. With equipment needing additional reinforcement to survive the conditions, this will bring additional cost and development.

e. Ocean acidity and salinity

The ocean is becoming more acidic, due to seawater absorption of carbon dioxide [14]. This is having a substantial negative impact on calcifying organisms, and therefore is a substantial risk to the shellfish industry. Ocean salinity is also becoming more polarised, with regions becoming more extreme in high and low salinity levels. This is affecting the water cycle, affecting currents and surface temperatures.

Increased acidity and salinity are problematic for any equipment at sea as it increases the rate of corrosion, makes plastics more brittle and bleaches pigments in paints more quickly. These effects will necessitate additional maintenance of GLA assets, and shorten the lifespan of assets at sea.

f. Pollution and biodiversity

Human operations and resultant pollution are having a devastating impact on marine life and water quality. Reducing stocks of key species is increasing competition in fishing waters, causing shifts to fishing practices such as the use of super-trawlers.

However, this pollution and an increase in water temperature is also increasing the prevalence of some species, including problematic invasive species [15]. These will potentially increase biofouling and its damage to assets at sea and to coastlines. Additionally, as algae blooms become more frequent [16], this will limit some human activities at sea due to health concerns, and the fishing industry will wish to predict and avoid such blooms as they render their catch unusable. The GLA may need to incorporate modelling and marking services as part of this.

4.5 Providing thought leadership

The GLA will continue to participate actively in the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) [17] at Council level and in the committees tasked with the creation and promotion of recommendations and guidelines applied by all AtoN authorities and service providers.

The GLA provide AtoN services to all mariners, ranging from navigators of the largest and fastest cargo and passenger vessels through the complete spectrum of craft and mariners to the most infrequent leisure and fishing user. We and our users operate in a complex multi-stakeholder environment comprising of user groups, government departments and other government agencies, international organisations, standards bodies, regulators, ship owners' charities and commercial customers. The GLA will seek to influence these maritime actors by sharing experience and expertise as required and requested to ensure the safety of the mariner.

The GLA welcome user input and are committed to consultation with these users when setting policy or determining AtoN requirements. The GLA consult with this diverse range of users through representative bodies of both professional mariners and leisure users. Each GLA has its own consultative group which is consulted on an ad hoc basis throughout the year as matters arise and meets formally at least annually. An over-arching Joint Users Consultative Group (JUCG) also meets annually as a combined GLA meeting.

4.6 Emerging technology benefits

Technology continues to advance at an astonishing speed, and this rate of technological development is expected to continue to 2040 and beyond. From improving performance, to enhancing the user experience, or to solving old problems with completely new techniques, a wide variety of benefits could be realised in the maritime sector. Key examples include:

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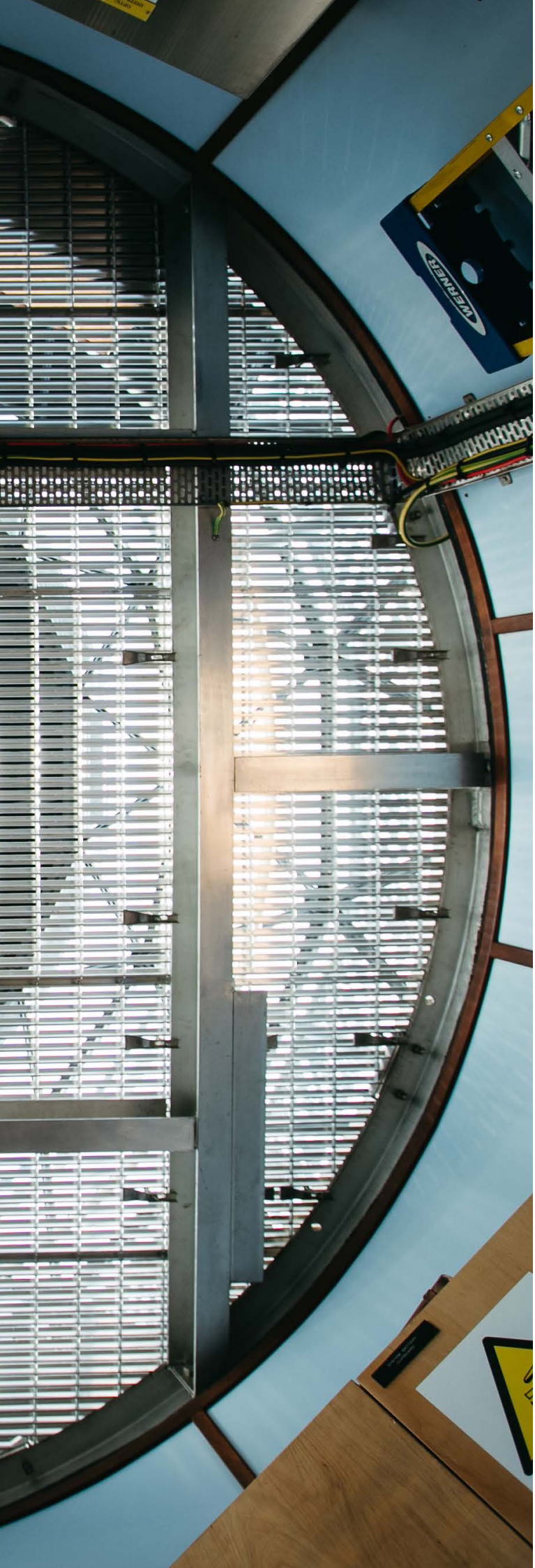


> Solutions to issues of navigational risk, congestion, and supply chain integration are likely to be addressed through increased communications to shore and between vessels, digital vessel routing and increased monitoring

a. Artificial Intelligence, big data, and cloud computing

The providers of AtoN services and wider SOLAS responsibilities will need to acknowledge the shift in maritime technology and digitalisation. Solutions to issues of navigational risk, congestion, and supply chain integration are likely to be addressed through increased communications to shore and between vessels, digital vessel routing and increased monitoring. In addition, the principles of big data analysis, machine learning and artificial intelligence (AI) will provide underpinning capabilities throughout (Annex B provides a technical overview of Big Data, AI, and Autonomy [18]). The operational role of maritime autonomy, in the forms of maritime autonomous surface ships (MASS), unmanned underwater vehicles (UUVs) and remote operations centres (ROCs), is likely to increase significantly through to 2040. [6].

There may be new vessel routing and traffic management solutions, including dynamic de-confliction and routing, integration of a wide variety of traffic, optimisation for both navigation and carbon efficiency, and close linkages to port operations, relevant marine infrastructure, and global supply chains. This may take the form of e-Navigation solutions and maritime digitalisation, and there is a real possibility that the European-funded Sea Traffic Management (STM) project [19] will see implementation in the life of this strategy, impacting navigation in the Channel and wider European waters.

The approach to risk analysis will also need to evolve, shifting from preparing for everything that can be predicted, towards having methods and tools in place to handle the unexpected, and to anticipate increasing unpredictability. Managing complexity will need to recognise the many factors that are increasing the pressure on shipping and mariners and constraining the sea area available. The task of mariners becomes more complex and their room for manoeuvre ever more constrained as the number of traffic pinch-points increase, notably on the approach to major ports.

b. New sensor systems, lights, markers, and communications

Novel advancements in visual signalling technology are likely to continue, with LED light sources becoming more powerful, smaller, and efficient. Careful use of smarter lighting monitoring and control systems could provide remote configurability.

Virtual AtoNs will continue to grow in use [20], allowing for rapid response to shipwrecks and other hazards. The GLA could have an important role as the trusted provider, using new communications approaches to authenticate Virtual AtoNs as being genuine. Physical markers and buoys may also benefit from emerging technology, including dynamic and responsive coatings that respond to conditions.

Over the next twenty years, new sensor technology will mature and emerge, opening up new capabilities to sense the environment on a local or broader level. Advancements in quantum technologies [21] are particularly relevant, as new optical, electric-field, and gravity sensing systems open up potential new capabilities in seabed mapping or detecting hazards and adverse weather conditions sooner.

New communication technologies are being unleashed [22], with recent plans for greater use of Low Earth Orbit (LEO) satellites [23], and development of green light communication from the seabed to aircraft by the oil and gas industry [24].

c. Improved Size, Weight, and Power (SWaP)

Advancements in manufacturing, electronics, and material science are driving development of smaller, lighter, and more energy efficient technologies. The GLA could benefit from this by the upgrading or replacing less efficient technology, leading to cost savings and lower emissions.

d. Interoperability

With a world that is increasingly connected, interoperability between different systems, users, humans and machines will become more important. The maritime sector will increasingly coordinate with the air, land, and subsea domains, unleashing new possibilities in shared data and capabilities. This interoperability brings benefits but will need to be carefully managed from the point of limiting cyber-risks.

4.7 Emerging technology threats

Alongside the benefits of new technology, a new series of threats and disrupters emerge, and these will need to be considered when planning and maintaining GLA AtoN services. These include:

a. Coping with big data

Modern technology will rely on the continuous collection and transmission of an ever increasing volume of data using high bandwidth efficient communications. Data transfer and exchange will see transformation everywhere in complex coastal sea-spaces.

Dependence on guaranteed communications is likely to increase, both in the context of autonomous vessels, and those with increasing dependence on shore- based management or cloud services concepts. With increasing numbers of users and devices accessing these services, careful management and allocation will be required to avoid congestion and service denial issues.

The need for high-bandwidth connectivity is adding to infrastructure requirements, 5G services (or future Generations) at sea may be a necessary part of this, as may the growth in availability of low earth orbit satellites, and the proliferation of ocean infrastructure may provide new ways to host and power enabling assets.

Ultimately, emerging technologies will universally depend on a resilient, cyber- secure, connected, data infrastructure as well as resilient positioning and timing information [23].

b. Manufacturing, obsolescence, and material availability

The sea-space is a particularly challenging environment for technology, with the unforgiving power and salinity of the water and extreme weather variance providing unique or exaggerated resilience issues compared to land. However, the boom of consumer electronics has shifted

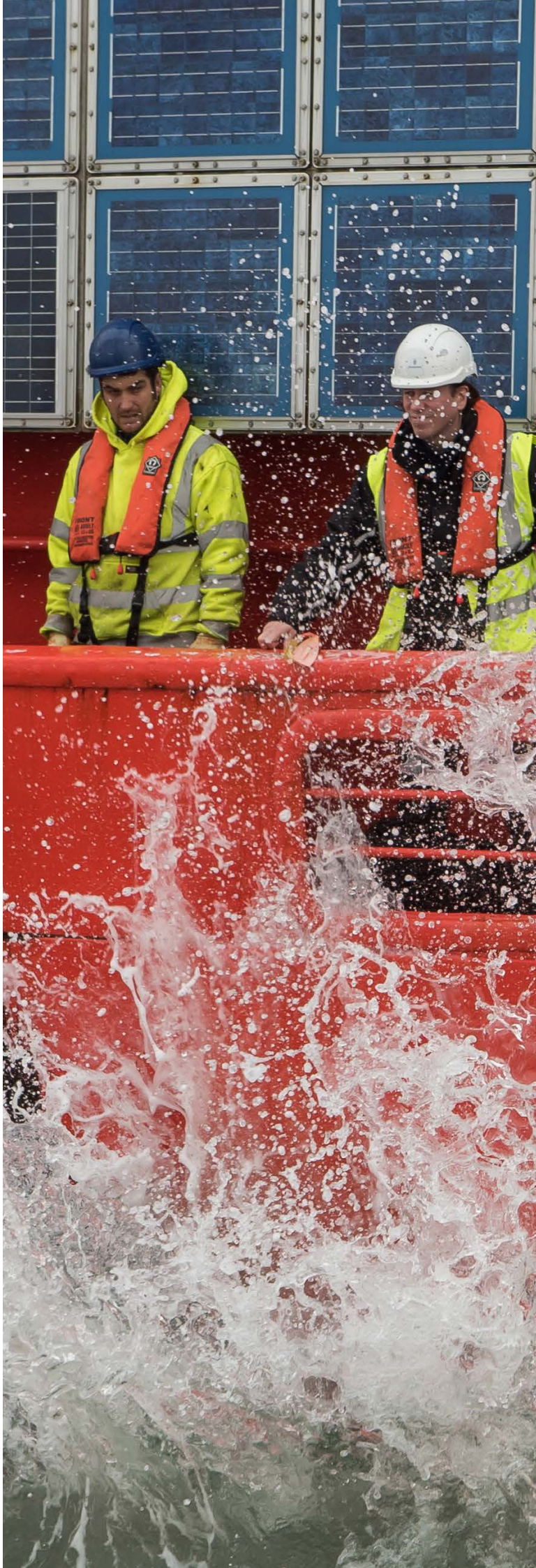
Modern technology will rely on the continuous collection and transmission of an ever increasing volume of data using high bandwidth efficient communications

the technology away from bespoke manufacture in order to benefit from reduced costs from more users. Unfortunately, it is often difficult or impossible to adapt these technologies to be robust enough for the maritime environment.

There is also a need to maintain existing assets, many of which were designed and made many decades ago. This requires careful servicing and management of component parts, as it is likely that replacement would require further bespoke manufacture due to obsolescence issues.

c. More technologically advanced adversaries

With the ongoing development and ubiquity of advanced technology, the instances of deliberate and accidental technology disruption are also increasing. The technology of the GLA will need to be resilient against jamming and spoofing, be resilient against cyber-attack, safeguard critical data, and maintain service throughout data blackouts [25]. Physical AtoN, whilst supporting day to day safety of navigation and providing a platform for these technologies, provide a fall back system for the mariner to utilise.



5 Navigating to 2040

The complex environment of the 2040s will be demanding and challenging, but also rich with opportunities for the GLA to play a key role as they continue to provide appropriate mix of AtoNs for the volume of traffic and degree of risk to support safe maritime operations around the UK and Ireland.

Core to realising these opportunities will be a forward-looking, data-savvy, approach to future AtoN and services, working in strong co-operation with both technology leaders and policy makers to enable operational change.

In the previous section, the changing landscape of 2040 and beyond, the impacts of this changing landscape on GLA operations were outlined. Here we give an overview of the potential opportunities and key areas for focus going forward.

The complex environment of the 2040s will be demanding and challenging, but also rich with opportunities for the GLA to play a key role

5.1 Thought leadership, partnering, and advisory roles

The GLA will continue to provide expert opinion on safety in British and Irish waters in matters of AtoN planning, risk management, technology development, and solution implementation. This includes advising on the opportunities of technology ubiquity, AtoN development, and human factors in a period of generational change in technology, operations, and decision making.

Whilst the overall responsibility for marine spatial planning lies with other bodies, the GLA are statutory consultees in the planning process. In partnership with other organisations, the GLA will ensure that the principles of safe and efficient navigation are recognised and maintained in national and regional marine plans that will be key to managing marine complexity.

Co-operation will be key to realising enduring safety around these islands. There is strategic benefit to the GLA seeking partnership, co-operation, and collaboration, developing their reputation for fresh thinking, developing new AtoN and digital infrastructure, pro-actively utilising existing and newly built ocean infrastructure to host services, all whilst maintaining safety at sea.

The GLA will need to keep abreast of relevant changing legislation and seek to be actively involved in policy development that impacts their operations. Many of the legislative decisions will reach far beyond just the maritime sector, for instance with regards to the increase of human activity and expansion of energy generation at sea, and the GLA will need to provide a strong voice for the mariner to ensure their ongoing safety is factored into wider strategic decisions that impact them.

5.2 Data authority

Today's mariners do more than navigate ships and, as the blue-economy expands, there could be more people who are dependent on AtoN and services for their commercial and leisure activities. If AtoN evolve within a wider digital infrastructure their use will become more central to all manner of at-sea activities requiring resilient data transfer.

The UK Hydrographic offices transition to S100 chart services coupled with the correlating data standards S125 and S201 for AtoN means that the GLA will likely be recognised as a data authority, and need to understand and prepare for a potentially growing role in data management and sharing provision. GLA collected and held data may also be an important part of building a trusted big data picture. Future concepts involving massive connectivity that require data sharing with no one operator having a sufficiently complete picture suggests that an organisation such as the GLA be a key data sharing partner.

Managing complexity may also require data on a far wider scale than is currently collected, needing co-operation within a supply chain constituting diverse data collection, fusion, analysis, and distribution. Data sharing has historically been hard to achieve, and trusted stewardship through co operation may be a necessary enabler.

5.3 Technology spearheading

In order for the GLA to continue to provide effective AtoN and services in this increasingly complex and challenging environment, new technology trends must be well understood, with benefits exploited and risks minimised. There will continue to be a key role in supporting and facilitating the introduction of new technology, and preserving legacy systems and facilities. This will be via smart procurement activities, ensuring acquired technologies are thoroughly tested as fit-for purpose, and also through in-house research and development by GRAD.

In particular, the following example technology development will need GLA involvement to ensure resilience, continuity of key services, and realise opportunities for improvement:

- Developments in optics and associated light technology;
- e-Navigation;
- Maritime digitalisation and digital infrastructure;
- Resilient PNT and new navigation systems, networks, and associated technologies;
- Big data exploitation and management;
- Cyber resilience and data assurance;
- Massive connectivity and new communication mechanisms used at sea;
- Marine autonomy;
- Smart coatings, paints, and physical AtoN material research;
- Machine Vision.

5.4 Climate change considerations

A wide range of climate change factors will impact on all aspects of GLA operation, and this requires forward planning and technology development in response. The current real estate and suite of physical assets will need to be adapted and reinforced to protect against increasingly challenging environmental conditions, opportunities for energy use and waste reduction should be comprehensively exploited, and the relationship of GLA operations with marine life, and the wider environment, respected and understood. The GLA will need to be prepared for the introduction of new stringent environmental legislation, but also understand the opportunities involved in measuring and reporting on climate change and new related hazards to the mariner and other users.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6 ANNEX A: Statutory Framework

Responsibility and authority are given to the GLA through the various Merchant Shipping Acts (MSAs). These Merchant Shipping Acts direct the GLA to undertake the superintendence and management of all lighthouses, buoys and beacons within their respective areas. This superintendence includes the inspection of all AtoN under Local Lighthouse Authority (LLA) management and making general reports as necessary to relevant Ministers. Additionally, the GLA consider and grant consent, where appropriate, to the establishment, alteration or removal of AtoN within their area of jurisdiction. In the superintendence of LLAs the GLA apply the principles of provision and reporting within the Port Marine Safety Code.

The MSA also lay requirements upon the GLA to mark, destroy, remove or raise any vessels which are sunk, stranded or abandoned (wrecks) that in their opinion are an obstruction or pose a danger to navigation and which lie outside areas controlled by harbour or conservancy authorities. In addition to the MSAs, the Harbours Docks and Piers Clauses Act 1847 vests in the GLA the same powers to grant sanction to harbour authority aids but also extends this power to apply to third party aids within the jurisdiction of the harbour authority and to the establishment of temporary or unlit AtoN.

In addition, the Wreck Removal Convention Act 2011 gives the UK Secretary of State (SoS) powers (when the convention is ratified) to instruct a GLA to mark or remove a sunken or stranded ship; or any part of a sunken or stranded ship, including any object that is or has been on board such a ship; or any object that is lost at sea from a ship and that is stranded, sunken or adrift at sea; or a ship that is about, or may reasonably be expected, to sink or to strand, where effective measures to assist the ship or any property in danger are not already being taken. The implementation of these powers is subject to a MoU between the GLA and SoS.

The GLA are consultees in several statutory licensing processes for marine based developments.

The costs of the GLA services are met from the General Lighthouse Fund (GLF), which derives its income mainly from light dues that are charged on commercial shipping calling at United Kingdom and Republic of Ireland ports, and UK fishing vessels over 10m in length. Charges are set by Government to ensure the user meets the costs of the services provided. The Irish Government makes a direct contribution to the GLF under the terms of an agreed formula. The GLF is administered by the UK Secretary of State for Transport who has a duty to ensure the effective management of the GLF. An advisory body, known as the Lights Advisory Committee, drawn from shipping and ports' representatives, is consulted by the Department for Transport on certain financial matters relating to the GLF.

7 ANNEX B: Big Data, Artificial Intelligence and Autonomy

7.1 Introduction

The landscape of maritime is shifting with the rising tides of technology. Advances in shipbuilding, materials, sensors, communication, big data, and autonomy – and many other areas of innovation – in conjunction with an increasingly digitally skilled workforce are having a profound impact on the maritime industry's approach to challenges and opportunities. Part of this change is captured in the breadth of maritime digitalisation, which is underpinned by big data, artificial intelligence (AI), machine learning (ML), and autonomy. This will introduce new requirements on safety (particularly even greater requirements for PNT & Data resilience, continuity, and integrity) as well as new ways of achieving safety through a better managed and connected sea-space. The purpose of this annex is to briefly describe what big data, AI, ML, and autonomy may mean for maritime safety in the context of AtoN infrastructure, maritime digitalisation, and GLA services.

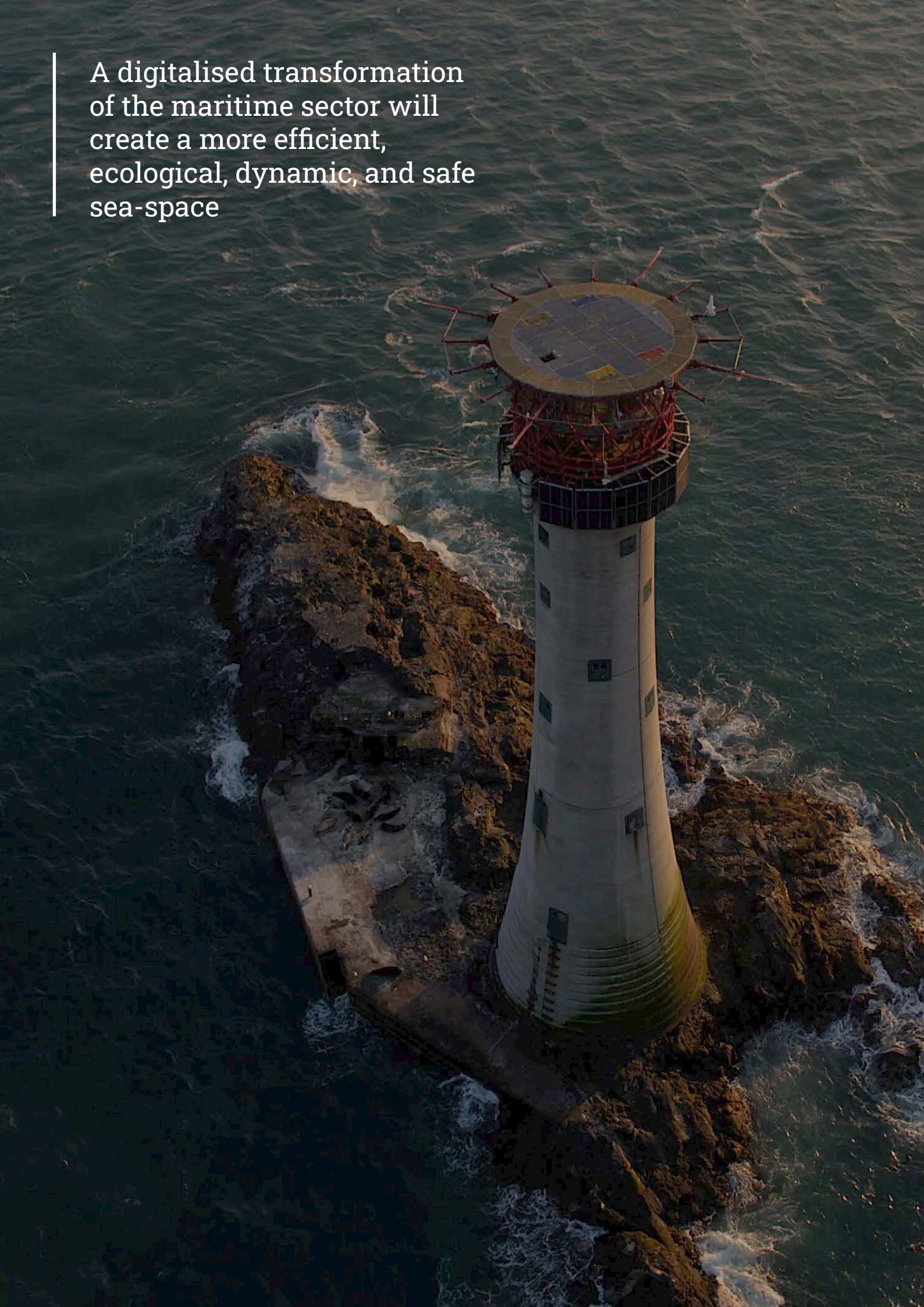
7.2 Supporting Maritime Digitalisation

Technological evolution is being driven by a balance of environmental and commercial necessity, with environmental policies acting as a significant catalyst for sustainable solutions. Digitisation in the maritime industry already assists with complex logistics, asset and supply chain management, this is now evolving to digitalisation of systems and operations.

Digitalisation is the use of digital technologies and processes to change a business, system, or operational model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business. It is shaping the shipping industry's future in every aspect and is seen as a key element of achieving the decarbonisation challenge. Digitalisation is happening ashore and onboard, taking advantage of new designs and technologies to improve efficiency and ensure safe operations. As systems (of systems) and operations are digitalised, operational logic may also change. Decision making will evolve from predominantly human, to digitally assisted, and potentially to predominantly algorithmic – underpinned by massively connected, real-time, data-driven situational awareness. The prevailing example of this is fully autonomous systems, but it will also influence how complexity is managed, whether in the context of supply chains, logistics, or sea traffic.

This will bring benefits, efficiencies, and cost-savings, but will also introduce significant complexity, change, and increased dependence on digital solutions. These solutions will be underpinned by big data, AI, ML, and connectivity, relying on a sophisticated data and sensor infrastructure. This change will be a generational shift in underpinning technologies, and as the sector digitalises there is a risk of heightened operational differences between technological front-runners and all other ocean users. A widening technological gap may introduce new dangers, and there will be a need to help all ocean users keep up with digitalised operations in a cost-effective fashion through thought and solution leadership. A digitalised transformation of the maritime sector will create a more efficient, ecological, dynamic, and safe sea-space, however the path there will require considered support. AtoN, e-Navigation, and digital services developed, implemented, and guided by the GLA will play a crucial role in managing complexity and maintaining safety during change.

A digitalised transformation of the maritime sector will create a more efficient, ecological, dynamic, and safe sea-space



7.3 Big Data, Artificial Intelligence, and Machine Learning

Maritime digitalisation, traffic management, autonomy, and remote operations will fundamentally depend on extensive, resilient, data infrastructure, enabling continuous high-bandwidth communication across sea-space. Central to these concepts is big data decision making, driven partially (or predominantly) by algorithms. This depends on wide ranging and diverse sensing, and the fusion of varied sources and modalities of data – all brought together in real time through the connectivity and capability offered by a coherent digital infrastructure.

This quantity and complexity of data is unlikely to be human interpretable, especially not at scale. ML and AI methods will be necessary to translate it to information and knowledge for decision makers and users alike. This last step towards interpretability and understandability will be key. Big data, no matter how comprehensive or well analysed, must be complemented by 'big judgment'. This extends to data sourcing and sharing, if we are to rely on data-driven analytics or decision making we must be certain that it reflects reality; digitalised systems will require careful testing, verification, validation, and audit. At a practical level, it may also require trusted organisations to facilitate data sharing. It will be challenging for any one organisation or maritime operator to have enough data to be sure they have the whole picture; a trusted organisation, such as the GLA, could play an important role in fusing and sharing data whilst protecting the sensitivities of their partners.

Led by research in academia, start-ups, and data giants, the methods that might support these capabilities are constantly evolving. Sectors that are already digitalised have grown used to data infrastructure and systems that are flexible and upgradable; a similar flexibility will be needed in the maritime sector, able to integrate new data types and sensors into the big data picture, and evolve underlying methods to improve learning and analysis. This will enable advanced, automated, marine situational awareness, including trends and changes in traffic patterns; navigational risk assessment; environmental and climate analysis; real-time applications for route optimisation; and deconfliction ahead of potential collision situations. Initial capabilities may focus on supporting navigation and traffic management, but the fullness of this capability bears much wider relevance to safety, security, and commercial activities.

Reliance on massive connectivity, big data, and cloud services will exacerbate issues of maritime cybersecurity and resilient PNT & Data. Continuity and integrity are already forefront issues, and remote operations and autonomy will heighten these needs greatly. In a brave new world, the long-standing fundamentals of safety and resilience will be more relevant than ever.

7.4 Autonomy

Autonomy and automation will play a key role in the future maritime sector in the form of Marine Autonomous Surface Ships (MASS), Autonomous Underwater Vehicles (AUVs), Remote Operation Centres (ROC), and more bespoke Marine Autonomous Systems (MAS). Soon there will be material advancement of supply of MAS to a variety of markets in the EU, and the MAS market is expected to expand rapidly. MAS will be scaled up and applied in British and Irish waters for oceanography, offshore oil/ gas, offshore renewable energy, deep-sea mining, underwater asset management, security and environmental compliance use cases. It is anticipated that both fleets of MAS and MASS will be successfully operating in British and Irish waters by the middle of the decade. Larger vessels may be 'lightly crewed' to conform with emergent maritime regulation, but there is a likelihood that implementation and deployment will largely outpace regulation; those who dare to implement will drive the pace of change invoking Darwinian principles on those who do not keep up.

This advancement in MAS/S operation will be accelerated by the demand of large scale offshore renewable programmes, as the UK and Ireland aim for their governmental 'Net Zero' Carbon strategies to 2050. Additionally, Brexit is driving large scale Research and Development in Maritime Autonomous Systems, as the UK Government sees a valuable export market.

MAS can only work within a complex digital infrastructure that is analogous to organisational and physical infrastructure. To operate effectively and safely, autonomous vessels will require large amounts of environmental, performance, and location data. At the same time, shore control centres will require a data and situational awareness picture to allow human operators and digital systems to make decisions on the day-to-day operations of remote and autonomous vessels.

All forms of MAS and ROC will rely on aspects of maritime digitalisation and cloud services, being enabled by a big data picture. Reliability, accuracy and integrity in PNT & Data will be core to all MAS developers and end users.

AI learning and system use will likely require reliable two-way communications and data transfer, depending on a potential big data infrastructure. Historic data for system development and training will also be important with GLA derived data playing a prominent role in the development of autonomous systems.

AtoN will continue to be central to safe navigation and increasingly the operation of MAS/S and ROC. These autonomous systems are currently being designed to leverage the existing mixture of physical and virtual AtoN. AtoN upgrades should recognise the need to improve visibility to digital systems (e.g. by way of QR codes that can be seen from cameras on MASS). Development of digital AtoNs and 'data lighthouses' will need to occur alongside the maintenance of current AtoN infrastructure capability. The challenge will be to avoid a two-track approach of potentially competing physical and digital infrastructure. Ubiquity is the target without confusing users while avoiding the risk of failing to support the safety of navigation for all.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8 ANNEX C: Glossary

AI	Artificial intelligence
AtoN	Aid(s) to Navigation
AIS	Automatic Identification System
Big Data	High-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation.
Carbon Neutrality	A state of net-zero carbon dioxide emissions achieved by balancing emissions of carbon dioxide with its removal or by eliminating emissions (the transition to the "post-carbon economy").
Climate Change	Includes global warming and its impacts on Earth's weather patterns.
Digital Twin	A digital model of the 'real world' fed by real-time data, allowing AI and predictive modelling software systems to predict future performance to enable more effective management/efficiency.
Digitisation	The process of converting information into a digital (i.e. computer readable) format.
Digitalisation	Involves moving a whole business to function digitally with the intention of improving efficiency by using digital programmes.
eLoran	enhanced Long Range Navigation System
e-Navigation	The harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment.
EU	European Union
GLA	General Lighthouse Authorities
GLF	General Lighthouse Fund
GNSS	Global Navigation Satellite Systems such as GPS, GLONASS, Galileo & BeiDou
GPS	Global Positioning System is a US satellite navigation system
GRAD	GLA Research and Development department
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IL	Irish Lights
IMO	International Maritime Organization
JUCG	Joint Users Consultative Group
LLA	Local Lighthouse Authority
Mariner	One who navigates or assists in navigating a ship.
MAS	Maritime Autonomous Systems comprise Un-crewed Surface Vehicles (USVs) under <25m length and Un-crewed Underwater Vehicles (UUVs)
MASS	Marine Autonomous Surface Ships, usually vessels >25m length.
ML	Machine Learning
MoU	Memorandum of Understanding
MSA	Merchant Shipping Act
NLB	Northern Lighthouse Board
Paradigm	A distinct set of concepts or thought patterns, including theories, research methods, postulates, and standards for what constitute legitimate contributions to a field
PNT	Positioning, Navigation and Timing
ROC	Remote Operations Centre(s)
STM	Sea traffic management (validated by MonaLisa, ACCSEAS, EfficienSea2, and SESAME Strait projects)
SOLAS	Safety of Life at Sea Convention
SoS	Secretary of State
TH	The Corporation of Trinity House
UK	United Kingdom

The operating environment and navigation context in 2040 is likely to be very different to today, nonetheless the UK and Ireland's prosperity and security will continue to depend, to a significant degree, upon trade by sea

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