

# Intelligent monitoring and maintenance of Aids to Navigation

Improving port resilience and cost efficiency of marine assets



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### Smarter UK Ports - Project Introduction

Smarter UK Ports is a series of five use cases for the use of technology in Smarter and Greener ports in the UK, developed and published by the Connected Places Catapult, in association with Royal HaskoningDHV UK.

The use cases are based on real-life challenges within many ports across the UK, co-created with five port authorities to give local context and relevance on how innovative technologies can be implemented to improve their business function, resilience, environmental impact and operational performance.

The five topics were selected together with the partner ports to give context and achievable, nearer-term initiatives that support the delivery of key Maritime 2050 themes. As challenges that exist at ports throughout the UK, these use cases present opportunities for collaboration and knowledge exchange to deploy and scale these potential solutions to realise wider sector impacts.

Meant as a snapshot of relevant challenges to port operators, these studies aim to inspire further discussion and collaboration, with clear next steps to make use of technology that deliver Smarter and Greener Ports.

All of the Smart Port Use Cases in this series engage a range of existing or evolving technologies to bring improved digitalisation and business change in the multi-stakeholder environment that UK ports operate within.

We would like to thank our partner port authorities for their contributions and discussions and hope you find the series both enjoyable and informative. We would also welcome you to reach out directly to us with your own challenges and initiatives on our journey to Smarter and Greener UK Ports.

**Henry Tse, Director of New Mobility Technologies, Connected Places Catapult**

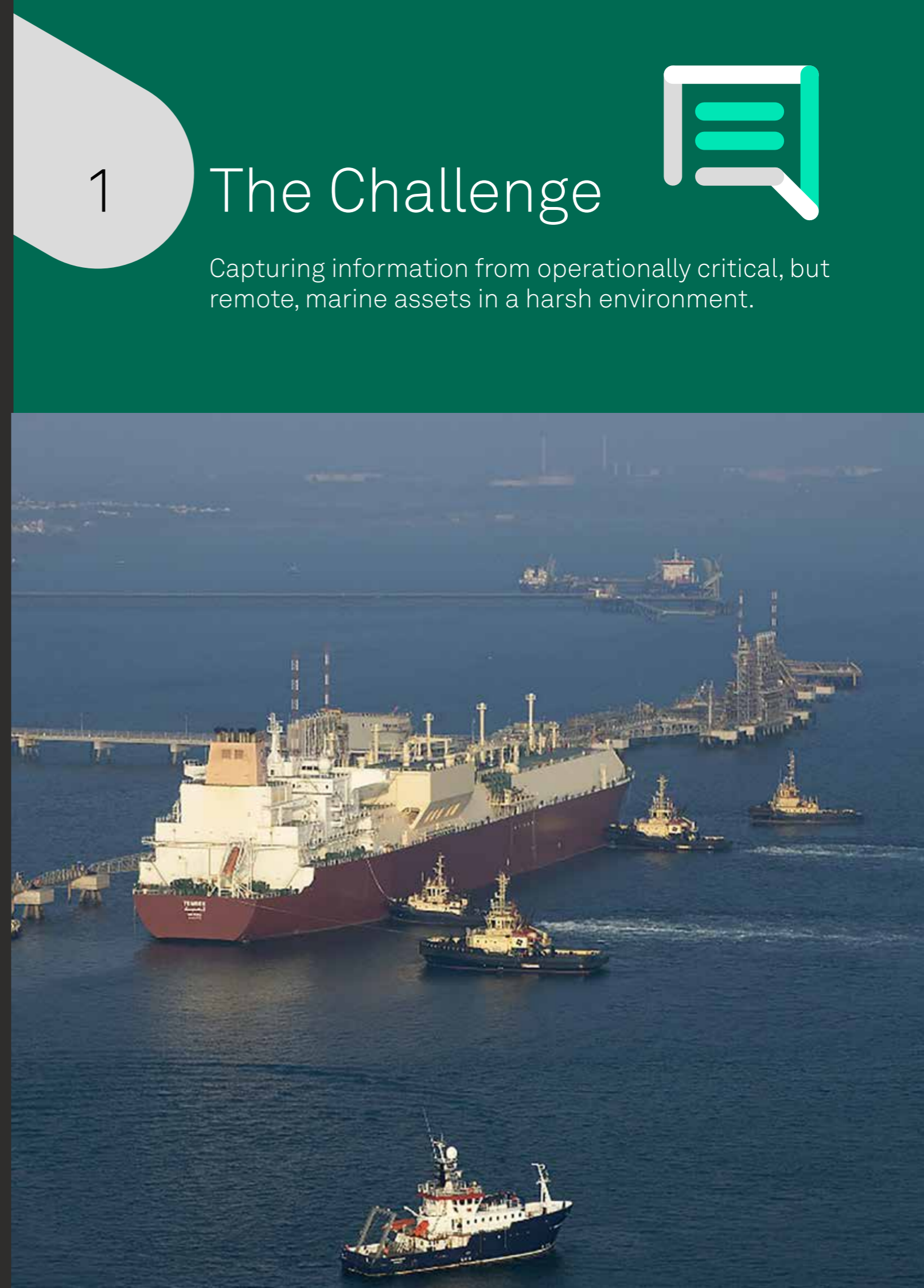
Topic	Supporting Port	Maritime 2050 Links
Connected Supply Chain – Virtual Pre-Gate for Ferry Operations	Portsmouth International Port	Trade Technology Environment
Automated Asset Inspection & Shared Port Insight	Shoreham Port	Infrastructure People
Green Energy – Shore Power for wind-farm Service Operation Vessels	Port of Tyne Authority	Environment Trade Infrastructure
Climate Resilient river operations in London by predictive level digital twin	Port of London Authority	Environment Trade Security & Resilience
Operational Resilience – Monitoring of marine assets in remote locations	Milford Haven Port Authority	Infrastructure Security & Resilience

# 1

## The Challenge



Capturing information from operationally critical, but remote, marine assets in a harsh environment.



Like most UK ports, the Port of Milford Haven has a regulatory duty to maintain and protect their harbour. Among other efforts, it does this by providing aids to navigation (AtoN), pilotage and towage services it considers are needed to secure the safety of ships navigating through the Haven.

These aids to navigation are often in remote and exposed sea locations, bringing inspection, monitoring and maintenance difficulties to the port authority.

There are two principal types of physical aid to navigation:

- **Beacons** are usually piled structures fixed rigidly to either the land or seabed. Where navigation has more risk, beacons are often fitted with tide, wind and wave monitoring equipment. This is the case for the Mid Channel Rock beacon located near the mouth of Milford Haven, which provides crucial data for pilotage decision-making.
- **Buoys** are floating markers anchored to one or more “sinkers” - usually concrete blocks - on the seabed via chains forming ‘catenaries’ - curves under their own weight. The chains allow buoys to absorb considerable energy from swell and wave direction, but means they drift about. The maximum horizontal distance between a buoy and its sinker is called the ‘swinging radius’.

Intrinsically, attempts to monitor condition are hampered by the location-dependent risks of physical inspection; often only feasible with divers and rope access teams, within limited windows of suitable tide and weather conditions. Notwithstanding, the following factors make it difficult to predict failures or outages:

- Limited surveys mean limited information, particularly regarding deterioration and any initiating incidents that significantly shorten the AtoN ‘working life’, when early replacement or refurbishment may become needed.
- The unpredictable weather, and the high likelihood that equipment will be damaged by wave attack; also worsening with climate change enhancing extreme weather events.
- The buoy-restraining chains being most vulnerable to failure at the underside of the buoy and seabed, where they are subject to the most wear and hardest to inspect without lifting the buoy or sifting through silt.
- The likelihood that links are failing due to an impulse load - a sudden, violent jerk - from a large wave or vessel collision when the chain is taught; rather than, or in combination with, progressive wear.
- The quantum of factors that affect AtoN performance - geography, wind direction and speed, tide direction and height, swell, nearby vessel manoeuvres, general hydrodynamic performance (i.e. heaving and pitching of the buoy, or vibration of the beacon) and the resultant wear/fatigue - and the challenge of identifying patterns that could be predicted.

As a result, the first notice of a missing buoy is usually when a regular vessel caller or a pilot makes the Port aware. In bad weather, loss of a buoy or two is possible; but this can take months to rectify due to weather restrictions and, given there are so many types of buoy, a lack of spares.

Similarly, common problems that are difficult to rectify are equipment outages on buoys and minor beacons. Such outages may be easy to identify from loss of equipment communication, except in the case of solar-powered lamps being obscured or otherwise impaired; but the cause of the equipment outage varies from weather-related damage to battery loss. The latter case is a greater concern, making the buoy structure difficult to find. Equipment outages on larger beacons like Mid Channel Rock are less common but more troublesome due to the impact of data loss on vessel movement decision-making in bad weather.

“The port manages well to monitor the wide variety of buoys and beacons to ensure a reliable service to visiting vessels, however, the complexity, cost and specialist equipment required to inspect and repair AtoN is a considerable challenge for safety and resilience at the port. Any ability to understand undersea wear and prediction of possible failures would allow us to plan and budget more effectively”

Tim Bownes, Executive Director, Port of Milford Haven

## FactBox

- Port of Milford Haven monitors 34 buoys and 8 beacons or lights as well as 5 shore stations along approximately 25 miles of waterway.
- Each year, the Port handles 32-35 million tonnes of cargo and 2,000 vessel calls, in their critical role in supplying energy to the UK.

# 2

## The Solution



Integrated data sources from reliable mobile sensing, interpreted by historical learning, for guided decision-making by port operators.



To aid decision-making and planning for AtoN equipment in remote or at-sea locations, an end-to-end 'intelligent' solution may be created as follows;

Buoys can be fitted with GPS equipment for 'geo-fencing', to identify when they are drifting or have broken away. Monitoring wear on the chain links, either directly or indirectly, should also take place. Direct monitoring of wear-induced metallurgical or acoustic changes may be possible; otherwise indirectly identifying shackles most prone to wear may be possible by monitoring heave, pitch and spin with gyroscopes. The chain could also be monitored for excessive slack or tautness via catenary monitoring equipment - with sensors placed at intervals along the chain. By cross-referencing all this data, a local baseline of the buoys' performance can be formed so that changes can be identified.

Beacons can have accelerometers, strain and thickness gauges for monitoring structural movements, stresses and deterioration. Note that gauges would ideally be placed on the inside of the structure where they are protected from wave attack, but such retrofit works are difficult so this may only be carried out during installation or major refurbishment.

For the harbour area, wind and wave monitoring equipment at key locations along the waterway can be correlated with information from the AtoNs to capture local effects and storm behaviours..

These at-sea and onshore data sources, gathered from remote sensors and transmitted over cellular or radio signals, powered by solar energy, can all be combined into an integrated data model, growing historical data patterns to learn from. Once baselines are established, properly benchmarked target dashboards can highlight those beacons or buoys subject to most wear and alert the user in real-time to any behaving unusually or requiring attention.

This will help the port operator to monitor the aids to navigation remotely, safely and in a timely manner, to support VTS obligations for providing safe navigation.

For asset management teams, the toolkit would predict and be more immediately aware of failures and improve overall safety by responding quicker with appropriate spares stock. When replacing and repairing buoys, this would support design of optimised chain lengths to limit the number of failures, by balancing an appropriate swinging radius against the risk of impulse failure and further limit the number of failures by considering the working conditions when designing and placing new AtoNs.

For forward investment planning, the historical data models would support a clearer view of the residual working life of the beacons without relying solely on visual inspections and allow for associated cost and repair decisions.



This challenge is UK-wide and so, to preserve portability and interoperability, the data platform could be hosted by a suitable independent agency, perhaps the Local Lighthouse Authority (LLA), or the General Lighthouse Authority (GLA). The latter is preferable as each of the 3 GLAs covering the UK and Republic of Ireland is ultimately responsible for all AtoNs, so this would bring advantages in terms of development cost, standardisation, sharing best practice and monitoring AtoNs which are not within ports.

Data would link via API to the port dashboards and data models, on an open-source model, so independent software vendors can tailor solutions to LLA-specific requirements and allow a flexible and integral approach to link with inventory and maintenance systems. This would enable the pricing and innovation advantages associated with a competitive market.

## 3

## How it Could Work

The remote monitoring of maritime aids to navigation combines IoT, networking, machine learning and visualisation for a resilience view on asset resilience.



```

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150 }
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196     </div>
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198 }
199
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206       </div>
207     </footer>
208   );
209 }
210 }
  
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# How it Works

The remote monitoring of maritime aids to navigation combines IoT, networking, machine learning and visualisation for a resilience view on asset resilience.

GLA data backend (off site)

ML Anomaly Detection via API

LLA (Port) Dashboard

Port Office

Milford Haven

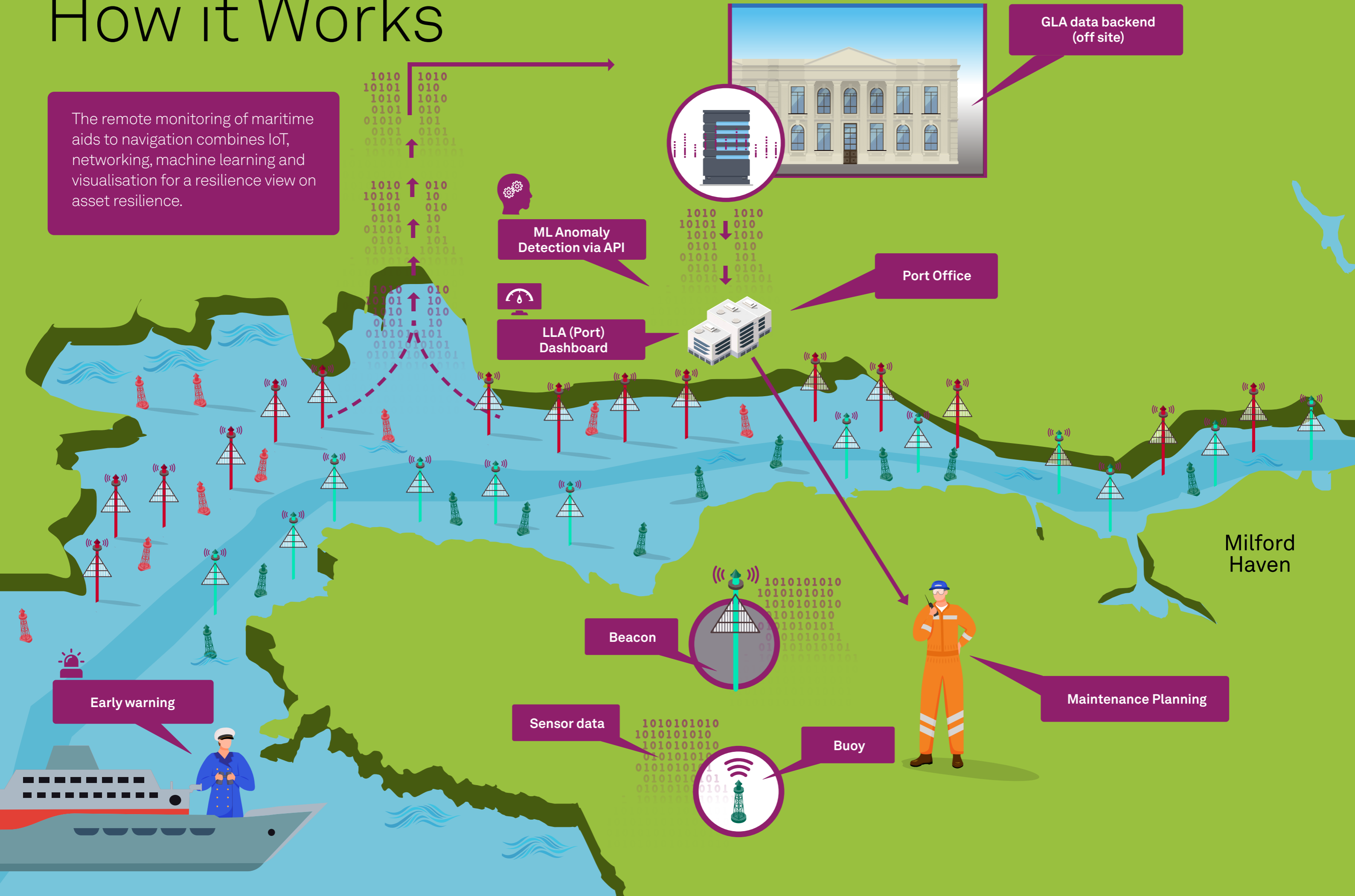
Beacon

Buoy

Sensor data

Early warning

Maintenance Planning



# 4

## Wider Impacts



Resilience of these vital port assets is crucial to UK supply chains and industry.



As a common problem across ports in the UK, and worldwide, several key positive benefits are delivered by this solution, including improved safety of mariners navigating UK coastal waters due to the improved reliability of beacons and buoys. Ports and lighthouse authorities can capture significant cost savings as failures can be prevented by optimising factors like chain length retrospectively and during design of new equipment, and the predictability tools would empower authorities to carry out preventative maintenance during suitable weather conditions when resources are available.

Where sufficient data is gathered, and there is visibility of local conditions along a port's waterway, there is potential to control risk dynamically enough to carry out more vessel movements during bad weather. Over time, dashboards may support such decisions by providing intuitive statistical data, such as how the wave conditions in one area are indicative of those in another.

This is particularly useful when monitoring equipment that is damaged or lost. There are occasions at the Port of Milford Haven where loss of tide and weather data from the Mid-Channel Rock beacon can limit vessel movements; this is where some of the worst conditions take place and the loss of equipment is usually associated with poor weather. However, if conditions at Mid-Channel Rock may be accurately inferred from conditions elsewhere, then vessel movement windows may not be restricted.

This would be a valuable benefit for key Port stakeholders like Irish Ferries, operating the Pembroke - Rosslare route, South Hook LNG and Valero Energy Company, operating the Pembroke Oil Refinery - one of the largest, most complex refineries in Western Europe; which receives all of its feedstock by sea.

The gathered data could also usefully feed back into the selection, placement and design of aids to navigation; and where it is shared with the General Lighthouse Authorities, ports and other Local Lighthouse Authorities this data can support a quantifiable approach to manage safety and risks.

The choice between fixed and floating aids, and the location in which they're placed, is based on factors like traffic volume and degree of risk. The latter is focussed on providing aids wherever their presence most benefits the vessels, but if conditions in these areas are shown as increasing the risk that beacons or buoys will be damaged or lost respectively, then the preferred type and location of the aids may be adjusted. This may also bring environmental benefits in sensitive area, as chains and anchors tend to cause damage over a wide area where beacons only cause damage within their footprint.

By preserving interoperability with an open platform and storing data with the Local or General Lighthouse Authorities, ports are free to fit different types of sensors from different providers as and when they require in order to balance cost, safety and port efficiencies, as well as to harmonise with other data sources if useful; but the core function of understanding the typical behaviour of buoys and beacons to make day-to-day decisions will be unaffected. Over time this may enable the adoption or even creation of other smart solutions for the maritime industry

**Trinity House works with local ports and harbours to inspect and audit over 11,000 local aids to navigation annually.**

Trinity House, General Lighthouse Authority for England, Wales, the Channel Islands and Gibraltar



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# Implementation Route

A collaborative, open and expert-led approach is vital in this complex environment



There have been attempts to monitor AtoNs with sensors in the past, but such attempts have seldom harmonised with other data streams, dashboards or machine agents. Hence, sensor data has 'manually' been post-processed on an as-needed basis - a laborious effort with little value after an incident. Consequently, such monitoring efforts are often abandoned.

By helping LLAs or GLAs to host and analyse data themselves, it is hoped that this solution would subvert the following problems often associated with data and technology:

- lack of awareness of, or the perceived cost-benefit imbalance associated with solutions like sensors and machine learning;
- the preclusive cost and legacy requirements of developing bespoke systems, leading to reliance on vendors' cloud-based solutions and difficulties integrating these with existing IT architecture;
- the desire to avoid 'vendor lock-in' - i.e. to retain the flexibility to change providers;
- security concerns around cloud data, especially where it is portable and interoperable; and
- the vendors' lack of awareness and the lacking maturity of interoperability standards for maritime assets, perceived or otherwise.

While initiatives to enable interoperability are growing, a national effort is still required to develop working solutions, as recognised in the Maritime 2050 Strategy. AtoNs, being within the purview of the UK and Republic of Ireland's General Lighthouse Authorities, are therefore well-suited to such efforts, and which also have international relevance for the IMO.

Some ports may initially be reluctant to share data with the General Lighthouse Authority, for this critical and sensitive area of port asset resilience and, notwithstanding the difficulties associated with vendor-hosted data, may prefer to retain their own data back-end. While this is still a positive step and, at this time, even encouraged; there may be long-term gains for both the ports and the wider industry from hosting data centrally. The storing of data with General Lighthouse Authorities should therefore be seen as an integral part of their service to industry.

**“[The] UK will lead efforts to set international standards at the IMO and ensure interoperability of systems. Agile UK regulation will allow transparency, competition, and improved efficiency while enabling secure and easy-to-use systems”** Department for Transport - Maritime 2050

## Next steps

- Form a collaboration of technology providers, AtoN design consultants and port operators / GLAs
- Establish objectives and supporting data structures and integration exchanges
- Create a pilot project to test the technology combination in a UK port with challenging weather conditions
- Deploy machine learning models to create baseline and predictive behaviour models for buoys and beacons
- Establish a data standard for UK-wide adoption, allowing ports and technology vendors to experiment within a framework



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