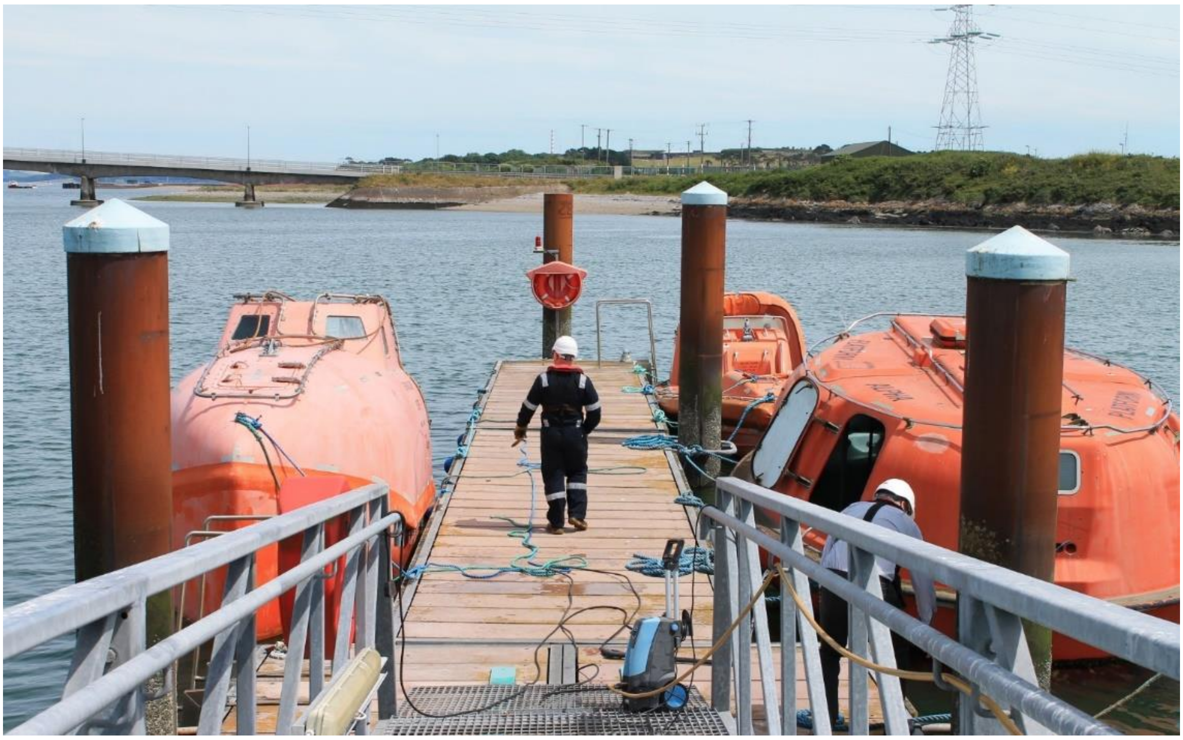
Internet of Things (IOT) solution for the National Maritime College of Ireland (NMCI)



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1. Introduction

1.1 AT-VIRTUAL Project Overview

The European Regional Development Fund backed AT-VIRTUAL project's overarching and long-term ambition is to improve operability and performance of Maritime Safety Training Centres (MSTC's) in the Atlantic Area (AA), thereby increasing maritime emergency incident preparedness and response capacity in Atlantic waters.

The project team set their sights on this objective after observing that MSTC's have adopted digitalization to a lesser extent than other industrial sectors hence potentially stand to make operational and efficiency gains in the way other industries have enjoyed benefits after embracing Industry 4.0 technologies (vision technology, Big Data/Data Analytics, Internet of Things and simulation-based training system technology). However, Industry 4.0 technology solutions generally scale to a size most effectively implemented by agile SME providers able to process commissions with no delay and rapidly turn around small projects. The team therefore teamed up with regional Business Incubation Centres (BICs) that could match MSTC's with technologically aligned SMEs suited to fast-tracking development of bespoke digital solutions.

The concept of combining digital advances with agile businesses capable of rapidly delivering technological solutions promises to not only to improve MSTC operational effectiveness and increase competitiveness in the training marketplace, but also to foster innovation and sustainable growth in businesses that partner them. Furthermore, knowledge and solutions developed under AT-VIRTUAL can be extrapolated by MSTCs in other regions, amplifying the exploitation and capitalization of AT-VIRTUAL's results. The project's legacy includes potential for collaborations between MSTCs and opportunities for start-up companies to branch out into new fields related to maritime safety training.

1.2 Project Methodology

To assess this concept the three MSTCs participating in the AT-VIRTUAL consortium, the National Maritime College of Ireland (NMCI), Sociedad de Salvamento y Seguridad Marítima (SASEMAR), and Escola Superior Náutica Infante D.Henrique (ENIDH), after surveying their own operations and those of end users closely affiliated with their organisations (for example parent nautical schools) identified three activities that could be improved by embracing Industry 4.0 solutions. Each MSTC fully defined one Vision technology themed project, one project involving Big Data/Data Analytic techniques and one IoT technology project.

Open calls for proposals were issued and successful contractors selected according to a three-stage framework developed by the AT-VIRTUAL consortium which included regional BICs as partners to bring entrepreneurial support and commercial know-how to the project and provide access to a ready audience of suitable entrepreneurs through their mentoring networks.

The AT-VIRTUAL philosophy encourages start-up companies with no prior experience in the maritime safety domain to undertake work for MSTCs and supports portfolio expansion efforts with relevant business and project management workshops. The term 'hybridization methodology' was coined to describe this approach – essentially bundling project development tools featuring agile methodologies with communications tools for facilitating interaction between members of start-up project development teams and MSTC project management personnel. This information is archived on the AT-VIRTUAL website (AT-VIRTUAL Project).

The first element of the AT-VIRTUAL framework took the form of an information dissemination event in which companies interested in tendering for projects were familiarized with MSTC challenges and introduced to the AT-VIRTUAL 'hybridization' philosophy.

Submissions received from start-ups were subsequently collected and assessed by representatives of MSTCs along with an external reviewer, being evaluated according to a set of corporate eligibility and proposal quality criteria comprising:

- Coherency
- Background experience of company relevant to the challenge
- Degree of innovation according to the state of art of technology involved
- Risks
- Company resource requirements
- Budget feasibility
- Added value

The score from this round of judging was added to the results of a selection event which formed the second element of the AT-VIRTUAL framework. Start-up companies were invited to pitch their capabilities in the context of the call they addressed in three minute 'fast-track' presentations, then to meet face-to-face with representatives of relevant MSTCs to discuss proposals in detail. Fast-track presentations were assessed according to

- Substance and delivery (clarity of the information presented, ability to grab and hold attention, eloquence).
- Creativity.
- Timing.

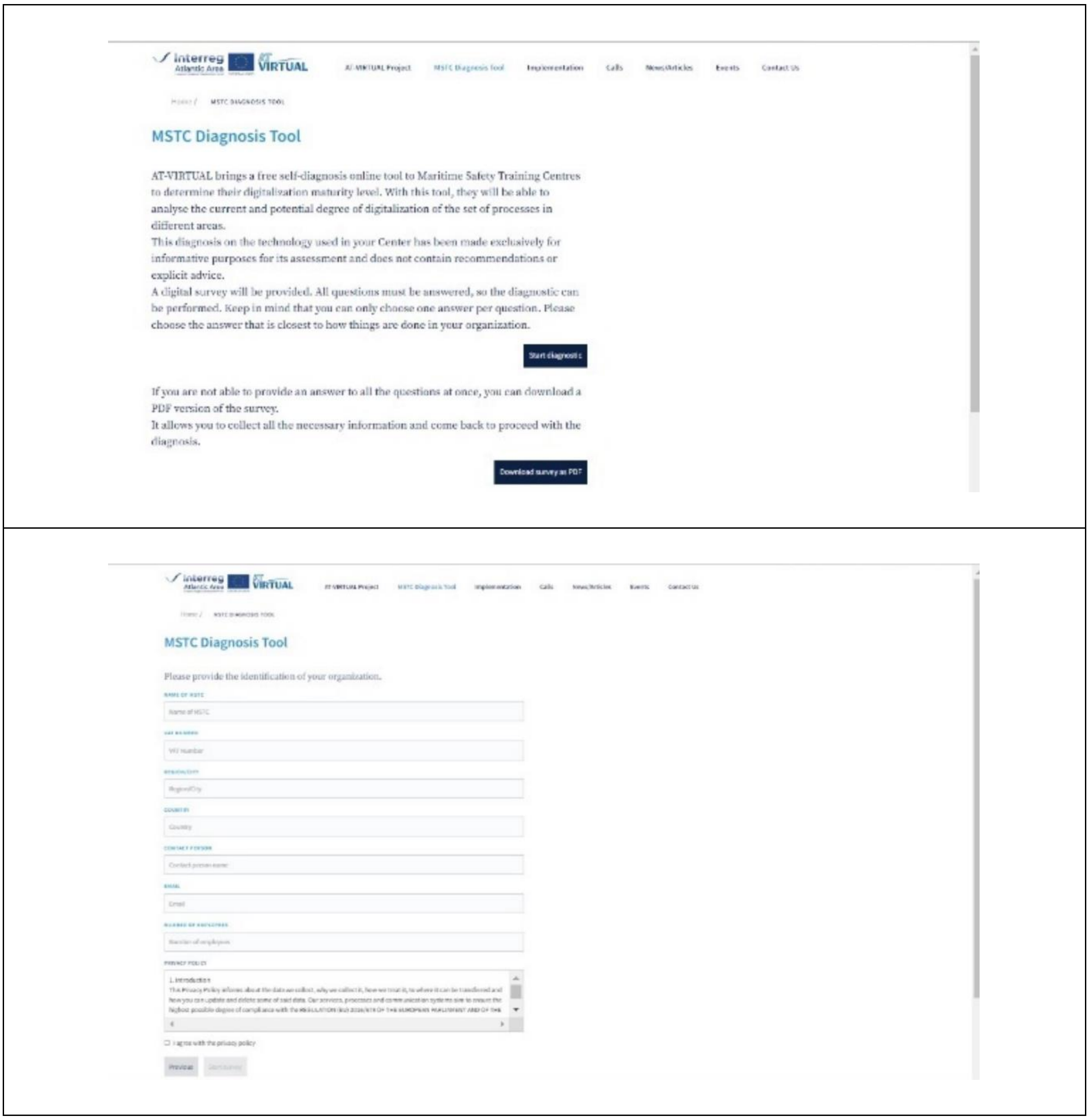
Assessing these criteria helped MSTCs determine whether companies possessed desirable qualities as project development partners.

Information day and selection events were held for each of the three Industry 4.0 themes (Vision Technologies, Big Data/Data Analytics and IoT Technology).

The project implementation phase, in which prototype solutions were developed in a six-month time frame, completed the AT-VIRTUAL framework. In total nine solutions (AT-VIRTUAL Project) were successfully delivered during the lifetime of AT-VIRTUAL.

1.3 MSTC Diagnosis Tool

The AT-VIRTUAL methodology presumes that MSTC managers are able to identify shortfalls in the adoption of digitalization by their organizations, compared to best practice in other industries. The project team therefore developed an on-line tool to aid managers analyze their organizations in the context of the current utilization of Industry 4.0 technology (AT-VIRTUAL Project).



The AT-VIRTUAL on-line MSTC digitalization level diagnostic tool

1.4 NMCI Overview

Munster Technological University is a leading Irish third level educational institute. The University has four main campuses, one of which is the National Maritime College of Ireland, an internationally recognized seafaring training and education college. NMCI was purpose-built on a ten-acre waterside campus in Ringaskiddy near Cork city in the south of Ireland. The campus was developed and is managed in collaboration with the Irish Naval Service (INS). It provides training and education for the Merchant Shipping Industry, and meets the non-military training needs of the INS. The NMCI provides education and training services of the highest quality and includes degree programs in Nautical Science, Marine Engineering, Marine Electrotechnology, and Supply Chain & Logistics.

Specialist spaces including survival facilities, seamanship workshop, firefighting/damage control, jetty and lifeboat facilities and ship engine room are provided. NMCI also provides modern simulation equipment in the areas of navigation, bridge training, communications, engineering machinery operations, liquid cargo handling/damage control and vessel traffic systems. These facilities fully comply with the most up to date international standards and requirements.

The Halpin Centre for Maritime Research and Innovation is the research arm of NMCI and is part of the Faculty of Science and Engineering at MTU. The Halpin Centre based at NMCI is a well-established research entity with a brand and reputation for demonstrating innovation, dedication, entrepreneurship, and vision. We have a strong track record in delivering European research projects with a multi-disciplinary team at our disposal. This team consists of a wide range of knowledge, skills, and expertise, which include Maritime Defence and Security, transport, Learning Development, Technology, and Blue Growth. As one of the key pillars of the NMCI, we are deeply engrained within the maritime research and higher education sector.

2. NMCI Internet of Things Technology Challenge

2.1 Problem Context

A key part of NMCI infrastructure is the pontoon and lifeboat deployment jetty located on the northern side of the campus. Free-fall lifeboats and davit-launched survival craft are deployed along with other types of small boat (e.g., fast rescue craft) from these structures. Vessels participating in survival craft/small boat training range as far as 3.2km into Cork harbor.

Panorama of Cork harbor viewing the gangway and looking towards the lifeboat deployment jetty and pontoon.

NMCI's small boat/survival craft training programs are constrained by environmental limitations (wind speed, wave height, swell, visibility, tidal flow, and tide height) which must be set low enough to avoid personnel or equipment being damaged or prevent negative learning outcomes.

Safe conditions in which to conduct exercises exist when prevailing wave amplitude, wind speed, swell and tidal stream combine to produce surface conditions less than Beaufort Sea State 2. When surface conditions are at or above Beaufort Sea State 3, training does not take place. When harbor conditions are (or forecast to be) between Sea State 2 and 3, instructors employ various mitigation strategies and take appropriate precautions to prevent risks escalating, according to the nature of the training exercise, the lesson, and candidates' experience levels.

In the absence of real-time environmental data upon which to base operational decisions, NMCI instructors (highly trained mariners with significant sea-going and small boat training experience) are forced to rely on local knowledge, tide tables and meteorology Apps with which they dynamically assess risks posed by hazards such as bridge arches or reaches of shallow water that amplify tidal flow, or rocky outcrops exposed by fast-falling tides when water volumes in the harbor are low.

2.2 Description of Needs

The NMCI IoT challenge was to:

1. Design and develop a prototype wireless 'Smart' buoy that would be docked at the jetty or anchored nearby for measurement of sea state.
2. Design and implement a data visualization and monitoring system.

2.3 Project Requirements

The solution for a wireless enabled 'Smart' buoy harbor training operational decision assistance system was required to satisfy the following criteria:

1. To include the suitable sensors for measuring wind speed, wind direction, wave characteristics (amplitude and period), water speed and water depth.
2. To include a self-sufficient power system and wireless connectivity (i.e., LoRa or 3G/4G).
3. To incorporate a flag, pendant, or windsock in order for instructors to estimate wind direction at buoy locations at a glance.
4. To incorporate a remotely controlled ultra-bright white LED, to serve as a warning beacon.

Moreover, data communication, processing and storage requirements were also specified:

1. Data should be reported via accessible and easily parsed network messaging protocol.
2. Data should be updated at least every 30 seconds.
3. The system for monitoring data should be accessible across multiple devices but with secure access.
4. Functionality should be achieved with relatively inexpensive hardware and software should not require licenses.
5. Data storage and real-time data monitoring systems should be based on open-source hardware and software.
6. Open-source firmware libraries (e.g. Arduino) and data-processing/back-end source code (Python or Java libraries) should be employed to facilitate expansion since in future multiple buoys or additional sensors might be added or the system utilized as a platform for educational projects.

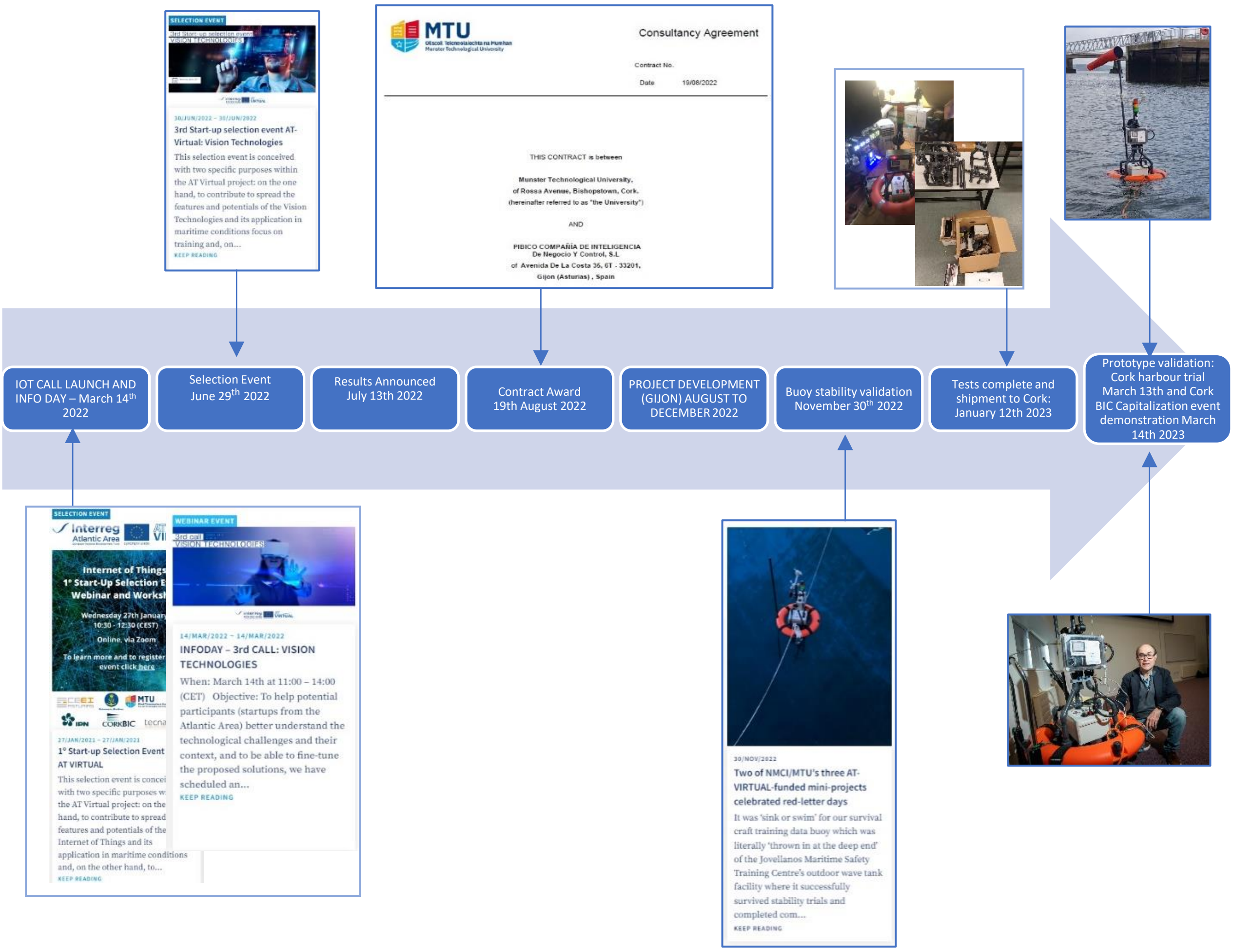
2.4 Information Day Video:

Click here to watch a video that was prepared for the IoT Challenge information day to introduce the open call.

3. Project Implementation

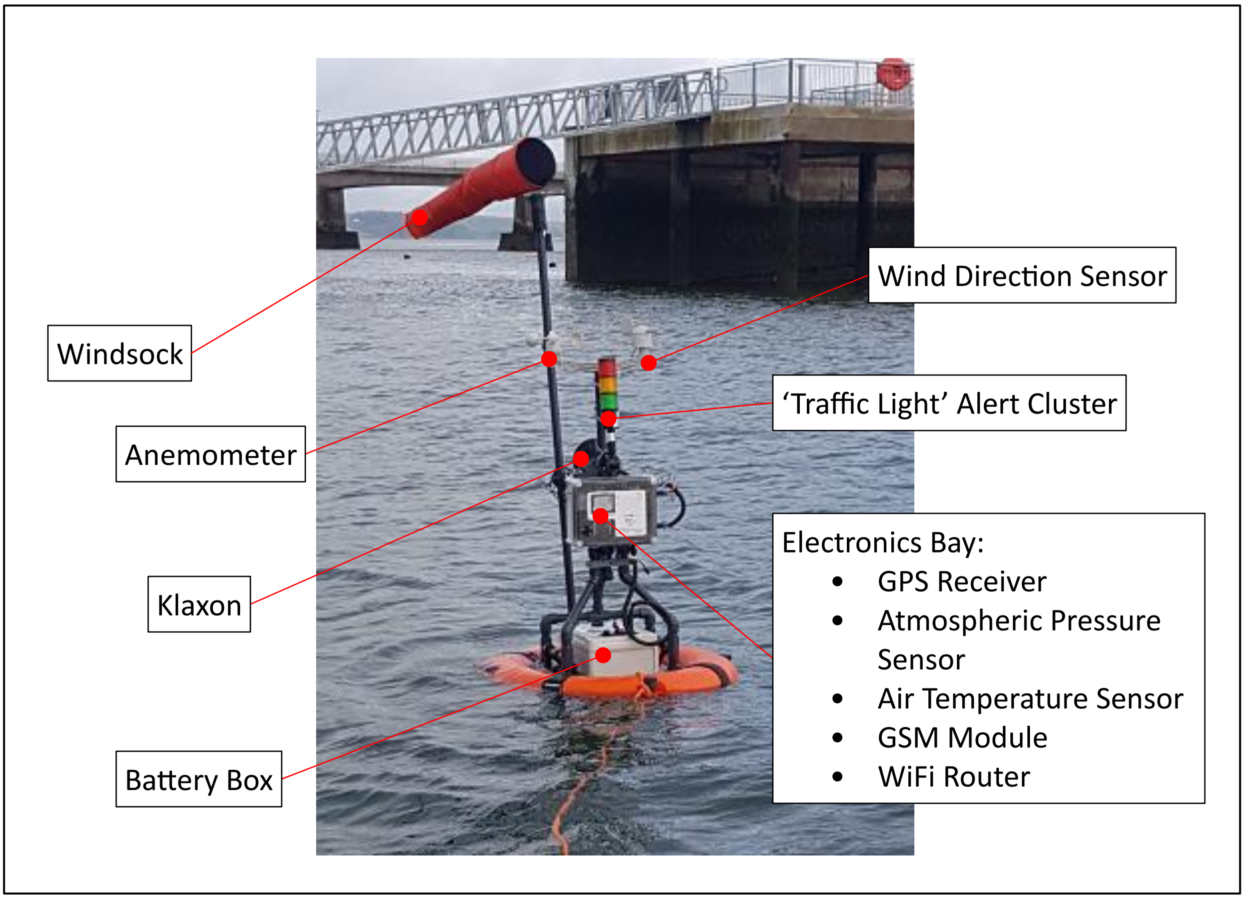
3.1 Timeline

NMCI's IoT call was originally launched in October 2020 and the successful startup company awarded a contact in January of the following year. However, following bureaucratic complications that prompted the company to withdraw shortly before activating its contract, it was decided to re-run the IoT call in tandem with another of AT-VIRTUAL's Industry 4.0-themed calls. The second IoT call was subsequently packaged with the final (Vision Technology) call according to the timeline below. Development of the NMCI 'Smart' buoy was contracted to a Spanish startup, Pibico, based in Gijon in the Asturias region of Spain.

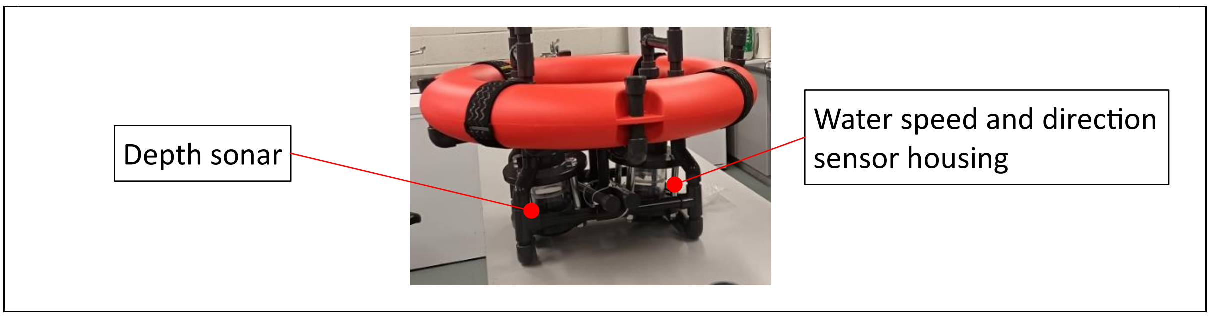


3.2 Physical Design

The sensor buoy developed by Pibico fully satisfies physical requirements listed in Section 2.3 and incorporates additional functionality – a remotely operated klaxon and a three-color light mast - that promise to increase the solution's versatility. The klaxon can be used to attract the attention of water users straying into the training area or, if replaced with a suitable loudhailer, to broadcast live or recorded warning messages. The light mast can be used to display status of the training area (clear, caution and danger) in a visual manner thereby reducing the number of radio messages that need to be sent from the shore and providing an alternative means for safety officers ashore to communicate with training craft in the event of radio failure.

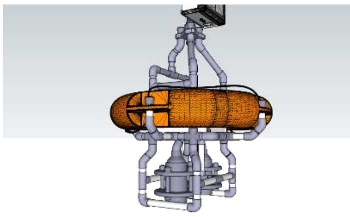


Sensor buoy – above water components.



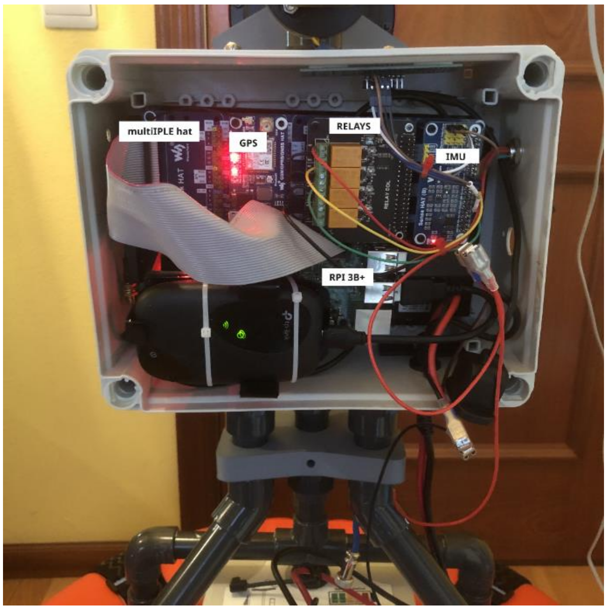
Sensor Buoy – Underwater sensor housings.

The framework supporting the electronics enclosure and the battery box is made from inexpensive UPV water pipe. This material proved to be rugged, rigid and versatile (allowing design modifications to be rapidly incorporated), and strong joints could be quickly fashioned with solvent glue. Furthermore, since virtual replicas of individual joint pieces could be modelled in CAD software, a dimensionally correct virtual version of the entire structure could be fashioned and accurate lengths for interconnecting tubes determined. The real-world version of the buoy was built quickly and with confidence.



Pipework 'skeleton' fashioned from off-the-shelf plumbing makes for straight-forward transition from CAD to physical implementation.

3.3 Sensor Electronics Bay



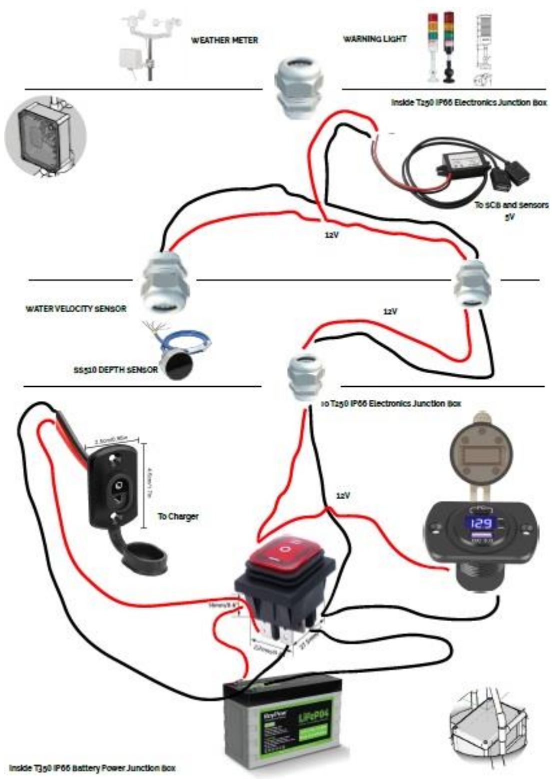
Principle components of the buoy data collection system.

A Raspberry Pi embedded computer lies at the heart of the buoy electronics. Capabilities of this device include interaction with sensor devices at digital logic levels as well as with sensors requiring microcontroller (I2C, SPI or Serial) connections and with wireless or Ethernet computer network interfaces. Versatility in low-level hardware compatibility is particularly important for a computer system required to 1) integrate sensors broadcasting local messages with diverse interface formats (a GPS receiver with NMEA serial messages and I2C bus data from wave motion detectors and air temperature and air pressure sensors), 2) interpret raw logic levels for anemometer measurements and relay operations, and 3) to manage data formatted in computer network message protocols.

3.4 Power

A single 18Ah Lithium-Ion Phosphate battery powers the buoy. The battery compartment comprises an IP66-rated waterproof box and similarly rated electrical connectors and switches that proved watertight in trials despite their proximity to the water surface.

Battery compartment showing waterproof voltage monitor, power switch, connector ports and 18 Ah battery.



Power distribution and waterproofing.

3.4 Communications

Communications architecture developed for the buoy system comprises a Raspberry-Pi-computer aboard the water-borne platform and to manage real-time data display and data archiving in a backend database ashore, a more powerful small-form-factor Intel Xeon E3 1505 mini-PC.

Both computers maintain independent Internet presences, hosting publicly accessible data portals. These services are exposed to client browser applications resulting in a highly flexible solution that users can access on any computer with Internet connectivity including mobile devices.

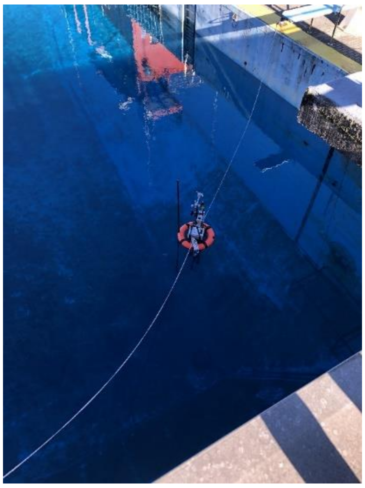
The buoy computer possesses a unique network identity, permitting any number of buoys to be deployed in an ad-hoc flotilla. Each buoy independently reports status and sensor data via Web pages viewable on mobile devices via cellular communications or, at close range, via the buoy local MiFi wireless network (the latter being primarily for adjusting sensor parameters and for operating the light mast and klaxon). From a user's perspective, a situational picture from multiple buoys can be gained by opening multiple tabs in a Web browser (one for each buoy being monitored) and switching between tabs. Examples of data visualizations are shown in Section 4.1 and 4.2.

Buoy communications hub (MiFi router highlighted).

Shore communications (Small-Form-Factor PC above MiFi router).

3.5 Fabrication and delivery

Communications systems, sensor interfaces and data processing algorithms were proven at Pibico's Gijon facility. Stability and 'seaworthiness' of the flotation platform was confirmed at the nearby SASEMAR Jollevanos outdoor wave tank facility.



Outdoor testing underway in the environmental pool at the Jollevanos MSTC facility in Asturias, Spain.

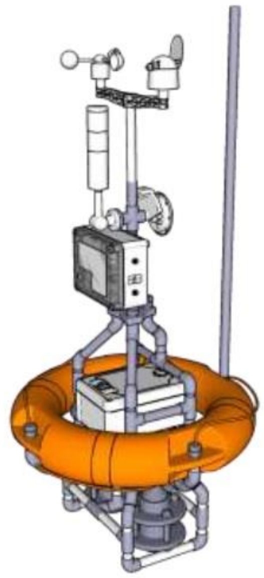
The prototype was built and tested at Pibico headquarters in Asturias, Spain, before being shipped to Cork for reassembly and commissioning.

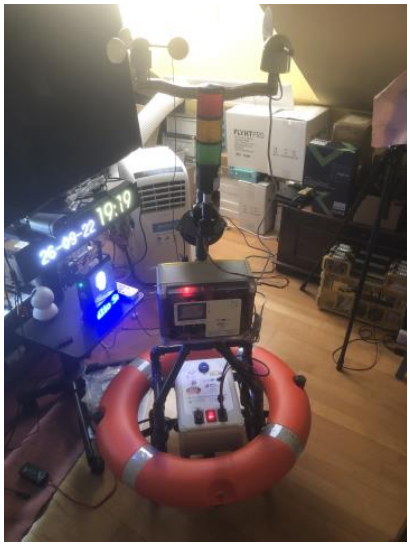
Views of depth sensor (highlighted) being tested in water and assembled in the underwater housing.

The entire prototype, including the shore-side computer, occupied only four packages and was light enough to be air-freighted.

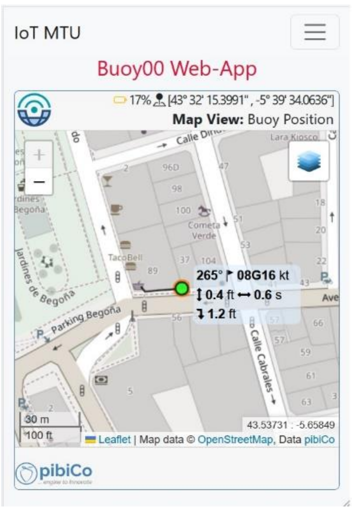
4. Test Results and Validation

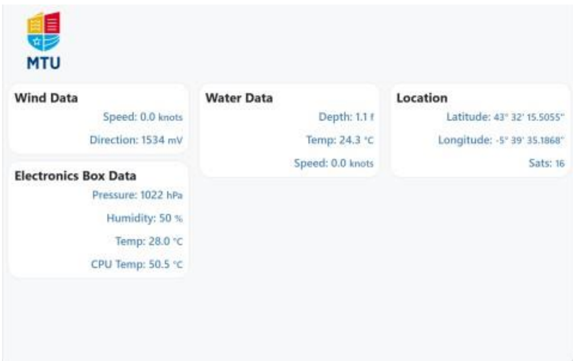
4.1 Local Testing



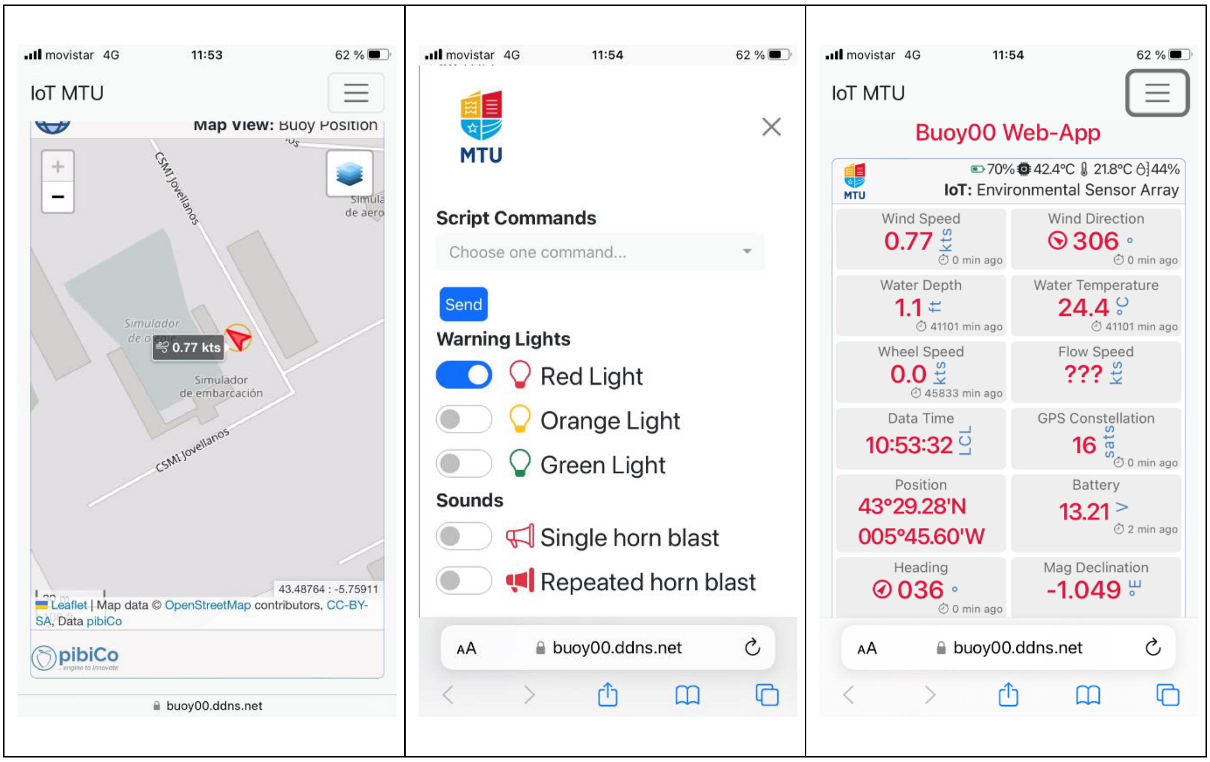


Final version of the design in CAD and with bench-testing underway.



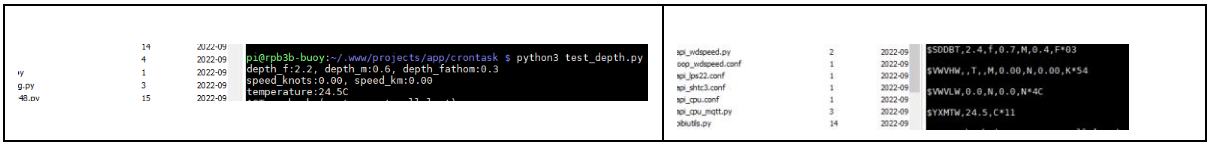


Mobile App iconography and desktop device browser web page showing local data results.



Buoy server views - middle page shows light mast and klaxon control commands.

In addition to confirming all sensors [data collected and reported by buoy, collected by functioned as expected and data handling frameworks correctly displayed data.



Raw data for water temperature, depth and speed received by the shore computer (left) and transmitted from the buoy (right).

Power consumption tests revealed battery capacity comfortably in excess of that required to satisfy the 12-hour duration specified in the challenge (after 48h continuous running, battery voltage dropped to 13.0V, indicating 50% charge remaining, a more than ample safety margin for the expected use case).

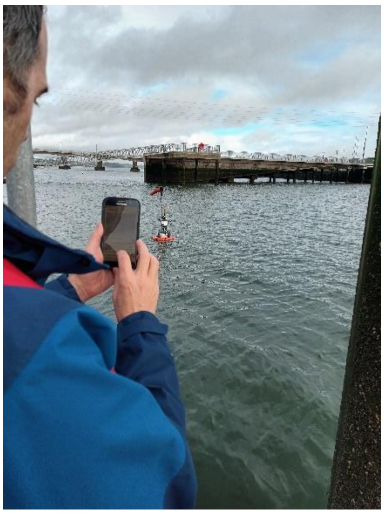
Computer network traffic was measured at 130MB/day on the server and 30 Mb/day on the buoy.

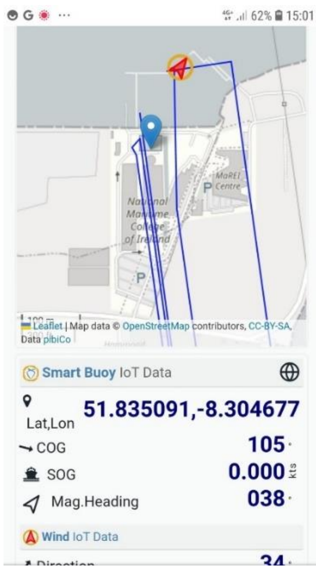
4.2 Validation

The solution's physical properties (compact size and low weight) afford portability and ease of manhandling during launch and recovery. These properties were demonstrated during trials conducted in Cork harbour on March 13th 2023.

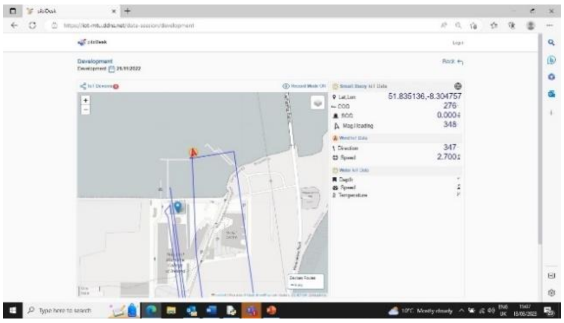
The prototype, which weights 15 kg and can be transported on a small hand trolly, does not require lifting equipment during launch and recovery as is evident by the following images which were captured during the Cork harbour trials.

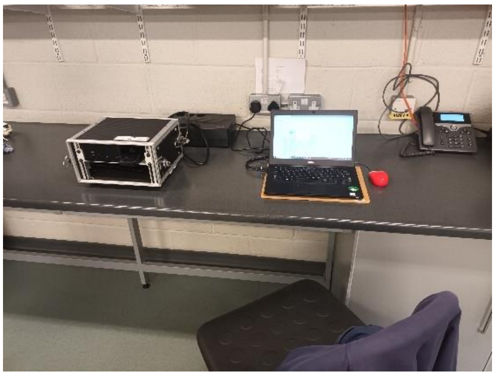
The buoy transported on land and safely launched by one person.





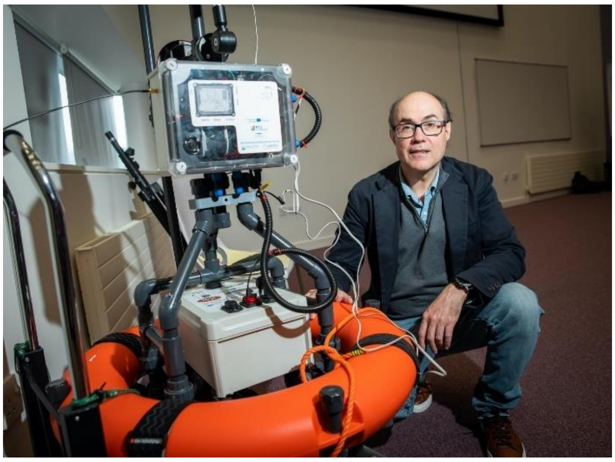
NMCI instructor's view of buoy data, monitored on a mobile device.





Real-time data broadcast by the buoy over 4G mobile phone link during Cork harbour trials. The setup simulates an office in which harbour training operations are monitored by a remote safety officer.

The buoy afloat in Cork harbour on March 13th 2023 during validation tests and seaworthiness proving trials.



Francisco Aláez Diez, co-founder of Pibico, posing beside the prototype during validation tests at the Cork BIC AT-VIRTUAL Capitalization event on March 14th 2023.

https://www.linkedin.com/posts/national-maritime-college-of-ireland_internet-of-things-iot-success-story-activity-7048971092253634560-SJBV?utm_source=share&utm_medium=member_desktop

5. Conclusions

In all technical respects, the environmental sensor buoy delivered by Pibico met or exceeded the brief set by the NMCI challenge.

It not only addressed the primary use case, to act as a cost-effective pathfinder in trials involving instructors whose feedback will determine whether discussions about future investment in sensor buoys will be held, but also satisfied the secondary agenda that the prototype should find alternative roles a) in education, as a test-bed for mechatronics student led projects, and b) in research, serving as a general-purpose floating test-bed for aquatic sensor development.

The Python language architecture employed in the solution treats input devices in a modular fashion, thus is inherently amendable to expansion and experimentation by virtue of the wide range of IoT-themed and AI libraries available. Computers employed in the buoy and ashore run Open-Source Linux-based operating systems for which access to low-level processes is straight-forward therefore the solution is an ideal educational platform.

Physical implementation of the buoy, utilizing an off-the-shelf life ring to provide flotation, proved to be stable and seaworthy, validating the original notion of taking this approach to build a cost-disruptive, easy to replicate, sensor platform.

The versatile communications architecture and data management scheme successfully provided the display and archive options upon which decisions about future investment in a flotilla of buoys will be based. However, dependence on static-IP computer locator addresses in combination with 4G mobile communications revealed an unexpected and expensive shortcoming of the scheme.

Data volumes in tests revealed bandwidth usage far greater than is common for IoT server applications and therefore beyond the scope of SIM cards marketed to developers of low bandwidth IoT solutions. Data only SIM card accounts for enterprise users are not commonly associated with static-IP addresses (these usually accompany data accounts for non-mobile public server computers). The cost of financing communications proved to be unexpectedly high and would need careful consideration were the scheme to be implemented across a flotilla of buoys.