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THE OCEAN PROJECT; IMPROVING SEAFARER'S AWARENESS IN NAVIGATION, BY DESIGN

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The OCEAN[1] project is exactly about this. Helping navigators, who we[2] believe are already very good at what they do, to become even better in terms of navigational safety. In this context, ‘better’ is much about situational awareness (Endsley, 1995) in the fullest meaning, including the stages of perception, appreciation and planning to avoid hazards to navigation, but it is also about executing evasive maneuvers in a timely, precise and effective manner. Moreover, in the OCEAN project, ‘navigational safety’ is not limited to the common types of accidents like collision and grounding, but also includes the growing concern with ship-whale strikes and the risk floating containers pose in case they are lost from ships.

The maritime industry is having a very good safety record, but how can it happen that ships are still running aground? In March 2020 the M/S ‘Kaami’ finished loading in the port of Drogheda, Ireland, and the Master planned the voyage to the next port of call, which was Slite, Sweden. Throughout the voyage, the ship followed the pre-planned route that the captain had prepared, according to the report subsequently issued by the Maritime Accident Investigation Branch (MAIB, 2021). The report narrates how the planned route did not follow the IMO[3] recommended route past the northern part of the Isle of Skye, how the watch-keeper possibly misunderstood a warning issued on VHF[4] by the fishing vessel ‘Ocean Harvest’, how the ship went to the north of the southern cardinal mark on Eugenie Rock and how the ‘Kaami’ eventually ran aground there. The way the ECDIS[5] on the ‘Kaam’i was designed and used arguably appears to play a significant role in the accident (Porathe et al., 2023).

How can it happen that ships still are colliding? On June 28th, 2023, the fast ferry M/S ‘Tyrhaug’ collided with the fish-farm service vessel ‘Frøy Loke’, in broad daylight and good visibility. Winds were calm. According to the Norwegian media NRK[6], a passenger on the ‘Tyrhaug’ stated that ‘I had just gotten a cup of coffee and noticed that a blue boat was dangerously close. I thought ‘somebody must turn soon’. At the same time, I wondered whether I could be mistaken. Then came the crash, pure and simple’[7]. It is too soon to speculate on the reasons for this accident, but at first sight, it seems likely that the ‘Tyrhaug’ bridge team did not notice the ‘Frøy Loke’. Hence, no decision was made to change the course or the speed of the ‘Tyrhaug’, in time to avoid the accident.
Other questions are relevant when it comes to navigational safety in the OCEAN project: Why are ships continuously striking whales, most often maiming or killing the animals? And why are containers lost overboard, and what can be done to reduce the associated risk to other seafarers, especially those in lightly built vessels?

[1] OCEAN, Operator-Centred Enhancement of Awareness in Navigation, www.ocean-navigtion-awareness.eu. The project has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement No. 101076983. UK participants in Project OCEAN are supported by UKRI grant numbers 10038659 (Lloyds Register) and 10052942 (The Nautical Institute).
[2] The OCEAN project is undertaken by a consortium which comprises 13 members from 7 European countries: Norway, Greece, Spain, Denmark, Portugal, Ireland, the UK and is coordinated by HVL, Western Norway University of Applied Sciences. Partner details are included in the section titled ‘The OCEAN Consortium’
[3] IMO, the International Maritime Organization.
[4] VHF, Marine Very High Frequency two-way radio.
[5] ECDIS, IMO Resolution MSC.232(82) Adoption of the revised performance standards for Electronic Chart Display and Informantion Systems (ECDIS), (2006).
[6] https://www.nrk.no/mr/hurtigbaten-tyrhaug-og-bat-kolliderte-utanfor-kysten-mellom-aure-og-smola-1.16464138
[7] Authors translation of the original quote in Norwegian: ‘– Eg hadde akkurat henta ein kopp kaffi og la merke til at ein blå båt var faretruande nær. Eg tenkte «no må nokon svinge snart». Samtidig lurte eg på om eg kunne ha sett feil. Så small det, rett og slett’.

The OCEAN Project at-a-glance

As a starting point, we see most navigational accidents as having a socio-technical background, involving longer timespans and many more causes and events than just last-minute 'human error'. From this perspective, as well as the one of the navigator, the OCEAN project addresses the most pertinent factors[8] contributing to events becoming accidents, such as cue acquisition and retention, training, the usability of technology as defined by ISO 9241-11 (1998) of technology, the human element, operational constraints, processes and procedures, and commercial pressures. We are especially interested in, and focused on, how information of navigational hazards is collected and distributed to the navigators, the rationale being that successful mitigating actions are entirely dependent on comprehending and anticipating the situation as it unfolds. We are also exploring how the design of ships bridges and existing bridge equipment may influence the performance of the human operator, and how a changed design practice involving the end-users could lead to improved navigational safety.

The OCEAN project will demonstrate how hazard information can be collected and shared among ships and craft, and will eventually recommend improvements and amendments to regulations, standards, and bridge equipment design approaches. At the time of writing (April 2024), the OCEAN project is exactly halfway, and has just published a new batch of deliverables. Together with earlier publications which all are available for download, we suggest that the overall picture being painted is of interest to the maritime industry.

Hazard Detection

Target detection in the SOLAS[9] fleet builds on human eyesight, supported by radar and AIS. But what about the targets which cannot be detected by these means, in time to avoid the hazards or not at all? Whales on or near the surface, whether resting or travelling, cannot be detected by radar, or by the human eye at nighttime or during reduced visibility. Even by daylight it is doubtful that the watch-keeper can see a whale in time to avoid it, especially with growing ship sizes. This poses a risk to small, lightly built ships, where a whale-strike may end being fatal for the crew on the boat, and at the same time, the animals themselves are at risk of being struck by larger ships, usually, when the ships' speeds are above 10 knots, with a fatal outcome for the whale[10] and detrimental effects on whale conservation: it is a fact that ship strikes pose a major threat to the survival of some whale species (Moore, 2014). Containers lost overboard pose a similar challenge. Being very difficult to detect by radar, and equally so by human eyesight, they are a risk to ships, especially the smaller, lightly built craft while they remain on or near the surface. Depending on the contents, some of these containers do not sink quickly, or at all, as recent accidents show, and especially reefer containers may possibly remain buoyant for sufficiently long to pose a threat to shipping.

Both topics are addressed by the OCEAN project, using crowdsourcing of observations facilitated by an app developed by the OCEAN project, which presently is in beta testing. In the app, sightings of whales or semi-sunk containers are reported to a central database (see below), where they eventually will trigger AI-based, automatic satellite image processing and thus provide a near-real time data-stream. For containers lost overboard, the very recent adoption of MEPC.384(81) 'Amendments to Protocol I of MARPOL Article V', concerning Reporting Procedures for the loss of containers also serves as a trigger of these actions, and augmented by the predictive capabilities of the OpenDrift[11] model, are enabling hazard forecasting[12].

[8] OCEAN Deliverable D1.1 'Identification of navigational accidents' root causes'
[9] SOLAS, Safety of Life at Sea, IMO
[10] OCEAN Deliverable D4.1 'Workshop Report (including specialist recommendations)'.

To further strengthen the hazard detection side, the OCEAN project is developing and testing advanced hydrophones with on-the-edge algorithms for marine mammal detection and classification, providing range-and-bearing to animals also in near-real time, which thus is constituting another data-stream. Longer-term predictions are being made by 'Environmental Niche Models' (ENM), which are suitable for voyage planning purposes – these models are presently being refined prior to demonstration. The longer-term aim is to explore the propagation of this information as T&P Notices[13], eventually also to be displayed on ECDIS via services such as the Admiralty AIO[14], and thus being able to guide routing and voyage monitoring.

Distribution of Hazard Information

The value of being able to detect hazards depends entirely on making them available to the navigators. A pivotal element of the OCEAN project is the 'European Navigational Hazard Infrastructure' (ENHI) which serves the purposes of collecting data from all data streams, fusing them, triggering the use of the ENM, the OpenDrift model and the satellite image processing to further augment and update the hazard information. Once processed, consistent messages are forwarded to the issuers of Navigational Warnings (NW), which subsequently can be broadcasted by the currently available means, i.e., by voice (VHF/MF/HF), by NAVTEX and/or EGC[15] and by AIS, in this case using Virtual Aids to Navigation (vAtoN). While the immediate need is to provide hazard to the existing fleet using existing means, the OCEAN project is also having an eye towards the future and is researching how S-124[16] and VDES[17] may have positive impacts on informing mariners. The design and implementation of the ENHI and the associated interfaces is well progressed and documented in detailed specifications[18] available for download. It is perhaps of particular importance that the OCEAN project is open for exchanging data with similar initiatives, the rationale being to reach critical mass by combining valid sighting reports from multiple sources. Demonstration of the end-to-end capabilities and benefits of the OCEAN data collection, concentration and redistribution is scheduled to commence towards the end of 2024.

Getting user attention and supporting decision-making

Once hazard information is available, whether from onboard sensors or from a novel source such as the ENHI, propagated via existing or future means, the usability of this information depends directly on how it is integrated with other information sources, and how the overall picture is presented to the operator. Part of the solution sits with human-centred design (as discussed in the following), but part of the OCEAN research[19] has also highlighted that simply registering such cues appears to be a hereto overlooked challenge. EMSA, the European Maritime Safety Agency is noting (EMSA, 2020) that mariners on watch are missing salient cues in 57% of navigational accidents – in other words, the watch-keepers never perceive the hazard or dismiss the risk as unlikely. With reference to both the 'Tyrholm' and the 'Kaami' accidents mentioned in the foregoing, not acquiring or dismissing cues is surprising but nevertheless a potential root cause in both cases, and from a design perspective, it highlights that the present design paradigm may need to be revised to take account of this issue.

[11] https://opendrift.github.io/
[12] OCEAN Deliverables D5.1 'Patterns relating to lost containers', D5.2 'Information needs relating to the recovery of lost containers', D5.3 'Lost container forecast for ships, small craft and recovery operations' and D5.4 'Proper future communications relating to dynamic navigational warnings'.
[13] T&P Notice, Temporary and Preliminary Notice to Mariners, see for instance https://msi.admiralty.co.uk/NoticesToMariners/Weekly
[14] AIO, Admiralty Information Overlay, see for instance https://www.admiralty.co.uk/charts/digital-charts/admiralty-vector-chart-service
[15] Enhanced Group Call
[16] S124, the IHO product specification for Navigational Warnings, see https://iho.int/en/s-100-based-product-specifications
[17] VDES, VHF Data Exchange System, see for instance https://www.iala-aism.org/technical/connectivity/vdes-vhf-data-exchange-system/
[18] OCEAN Deliverable D6.1 'Overall infrastructure design' and D6.2 'Tracking navigational hazard databases design and implementation'.

Another aspect which possibly requires a revision of design thinking in the maritime domain is that navigators quite likely are making decisions differently from what is usually described as normative decision-making. According to literature (March, 1994; Zsambok & Klein, 2014), normative decision-making relates to situations where all data required to make decisions are available, constant and unambiguous, and where the decision-maker has all the time required to deliberate and eventually arrive at a decision. This is however not congruent with the typical situation on a ship's bridge. Information is often incomplete, ever changing, risks are putting a pressure on the decision-maker, and time is often short. In such cases, humans tend to employ naturalistic decision-making, which largely builds on experience and recognition of patterns – you do what you have successfully done before in comparable situations. From a maritime design perspective, it is however an open question whether the current design regime is taking account of this, and whether the resulting designs are supporting naturalistic decision-making. At the very least, we are suggesting that when testing any piece of bridge equipment with users, the test-suite should include tests designed to ensure that the Equipment Under Test (EUT) dovetails with the decision-making process, and how the information provided from the equipment supports the end-user. It is also suggested that a continued type-approval process which sees products out of context potentially needs to be revisited.

Design for user needs

The OCEAN participants are fully respecting and appreciating the importance and value of the IMO and IEC[20] performance and test standards for radar, ECDIS and AIS, which largely forms the features and capabilities of these instruments. However, it is suggested that even within the present framework of rules, designs of current and especially novel technology can be enhanced through user-centred design, i.e., multi-disciplinary teamwork involving the end-users throughout the design process (ISO9241-210, 2019), which eventually is leading to products with greater usability. Considerations of maritime ergonomics and design for usability is not new, and a significant volume of high-quality guidance exists in the public domain[21], a summary of which is provided and updated by the OCEAN project[22]. It is however so that human-centred design (HCD) continues to have less traction in the in the maritime domain than we see as the objective, judging from a lack of published accounts of applying HCD, a status which has been confirmed by a series of interviews[23] undertaken by the OCEAN project. In way of these results, development organizations are now increasingly aware of the need for designing for usability but appear to be at a loss in way of practical methods. It is also found that the cultural change needed to increase the usability capability maturity of such organizations is only progressing slowly.
A very recent result in the OCEAN project points out that among a 300+ participant sample of experienced seafarers, 87% are experiencing what they see as design problems pertaining to bridge design and the design of bridge equipment (see Figure 1). Being willing to share knowledge and experience, as well as participate in design activities, only 20% of the respondents had however been actively engaged in such ventures, in full or partially, and it was additionally found that several barriers existed towards providing feedback to the shore-based organization[24] (see Figure 2).

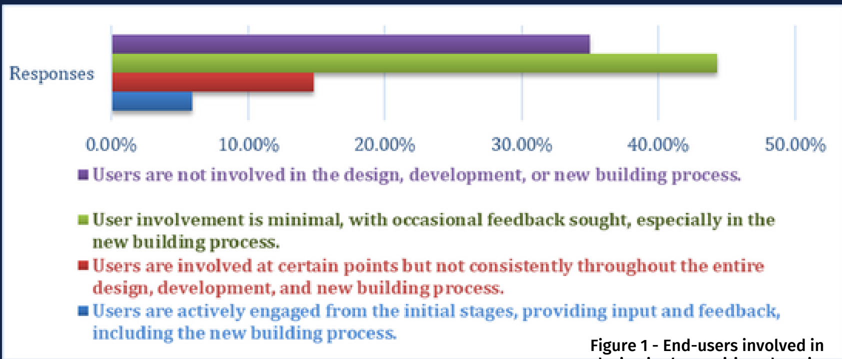

Figure 1 - End-users involved in design in the maritime domain (Source: OCEAN D2.2)

[19] OCEAN Deliverable D2.3 'Improved operator Decision-making'.
[20] IEC, the International Electrotechnical Commission.
[21] See for instance ABS. (2010, 2018). Guide for Bridge Design and Navigational Equipment/Systems. In. Houston, TX, USA: American Bureau of Shipping., ABS. (2003, 2018). Guidance Notes on Ergonomic Design of Navigation Bridges. In. Houston, TX, USA: American Bureau of Shipping., ABS. (2013, 2018). Guidance Notes for The Application of Ergonomics to Marine Systems. In. Houston, TX, USA: American Bureau of Shipping.
[22] OCEAN Deliverable D3.1 'Gap analysis of methods and practice'.
[23] OCEAN Deliverable D3.2 'HCD applicant interview analysis'. This deliverable has limited circulation to protect the interviewees.
[24] OCEAN Deliverable D2.2 'Improved training standards'.

Part of the work in the OCEAN project is to understand whether, and to which extent, the HCD methods and overall methodology are at odds with the development practice in the maritime domain, and if so, how HCD could be adapted, or reengineered, to fit practice – in other words, a user-centred approach to make HCD fit for purpose also in the maritime equipment industry. Using the design of a novel piece of equipment, the 4-dimensional Situation Awareness Display (4D-SAD), as a case study[25], several of the OCEAN participants are researching not only which impact such a device would have on end-user situation awareness but are also applying HCD methods in a real-life scenario. Evaluating the pros and cons, and the effectiveness, efficiency and the overall satisfaction these methods bring to the development organization is forming a basis for dual recommendations, partly to changes of design practice and partly to a possible redefinition of HCD methods. Both subjects will be reported in future OCEAN deliverables, due in the spring of 2025.

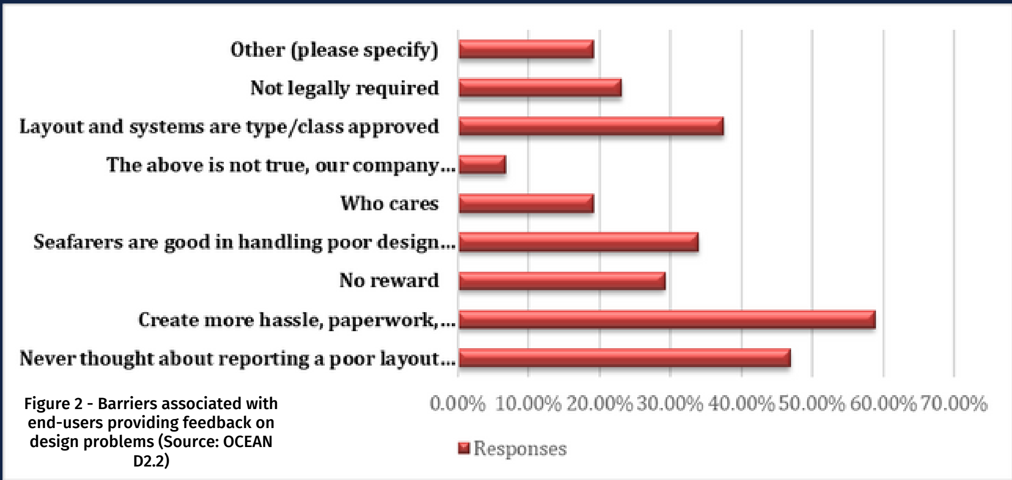

Figure 2 - Barriers associated with end-users providing feedback on design problems (Source: OCEAN D2.2)

Integrating evasive manoeuvring

The focus of the OCEAN project is quite 'here and now', rather than aiming towards Maritime Autonomous Surface Ships (MASS). The OCEAN project does however include a component heavily inspired by the development relating to MASS concepts, in the shape of the Evasive Manoeuvring Agent (EMA). The function foreseen is primarily that of an advisory, a perception-based and COLREG-aware guide to the watch-keeper, to help plan and undertake effective evasive manoeuvres once approved by the navigator. With the focus on the present fleet, it is an aim that the EMA is a bolt-on solution, applicable to existing ships as well as new buildings, and to keep cost under control, integration with existing ship sensor and actuator systems is to be based on already available standards to the extent feasible. Having just completed the research associated[26], it is clear that most of the information exchange between the EMA and the traditional onboard sensors can be based on the IEC 611162 series of standards, supplemented with a few industrial standards for video and middleware. There is only a limited need to introduce novel interfaces, but in the cases where this is seen as the better choice, it is part of the project scope to provide such information to the IEC for further consideration, see also OCEAN D8.2.

Dependable software solutions

Arguably, dependability is a constituent of usability – who would be satisfied with using a piece of equipment which is unreliable? 20 years ago, software reliability was a subject in the ATOMOS[27] series of projects, and with more complexity and a higher degree of automation being introduced in the maritime domain, the need for dependable software has grown significantly since then. Part of the OCEAN project is to revisit ISO 17894 (2005), which originated as an ATOMOS work product, and which has been unchanged and unchallenged since, the rationale being that the software development tools and processes have changed greatly over the last two decades, which means that the 20 dependability principles described by the standard potentially could benefit from updating. An increased use of Agile Programming techniques, the advent of Artificial Intelligence (AI), the increased use of Machine Learning (ML), cyber security concerns and – challenging that – Over-The-Air updates all serves to complicate matter even further, especially on the verification and validation side, further driving the need for change, or revision. Presently, this work is ongoing, and a training course has been made available[28].

[25] OCEAN Deliverable D7.1 'Identification of information conducive to enhanced tactical situation awareness' and D7.2 'Validation of selected data sets'.
[26] OCEAN Deliverable D8.2 'EMA interface description and identification of marine standard needs', available for download on the OCEAN website.
[27] https://cordis.europa.eu/project/id/WA-95-SC.0205, https://cordis.europa.eu/project/id/WA-97-SC.2088
[28] OCEAN Deliverable D3.5 'Initial training on dependable systems review', which also includes a comprehensive section on the revision work of the standard itself.

Winding Down

Now at the midpoint of the OCEAN project, and as in the past, we are constantly seeking dialogue and feedback from stakeholders across the maritime industry. Since many of the results forthcoming are having implications on design of maritime equipment, we see it as highly beneficial to keep the project's ear to the ground, and we would like to welcome any organization or enterprise interested in interacting with the project and the members of the consortium. The OCEAN Stakeholders' Forum, counting around 25 entities, is set up for exactly that purpose, and membership is the simple matter of signing up on the project website at **https://www.ocean-navigation-awareness.eu.**

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