E-navigation – a vision and its practical implementation?

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It can be difficult to envisage e-navigation as a practical entity, not least because its scope is potentially huge. This discussion document attempts to present a simplified vision, directed towards its early implementation onboard a vessel and purposefully not considering the scope of its potentially extensive shore-based infrastructure.

It is a personal view and does not necessarily reflect the view of the organisations to which the author is connected. It is a collation of ideas, many of which are based on or reflect the thinking of others, mainly arising from a number of recent formal and informal discussions on the topic. It is aimed at promoting and facilitating further discussion.

1. Vision

An e-navigation bridge of the foreseeable future is likely to be based on the architecture displayed in Figure 1, which is shown in a highly simplified form for clarity. It is depicted as being based around a simple local area network. In practice, the architecture would be considerably more complex for reasons of resilience, security and performance.

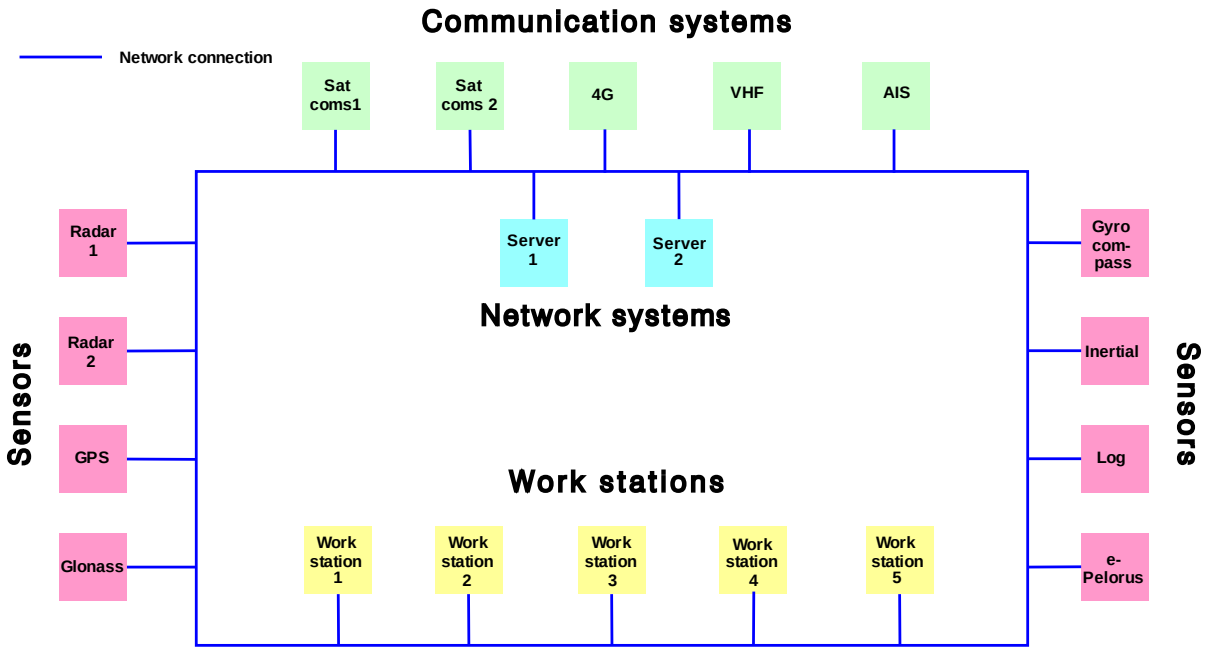

Figure 1 Simplified e-navigation bridge architecture showing example communication systems, navigation sensors , work stations and network systems

Shown connected to the network are the following:

- External communications links, all shown as digital but could include analogue channels with relevant digital/analogue conversion. Example links are satcoms, VHF, 4G, AIS, HF
- Navigation and other sensors. Examples include GNSS, radar, echo sounder, gyro compass, rudder angle indicator
- Operator work stations, each with a powerful computing facility, a display, associated user controls, and audio input and output devices, particularly for use with voice communications channels
- Networked additional processors and memory storage devices, etc

The software packages running on processors are not shown. These basically run e-navigation applications, which could include, for instance, ECDIS, radar and an integrated navigation system (INS). In some ad hoc e-navigation discussion circles *e-nav apps* is the colloquial name given to such software and the term is used here. The basic architecture allows redundancy of subsystems, giving options of resilience.

E-nav apps are envisaged to cover all officially defined applications, such as those that will form the future IMO e-navigation requirements for ECDIS, radar and INS. They are also envisaged to cover other, non-IMO, applications that are designed to run on e-navigation displays and processor systems. The latter may be defined and developed by state organisations or by commercial sources. However, such non-IMO defined apps will need to conform to stringent general standards laid down by IMO and be independently assessed to establish conformance, perhaps along similar lines to existing type approval but generally following a simpler process.

Such general requirements for independent e-nav apps are likely to cover the following: the message structure; the displayed symbology – together with other portrayal requirements ; software development standards; and other to-be-defined factors. Any use of e-nav apps at sea will be permitted only by those having received verifiable training that meets the requirements of IMO.

IMO defined e-nav apps may include such applications as:

- ECDIS
- Radar
- INS
- Ship/shore integrated reporting system
- Integrated communication system
- Integrated alert management system
- Maritime Safety Information system

E-nav apps developed outside of specific IMO requirements may include:

- Route planning information systems
- Enhanced navigation displays, eg using new optical sensors such as the ePelorus
- Cost-optimising integrated communications
- Low emission, fuel optimising or time sensitive navigation planning

Each e-navigation display on the bridge is potentially able to be user configurable to run specific e-nav apps, but with certain restrictions that will be defined as part of IMO's e-navigation requirements. For instance, if these somewhat mirror those of the present day, at least one display may have to be running an IMO approved ECDIS app and up to two displays, depending on ship size, as approved radar apps. It is likely that e-navigation will require INS to be continuously running, with a specific and detailed INS display being able to be shown on demand. Depending on the actual situation, different apps are likely to be able to be operator configured to run on specific displays, with their respective positions optimally suiting the task in hand. Checking that all IMO requirements on maintaining the display of critical apps would be automatic.

Unquestionably, the development of suitable general requirements for non-IMO e-nav apps would be a demanding task. However, in the evermore rapidly evolving technological future it is probably an essential step and the following points need to be borne in mind:

- It would provide solutions to evolving user needs
- It would generally not be feasible (or desirable?) to evolve specific IMO standards for fast moving areas
- Certain standards in software development procedures, presentation, operator use and training are essential to maintain safety and usability
- It would encourage the development of improved systems and not stifle innovation

2. Practical issues

Although e-navigation, in concept, is an evolutionary process, particularly with regards to the navigational practices onboard a vessel, its implementation to the levels discussed in Section 1 requires a fundamental and major restructuring of all onboard navigation and communications facilities. In an 'ideal' e-navigation centred world this would necessitate all ships to be fitted over a relatively short period of time with e-navigation compliant equipment and systems, totally replacing the equipment used today. There are obvious practical difficulties of achieving this, including:

- The parallel training of all seafarers
- The enormous expense to shipowners over a short period
- The parallel development of many new standards
- The cost of R&D to equipment manufacturers over many product ranges during a period of much reduced sales of existing equipment in anticipation of the e-navigation era
- The limited number of personnel available worldwide with the right skills for standards development, R&D, ship fitting programmes and user training

If the fitting was restricted to new builds, the growth in its use would be highly restricted and the implementation would still generally suffer from the major issues identified in the last three bullet points above.

To be practical, what is required is an approach that has the following attributes:

- An early introduction of minimal but highly useful e-navigation functionality

- An overall plan that provides further affordable retrofit steps into the future
- Obvious benefits to mariners and ship owners at every step
- Practical and affordable training concepts
- The relatively short term possibility of highly enhanced new build concepts becoming a reality
- A steady rate of growth in e-navigation implementation, learning from earlier phases

Such an approach would allow the necessary standards to be evolved over an extended period of time. In particular, it would allow the shore-based infrastructure to develop steadily, giving users ever increasing e-navigation functionality.

3. A possible solution

The possible solution discussed here appears to give the basis of a pragmatic approach that perhaps for many stakeholders would potentially not only be acceptable but also desirable. Nevertheless, it is not a perfect concept. However, the concerns identified here and listed in Section 4.2 below, may be adequately surmountable, especially when compared to the advantages of the proposed solution. It is far from being a fully developed concept; other disadvantages (and solutions) may also come to light when further explored.

The concept is based around introducing to existing bridges an additional 'e-navigation display'. In fact it would not just be a display but an e-navigation workstation that would meet certain to-be-defined IMO requirements, including the need for audio input and output capability, for use with (future) voice communication applications. Initially, on many vessels this will be considered to be *the* e-navigation display but more than one may be fitted. In particular, on future new builds, all the displays could be designed to be e-navigation compliant, as described in Section 1 of this document.

However, the basis of the current idea is for a minimum expense retrofit – a single e-navigation display, which will at least accompany the existing radar and ECDIS equipment displays on the vessel. It is envisaged that the minimum retrofit will only be permitted to be fitted to vessels carrying an ECDIS. An essential function required for the initial fit single e-navigation display will be that it will provide at least the portrayal of a to-be-defined standard e-navigation integrated navigation system display, which is termed here INS S-Mode[1].

A particular problem on some vessels will be the positioning of this display, simply because of space and layout problems. This should be fully taken into account when the requirements for such displays are being derived. There may need to be flexibility such that it is not necessary for it to form part of a major standalone unit, similar to many present day radar or ECDIS displays. The important issue is that it is placed ergonomically so that it can be used easily in conjunction with other equipment, particularly ECDIS and radar.

[1] In this document such IMO defined standard portrayal functionality is referred to as Standard Mode (S-Mode). Other portrayals are acceptable but the user must always be able to revert to S-Mode by a simple command.

3.1 INS functionality

The required e-navigation INS functionality, probably based on the existing IMO INS Performance Standard, will be provided by a minimum set of navigational sensors, some potentially already fitted to the ship and others supplied as part of the initial e-navigation retrofit, together with appropriate software running as an IMO approved e-nav app.

As well as being able to operate with the to-be-defined e-navigation messages structure (currently expected to be based on principles defined within S-100[2]), the e-navigation display must also be able to operate with the digital messages based on the current standards issued by the International Electrotechnical Commission (IEC)[3]. This will allow the installed e-navigation facility to have basic communication with existing navigational equipment, such as ECDIS, radar, AIS, GPS receiver, gyrocompass, etc. However, future navigation equipment (sensors) will themselves also need to include an 'S-100' message capability as part of the e-navigation requirements. This will permit more detailed messages to be used that will eventually further enhance the integrity of e-navigation.

The advantage of such an initial e-navigation fit is that as a minimum it would provide IMO-defined INS functionality. Current navigation sensor fits to ships (such as GPS receivers) are vulnerable to a number of inaccuracy conditions and INS provides significantly enhanced resilience when issues arise with any navigational sensor. In particular, the INS will give intelligent alerts to the user when a problem occurs. Today, many such problems are unlikely to be detected by existing non-INS systems, which is the case for the vast majority of ships. The present onus on detection on many faults lies almost entirely on the user. Unfortunately, users can be slow in identifying such problems, even when making regular checks. As identified by numerous accident investigations, problems can become significant if there is over-reliance, for instance, on indicated GNSS-derived position.

Fail-to-safe issues need to be addressed. On early retrofit implementations of e-navigation INS it may be acceptable if the system allows the continued independent viewing of all navigation sensors if there is an INS system level failure. In the future, redundancy of equipment with automatic reversion in the event of failure would probably become a full requirement.

The envisaged e-navigation INS functionality would be able to provide existing equipment, such as ECDIS and radar, with the integrated navigational inputs such as position, heading, SOG, STW, etc. A software upgrade for the ECDIS and radar to enable this would be ideal but may not be essential.

3.2 Other e-navigation applications

A significant advantage of the proposal is that because the retrofit is based around an e-navigation display it can be configured to run and display other e-nav apps, whether IMO or non-IMO. This should give mariners important information, structured in a user-friendly way that is not available in a convenient form today. Many e-nav apps have the potential for cost savings compared to conventional systems, making their purchase and use particularly attractive to shipping companies. In particular, apps aimed at improving ECDIS-based route planning by displaying context relevant and up-to-date information are likely to become common.

[2] S-100 is an International Hydrographic Organization standard for data structures that is likely to be used as the basis for e-navigation messages

[3] Based on the IEC 61162 set of standards, as footnoted in SOLAS

In principle, the new e-navigation display could also be the focus of a new digital ship/shore reporting system, which is seen by many as an important potential facet of e-navigation. The requirements for such an app and its display would be fully defined by IMO. However, full consideration needs to be given to fail-to-safe functionality if there is a system level failure.

An important cost advantage of the proposal is that it retains the existing ECDIS and radar equipment fit to the vessel. Training should emphasise the continued need to use these fundamental tools, especially when also using non-IMO defined e-nav apps. In the future, when ECDIS and radar are also defined as e-nav apps, the training will emphasise that only reversion to S-Mode functionality of such apps guarantees total visibility of the basic data. Non-official overlays and underlays on ECDIS and radar can obscure critical information.

The initial e-navigation fit may need to rely totally on existing communications services and therefore may not be as flexible as a more complete future service. Some data may have to get to the ship via CD/DVD ROM memory, unless the ship has access to suitable and affordable commercial digital communication services. As e-navigation compliant digital communications become available there will be increasingly less reliance on such external ROM packages.

Consideration should be given to the provision of Maritime Safety Information as 'S-100' messages, perhaps by a revamp of the existing NAVTEX and other MSI channels. The display of such information as an IMO defined (S-Mode) app on early fits of e-navigation displays would be a highly useful addition. However, it may be difficult to implement this change in the short term, unlike the provision of INS functionality and a general e-nav app capability.

In order to facilitate the exchange of other information from the e-navigation display to the existing ECDIS, such as from route planning apps and a possible IMO MSI app, existing ECDIS equipment would definitely need a software update. In principle the requirements could be defined as an amendment to IMO's ECDIS Performance Standard and implemented on ships as a software update, following SN.1/Circ. 266. This should be a smooth process for most ECDIS equipment within the timescales envisaged for the initial implementation of e-navigation.

4. Summary issues

4.1 Advantages of the proposal

- An understandable and practical introduction to the benefits of e-navigation
- Significantly lower cost implementation, compared to a full e-navigation retrofit
- Prospect of relatively short term implementation (say, 6 years)
- Addresses positional resilience, a major weakness in most current ship systems
- Potentially allows early MSI digital implementation
- Allows e-nav apps, including those addressing the current day paucity of easily accessible and up-to-date digital route planning information
- Its general usefulness should encourage early adoption even without a carriage mandatory requirement

- Provides an evolutionary basis – a first step to e-navigation, which can be built upon with subsequent retrofits
- Allows use with existing onboard equipment, particularly including ECDIS, radar and AIS
- Gives a path to allow innovation with essential controls in place
- Allows new ships to be completely configured for e-navigation, albeit with a requirement to use existing systems when e-navigation alternatives are not yet available
- Allows non-IMO e-nav apps to keep abreast of future technical developments

4.2 Concerns that need to be addressed

- Full consideration needs to be given to the problems of installing an additional display on smaller vessels
- The use of non-IMO specific e-nav apps may appear to be more attractive to many mariners than that of S-Mode displays, including existing ECDIS and radar systems. Training will need to emphasise the importance of always making reference to S-Mode and/or existing systems
- It will not be easy to generate the suitable criteria that non-IMO e-nav apps need to adhere to, without compromising either safety or the practical development of highly innovative apps that may enhance safety
- Ideally MSI information is included on the initial fit but this will cause significant shore infrastructure issues that may be insurmountable in the envisaged timescales to a first implementation of e-navigation on the bridge
- Fail-to-safe functionality, not least if there is only one e-navigation display on early retrofits must be taken properly into account

4.3 Further phases of e-navigation

This could include services and enhancements such as:

- IMO definition of ECDIS, radar and other official e-nav apps
- Provision of e-navigation consistent aids-to-navigation services
- Enhancement of AIS, especially integrity enhancement
- Potential use of commercial satcoms and ground based telecommunication services for broadband digital and voice (eg VOIP) for ship-to-shore and ship-to-ship services
- Standardised digital reporting for security and safety

5. Conclusions

This document is offered as a discussion document with the aim of helping to drive e-navigation into a welcome, timely and affordable implementation phase.

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