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DEVELOPMENT OF AN E-NAVIGATION STRATEGY IMPLEMENTATION PLAN

Report of the Correspondence Group on e-navigation to NAV 59

Submitted by Norway

SUMMARY

Executive summary:	The Correspondence Group (CG) has reviewed the preliminary list of potential e-navigation solutions (NAV 58/WP.6/Rev.1,) and prioritized five potential main solutions, presented the finalized Risk and Cost-Benefit Analysis, taking into account the Formal Safety Assessment (FSA) process. A high-level FSA has been performed in order to evaluate possible Risk Control Options (RCOs) for new ships. The CG has also considered the further development of the detailed ship and shore architecture, further developed the concept of Maritime Service Portfolios (MSPs) and considered the issue of Software Quality Assurance taking into account document NAV 58/6/4. The CG has further progressed the development of draft guidelines for usability evaluation of navigational equipment, and its harmonization with the Human Element Analysing Process (HEAP) and presented a proposal for a guideline on Human Centred Design (HCD) for e-navigation equipment and systems. The CG has also progressed development of draft guidelines for the harmonization of test-bed results, as well as a draft framework for the Strategy Implementation Plan (SIP). The CG has noted documents NAV 58/6/1 and NAV 58/6/3 on resilient integrated Position, Navigation and Timing (PNT) system and a procedure to determine RCOs for the Risk and Cost-Benefit Analysis on the basis of goal based solutions.
Strategic direction:	5.2
High-level action:	5.2.6
Planned output:	5.2.6.1
Action to be taken:	Paragraph 84
Related documents:	MSC 85/26, annexes 20 and 21; MSC 86/23/4, MSC 86/26, section 23; NAV 55/WP.5; NAV 56/8, NAV 56/WP.5, annex 1; NAV 57/6, NAV 57/WP.6, NAV 57/15; NAV 58/6, NAV 58/6/1, NAV 58/6/3, NAV 58/6/4, NAV 58/6/6, NAV 58/6/8, NAV 58/14, NAV 58/INF.10, NAV 58/INF.12, NAV 58/INF.13, NAV 58/WP.6/Rev.1; COMSAR 14/12; COMSAR 16/17, COMSAR 16/WP.5/Rev.1; COMSAR 17/11, COMSAR 17/11/1, COMSAR 17/INF.6 and COMSAR 17/17

Background

1 The work programme on e-navigation (MSC 86/23/4) outlines a joint plan of work for COMSAR, NAV and STW Sub-Committees for the period 2009-2012. At MSC 90, the Committee approved the proposed joint plan of work on e-navigation for the COMSAR, NAV and STW Sub-Committees, for the period 2012-2014 (MSC 90/28, section 10.10.4). NAV 58 re-established the Correspondence Group (CG) on e-navigation under the coordination of Norway and instructed it to take into account the revised joint plan of work for the COMSAR, NAV and STW Sub-Committees for the period 2012-2014, as approved by MSC 90.

2 NAV 58 noted that the Gap Analysis had been completed and approved the final list of gaps for e-navigation (NAV 58/14).

3 The coordinator of the CG would like to thank the following Member States, Intergovernmental organizations, governmental and non-governmental organizations for their participation in the Correspondence Group: Argentina, Australia, the Bahamas, Belgium, Brazil, Bulgaria, Canada, Chile, China, Côte d'Ivoire, Denmark, Estonia, Finland, France, Germany, Ghana, Greece, India, Iran (Islamic Republic of), Ireland, Italy, Japan, Kenya, Luxemburg, the Marshall Islands, the Netherlands, Nigeria, Norway, Peru, the Philippines, Poland, Portugal, the Republic of Korea, the Russian Federation, Senegal, Singapore, South Africa, Spain, St. Kitts & Nevis, Sweden, Turkey, Ukraine, the United Kingdom, the United States, the European Commission, BIMCO, CIRM, IALA, ICS, IFSMA, IHMA, IHO, IMPA, IMRF, IMSO, the Nautical Institute, OCIMF and WMO.

4 COMSAR 17 considered documents COMSAR 17/11 and COMSAR 17/11/1 (Norway), containing the Report of the Correspondence Group on e-navigation and noted document COMSAR 17/INF.6 (Norway), containing information on a workshop on information exchange and communications in the Polar and other remote regions, and expressed general appreciation for the work carried out by the CG. STW 44 considered document STW 44/6 (Norway), containing the Report of the Correspondence Group on e-navigation and noted the ongoing processes of Cost/Benefit and Risk Analysis for e-navigation, and agreed that the Human Element Analysing Process (HEAP) would benefit from a general review to ensure that it is fit for wider use. Accordingly the STW Sub-Committee invited interested Member Governments to submit a proposal for reviewing the HEAP as an unplanned output to MSC 93.

Terms of reference

5 The CG on e-navigation was re-established by NAV 58 with the following terms of reference (ToR):

.1 review the preliminary list of potential e-navigation solutions (NAV 58/WP.6/Rev.1, annex 2) and, if necessary, prepare additional potential e-navigation solutions in order to address all gaps identified in annex 1 to NAV 58/WP.6/Rev.1;

.2 finalize the Cost Benefit and Risk Analysis, with a view to final approval by NAV 59, using as input documents namely, the final list of gaps and the preliminary list of potential e-navigation solutions that would cover all the identified gaps and taking into account the Formal Safety Assessment process and the Methodology of the Human Element Analysing Process (NAV 58/6, annex 3);

.3 further develop:

   .1 the detailed ship and shore architecture;

   .2 the concept of Maritime Service Portfolios; and

   .3 the draft Strategy Implementation Plan;

.4 consider documents NAV 58/6/1 and NAV 58/6/3 (Germany) and provide comments and recommendations, as appropriate;

.5 consider the issue of software quality assurance, taking into account document NAV 58/6/4 (Republic of Korea), and provide comments and recommendations, as appropriate;

.6 progress the development of draft Guidelines for usability evaluation of navigational equipment and its harmonization with the HEAP, taking into account documents NAV 58/6/6 and Corr.1, NAV 58/INF.12 and NAV 58/INF.13 and Corr.1 (Japan) and NAV 58/INF.10 (Australia);

.7 progress the development of draft Guidelines for the harmonization of test beds, taking into account document NAV 58/6/8 (Republic of Korea);

.8 submit reports to COMSAR 17 and STW 44 raising specific questions, as required, that should be addressed by the STW and COMSAR Sub-Committees; and

.9 submit a consolidated progress report to NAV 59.

A general description of the concept of e-navigation

6 The vision of e-navigation was defined in MSC 85/26, annex 20, paragraph 4, and describes the onboard, ashore and communication elements as follows:

- ***On board*** *– navigation systems that benefit from the integration of own ship sensors, supporting information, a standard user interface, and a comprehensive system for managing guard zones and alerts. Core elements of such a system will include, actively engaging the mariner in the process of navigation to carry out his/her duties in a most efficient manner, while preventing distraction and overburdening;*

- ***Ashore*** *– the management of vessel traffic information and related services from ashore enhanced through better provision, coordination, and exchange of comprehensive data in formats that will be more easily understood and utilized by shore-based operators in support of vessel safety and efficiency; and*

- ***Communications*** *– An infrastructure providing authorized seamless information transfer on board ship, between ships, between ship and shore and between shore authorities and other parties with many related benefits.*

7 The purpose of e-navigation is to enhance berth-to-berth navigation and related services for safety and security at sea, and protection of the marine environment. E-navigation seeks to enhance maritime safety through simplification and harmonization, and facilitate and increase efficiency of maritime trade and transport by improved information exchange.

8 The emerging e-navigation solutions, based on identified user needs, focus on efficient transfer and harmonization of marine information/data between all appropriate users (ship-ship, ship-shore, shore-ship and shore-shore). These solutions should promote analysis and the workable and practical use of the information/data on board. The combination of solutions should ensure a holistic approach to the interaction between shipboard and shore-based users.

9 The e-navigation concept is based on structured and verified information as an enabler for improved decision support. It relies on a largely automated communication infrastructure, seamlessly connecting ship and shore. The e-navigation architecture is based on a Common Maritime Data Structure (CMDS), and when relevant uses the IHO Geospatial Standard for Hydrographic Data, S-100.

Reviewing the preliminary list of potential e-navigation solutions

10 The CG has reviewed the preliminary list of potential e-navigation solutions (NAV 58/WP.6/Rev.1) and has also considered additional potential e-navigation solutions in order to address all gaps as identified in annex 1 to NAV 58/WP.6/Rev.1.

11 A large number of solutions have been further reviewed, broadening the scope to such an extent that it became necessary to focus on a number of generalized and prioritized solutions. This was in order to describe a well-defined and manageable starting point for the draft Strategy Implementation Plan (SIP) for e-navigation.

12 In light of this, it has been necessary to integrate and prioritize the list of solutions given in NAV/58/WP6/Rev.1, annex 2, to a maximum of five main practical solutions, covering ship-ship, ship-shore, shore-ship and shore-shore users. These solutions focus on workable and efficient transfer of marine information/data between ship and shore and vice versa.

13 Accordingly, the CG focused its attention on the following criteria:

.1 seamless transfer of data between various equipment on board;

.2 seamless transfer of electronic information/data between ship and shore and vice versa;

.3 the work should be based on systems that are already in place (according to the already adopted e-navigation strategy (MSC 85/26/Add.1, annex 20) and development of potential future carriage requirements should therefore be strictly limited;

.4 the CG should not concentrate on determining causes of marine casualties; and

.5 the list of potential e-navigation solutions should be limited solely to achieve 1 and 2 above.

14 There were views within the CG that whilst every effort should be made to use equipment and systems already in place, limiting as much as practicable the requirement for new equipment carriage requirements, there could be a need for new high-level, functional and goal based equipment performance standards.

15 The CG prioritized the following five main potential e-navigation solutions:

S1: improved, harmonized and user-friendly bridge design;

S2: means for standardized and automated reporting;

S3: improved reliability, resilience and integrity of bridge equipment and navigation information;

S4: integration and presentation of available information in graphical displays received via communication equipment; and

S9: improved Communication of VTS Service Portfolio.

These five prioritized potential e-navigation solutions are the basis for the Risk and Cost-Benefit Analyses.

16 The e-navigation solutions S2, S4 and S9 focus on efficient transfer of marine information/data between all appropriate users (ship-ship, ship-shore, shore-ship and shore-shore). Solutions S1 and S3 promote the workable and practical use of the information/data on board. The combination of these solutions ensures a holistic approach to the interaction between shipboard and shore-based users.

17 The prioritization and limiting of solutions should not be seen as a reduction in the ambition level required for e-navigation. The remaining solutions should be assigned to a roadmap for ongoing review and implementation as part of the e-navigation SIP.

18 The Sub-Committee is invited to endorse the prioritized five potential main solutions based on the reviewed preliminary list of potential e-navigation solutions.

Finalizing the Risk and Cost-Benefit Analysis

19 The CG has finalized the Risk and Cost-Benefit Analysis, with a view to obtaining final approval by NAV 59, taking into account the Formal Safety Assessment (FSA) process and the methodology of the HEAP (NAV 58/6, annex 3).

20 The five main prioritized solutions have undergone Risk and Cost-Benefit assessments for decision-making as per the *Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process*.

21 The five main prioritized solutions have further been used as the basis for creating of Risk Control Options (RCOs) that were believed to be tangible and manageable in terms of quantifying the risk-reducing effects and the related costs.

22 A high-level FSA has been performed in order to evaluate possible RCOs for new ships covering the following ship types:

- general cargo ships,
- oil tankers,
- passenger ships, and
- offshore ships and other ships (not fishing).

23 The development of the e-navigation concept was based on the prevalence of human error as a contributing cause in the majority of collisions and groundings (MSC 85/26/Add.1, annex 20, paragraph 3.2). Therefore, the scope of the e-navigation RCOs is limited to addressing these accident categories.

24 The risk reducing effect as part of the Cost-Benefit Analysis was estimated by a group of experts based on their nautical experience at sea and their knowledge about maritime systems and services. Their work is based on the identified and agreed user needs.

25 The basis for the recommendations given in this study is the following:

- with respect to safety, an RCO is considered cost-effective if the GrossCAF (Gross Cost of Averting a Fatality) is less than US$6.24 million. This is the value commonly used in all decisions made following the FSA studies submitted to IMO, and

- with respect to safety, an RCO is also considered cost-effective if the NetCAF (Net Cost of Averting a Fatality) is less than US$6.24 million.

26 The study demonstrates that the following RCOs provide cost-effective risk reduction in a cost-effective manner:

RCO 1: integration of navigation information and equipment including improved software quality assurance;

RCO 2: bridge alert management;

RCO 3: standardized mode(s) for navigation equipment;

RCO 4: automated and standardized ship-shore reporting;

RCO 5: improved reliability and resilience of onboard PNT systems;

RCO 6: improved shore-based services; and

RCO 7: bridge and workstation layout standardization.

27 Whilst the Cost-Benefit Analysis has considered the RCOs separately, for implementation, it is important to recognize that there are clear linkages between them. The FSA has demonstrated that there are improvements to the bridge systems including layout, integration and standardization which are cost-effective. It could be argued that RCO 1, RCO 2, RCO 3, RCO 5 and RCO 7 will also make familiarization and training easier for crew transferring between ships and thus lower the associated costs for the shipowner or operator.

28 In addition, a standardized system for transfer of information and data between ship and shore and vice versa would potentially make RCO 6 and RCO 4 more cost-effective. The system should make transfer of broad datasets feasible and practical and there are, at present, several options for accomplishing this with the current communication channels.

29 The Sub-Committee is invited to endorse the finalized Risk and Cost-Benefit Analysis with the five prioritized main solutions and the seven corresponding RCOs, as per the *Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process*.

Capturing lessons learned

30 The CG recognizes that whilst the finalized Risk and Cost-Benefit Analyses are the agreed and recognized analysis tools to enable the work on e-navigation to commence, the Organization may consider the need for new or alternative analysis tools that could better evaluate the benefits of e-navigation solutions, such as:

- improved efficiencies,
- reduced duplication of systems and inappropriate or excessive workload,
- meeting the demands of future navigation challenges,
- establishing an intelligent infrastructure for future maritime e-navigation solutions, and
- proactive measures to support sustainability of oceans and shipping.

31 The Sub-Committee is invited to provide comments on whether the SIP should include a potential future need to use additional and/or alternative analysis tools.

Further development of the detailed ship and shore architecture

32 The CG has received inputs from Member States on the further development of detailed ship and shore architecture, as set out in annex 2. This development should be in accordance with the approved overarching e-navigation architecture and the agreed recommendations of the FSA. One Member State was of the opinion that this development is premature at this time, whilst other Member States were of the view that commencing work on this is not premature. Additional e-navigation solutions could also require adjustments to the detailed architecture.

33 Annex 2 gives examples of technical e-navigation infrastructure, based on prioritized main solutions, which might fit in to the future detailed ship-shore architecture.

34 The Sub-Committee is invited to consider the possible use of the examples of technical e-navigation infrastructure as the basis for the development of a more detailed ship-shore architecture, and provide comments, as appropriate.

Further development of the concept of Maritime Service Portfolios

35 A "Maritime Service Portfolio (MSP)" defines and describes the set of operational and technical services and their level of service provided by stakeholders in a given sea area, waterway, or port, as appropriate. An MSP may also be construed as a set of "products" provided by a stakeholder.

36 Several elements of the MSP concept could be examples that fit with Solution 9, which describes the Improved Communication of a VTS Service Portfolio. The MSPs could provide potential opportunities for digital information and communication services on board and ashore. The development of MSPs will require a communication infrastructure capacity that can provide information services. The CG has noted that elements of the MSPs are sometimes organized differently in the different countries. In the future as technology and opportunity allows it may for example be advantageous to consider combining some MSP elements such as MSI, hydrographic and meteorological services.

37 Examples of elements of MSPs include:

- (MSP 1) VTS Information Service (IS);
- (MSP 2) VTS Navigation Assistance Service (NAS);
- (MSP 3) VTS Traffic Organization Service (TOS);
- (MSP 4) Local Port Service (LPS);
- (MSP 5) Maritime Safety Information (MSI) service;
- (MSP 6) pilotage service;
- (MSP 7) tugs service;
- (MSP 8) vessel shore reporting;

- (MSP 9) remote monitoring of ships systems;
- (MSP 10) Telemedical Maritime Assistance Service (TMAS);
- (MSP 11) Maritime Assistance Service (MAS);
- (MSP 12) nautical chart service;
- (MSP 13) nautical publications service;
- (MSP 14) ice navigation service;
- (MSP 15) Meteorological information service;
- (MSP 16) real-time hydrographic and environmental information services; and
- (MSP 17) Search and Rescue (SAR) Service.

38 The CG had some opinions on the content of particular MSPs. Some Member States' view was that the provision of AtoN, VTS, tugs and pilotage were all services that assist in the process of safe berth to berth navigation. One Member State felt that MSP9 was out of the scope of e-navigation development.

39 Previous work on MSPs considered the following operational areas (NAV 57/6, paragraph 24):

a. harbour operations;
b. operations in coastal and confined or restricted waters;
c. transocean voyages;
d. offshore operations; and
e. operations in Arctic, Antarctic and remote areas.

40 A description of the preliminary MSPs can be found in annex 3.

41 The Sub-Committee is invited to review the preliminary list of MSPs contained in annex 3 and provide comments, as appropriate.

Further development of the draft Strategy Implementation Plan (SIP)

42 In accordance with the work program on e-navigation (MSC 86/23/4), the SIP should at least include:

a) identification of responsibilities to appropriate organizations/parties;

b) transition arrangements;

c) a phased implementation schedule along with possible roadmaps;

d) priorities for deliverables, resource management and a schedule for implementation and the continual assessment of user needs;

e) proposals for a systematic assessment of how new technology can best meet defined and evolving user needs;

f) a plan for the development of any technology and institutional arrangements necessary to fulfill the requirements of e-navigation in the longer term;

g) proposals on public relations and promotion of the e-navigation concept to key stakeholder groups; and

h) identification of potential sources of funding for development and implementation, particularly for developing regions and countries and of actions to secure that funding.

43 In general terms, the SIP should set in place the foundation stones for the IMO-led development of e-navigation. It should be a road map for the next steps, which would include possible changes to regulation enabling appropriate technical solutions. In order to ensure global implementation, the CG has noted that the implementation plan should identify responsibilities to the appropriate parties – IMO, other international organizations, States, users and industry – as well as timelines for implementation actions and reviews (MSC 85/26/Add.1, annex 20, paragraph 9.8). Therefore, the SIP should:

- outline the steps that will be needed to bring about marine navigation systems that are increasingly more integrated, resilient and usable;

- result in the exchange of information and data between sensors, equipment and systems that have a common logic (e.g. including the use of the IHO S-100 Standard);

- include a process for the systematic assessment of test-bed results (e.g. annex 5) to inform the best fit for future user requirements and emerging technologies; and

- provide a focus on the future of marine communications infrastructure so that e-navigation solutions may be realized.

44 The CG has recognized that the revision, updating or development of training elements should be considered after having a clear understanding of the potential technical, operational and regulatory e-navigation solutions (STW 43/14, paragraph 6.13.2). Information contained in the SIP might enable the consideration of training elements.

45 Document MSC 85/26/Add.1 describes an initial framework for the implementation of e-navigation. This information has been further developed to assist in preparing the SIP and is contained in annex 6. Due to the limited time available to the CG, the CG has not considered annex 6. However, the coordinator has invited members of the CG to provide submissions to NAV 59 commenting on the proposed draft SIP framework. The proposed SIP framework will require ongoing development by the Sub-Committee.

Communication Strategy

46 MSC 86/23/4 states that the SIP should include a section regarding "Proposals on public relations and promotion of e-navigation to key stakeholder groups". This task could be approached through the development of a Communication Strategy, as a part of the SIP (SIP 7). The intention should be to communicate systematically and effectively when implementing e-navigation.

47 The Communication Strategy should be based on solutions and stakeholders considered in the SIP, and should be aligned with recommendations and guidance provided in document NAV 57/6, annex 3. A clear and well-defined Communication Strategy should cover the goals and consequences of e-navigation. This could be used as the basis for public relations and engagement, facilitating a common, systematic and integrated approach for communicating the benefits of e-navigation to relevant stakeholders.

48 The aim of the Communication Strategy should be to improve the overall knowledge of the e-navigation concept among relevant stakeholders, and garner wide support for the initiative.

49 Important communication objectives could be:

- promotion of e-navigation to relevant stakeholders;
- attract interest and stakeholders;
- establish a basis for sufficient participation, and ensure that e-navigation is understood by member States, organizations, industries and other stakeholders; and
- support a convergence of initiatives.

50 Communicating the outcome, value and benefits of e-navigation to relevant stakeholders is an integral part of the implementation process.

51 The Communication Strategy should ensure that systematic communication and public relations efforts are carried out using a wide range of different communication channels, both digital and conventional.

52 The Communication Strategy should ensure that Member States develop customized communication plans based on relevant stakeholder needs, and include guidance on how to communicate with relevant stakeholders.

53 Customized communication plans should include a description of relevant stakeholder groups, key messages for each group, appropriate channels, timing/deadlines, roles and responsibilities. A proposed template for developing a practical communication plan should be included in the SIP.

54 E-navigation stakeholders have been identified based on the list provided in document MSC 85/26, annex 2, as well as through stakeholder analysis. The stakeholders have been grouped into four different levels and relevant key messages will be identified for each stakeholder level, to ensure that communication measures are targeted and relevant. These key messages could be presented at a later stage, and could be used prior to and during the implementation of e-navigation to promote and gather support for the initiative.

Stakeholder group	Examples of stakeholders
1. Supranational organizations	• Multinational organizations such as IMO, other UN bodies, NATO, EU and other similar organizations
2. State	• Flag States • Coastal States • Port States
3. Branch/industry	• Branch organizations such as shipowner associations and branch organizations for equipment manufacturers • Equipment manufacturers, service providers and shipbuilders • Maritime advisory firms and superintendents
4. Users	• Shipborne: All different types of ships, both commercial and non-commercial. • Shore-based users such as VTS, Pilots, Meteorological, hydrographic institutions/service providers, ship handling agencies, and other ports

Funding/financing

55 MSC 86/23/4 states that the SIP should include a section regarding "Identification of potential sources of funding for development and implementation, particularly for developing regions and countries and of actions to secure that funding" (SIP 8).

56 Financing of international projects, such as Marine Electronic Highways, usually comprises two components split between in-kind and in-cash contributions, the former being normally provided by participating government agencies and the latter by donors operating under the aegis of an institution such as the World Bank. Be they in-kind or in-cash, several financing options have been identified:

- National governments to front expenditure financed over general budgets.

- Investments made by international financing Institutions such as banks or regional development banks. These investments are in principle loans to the country, however, such associations also provide important consultancy. The World Bank assists with identifying and negotiating with Donors and provides contract procedures and supervises the project management.

- Aid or investments made by one/some selected nations in another nation due to commercial motives, such as investment in the Gulf of Aden by large maritime nations to ensure safety of commercial ships. Such investments could also be combined with financing managed by the World Bank. Examples of such coordinated funding includes:

    - The demonstration phase of the Marine Electronic Highway project in Strait of Malacca (terminated 1 May 2013) where the preparatory phase (Block B activities) was financed in-cash by GEF/World Bank and the implementation phase was jointly financed by the Republic of Korea, GEF/World Bank and IMO.

    - The Western Indian Ocean MEH (terminated 31 December 2012) where the preparatory phase (Block B activities) was financed in-cash by GEF/World Bank and the implementation phase was jointly financed by the EU, GEF and stakeholders (INTERTANKO, etc.) under the aegis of the World Bank.

57 The Sub-Committee is invited to further develop the draft SIP, taking into account the information provided on the Communication Strategy and funding/financing.

Documents NAV 58/6/1 and NAV 58/6/3

58 The CG has noted the information provided in NAV 58/6/1 about a resilient and integrated Position, Navigation and Timing (PNT) system as part of Integrated Navigation Systems (INS). The aim being to, support meeting e-navigation user needs, such as improving integrity monitoring and indication of position reliability. This concept takes into account the enhancement of radio navigation equipment and fits within the modular structure of INS.

59 The CG has further noted trials under the ACCSEAS (Accessibility for Shipping, Efficiency Advantages and Sustainability) project which have demonstrated a prototype resilient PNT system. The system made use of GPS and alternative technologies to enable an automatic and seamless provision of PNT data in event of GPS loss or failure.

60 The CG has also noted the information provided in document NAV 58/6/3 about a procedure to determine RCOs for the Risk and Cost-Benefit Analysis on the basis of goal based solutions determined from the gap analysis

61 The Sub-Committee is invited to note that there is an identified user need for resilient PNT for the implementation of e-navigation and that technical solution are continuing to be developed.

Software Quality Assurance

62 In document NAV 58/6/4, the Republic of Korea recommends that the development and implementation of e-navigation should also consider quality assurance. Similar to the recommendation made in document COMSAR 14/12, both navigation and communications equipment should be able to reliably indicate that they are functioning correctly. In order for this to occur, high-quality software that is both stable and complete would be needed to be installed and used. To do this for both shipborne and shore-based systems – in a harmonized manner – practical guidelines would be needed to be developed and agreed. Document NAV 58/6/4, paragraph 16.7 invites the Sub-Committee to develop SQA guidelines and best practices related to e-navigation implementation.

63 The CG has considered the issue of Software Quality Assurance (SQA), taking into account document NAV 58/6/4 (Republic of Korea).

64 The CG notes that high quality software that is stable and reliable would need to be used in the marine navigational and communication equipment installed onboard ships and in related shore facilities. A mechanism is required to keep software up-to-date and ensure there are provisions for updates and bug fixes. Additionally, SQA should take into account best practice, so as to achieve harmonization. The CG also noted SN.1/Circ.266/Rev.1 (7 December 2010) on Maintenance of electronic chart display and information systems (ECDIS) software, including MSC.1/Circ.1389 relating to Guidance on procedures for updating shipborne navigation and radiocommunication equipment, which emphasizes the above points.

65 As bridge systems become more integrated, there would be an increasing need for SQA. RCO 1 "Integration of navigation information and equipment including improved SQA" includes performing improved software testing of bridge systems as part of their development. The software testing should consist of both functional and non-functional testing to ensure optimal performance of the equipment in all situations.

66 The software quality standards ISO/IEC 9126-1, ISO 90003 and ISO/IEC 12207 describe a number of quality characteristics. Software safety is about avoiding potential harm caused by software, and should be part of SQA. As software may be found in many e-navigation solutions, and the quantity of software would increase with automation and with inter-connectivity, SQA could be considered as an important element in the implementation of e-navigation solutions, and the CG supports, in general, the content of the document NAV 58/6/4 (Republic of Korea).

67 During NAV 58 (NAV 58/WP.6/Rev 1, paragraphs 3.24 to 3.26), it was noted that one of the identified gaps had been amended to include the need for an updating regime for software driven applications within the e-navigation framework, and recognized the importance of SQA in the process of e-navigation. Some members of the CG felt that there were links between the usability evaluation of navigational equipment, SQA and human element considerations. As such, the CG recognized there is a link between SQA and Human Centred Design (HCD).

68 The Sub-Committee is invited to consider the inclusion of Software Quality Assurance, including a software updating regime, within the overarching Human Centred Design framework (see paragraphs 69 to 74 below).

Guidelines for usability evaluation of navigational equipment and its harmonization with the HEAP

69 The CG has progressed the development of draft guidelines for usability evaluation of navigational equipment and its harmonization with the HEAP, taking into account documents NAV 58/6/6 and Corr.1, NAV 58/INF.12 and NAV 58/INF.13 and Corr.1 (Japan) and NAV 58/INF.10 (Australia).

70 Following initiatives led by Japan, in which Australia and other Member States and observers participated, e-navigation work on usability continued with an international workshop in January 2012 in Sweden of which the outcome was provided to the CG. A second international workshop, held in March 2013 in Australia, further discussed usability issues, to help ensure that any future e-navigation systems address usability requirements. The outcome from this workshop has been considered by the e-navigation CG, with a majority commenting favorably on it, as an input to the development of guidelines on usability evaluation.

71 One of the important principles of usability, as described within the International Standard Organization (ISO), is that of Human-Centred Design (HCD). HCD describes the methodology used to implement usability goals and to assess the result (it is interchangeably referred to as User Centred Design in some references). The premise of HCD is that designable components of a system need to be fitted to the characteristics of the intended user(s), rather than selecting and/or adapting humans to fit the system, product or service.

72 In addressing the issue of usability, the CG has considered and agreed on an initial draft guideline on Human Centred Design (HCD) for e-navigation equipment and systems (see annex 4). The application of HCD could assist in the proper consideration of human element issues, and along with the use of test beds help ensure practical and usable solutions. Allied to this is the importance of software quality assurance in navigation equipment and systems.

73 The CG developed draft guidelines on HCD, as set out at annex 4, embodying a holistic approach to design that includes achieving usability, its evaluation and SQA. The evaluation of usability is assessed within HCD using the most appropriate Test, Evaluation and Assessment process (TEA). TEA is a fundamental element of the overall HCD process.

74 The Sub-Committee is invited to note the progress that has been made and to review the draft guidelines on Human Centred Design for e-navigation equipment and systems with a view to formalizing the use of Human Centred Design within the e-navigation Strategy Implementation Plan.

Harmonization of test-beds

75 The CG has progressed the development of draft guidelines for the harmonization of test-beds, taking into account document NAV 58/6/8 (Republic of Korea).

76 Several test-beds for e-navigation applications have previously been set up and it is necessary to harmonize the testing of e-navigation solutions, systems and services. It is the intention of the CG that the further development of the guidance should interface with the development of the SIP to ensure that test-beds are identified, assessed and addressed through a goal-based approach. The link with the HCD guidance should be considered as

well. Furthermore, test-beds could provide a useful opportunity for early implementation and user testing, evaluation and assessment (i.e. TEA) while the e-navigation concept continues to evolve. The CG will also emphasize that guidelines should not limit the potential of innovative initiatives.

77 Proposed preliminary guidelines on e-navigation test-beds is described in annex 5.

78 The Sub-Committee is invited to review the preliminary guideline on e-navigation test-beds (annex 5) and provide comments, as appropriate.

Previous and upcoming test-beds:

79 Norway has hosted a workshop on information exchange and communications in the polar and other remote regions. The workshop was held in Haugesund, Norway, on 17 and 18 October 2012. Norway has conducted a test-bed to evaluate the performance of communications in the Arctic region. This involved tracking a vessel during the course of its voyage in the Arctic (using a specially programmed box linked via satellite to a base station) and evaluating its access to communication links. For more information, see document COMSAR 17/INF.6.

80 An upcoming test-bed is planned in Chile on 21-22 October 2013 with the theme Search and Rescue (SAR) and e-navigation. The topic of the workshop will be related to an electronic simulation of a Search and Rescue (SAR) situation, where LRIT and satellite AIS data will be received. The exercise will be executed with data adapted to the IHO S-100 standard. In addition, during the workshop SAR needs and challenges in relation to communication systems in remote areas will be discussed.

81 The International Harbour Masters' Association (IHMA), in collaboration with key maritime industry organizations, has developed a standard format for the presentation and reference of nautical port information, which is presented on the web-based AVANTI (Access to Validated Nautical Information) portal. This initiative has been developed in conjunction with the United Kingdom Hydrographic Office. AVANTI is an online system, aligning with the IHO S-100 standard. AVANTI provides relevant (Admiralty ARCS) charts, the easy storage and retrieval of associated documents and images, details of admission policies for the port as a whole as well as for specific sections and waterways. Substantial work has been undertaken to develop a common set of terminology relating to ports and their operation. AVANTI enables harbor masters to easily manage their nautical port information, providing accurate and timely information to a world-wide audience. The ready availability of reliable, accurate and up-to-date information supports increased port efficiency, improved berth-to-berth passage planning, enhanced port safety and reduced emissions from ships in port. AVANTI is currently in trial with a limited number of ports, including Port of Rotterdam. A more extensive test of the system using the IHO S-100 standard is planned for 2014 in various regions World-wide.

82 E-navigation test-bed with trials incorporating advanced technologies, standards and Maritime Service Portfolio (MSP), including Earth Observation based services is also planned for 2014, as part of a potential project on optimizing situational awareness in the Arctic through integrated space technologies (ARCTICSAT). The trials could provide potential opportunities for digital information and communication services on board and ashore in polar regions, taking into account the IHO S-100 standard.

83 The CG noted information on e-navigation test-beds available on IALA's e-navigation.net website.

Action requested of the Sub-Committee

84 The Sub–Committee is invited to:

1. endorse the prioritized five potential main solutions based on the reviewed preliminary list of potential e-navigation solutions;

2. endorse the finalized Risk and Cost-Benefit Analysis with the five prioritized main solutions and the seven corresponding RCOs, as per the *Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process* (annex 1);

3. provide comments on whether the SIP should include a potential future need to use additional and/or alternative analysis tools;

4. consider the possible use of the examples of technical e-navigation infrastructure as the basis for the development of a more detailed ship-shore architecture, and provide comments, as appropriate (annex 2);

5. review the preliminary list of Maritime Service Portfolios contained in annex 3 and provide comments, as appropriate;

6. note that there is an identified user need for resilient PNT for the implementation of e-navigation and that technical solution is continuing to be developed;

7. consider the inclusion of Software Quality Assurance, including a software updating regime, within the overarching Human Centred Design framework (see paragraphs 69 to 73);

8. note the progress that has been made and to review the draft *Guidelines on Human Centred Design for e-navigation equipment and systems* (annex 4), with a view to formalizing the use of Human Centred Design within the e-navigation Strategy Implementation Plan;

9. review the preliminary guideline on e-navigation test-beds and provide comments, as appropriate (paragraph 77 and annex 5); and

10. further develop the draft SIP (annex 6), taking into account the information provided on the Communication Strategy and funding/financing.

***

ANNEX 1

FORMAL SAFETY ASSESSMENT (FSA), INCLUDING THE FINALIZED RISK AND COST-BENEFIT ANALYSIS

1 Summary

A high-level Formal Safety Assessment (FSA) has been performed in order to evaluate possible Risk Control Options (RCOs) for new ships covering the following ship types:

- cargo carrying ships (except tanker for oil);
- tanker for oil;
- passenger ships; and
- offshore ships and other work ships (except fishing).

The e-navigation concept was established based on the fact that about 60 per cent of all collisions and groundings are caused by human error (MSC 85/26/Add.1, annex 20, paragraph 3.2). Therefore, the scope of the e-navigation project limits the accident categories under review to collision and grounding.

Seven RCOs were based on the scope of e-navigation, five prioritized solutions and the solution's relevance towards identified risks (Chapter 0). Please note that even though the RCOs are based on the five prioritized categories of solutions, not all sub-solutions as per [8], are necessarily covered by the RCOs.

The basis for the recommendations given in this study is the following:

- with respect to safety, an RCO is considered cost-effective if the GrossCAF (Gross Cost of Averting a Fatality) is less than US$6.24 million. This value is derived according to the method in the FSA Guidelines, see chapter 0; and

- with respect to safety an RCO is also considered cost-effective if the NetCAF (Net Cost of Averting a Fatality) is less than US$6.24 million.

The study demonstrates that the following RCOs are providing risk reduction in a cost-effective manner:

- RCO 1: Integration of navigation information and equipment including improved software quality assurance
- RCO 2: Bridge alert management
- RCO 3: Standardized mode(s) for navigation equipment
- RCO 4: Automated and standardized ship-shore reporting
- RCO 5: Improved reliability and resilience of onboard PNT systems
- RCO 6: Improved shore-based services
- RCO 7: Bridge and workstation layout standardization.

2 Definition of the problem

2.1 The problem to be assessed

The following is an excerpt from "Strategy for the development and implementation of e-navigation" given in [1]:

> "*Rising trends of marine accidents both in terms of numbers and costs are mainly associated with collisions and groundings. There are numerous examples of collisions and groundings that might have been avoided had there been suitable input to the navigation decision-making process; and*

Research indicates that around 60 per cent of collisions and groundings are caused by direct human error."

2.2 The e-navigation concept

The scope of the e-navigation project is defined as "*the harmonized collection, integration, exchange, presentation and analysis of marine information on board 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."* [1].

Based on identified user needs, the project has established strategic key elements and potential categories of solutions for improving navigational safety and efficiency on board and ashore, and related communications between the two. The potential categories of solutions will undergo risk and cost benefit assessments for decision-making as per the *Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process* [2], and recommendations will be presented in the final e-navigation Strategy Implementation Plan [3].

2.3 Objective

The objective of this study is to identify relevant hazards pertaining to navigation, to quantify relating safety risks, and to identify and prioritize a set of Risk Control Options (RCOs) deemed to reduce said risks on *future new ships,* i.e. not retroactive on the existing fleet. The objective includes a Cost-Benefit Analysis.

3 Background information

For application in the subsequent steps of the study, a generic risk model is defined to describe the attributes which are common to all relevant accidents and ships or areas relevant to the problem in question.

In its work, the CG has agreed not to concentrate on determining cause of marine casualties.

3.1 Casualty statistics

The IHS Fairplay casualty database is considered the most complete and reliable maritime casualty data source in the world, including over 113,000 non-serious and serious casualties, as well as total losses [4]. The database contains comprehensive details of all reported serious casualties to propelled sea-going merchant ships in the world of 100 gross tons and above from 1 January 1978. Statistics from this database has been applied to represent world-wide accident statistics and ship-years for the selected ship types. The accidents recorded in database is believed not to be complete and a degree of underreporting would also underestimate the risk reduction potential.

However, the IHS Fairplay database does not contain root cause investigation, only a complementary text which is most often only a description of the initial accident. In this regard accident cause investigation statistical accident data for Norwegian waters from the Norwegian Maritime Authority (NMA) has been applied [5].

A comparison between the historical trends based on the IHS Fairplay database and the NMA statistics are analysed (see Figure 1 and Figure 4). The focus of the comparison has been on the period from 2001 to 2010 which have been used in the risk analysis (see chapter 6). Both the NMA and IHS Fairplay statistics shows an increasing trend over this period, even though the increase starts somewhat later in the IHS Fairplay dataset. In order to align the datasets of the two data sources, similar filters have been applied to the NMA statistics as for the IHS Fairplay statistics.

In the following the distribution of accident causes from NMA is applied to the world fleet. Even though the trends of accidents are similar in the two sets of statistics, uncertainties are introduced in the assessment by use of the NMA statistics.

3.2 Ship types

A selection of ship types has been included to represent the world fleet in the study. The following ship types from the IHS Fairplay database are included in the risk model:

Ship type	IHS Fairplay code	Limitation
Cargo carrying ships (except Tanker for oil)	A	> 500 gross tons
Tanker for oil	A13	> 500 gross tons
Passenger ships	A32, A36 and A37	-
Offshore ships and other work ships (except fishing)	B2 and B3	-

* Tanker for oil has only been separated out for the environmental risk.

Table 1: Ship types included in the dataset

Exclusions from the dataset are based on general exceptions in the SOLAS Convention [7]. Yachts, fishing ships, non-propelled crafts and cargo ships below 500 gross tons are excluded.

3.3 Accident categories

Rising trends of marine accidents both in terms of numbers and costs are mainly associated with collisions and groundings. (MSC 85/26/Add.1, annex 20, paragraph 3.1).

There are several additional maritime accident types, as seen in Table 3. However, the risk analysis is based on the navigational accidents categorized by and limited to collisions and groundings. It could be argued that the accident category Contact, as defined in Table 3, should be included as a navigational accident. However, the e-navigation project was established based on the fact that 60 per cent of all collisions and groundings are caused by human error (MSC 85/26/Add.1, annex 20, paragraph 3.2). Therefore, the scope of the e-navigation project limits the accident categories under review to collision and grounding.

The navigational accident categories applied in the FSA are detailed in
Table 2.

Category number	Initial accidental event	IHS Fairplay code	Description
4	Collision	CN	Striking or being struck by another ship, regardless of whether under way, anchored or moored. This category does not include striking under water wrecks.
2	Grounding	WS	Includes ships reported hard and fast for an appreciable period of time as well as incidents reported touching the sea bottom. This category includes entanglement on under water wrecks or obstructions

Table 2: Included IHS Fairplay accident categories

Category number	Initial accidental event	IHS Fairplay code	Description
1	Foundered	FD	Includes ships which sank as a result of heavy weather, springing of leaks, breaking in two, etc., and not as a consequence of categories 2-7 or 9.
3	Contact	CT	Striking or being struck by an external substance but not another ship or the sea bottom. This category includes striking drilling rigs/platforms, docks, piers, etc. regardless of whether in fixed position or in tow.
5	Fire & Explosion	FX	Where the fire and/or explosion is the first event reported (except where first event is a hull/ machinery failure leading to fire/explosion).
6	Missing Ship	MG	After a reasonable period of time, no news having been received of a ship and its fate being therefore undetermined and is included in the Missing category on the data base together with similar cases reported by other reliable sources.
7	War Loss/Damage During Hostilities	LT	This category is intended to encompass damage or other incidents occasioned to ships by hostile acts. Also includes damages incurred by piracy attacks.
8	Hull/Machinery Damage	HM	Includes ships lost or damaged as a result of hull/machinery damage or failure which is not attributable to categories 1-7 or category 9.
9	Miscellaneous	XX	Includes ships which have been lost or damaged which, for want of sufficient information, or for other reasons, cannot be classified.

Table 3: Excluded IHS Fairplay accident categories

3.4 Historical trends

Below historical trends based on IHS Fairplay and NMA accident statistics are presented for the selected accident types and ship types.

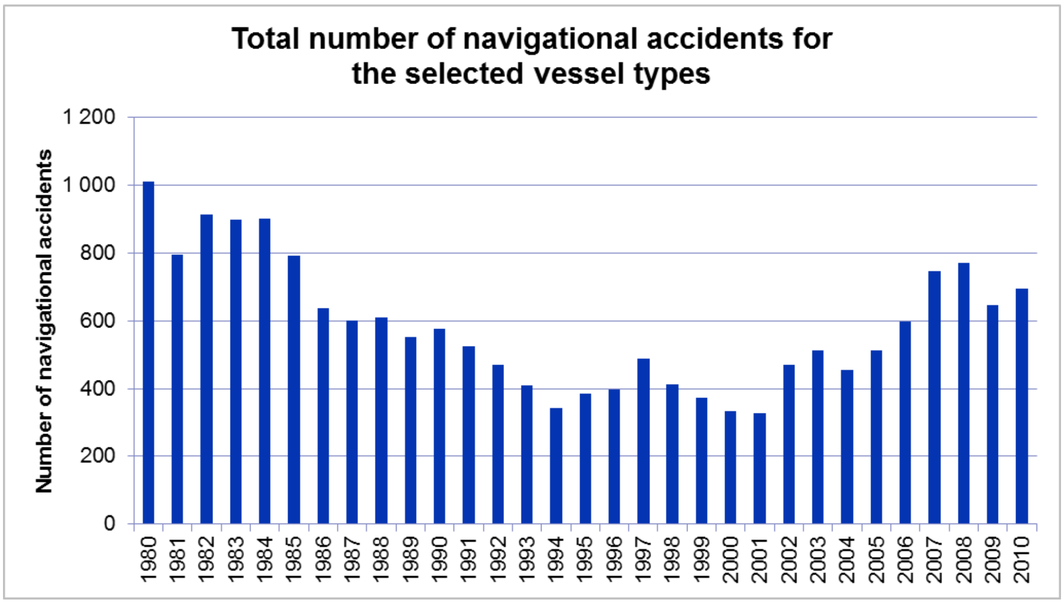

Figure 1: Total number of navigational accidents for selected ship types (IHS Fairplay)

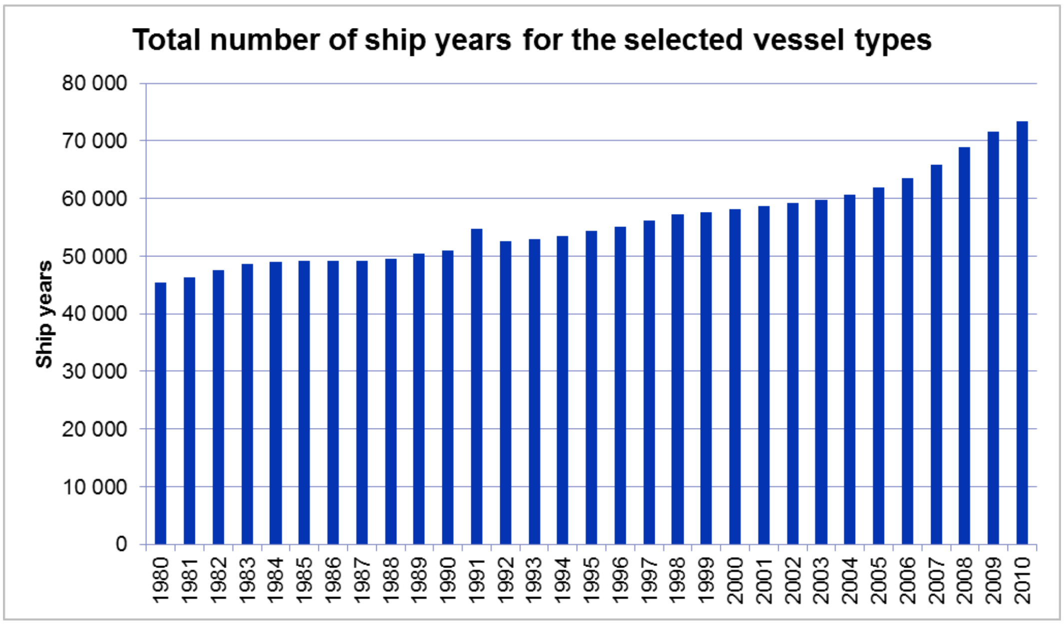

Figure 2: Total number of ship-years for the selected ship types (IHS Fairplay)

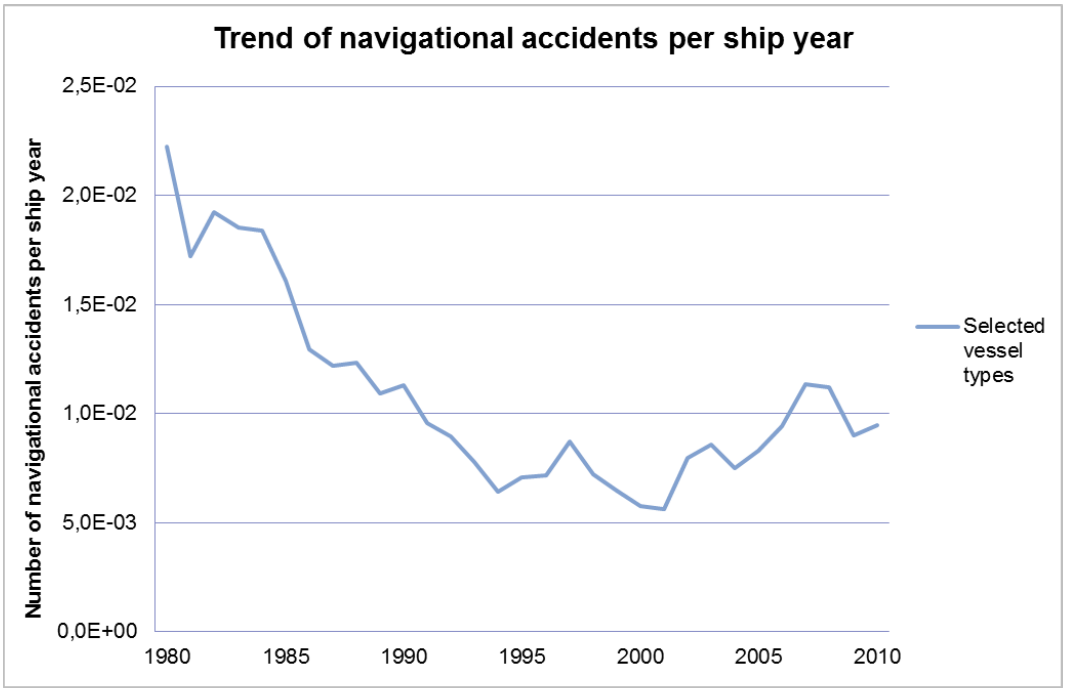

Figure 3: Trend of navigational accidents per ship-year (IHS Fairplay)

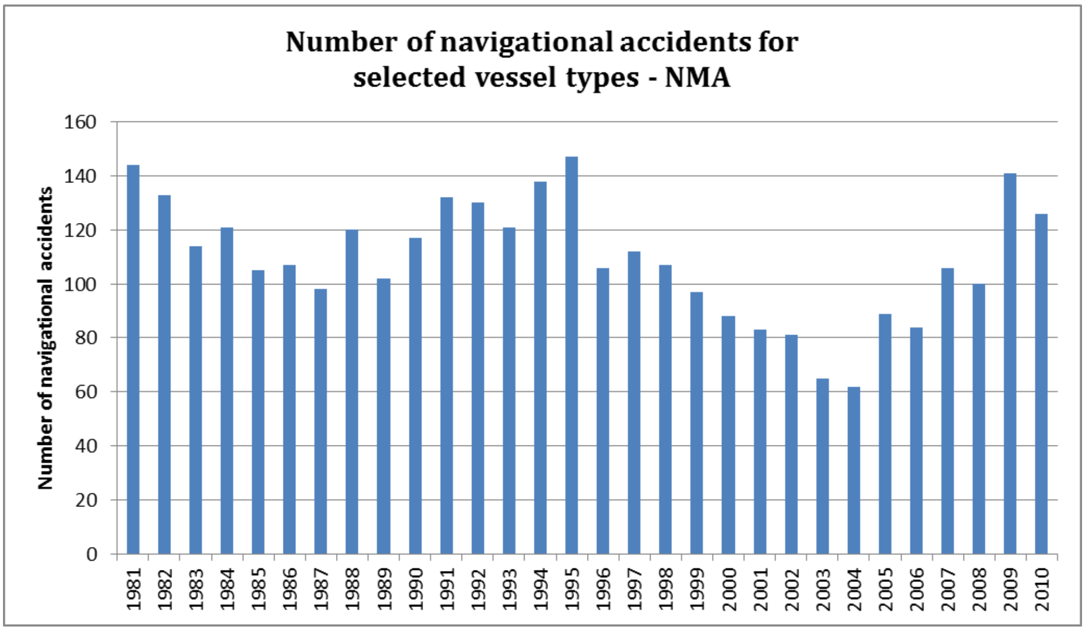

Figure 4: Total number of navigational accidents for selected ship types (NMA Database)

The number of accidental events annually from 1981 to 2010 registered in the IHS Fairplay database and the NMA database are given in Figure 1 and Figure 4 respectively (the NMA database does not have data further back than 1981). The trends differ in the years up until the early 2000s, after which both databases show rising trends. This rising trend may be in part due to an increased focus on accident reporting seen in later years [6], and both databases are considered to be more reliable in this time period compared to earlier data. Chapter 5 presents the data on accident causes retrieved from the NMA database. Despite the variations in trends in terms of number of reported accidents between the two databases, the distribution of causes is considered to be representative for both.

It should be noted that, as shown in Figure 3, accounting for the increase in ship years does not explain the rising trend in accident numbers seen in the past ten years.

3.5 Timespan

Due to the trend in the historical data the dataset has been limited to include casualties from the timespan 2001-2010. The limitation is also based on the assumption that the fleet has gone through continuous improvements over the years, and that these improvements have an impact on the casualty statistics. Therefore limiting the dataset to the last ten years will most probably provide an improved picture of the current situation pertaining to navigational risks.

3.6 Frequency development

Table 4 shows the statistics on accidents for the selected ship types, over the timespan from 2001 to 2010, retrieved from the IHS Fairplay accident database. The numbers of accidental events and loss of lives, combined with the number of ship years for each ship category, give frequencies for the accident categories as well as PLL, and are shown in Table 5 and Table 6, respectively.

Ship type	Accident category	Number of accidental events	Loss of life
Cargo ship (including tanker for oil) (351,741 ship-years – 55%)	Collision	2336	238
	Grounding	2286	200
	∑ (Navigational accident)	**4622**	**438**
	Other accidents	5133	1563
	∑ (All accident)	**9755**	**2001**
Passenger ship (67,254 ship-years – 10%)	Collision	245	53
	Grounding	321	836
	∑ (Navigational accident)	**566**	**889**
	Other accidents	1543	3166
	∑ (All accident)	**2109**	**4055**
Work ship (224.429 ship-years – 35%)	Collision	194	41
	Grounding	162	4
	∑ (Navigational accident)	**356**	**45**
	Other accidents	599	163
	∑ (All accident)	**955**	**208**

Table 4: Number of events and loss of life (IHS Fairplay)

3.7 Resulting accident frequencies

Table 5 shows resulting accident frequencies for the selected ship types over the timespan from 2001 to 2010.

The distribution of accident types is shown in Figure 5. For a generic ship, collisions and groundings account for about 44 per cent of all accidents per ship year.

Ship type	Accident category	Initial accident frequency per ship year	%
Cargo ship (including tanker for oil) (351,741 ship-years - 55%)	Collision	6.6E-03	24%
	Grounding	6.5E-03	23%
	∑ (Navigational accident)	**1.3E-02**	**47%**
	Other accidents	1.5E-02	53%
	∑ (All accident)	**2.8E-02**	**100%**
Passenger ship (67,254 ship-years – 10%)	Collision	3.6E-03	12%
	Grounding	4.8E-03	15%
	∑ (Navigational accident)	**8.4E-03**	**27%**
	Other accidents	2.3E-02	73%
	∑ (All accident)	**3.1E-02**	**100%**
Work ship (224.429 ship-years – 35%)	Collision	8.6E-04	20%
	Grounding	7.2E-04	17%
	∑ (Navigational accident)	**1.6E-03**	**37%**
	Other accidents	2.7E-02	63%
	∑ (All accident)	**4.3E-03**	**100%**
Generic ship (weighted average of ship types above)	Collision	4.3E-03	22%
	Grounding	4.3E-03	22%
	∑ (Navigational accident)	**8.6E-03**	**44%**
	Other accidents	1.1E-02	56%
	∑ (All accident)	**2.0E-02**	**100%**

Table 5: Accident frequencies

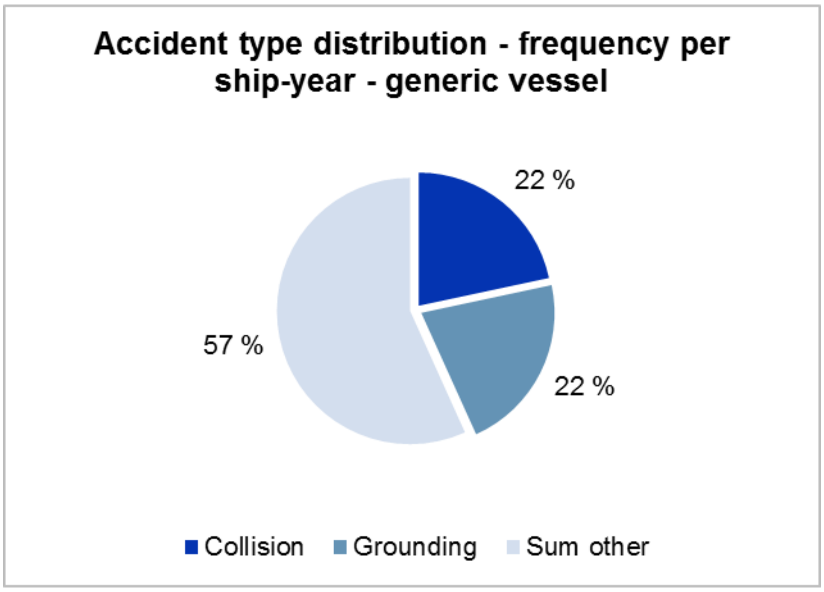

Figure 5: Distribution of accident types

4 Method of work

The study follows standard reporting format for an FSA as detailed in the Guidelines for FSA in the IMO Rule Making Process [2]. Figure 6 below shows the five main steps of the FSA approach, detailing what each step is comprised of and how the various steps are interrelated. The total risk, defined as the combination of frequency and consequence summed up over all identified accident scenarios may be controlled by a number of well-known or newly identified RCOs. Finally, the objective of the cost-benefit assessment is used to rank the RCOs with regards to cost-effectiveness, i.e. the risk reduction in relation to cost.

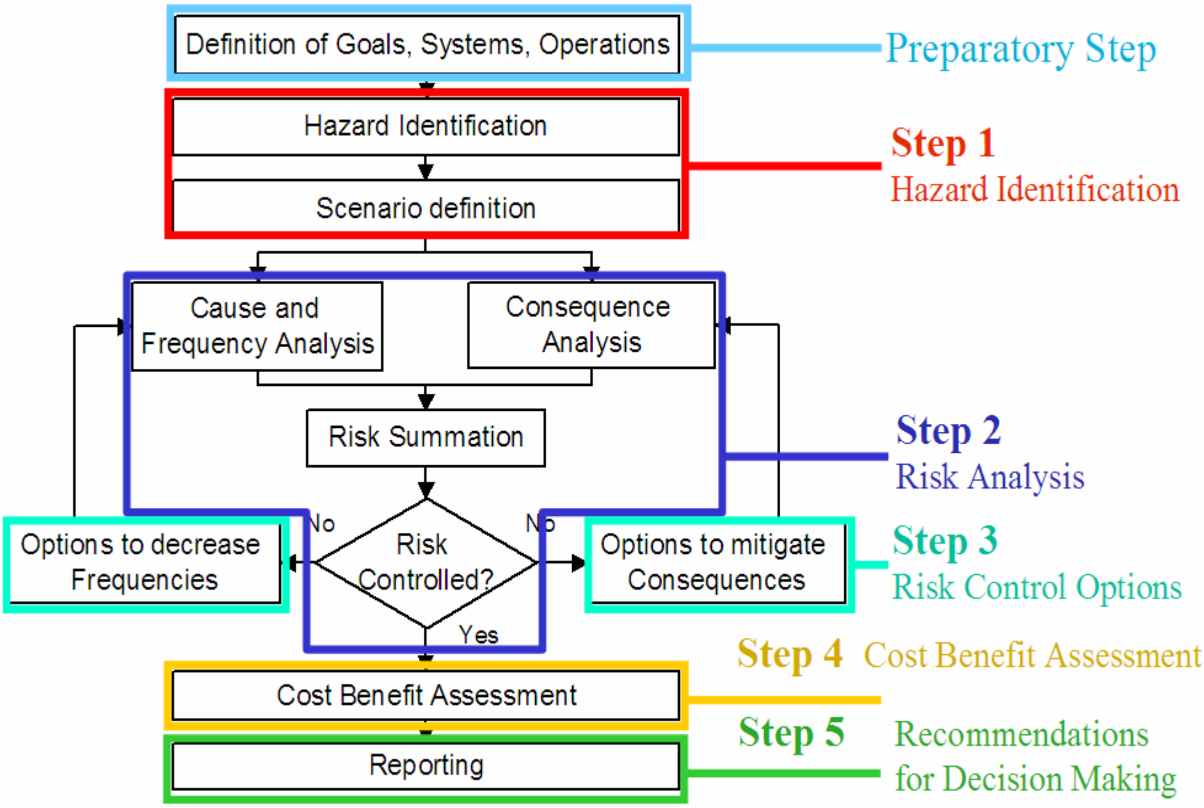

Figure 6: The five steps of a Formal Safety Assessment

The purpose of Step 1 is to identify a list of hazards and describe causes and effects specific to the problem under review.

The purpose of the risk analysis in Step 2 is to quantify the level of risk for the hazards identified in Step 1. Accident data and fatality statistics is gathered from recognized sources of information, e.g. IHS Fairplay Casualty Database (Fairplay), as appropriate to the level of analysis. Where data is unavailable, calculation, simulation or the use of expert judgment may be applied. The output from Step 2 comprises the identification of the high risk areas which need to be addressed.

The purpose of Step 3 is to identify effective and practical RCOs that address both existing risks and risks introduced by new technology or new methods of operation and management.

The purpose of the cost-benefit assessment in Step 4 is to identify and compare benefits and costs associated with the implementation of each RCO identified and defined in Step 3. The RCOs will be ranked in order to facilitate the decision-making recommendations in Step 5.

The purpose of Step 5 "Recommendations for decision-making" is to develop recommendations that can be presented to the relevant decision-makers in an auditable and traceable manner. Those recommendations are based upon the comparison and ranking of all hazards and their underlying causes; the comparison and ranking of risk control options as a function of associated costs and benefits; and the identification of those risk control options which keep risks as low as reasonably practicable. This step will be included in the next version of this report.

5 Identification of Hazards

Due to this study being part of the ongoing e-navigation project, parts of the hazard identification process has already been carried out prior to the study. Among other things the e-navigation project was established based on the fact that 60 per cent of all collisions and groundings are caused by human error (MSC 85/26/Add.1 ANNEX 20, Paragraph 3.2).

Also, the scope of the e-navigation project limits the accident categories under review to accidents pertaining to navigation, i.e. collision and grounding as defined in chapter 0.

As mentioned, NMA statistics are applied for root cause analysis of navigational accidents. The accident cause investigation is performed to determine the distribution of accident causes. This allows attention to be focused upon the factors which influence the level of risk.

The methodology used is described in Figure 7 below. Firstly, the initial accidental events are listed. Secondly, the direct causes of the accidents are identified.

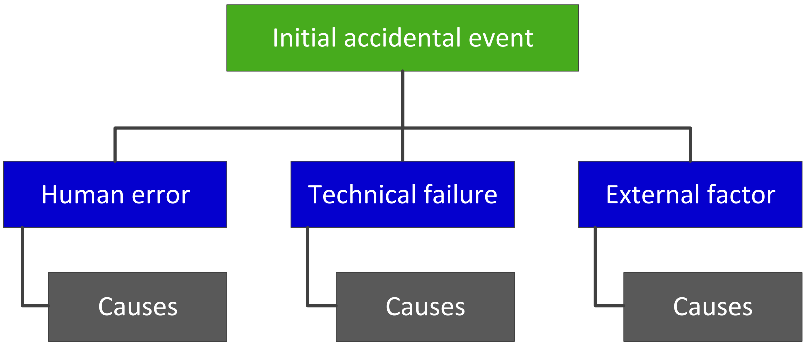

Figure 7: Work method for identifying direct- and underlying causes of navigational accidents

5.1 Direct causes

The NMA statistics split accidents into three main cause categories: human error, technical failure and external factors. In the NMA statistics some of the accidents are recorded as combinations of human errors, technical failure and external factors. These account for about 11 per cent of the total reported accidents. In order to simplify the cause analysis such combinations have been neglected.

As mentioned in chapter 0, research indicates that around 60 per cent of collisions and groundings are caused by human error. This statement is supported by findings from studies of NMA statistics. As it can be seen from Figure 8, according to NMA statistics from all ships Norwegian waters and all Norwegian-flagged ships worldwide, 65 per cent of all navigational accidents (collision and grounding) are caused by human error.

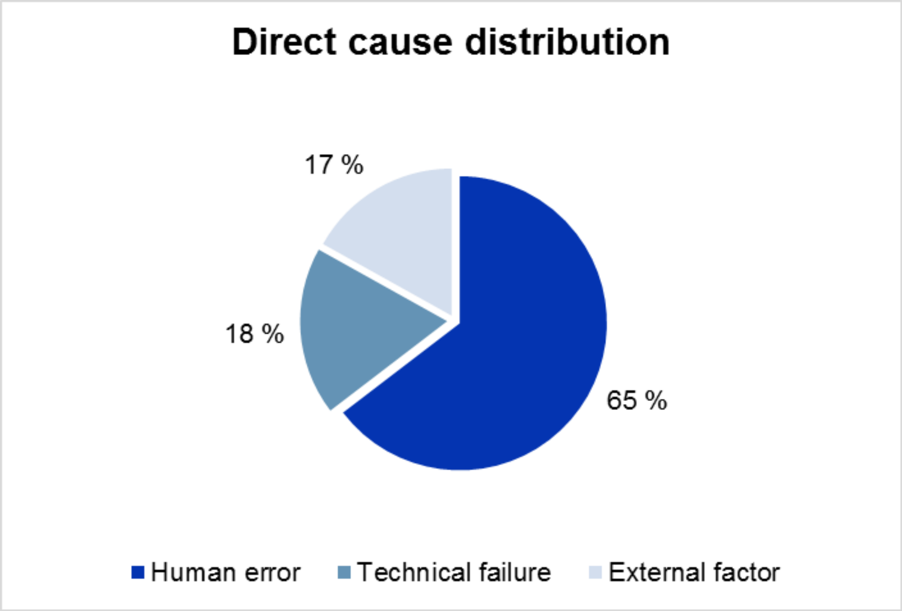

Figure 8: Direct cause distribution

In addition it can be argued that some of the causes categorized as external factors could be included in the human error category.

The study confirms the case for e-navigation (MSC 85/26/Add.1, annex 20, paragraph 3), reflected in the Strategy for the Development and Implementation of e-navigation (MSC 85/26/Add.1, annex 20).

5.2 Detailed cause distribution

Figure 9, Figure 10 and Figure 11 show the distribution of detailed causes for human errors, technical failures and external factors, based on statistics from NMA. As can be seen from the figures some overlap between the categories seem to be present, however, the full details of how each accident has been assigned a cause have not been available. The distribution of causes has therefore been kept as given by the NMA in the assessment presented in this report.

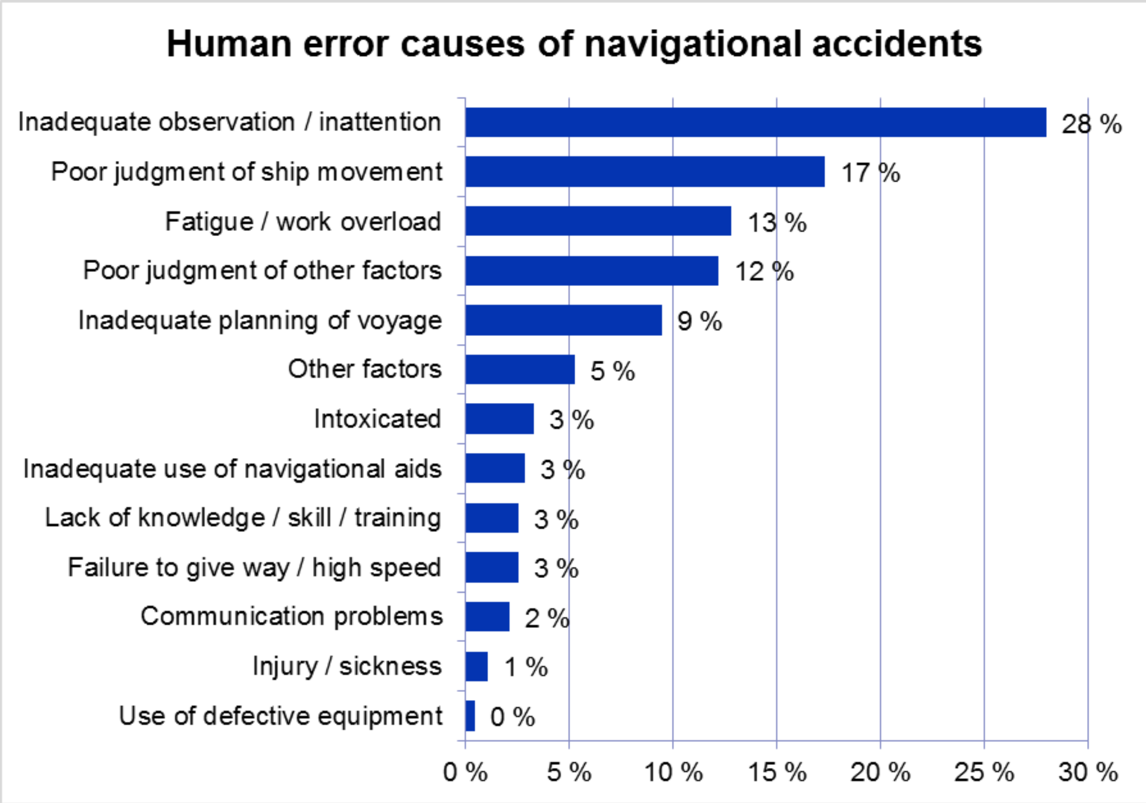

Figure 9: Human error cause distribution

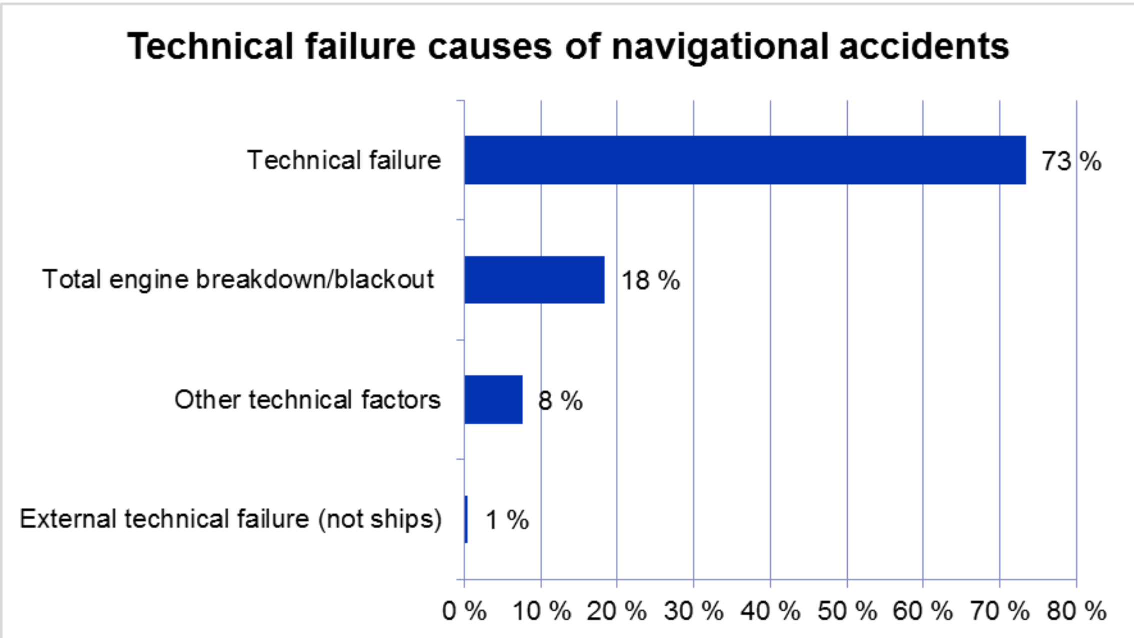

Figure 10: Technical failure cause distribution

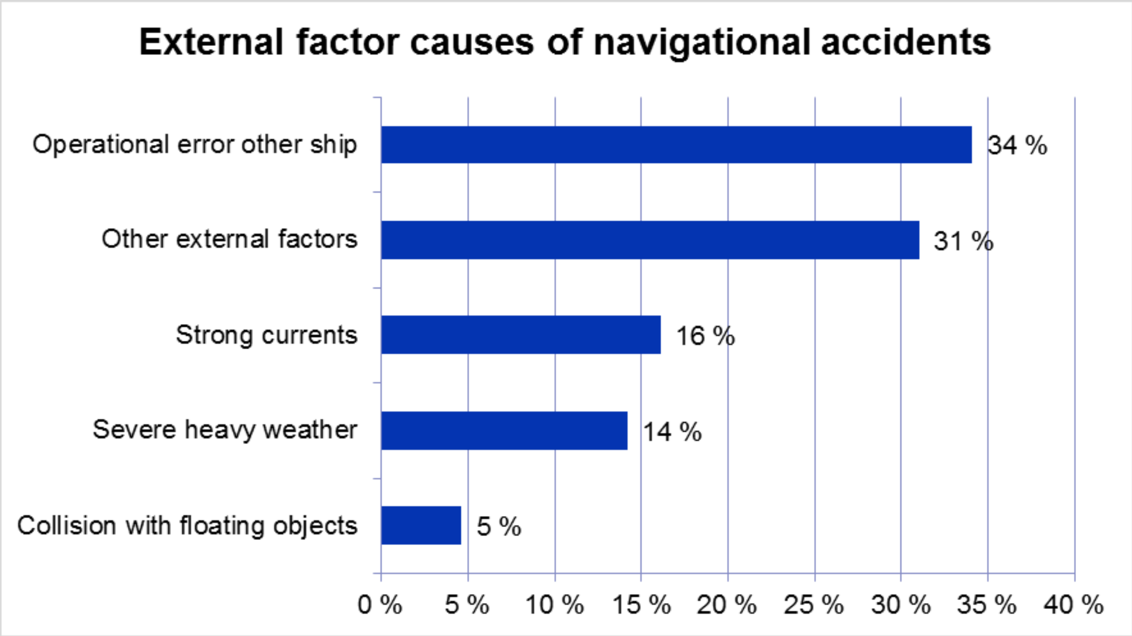

Figure 11: External factor cause distribution

It can be argued that some technical failures are relevant (i.e. failure of navigation equipment), but these are disregarded due to lack of information regarding the share of failures pertaining to such equipment.

Regarding external factors the cause "other external factors" is disregarded. The cause "other ship operational failure" could be argued as being a human error cause. Adding it to the human error category brings the share of human errors up to about 70 per cent.

5.3 Summary

The above demonstrates that the majority of navigational accidents are caused by human errors (above 65%). The most significant causes for human errors are "Inadequate observation/inattention" (28%), "Poor judgement of ship movement" (17%) and "Fatigue/ work overload" (13%).

6 Risk analysis

The risk analysis comprises an investigation of risk for the accident categories defined in chapter 0. The generic risk model, IHS Fairplay casualty statistics and findings from the hazard identification study is applied to produce a representative risk picture for the defined problem.

The frequency and consequence evaluation provides the frequency and risk associated with the different accident categories. The risks are summarized to estimate the individual risk and societal risks to crew members resulting from the operation of a generic ship.

6.1 Risk categories

Risk of human fatality and environmental damages (with respect to volume of oil spill) are included in this study. Risks of economic losses are only accounted for with respect to the costs of oil spill clean-up, as explained in chapter 0.

Further studies based on detailed risk modelling may also be required at a later stage – that is if a major change to legislation will be proposed in the future, then the analysis would have to be focused towards very specific areas and risk control options.

The risk to personnel on board the ships is expressed in terms of Potential Loss of Life (PLL) [2].

6.2 Estimated risk

For societal risk value estimates have been produced based on IHS Fairplay statistics. Estimates for accident consequence are created by utilizing fields in the database stating the number of fatalities and the number of missing persons per casualty record.

Based on the risk modelling, i.e. frequency- and consequence modelling, contributions from the different accident categories to the total potential loss of lives (PLL) are extracted. The resulting risk estimates are presented in Table 6.

Ship type	Accident category	Potential Loss of Life for crew and passengers (per ship year)	%
Cargo ship (including tanker for oil) (351,741 ship-years - 55%)	Collision	6.8E-04	12%
	Grounding	5.7E-04	10%
	∑ (Navigational accident)	**1.2E-03**	**22%**
	Other accidents	4.4E-03	78%
	∑ (All accident)	**5.7E-03**	**100%**
Passenger ship (67,254 ship-years – 10%)	Collision	7.9E-04	1%
	Grounding	1.2E-02	21%
	∑ (Navigational accident)	**1.3E-02**	**22%**
	Other accidents	4.7E-02	78%
	∑ (All accident)	**6.0E-02**	**100%**
Work ship (224.429 ship-years – 35%)	Collision	1.8E-04	20%
	Grounding	1.8E-05	2%
	∑ (Navigational accident)	**2.0E-04**	**22%**
	Other accidents	7.3E-04	78%
	∑ (All accident)	**9.3E-04**	**100%**
Generic ship (weighted average of ship types above)	Collision	5.2E-04	5%
	Grounding	1.6E-03	17%
	∑ (Navigational accident)	**2.1E-03**	**22%**
	Other accidents	7.6E-03	78%
	∑ (All accident)	**9.7E-03**	**100%**

Table 6: Risk estimations

6.3 Environmental risk

The number of oil spills and corresponding oil spill frequency per ship year given in Table 7 has been based on the pollution indicator, indicating pollution or not, provided in the IHS Fairplay statistics. The amount of oil spilled in each accident is based on the statistics from The International Tanker Owners Pollution Federation Limited (ITOPF) "Oil Tanker Spill Statistics 2012" [15]. In this statistics only oil spills larger than 7 tonnes have been included and according to ITOPF in the timespan included a total of 182 accidents resulting in 212,000 tonnes of oil spilled was recorded. No direct link between accident category and oil spilled is given and thus it is here assumed that the sizes of spills are representative for grounding and collision. Therefore the average value is used for oil spill amount from spills from tanker for oil and calculated to 1,164 tonnes per oil spill.

No statistics on the oil spill amount given a bunker oil spill have been found and therefore it is assumed that given an accident the amount of bunker spilled would be proportional with the amount of bunker oil to cargo volume of an oil tanker. Based on the IHS Fairplay database one can see that the bunker volume on average is about 5 per cent of the cargo volume and thus the average spill given a bunker spill is taken as 5 per cent of the cargo oil spill or from 60 tonnes per accident.

In order to evaluate the positive impact on the environmental risk from implementing the RCO 2, the Cost of Averting a Ton of oil Spilled (CATS) value of $80,000 is proposed [12].

Ship type	Accident category	Number of oil spills	Oil spill frequency
All chosen categories excluding tanker for oil (590,190 ship-years - 92%)	Collision	85	1.4E-04
	Grounding	116	2.0E-04
	∑ (navigational accident)	**201**	**3.4E-04**
Tanker for oil (53,234 ship-years - 8%)	Collision	36	6.8E-04
	Grounding	20	3.8E-04
	∑ (navigational accident)	**56**	**1.1E-03**

Table 7: Number and frequency of oil spills

The data in Table 7 is not divided into the same categories as in Table 4, Table 5 and Table 6. The reason for this is that tankers for oil obviously differ with regards to the potential volume of oil spills when compared to any other ship category. Thus, the total selection of ships in Table 7 is the same as in Table 4, Table 5 and Table 6 (as seen by the sum of ship years), but extracted from the IHS Fairplay database and presented, in categories suitable in the case of oil spill.

6.4 Risk-cause distribution

By applying findings from the hazard identification study it is possible to distribute the risk among the probable accident causes. The objective is to produce an improved picture of where the highest risks originate from.

#	Description	% of category	PLL per ship year	% total
1	Inadequate observation/inattention	28%	3.8E-04	24%
2	Poor judgment of ship movement	17%	2.3E-04	15%
3	Fatigue/work overload	13%	1.7E-04	11%
4	Poor judgment of other factors	12%	1.7E-04	10%
5	Inadequate planning of voyage	9%	1.3E-04	8%
6	Operational error other ship	34%	1.2E-04	8%
7	Other factors	5%	7.2E-05	4%
8	Strong currents	16%	5.7E-05	4%
9	Severe heavy weather	14%	5.0E-05	3%
10	Intoxicated	3%	4.5E-05	3%
11	Inadequate use of navigational aids	3%	3.9E-05	2%
12	Failure to give way/high speed	3%	3.5E-05	2%
13	Lack of knowledge/skill/training	3%	3.5E-05	2%
14	Communication problems	2%	2.9E-05	2%
15	Collision with floating objects	5%	1.6E-05	1%
16	Injury/sickness	1%	1.4E-05	1%
17	Use of defective equipment	0%	6.1E-06	0%

Table 8: Total generic risk distributed among accident causes

6.5 Summary

As shown in Table 6, collisions and groundings contribute with an estimated 5 per cent and 17% respectively of the total estimated societal risk (PLL) for the generic ship category.

It should be noted that societal risk varies quite a bit between different ship types. This is especially obvious if comparing the PLL values in Table 6 for passenger ships (1.3E-02) with work ships (2.0E-04), and is in part explained by the difference in the number of individuals exposed to hazards given an accident.

7 Risk control options

The definition and assessment by decision-makers of the navigational problems within the context and scope of e-navigation, identifying several gaps and user needs, was part of the process undertaken before the Formal Safety Assessment (FSA) process began. The user needs – outcome of an international survey, were mainly threefold and categorized into shipboard, shore-based and communication related. From the gap analysis results, strategic key elements and practical e-navigation solutions were developed and proposed for improving navigational safety and efficiency on board, ashore and related communication between the two, encompassing technical, operational, regulatory and training features.

In particular, a preliminary list of nine main categories and practical e-navigation solutions (shown below) was obtained from NAV 58/WP.6/Rev.1, annex 2, and formed a reference point for undertaking the FSA.

- S1: Improved, harmonized and user-friendly bridge design.
- S2: Means for standardized and automated reporting.
- S3: Improved reliability, resilience and integrity of bridge equipment and navigation information.

S4: Integration and presentation of available information in graphical displays received via communication equipment.
S5: Information management.
S6: Improved access to relevant information for Search and Rescue.
S7: Improved reliability, resilience and integrity of bridge equipment and navigation information for shore-based users.
S8: Improved and harmonized shore-based systems and services.
S9: Improved communication of VTS service portfolio.

7.1 CG solution prioritizing

Regarding the scope of the e-navigation project and defined as "*the harmonized collection, integration, exchange, presentation and analysis of marine information on board 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*", and due to the limited timeframe of the project, the Correspondence Group (CG) members were tasked to propose a list of five out of the nine predefined categories of e-navigation solutions based on three main criteria. The criteria for the selection process were described as follow:

1. Seamless transfer of data between various equipment on board.

2. Seamless transfer of electronic exchange of information/data between ship-shore, shore-ship, inter-shore, intra-shore communications, and ship-ship.

3. The work should be based on systems that are already in place (according to the already adopted IMO's e-navigation strategy [1]) and development of potential futuristic carriage requirements should therefore be strictly limited.

The result of the exercise is presented in Table 9. "X" marks the categories of solutions chosen by the different countries.

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
Germany	x	x	x	x					x
USA	x	x	x	x					x
Canada	x	x	x	x					x
Norway		x	x	x				x	x
Denmark	x	x		x			x		
Sweden	x	x		x		x			x
Marshall Islands		x	x	x	x				x
Korea	x	x			x	x		x	
UK	x		x	x				x	x
Sum	**7**	**8**	**6**	**8**	**2**	**2**	**1**	**3**	**7**
Rank	**3**	**1**	**5**	**1**	**7**	**7**	**9**	**6**	**3**

Table 9: CG solution prioritizing

Based on the majority principle the following categories of solutions were thus retained for the FSA:

- S1: Improved, harmonized and user-friendly bridge design.
- S2: Means for standardized and automated reporting.
- S3: Improved reliability, resilience and integrity of bridge equipment and navigation information.
- S4: Integration and presentation of available information in graphical displays received via communication equipment.
- S9: Improved communication of VTS service portfolio.

The prioritized e-navigation solutions S2 and S4 and S9 focus on efficient transfer of marine information/data between all appropriate users (ship-ship, ship-shore, shore-ship and shore-shore). Solutions S1 and S3 promote the workable and practical use of the information/data on board. The five prioritized potential solutions in combination ensure a holistic approach and interaction between the shipboard and shore-based users, which is at the core of e-navigation.

7.2 Description of Risk Control Options

Based on the sub-solutions from the five retained categories of solutions, seven RCOs for the FSA were created by the FSA team. Sub-solutions were combined serving as the basis for the final seven RCOs, irrespective of the solution categories from which they originated. In other words, sub-solutions from different solution categories have been joined into the same RCO were appropriate with regards to the FSA, and not all aspects of all sub-solutions are necessarily covered as part of a RCO. The solutions served as the *basis* for the creation of RCOs that were believed to be tangible and manageable in terms of quantifying the risk reducing effect and the related costs.

All Risk Control Options are created and assessed with regards to new builds only. Additional positive consequences for the existing fleet are thus not quantified in this report.

The process resulting in the final seven RCOs is illustrated in Figure 12.

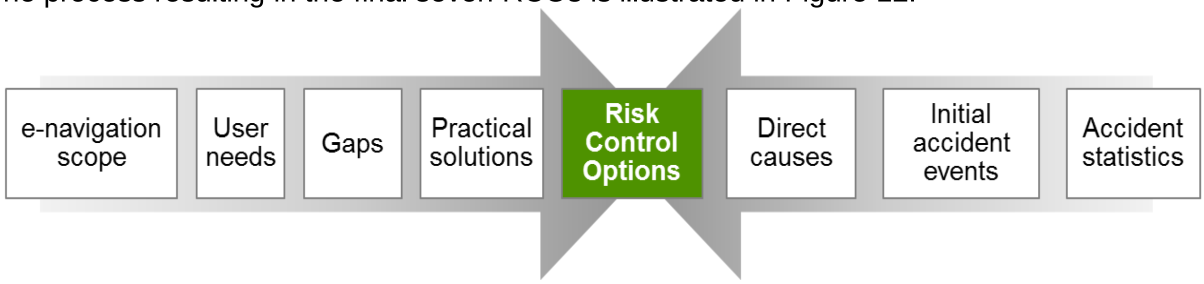

Figure 12: RCO identification process

It is imperative to emphasize that the five suggested main e-navigation categories of solutions do not constitute the complete scope of the e-navigation project, but rather the initial step in the process of the e-navigation project.

7.2.1 RCO 1: Integration of navigation information and equipment including improved software quality assurance

The basis for RCO 1 is the following e-navigation sub-solutions: 1.6, 1.7, 3.1, 3.2, 3.3, 4.1.2 and 4.1.6 as per [8]; however, recognizing that not all aspects of each sub-solution have necessarily been fully included.

Background driving force

There is a potential for various navigational information to be presented in an increasingly centralized way that may reduce workload and otherwise ease the task of navigation.

Sophisticated bridge navigational systems are increasingly integrated with each other and with other kinds of systems on the ship. This fact, as well as the implicit ability of these systems to influence each other, increases complexity. As such it is of increasing importance that these systems are available, reliable and resilient.

Current situation

Many suppliers have integrated bridge systems in their product portfolios. However, there exists no requirements for the extent of integration of navigation systems, or otherwise how it is to be implemented.

The highly-integrated systems of today are generally only verified based on function testing. However, regulations do not cover testing of reliability and code quality. The use of sophisticated software in bridge systems is increasing along with increasing complexity and integration of systems. Consequently the reliability and endurance of system and software is of increasing importance. As such, some form of type approval scheme covering testing and quality assurance *beyond todays existing function testing*, as well as service during the system's lifetime, is envisaged. Software change management, i.e. ensuring that all software updates to navigational equipment have been executed in a satisfactory manner, is envisioned to specifically cover the aspect of software updates during the life of the system.

RCO as used for basis for cost/benefit assessment

The purpose of integrating navigation information and equipment is to provide integrated and augmented functions to the navigator, i.e. an improved basis for navigational decision-making.

In order to assess effects and costs, RCO 1 is made tangible by *basing* it on Integrated Navigation Systems (INS) as described in IMO resolution MSC.252(83) in [9]. Other technologies and solutions that fulfil the RCO are thus not excluded, but are not quantified in terms of costs and effects.

The following elements (taken from the INS standard) have been chosen to represent RCO 1:

- **Task: Route planning and monitoring**
  - The INS should provide the route planning and monitoring functions and data as specified in Module A and B in the ECDIS performance standards.
  - Having the route check against hazards based on the planned minimum under keel clearance as specified by the mariner.
  - Overlaying radar video data on the chart to indicate navigational objects, restraints and hazards to own ship in order to allow position monitoring evaluation and object identification.
  - Determination of deviations between set values and actual values for measured under-keel clearance.
  - The alphanumeric display to present values of Latitude, Longitude, heading, COG, SOG, STW, under-keel clearance, ROT (measured or derived from change of heading).

- **Task: Collision avoidance**
    - The INS should provide the collision avoidance functions and data as specified in Module A and B of the Radar performance standards.

- **Task: Navigation control data**

For manual control of the ship's primary movement the INS navigation control display should allow at least to display the following information:

- under keel clearance (UKC) and UKC profile, STW, SOG, COG, position, heading, ROT (measured or derived from change of heading), rudder angle, propulsion data,
- set and drift, wind direction and speed (true and/or relative selectable by the operator), if available,
- the active mode of steering or speed control,
- time and distance to wheel-over or to the next waypoint,
- safety related messages e.g. AIS safety-related and binary messages, NAVTEX, SafetyNet or other GMDSS information.

- **Task: Status and data display**
    - The INS should provide the following data display functions:
    - presentation of mode and status information
    - presentation of the ship's static, dynamic and voyage-related AIS data
    - presentation of the ship's available relevant measured motion data together with their "set – values"
    - presentation of received safety related messages, such as AIS safety-related and binary messages, Navtex, SafetyNet or other GMDSS information. Binary messages or other machine readable data received via communication equipment should be presented in its relevant geographical context using standard symbology.
    - presentation of INS configuration
    - presentation of sensor and source information.
    - The INS should provide the following management function:
    - editing AIS own ship's data and information to be transmitted by AIS messages.

- **Displays**
    - A task station should be provided for each task of:
        - route monitoring
        - collision avoidance
        - navigation control data

- **Redundancy of important equipment**
    - Adequate back-up arrangements should be provided to ensure safe navigation in case of a failure within the INS.
    - The failure of a single task station should not result in the loss of a function mandated by the carriage requirements of SOLAS.

   - In case of a breakdown of one task station, at least one task station should be able to take over the tasks.
   - The failure or loss of one hardware component of the INS should not result in the loss of any one of the INS tasks.

- **Software testing**

   - It is believed that increased focus and requirements to software testing will increase the reliability of the INS bridge system.
   - The following elements are included:

      - Follow-up of software development during system design at manufacturer by 3rd party in order to ensure quality in software development.
      - Extensive testing of INS system with testing of error modes and failures of single components to ensure performance.

As a basis for comparison, ships are thus assumed to have either a bridge fulfilling the above mentioned requirements, or a bridge complying only with the minimum requirements in SOLAS chapter 5.

This obviously differs from the situation on board most ships today, where the extent of integration will be somewhere in between these. However, in the context of this report and the e-navigation project, the results are believed to be indicative.

7.2.2 RCO 2: Bridge alert management

The basis for RCO 2 is the e-navigation sub-solution 1.5 as per [8], however, recognizing that not all aspects of the sub-solution have necessarily been fully included.

Background driving force

On a bridge with no centralized alert management system, problems identifying alerts may arise. Additionally, alerts from various sources may not be prioritized by importance with regards to safe navigation. Potentially unnecessary distractions of the bridge team by redundant and superfluous audible and visual alarm announcements may occur, increasing the cognitive load on the operator.

Current situation

Even though there are equipment and bridge suppliers today that extensively consider the effectiveness of alarms and alarm management, there still exists a lack of standards and regulations specifically covering the concept of a centralized system for bridge alert management.

RCO as used for basis for cost/benefit assessment

The goal of alert management is the harmonized priority, classification, handling, distribution and presentation of alerts, to enable the bridge team to devote full attention to the safe navigation of the ship and to immediately identify any abnormal situation requiring action to maintain the safe navigation of the ship.

It is suggested to implement an alert management system as described in [10]. A central alert management Human Machine Interface (HMI) is envisaged to support the bridge team in the immediate identification of any abnormal situation, of the source and reason for the abnormal situation and support the bridge team in its decisions for the necessary actions to be taken.

The performance standards in IMO resolution MSC.252(83) specify a central alert management HMI to support the bridge team in the immediate identification of any abnormal situation, of the source and reason for the abnormal situation and support the bridge team in its decisions for the necessary actions to be taken. The alert management architecture and the acknowledgement concept specified, avoid unnecessary distraction of the bridge team by redundant and superfluous audible and visual alarm announcements and reduces the cognitive load on the operator by minimizing the information presented to which is necessary to assess the situation.

For this system to be effective at reducing distractions to the safe navigation of the ship, all audible alarms on the bridge, regardless of system it is associated with, should be included.

The base for comparison is a bridge system with no form of alert management between systems, and the specific requirements for the alert management system is:

- The system is able to prioritize alarms, e.g. Category A alerts should include alerts indicating:
  - Danger of collision
  - Danger of grounding
- All alerts should be displayed on the central alert management HMI
- The acknowledgement of alarms and warnings should only be possible at an HMI (task station) where an appropriate situation assessment and decision support can be carried out.

7.2.3 RCO 3: Standardized mode(s) for navigation equipment

The basis for RCO 3 is the e-navigation sub-solution 1.4 as per [8], however, recognizing that not all aspects of the sub-solution have necessarily been fully included.

In order to aid the navigator, the navigation equipment suppliers are continuously developing their products to include a rapidly increasing number of sophisticated functionalities. As the different suppliers follow different presentation philosophies this introduces the risk of navigators or pilots getting lost in the jungle of available functions, not being able to produce a familiar setup of the equipment, and consequently not being able to obtain information required for navigational decision-making.

Background driving force

Safe navigation relies on the ability of key personnel to easily operate navigational equipment as well as comprehend the information that is presented to them. This will not always be the case when someone is new to a particular setup. Lack of familiarity with bridge equipment and/or slow response due to not finding correct information/control/alarm is thus considered to adversely affect safe navigation.

Standard modes or default display configurations are envisaged for relevant navigational equipment. Such standard modes should be selectable at the task station and would reset presentation and settings of information to provide a standardized and common display familiar to all stakeholders. The standard mode should be accessible by a simple operator action.

Current situation

Every equipment manufacturer can potentially create its own Human Machine Interface (HMI). Differences in HMIs on essential navigational equipment may adversely affect personnel, such as pilots, unfamiliar with a particular solution.

RCO as used for basis for cost/benefit assessment

Requiring equipment manufacturers to incorporate the possibility to easily present information in a standard manor would reduce the need for personnel to familiarize themselves with variations of HMIs in order to safely navigate. This does not imply a reduction in manufacturer's freedoms to innovate, since the standard mode may be implemented as an addition to the HMI intended for normal operations.

For the purposes of this report, standard mode is chosen to mean the following:

- Offer default display configurations for the ECDIS and the radar to provide the bridge team and pilot with a standardized display. This configuration should be accessible by a simple operator action.
- Provide operational modes for a set of predefined operational areas such as open sea, coastal, confined waters (pilotage, harbour berthing, and anchorage).

It is recognized that the terms S-mode and default mode have certain meanings and implications from earlier discussions concerning the same theme [20]. For the purposes of this RCO standard mode is limited to the points described above[1].

7.2.4 RCO 4: Automated and standardized ship-shore reporting

The basis for RCO 4 are the following e-navigation sub-solutions: 2.1, 2.2, 2.3 and 2.4 as per [8], however, recognizing that not all aspects of each sub-solution have necessarily been fully included.

Background driving force

A potential for reducing workload due to filling out and delivering reportable information is identified. Forms are usually manually filled out and sent individually to each authority requesting the information. Compliance with IMO FAL forms normally takes about two hours to fill. Thus a significant potential for reduction in paper work exists.

Current situation

An investigation undertaken by the MarNIS project of 15 European ports found that around 25 documents had to be sent from the ship, or the ship's agent, in conjunction with a port call. This does not include documents related to services in port such as cargo on- and off-loading, waste disposal and ordering of supplies, nor documents related to customs clearance of the cargo [5].

The data requested in many of these documents are fully or almost identical. As an example, in one port, four different documents with identical content had to be sent to four different parties. The problem is further increased by different reporting requirements in different countries, and even between ports in the same country. Documents are also often in paper

[1] The principle of s-mode could also be applied (i.e. beneficial) to other equipment, such as GNSS and AIS.

or other non-computer-compatible formats. This requires shore organizations to manually enter the data into their data systems, which is a time-consuming and costly affair [5].

Electronic port clearance of ships is in the process of being a reality [4]. The US has implemented their system (eNOA/D), which all ships above 300 GRT have to use for in/out clearance in the US [4].

In Europe SafeSeaNet (SSN) is developed as an internet based system. This system is mainly used for exchange of information between different authorities (countries) [4].

The establishment in 2005 of SafeSeaNet Norway as a national ship reporting system was the first step towards simplifying reporting and information flow between ships and shore-based facilities in Norway [6].

RCO as used for basis for cost/benefit assessment

In order to make the concept of automated and standardized ship-shore reporting more tangible for evaluation, the following elements have been chosen:

- The system envisaged would allow bridge crew to edit all reportable information in one interface. The system would integrate relevant onboard systems enabling collection of information and data needed for reporting.

- The system should allow for automated digital distribution of required reportable information (single window solution), including both static, dynamic, voyage related and SAR information to authorized authorities, with the least possible intervention required by the ship during and/or before navigation.

- Secure ship-shore data communication would be a prerequisite for an automated reporting solution. In order to reduce the amount of ship-shore data communication, a system for shore distribution to stakeholders is envisaged.

- The system should facilitate information to be entered only once.

7.2.5 RCO 5: Improved reliability and resilience of onboard PNT systems

The basis for RCO 5 is the e-navigation sub-solution 3.4 as per [8], however, recognizing that not all aspects of the sub-solution have necessarily been fully included.

Background driving force

Primary aim of position fixing is to provide position, velocity, and time data (PVT) for navigators and navigational functions. PNT data encompasses PVT data and ship's parameters describing ship's current movement and attitude (e.g. heading, rate of turn). Ensuring reliable and resilient PNT data is considered to be important for safe navigation at sea.

Resilience is the ability of the PNT system to detect and compensate external and internal sources of disturbances, malfunction and breakdowns in parts of the system. This concept does not include any additional GNSS system neither space-based nor terrestrial systems, but may use information from such systems should they exist.

Current situation

Due to insufficient redundancy within single sensors and unsupported exploitation of multi-sensor based redundancy the classic approach is considered unable to meet e-navigation user needs such as improvement of availability, reliability and indication of integrity based on monitored and assessed data and system integrity.

RCO as used for basis for cost/benefit assessment

Provision of resilient PNT data relies on the exploitation of existing, modernized and future radio navigation systems, sensors and services. The proposed PNT concept (NAV 58/INF.5) is an onboard system that supports the exploitation of the modernization processes in radio navigation systems (space-based and terrestrial), ship-side sensors and shore-side services.

In order to improve reliability and resilience of position, navigation, and timing data (PNT) an integrated and harmonized utilization of PNT related systems and services is envisioned. PNT data encompasses position, velocity, and time data (PVT) and ship's parameters describing ship's current movement and attitude (e.g. heading, rate of turn).

The PNT concept is an open framework supporting the usage of any sensors, services and data sources improving the accuracy or assessing the integrity of provided PNT data and applied components.

The Integrated PNT Concept as described in [11] "Modular and open concept of Integrated PNT System" is suggested as basis for the RCO. The effects and cost of improved reliability and resilience of PNT systems are based on the comparison between the classic approach as shown in Figure 13 and the onboard PNT module with a PNT data processing unit as shown in Figure 14, both described in NAV 58/INF.5. Hence, the base case is the classic approach, assumed to be minimum standard for new ships.

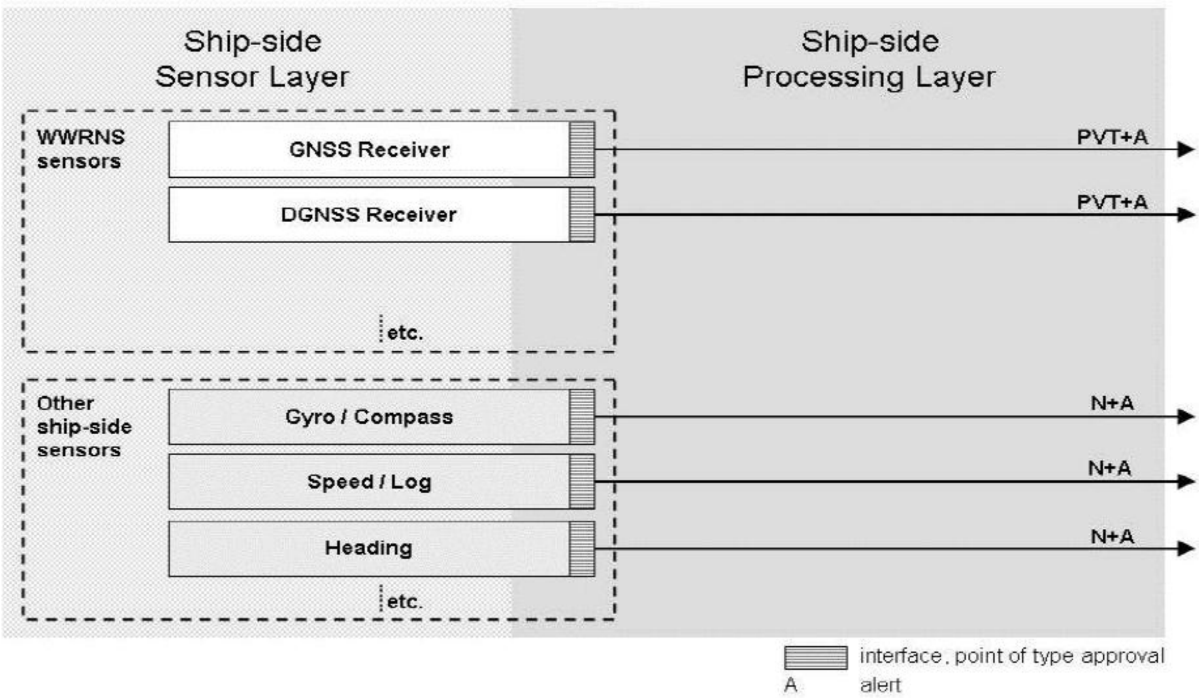

Figure 13: Classic approach of ship-side PNT module, from NAV 58/INF.5

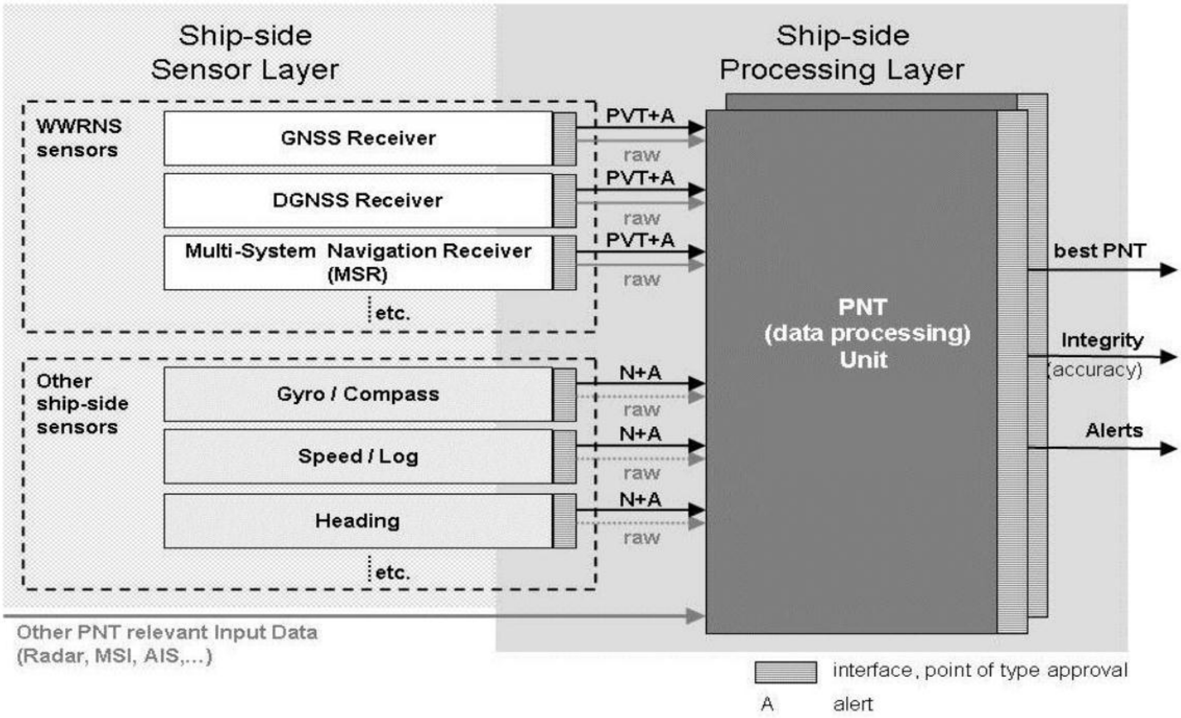

Figure 14: Ship-side PNT module with PNT (data processing) Unit, from NAV 58/INF.5

7.2.6 RCO 6: Improved shore-based services

The basis for RCO 6 are the following e-navigation sub-solutions: 4.1.3 and 9 as per [8], however, recognizing that not all aspects of each sub-solution have necessarily been fully included.

VTSs and other shore-based stakeholders gather and hold a lot of information regarding navigational warnings, incidents, operations, tide, AIS, traffic regulations, chart corrections, meteorological conditions, ice conditions, etc., which often is referred to as the Maritime Service Portfolio. As per today this information is mostly communicated via voice VHF and paper documents. Information transfer via voice communication can be time-consuming and distractive as navigators may need to make notes of information received and possibly consult various written documentation on the bridge. The voice communication procedure also holds a potential for incorrect transfer and misinterpretation of information. It is clear that there is a significant potential for improving the way such information is administered and communicated to the fleet.

Implementation of system for automatic and digital distribution of shore support services would make information more available, updated and applicable for navigators.

Background driving force

Firstly, Maritime Safety Information (MSI) received by the ship should be applicable to the ship's specific voyage, i.e. it should not contain information related to other areas which is not relevant to that ship. Today, broadcasted MSI is printed on a NAVTEX receiver on-board and put on the "wall". As the Officer of Watch (OOW) may potentially receive several MSI messages daily, of which a large portion of the messages may not be of his concern, there is the risk of missing vital MSI. Basically, one important MSI could accidentally be overlooked due to the failure to sort out and conceive the most essential MSIs. The MSI should be displayed on the correct place on the bridge. One location to present the MSI has been proposed to be the ENC/ECDIS or AIS/RADAR display.

There are several examples on accidents where broadcasted navigational warnings are either missed or disregarding, e.g. the "Tricolor" accident in the English Channel. Because of the location of the sunken ship, at a point where two lanes combine in the Traffic Separation Scheme (TSS) of the English Channel/Southern part of the North Sea and the fact that "Tricolor" was just completely submerged under water, the wreck was considered as a "hazard to navigation". Despite standard radio warnings, three-guard ships, and a lighted buoy, the Dutch ship "Nicola" struck the wreck the next night, and had to be towed free. After this, two additional patrol ships and six more buoys were installed, including one with a Racon warning transponder. However, on 1 January 2003 the loaded Turkish-registered fuel carrier Vicky struck the same wreck; she was later freed by the rising tide.

Secondly, notices to mariners, ENC updates and corrections to all nautical publications should be received electronically without any delays in the delivery. Distribution via post is time consuming and the ships risk to sail in waters, for which the nautical charts are not up to date.

Current situation

Shore-based authorities gather and hold a lot of information regarding navigational warnings, incidents, operations, tide, AIS, traffic regulations, chart corrections, meteorological conditions, ice conditions, etc. In Norway, the Norwegian Coastal Administration (NCA) coordinates and sends out approximately 600 navigational warnings within Norwegian waters each year [1].

As per today this information is received via:

- Automatically via NAVTEX (printed) and communicated via VHF (voice).
- Ships which sail beyond the coverage of NAVTEX will receive Maritime Safety Information (MSI) over the Inmarsat C SafetyNET service, a satellite-based worldwide broadcast service of MSI.
- Nautical chart corrections are provided by suppliers either per CDs (post) or electronically per satellite.

RCO as used for basis for cost/benefit assessment

System on board the ship to ensure that at any given time the ship receives information sent from shore side by the most cost efficient means available to the ship. The system should ensure that the cost for the ship is kept at a minimum at the same time as the data is transferred in a timely manner. The system is envisioned to select between the means of communication available today (e.g. satellite and Wi-Fi), however should new means become available these should be able to be connected and used as well.

All MSI to be sent out digitally and using a standard such as the IHO S-100 data framework standard enabling better visualization on board. One example of use will be for Virtual Aids to Navigation (AtoN) for warning of new navigational hazards, such as wrecks, obstructions or floating debris. It is expected that the above information will be displayed on ships that have AIS/ECDIS capabilities improving the navigators' awareness of new navigational hazards, such as wrecks, obstructions or floating debris.

In addition automatic updating and correction of nautical charts via satellite is envisioned. It is expected that the information will be displayed on ships that have ENC/ECDIS capabilities. The updates will be downloaded and installed automatically and will ensure that ships with ECDIS will have updated charts at frequent intervals.

7.2.7 RCO 7: Bridge and workstation layout standardization

The basis for RCO 7 is the e-navigation sub-solution 1.1 as per [8], however, recognizing that not all aspects of the sub-solution have necessarily been fully included.

Cumbersome equipment layout on the bridge adversely influences the mariner's ability to optimally perform navigational duties. Although there exist many good bridge layout designs with respect to ergonomics, this is an area identified as insufficiently regulated as to ensure a consistent level of minimum quality.

Background driving force

Seafarers may experience difficulties in accessing necessary information because of ergonomic problems, such as unpractical physical bridge locations of navigational equipment. Ergonomic problems of navigation equipment also exist in the sense that there is a lack of intuitive human-machine interface for communication and navigation means. Bridge layouts, equipment and systems have not consistently and sufficiently been designed from an ergonomic and user-friendly perspective. Lack of familiarity with bridge equipment and/or slow response due to not finding correct information/control/alarm is considered to adversely affect safe navigation.

Current situation

Even though there are bridge suppliers today that thoroughly consider ergonomics, there is a lack of sufficient ergonomic standards and regulations, as well as guidance for usability evaluation to ensure a minimum level of ergonomic quality. Existing documents (performance standards, guidelines, etc.) with regard to ergonomics are missing harmonization and are seldom applied.

RCO as used for basis for cost/benefit assessment

Regulation, based on existing guidelines and standards, regarding the physical layout of all bridge equipment regarded as essential for safe and efficient navigation, is envisaged. The starting point[2] would be MSC/Circ.982, *Guidelines On Ergonomic Criteria For Bridge Equipment And Layout* and the following elements have been included in the RCO:

- Workstation for navigating and manoeuvring including (for full list see annex 2 of MSC/Circ.982):
  - radar/radar plotting
  - ECDIS
  - information of AIS
  - Indications of: rudder angle, rate-of-turn, speed, gyro compass heading, compass heading and other relevant information
  - VHF point with channel selector

2 Consideration could also be given to other relevant content related to arrangement of equipment in IMO circulars, such as SN.1/Circ.265 and SN.1/Circ.288.

It is emphasized that these regulations are only envisioned to regulate the placements of these with regard to each other. It does not imply requiring that any new systems be added.

8 Cost Benefit Assessment

The purpose of step 4 in the FSA is to identify and compare benefits and costs associated with the implementation of the RCOs to be considered further. The cost-effectiveness of each RCO is estimated and is compared in terms of the cost per unit risk reduction by dividing the cost values by the risk reduction achieved as a result of implementing the RCO. RCOs are ranked from a cost-benefit perspective in order to facilitate the decision-making recommendations in step 5, i.e. those RCOs which are not cost-effective or impractical are not recommended.

8.1 Cost assessment

Following the definitions in the FSA guidelines a RCO is regarded to be cost-effective if the societal benefit is greater than the costs of the RCO. The societal benefit is defined by a threshold. In the cost-effectiveness evaluation the lifetime costs of an RCO are put in relation to the risk reduction and the result is compared with the threshold.

The various costs and benefits of the RCOs will typically be spread over the lifetime of the ship. Thus costs are expressed in terms of lifecycle costs by calculating the present value, as given in Equation 1:

$$PV = A + \sum_{t=1}^{T} \frac{X_t}{(1+r)^t}$$

Equation 1

Where:

- X_t cost of RCO in year t;
- A is the amount spent initially for implementation of RCO;
- r is the depreciation rate of 5 per cent;
- T is the estimated usage time of risk control option, i.e. remaining operational lifetime of the ship. Since this report has assumed that only new builds will be affected, T will equal the lifetime of the ship, set to 25 years in this report.

Cost estimates are based on information from suppliers, service providers, training centres, yards, technical experts or previous studies where appropriate. Costs will vary with, among other things, manufacturer, equipment accessories, provider and country. Within the scope of this FSA the determination of costs is only an estimation of values considered significant. Where possible, cost ranges and average values are specified.

The direct costs of the measures have been divided into two parts: Initial costs and running costs over the lifetime of the ship. The initial costs include all costs of implementing the measure, e.g. acquiring and installing equipment, writing of procedures and training of crew. Thereafter, there are included additional costs at regular intervals where relevant, in order to maintain the effect of the measure, e.g. equipment service and replacement costs. The additional cost might for example occur annually, bi-annually or every fifth year.

General comments on costs:

- Scope is limited to new builds (as stated in the FSA objective in chapter 0)
- A ship lifetime of 25 years has been assumed.
- All costs related to IMO regulation and standards developments are not included.
- All newbuilds are assumed to have connectivity capabilities with modern technologies, (for instance internet connectivity). Internet provider service costs are included.
- All manufacturers are assumed to have continuous development costs covered by current pricing. Any alterations on existing equipment available for purchase to comply with IMO requirements are assumed to be covered by these normal costs.
- As with any computer based system a total update and renewing of such systems is envisioned at regular intervals. It is here assumed that the system developed would be able to run for 10 years with annual maintenance before it would need a complete renewal. Therefore an investment cost equal to the initial investment is added every 10 years.
- Depreciation rate set to 5 per cent, as in all previous FSAs.

8.1.1 RCO 1: Integration of navigation information and equipment including improved software quality assurance

Initial investment premium compared to minimum requirements in SOLAS chapter 5

Suppliers will need to develop and/or adjust their systems in order to comply with the RCO. Due to the fact that many suppliers already integrate navigational systems, compliance should not imply significant cost increases as compared with similar systems available in today's market. Also, requiring this on new builds will diminish the opportunity for charging a premium for integrated bridge systems, due to competition. Thus it is assessed to be within reason to base cost estimates on existing bridge solutions that are close in specifications to that which is specified in chapter 0.

The initial investment cost of this RCO, based on data from bridge suppliers, is in the range of US$40,000-60,000, recurring every 10 years. It is assumed that the price of a new system includes the necessary initial software testing and type approvals, as described in chapter 0.

Software change management, yearly over the lifetime of the ship

Software change management (i.e. ensuring that all software updates to navigational equipment have been executed in a satisfactory manor) is, on average, envisioned as a yearly activity along with ordinary survey activities, and is estimated at $1,800 per year per ship [17].

8.1.2 RCO 2: Bridge alert management (BAM)

Initial investment premium compared to minimum requirements in SOLAS chapter 5

A BAM standard exists for example as part of the INS standard today and suppliers will need to develop and/or adjust their systems in order to fully comply with it. Compliance is assessed to not imply significant cost increases as compared with systems available in today's market. Also, a requirement of the Bridge alert management on new builds will diminish the opportunity for charging a premium for it, due to competition. Thus cost estimates have been based on the existing alert management solutions that are closest in specifications to the standard.

As with any computer based system a total update and renewing of the system is envisioned at regular intervals. It is here assumed that the system developed would be able to run for 10 years with annual maintenance before it would need a complete renewal. Therefore an investment cost equal to the initial investment is added every 10 years.

The initial investment cost of this RCO, based on data from bridge suppliers, is thus in the range of $10,500-14,000, recurring every 10 years.

Software change management, yearly over the lifetime of the ship

Software change management (i.e. ensuring that all software updates to the BAM system have been executed in a satisfactory manor) is, on average, envisioned as a yearly activity along with ordinary survey activities, and is estimated at $1,800 per year per ship [17].

8.1.3 RCO 3: Standardized mode(s) for navigation equipment

Suppliers will need to develop and/or adjust their equipment in order to fully comply with the standard to be developed, but compliance is assessed to not imply significant cost increases as compared with systems available in today's market. Also, a requirement of the standard mode on all new builds will diminish the opportunity for charging a premium for it, due to competition. Thus, initial implementation of the standard mode functionality is not seen to increase the price of affected equipment.

Equipment affected will have costs associated with various forms of maintenance. However, the assessment in this FSA is that there should not be any increases in the already existing maintenance costs due to the implementation of the standard mode.

Thus, this RCO has no direct cost increases associated with it.

8.1.4 RCO 4: Automated and standardized ship-shore reporting

There are a lot of online reporting systems globally. The systems are not harmonized, often duplicated, and based on different formats and platforms. It is believed that the harmonization and automation will lead to more efficiency and cost reduction for the member states. Separate systems already represent a cost. A SafeSeaNet system that covers reporting requirements in relation to EU directive 2002/59, has been developed in Europe. The system will now be developed further to cover directive 2010/65, the so-called FAL directive. This is work that also takes into account IMO's work in the FAL Committee.

In Norway the system has been designed into a Single Window that includes reporting requirements for a number of authorities such as customs, police, PSC, defence, NCA (VTS, Pilot) and health authorities. The system is developed in close cooperation with users to ensure usability. This has been a major key to success.

The costs for RCO 4 have been based on the costs for the Norwegian Single Window system. Costs for the Norwegian system are expected to be relatively high and not directly representative for many other parts of the world. It should be noted that any costs related to agreeing what information needs to be reported into the system from individual ships are not included here has this is believed to be a task for IMO and the port states to agree upon.

As with any computer-based system a total update and renewing of the system is envisioned at regular intervals. It is here assumed that the system developed would be able to run for 10 years with annual maintenance before it would need a complete renewal. Therefore an investment cost equal to the initial investment is added every 10 years.

The Norwegian price level for machinery and equipment is about 20 per cent higher when compared to European countries [22]. Wage comparisons with European countries as well as other continents show very high variations. For example 9 per cent of Norwegian levels in Mexico, 79 per cent in the Netherlands and 57 per cent in the U.S [22].

Costs in other countries are therefore based on the following assumptions:

- Investment in computer equipment and other expenses, etc., in other countries costs about 80 per cent of Norwegian costs.
- Wages in Norway are 50 per cent higher than in other countries.
- Already existing available infrastructure like buildings, power grids, network connectivity.

The costs *per system* are thus the following (converted from NOK to $ using a conversion rate of 5.8 NOK/$ [19]):

- The annual operating costs were reported to $152,000 per year. However the existing systems used in each country will incur operational costs as per today and it is assumed that the operational costs overall will be in the same order of magnitude and therefore no additional operational costs have been used in the calculations.
- Investments in software development, consultant services and project management: $2,855,000
- Investments in infrastructure: $55,000 (dedicated servers and databases, etc.)

Benefits for this RCO are calculated as the total benefits for the entire fleet of new build ships in the 25-year scope of this report, i.e. 4,000 new build added every year [21]. It should be noted that, if such a reporting system was implemented it would in practice also be applicable to existing ships as having two independent systems would not be feasible.

Costs are calculated for the same 25-year period, assuming one system for each of the 133 SOLAS countries currently without an electronic ship reporting system (there are 170 SOLAS countries, of which all 27 EU Member States and 10 additional countries [25], including Norway outside the EU already have electronic ship reporting systems).

8.1.5 RCO 5: Improved reliability and resilience of onboard PNT systems

Initial investment premium compared to minimum requirements in SOLAS chapter 5

The PNT standard will be provided by IMO for suppliers to develop and/or adjust their systems in order to fully comply. Since various integrated bridge systems today already include the functionality described in this RCO, it is assessed to be within reason to base cost estimates on existing PNT solutions that are part of these systems and close in specifications to the system proposed in NAV 58/INF.5. This concept does not include any additional GNSS system neither space-based nor terrestrial systems, but may use information from such systems should they exist.

As with any computer based system a total update and renewing of the system is envisioned at regular intervals. It is here assumed that the system developed would be able to run for 10 years with annual maintenance before it would need a complete renewal. Therefore an investment cost equal to the initial investment is added every 10 years.

The initial investment cost of this RCO, based on data from bridge suppliers, is thus in the range of $8,500-12,000, recurring every 10 years.

Software change management, yearly over the lifetime of the ship

Software change management (i.e. ensuring that all software updates to navigational equipment have been executed in a satisfactory manor) is, on average, envisioned as a yearly activity along with ordinary survey activities, and is estimated at $1,800 per year per ship [17].

8.1.6 RCO 6: Improved shore-based services

As described in chapter 0, there are various different kinds of data covered in this RCO. Costs are estimated based on the most data intensive information category within the scope of the RCO, which are Electronic Navigational Chart updates.

VHF and similar systems are normally available and assumed used for things like MSI. Chart updates may similarly use land based systems when in port. Using existing systems like these will represent no additional cost compared to the current situation.

Since the maximum cost of transferring this kind of information is over a satellite internet connection, a top estimate is based on data from satellite internet suppliers. According to this, the cost per megabyte ranges from $6 to 13 [23] and [24]. An average value of $9 is used in the cost calculations.

Updates are normally made available by suppliers once every week. These updates are provided as delta patches, meaning that only the differences between the on-board charts and the newest available charts are downloaded, saving internet bandwidth usage. Each weekly update weighs in at roughly 10MB [18], and it is assessed as normal operating practice that the charts are in fact downloaded and updated on a weekly basis. Assuming 10MB per week at 9$/MB, give a yearly internet cost per ship of $4,680, and a discounted cost per ship over the 25-year period of $65,960. These costs may come down as internet connectivity via satellite becomes increasingly ubiquitous. However, this potential price reduction is not accounted for in this report.

It is assumed that the onboard system will choose the best and cheapest method of data transfer available at any point in time. The actual yearly cost is thus estimated to be in the range of $0-4,680, but for the sake of the cost benefit calculation, the maximum cost is used. The cost of having a system which chooses the best and cheapest method of data transfer is assumed to be offset by a reduced cost of data transfer and thus no additional cost is included here.

It is assumed that sending MSI over a new format will not increase costs beyond the current level, and the amount of data required is far lower than for chart updates. Preparing MSI in the new format required is not believed to increase the cost already taken to prepare MSI today and in many cases the MSI is already prepared digital. The cost associated with sending out MSI is therefore assumed to be equal as today and thus no additional cost has been assumed.

8.1.7 RCO 7: Bridge and workstation layout standardization

Placing equipment on new builds in accordance with "Workstation for navigating and manoeuvring" as per MSC/Circ.982, *Guidelines on Ergonomic Criteria for Bridge Equipment and Layout* is assessed to not infer additional costs compared to current practices.

Bridge equipment will have costs associated with various forms of maintenance. However, the assessment in this FSA is that there should not be any significant increases in these costs due to variations of equipment placement on the bridge.

Thus, this RCO has no direct cost increases associated with it.

8.2 Previous risk reducing measures

The accident frequencies presented in Chapter 0 (**6 Risk analysis**) are based on historical data. However, this data will not sufficiently reflect the effect of risk reducing measures recently implemented, such as the requirement for carriage of an ECDIS. The result of a Formal Safety Assessment of ECDIS [28] demonstrates that ECDIS has a risk reducing effect of 36 per cent on grounding accidents. Based on this, grounding frequencies have been reduced to 64 per cent of the values seen in Chapter 0 before applying the risk reducing effects of the RCOs identified in Chapter 0 in this report.

8.3 Risk reduction effect

Estimations of risk reduction have been done in terms of percentage reduction of navigational accidents due to each direct cause, as identified in Chapter 0, e.g. 21 per cent of navigational accidents caused by "Failure to use navigational aids" may potentially be prevented by the implementation of RCO 1. It is important to note that all RCOs where evaluated in isolation, meaning that the implementation of more than one RCO will not reduce an accident cause by the sum of each RCOs estimated reduction potential.

Estimates of risk reduction potentials were obtained through a workshop consisting of five experts (details on participating experts are given in Table 22 in 10.2 Annex II: FSA team). After gaining a common understanding of the RCOs, the workshop participants separately filled out a table similar to Table 10 with their individual estimates of the risk reducing potentials for each individual RCOs and for all causes under each RCO. The workshop facilitator provided an anonymous summary of the results and encouraged the experts to revise their earlier answers in light of the replies of other members of their panel (this is called a Delphi session). In addition, input was received from four experts who were not present at the workshop in order to get a broader basis for the expert judgements.

The group of experts from USA, Netherlands, Denmark and Norway has a total of over 190 years of maritime experience, and were selected for their diverse experience on board ships as well as in areas such as approval, inspection and consulting related to navigation.

Table 10 shows the results from the workshop in terms of the average values derived from the expert's individual assessments.

	RCO 1	RCO 2	RCO 3	RCO 4	RCO 5	RCO 6	RCO 7
Human error							
Inadequate observation/ inattention	16%	23%	14%	18%	10%	11%	32%
Poor judgment of ship movement	21%	8%	11%	4%	20%	3%	20%
Fatigue/work overload	20%	26%	11%	33%	5%	17%	24%
Poor judgment of other factors	11%	12%	10%	11%	11%	12%	19%
Inadequate planning of voyage	26%	3%	8%	1%	0%	15%	4%
Intoxicated	1%	1%	0%	0%	0%	0%	0%
Failure to use navigational aids	18%	8%	17%	9%	5%	13%	21%
Failure to give way/high speed	18%	11%	12%	9%	9%	5%	27%
Lack of knowledge/skill/training	3%	7%	18%	7%	6%	1%	10%
Communication problems	8%	5%	9%	19%	3%	11%	15%
Injury/sickness	0%	1%	0%	0%	0%	0%	0%
Use of defective equipment	11%	18%	3%	1%	18%	0%	8%
Technical failure							
Technical failure not related to main engine	6%	9%	1%	1%	10%	1%	2%
External factor							
Strong currents	9%	1%	2%	0%	11%	14%	7%
Severe heavy weather	2%	0%	1%	0%	6%	23%	7%

Table 10: Workshop estimate of risk reducing potential

Estimations of potential PLL frequency reductions due to implementation of each RCO are given in Table 11.The values were calculated by combining the PLL frequency of 2.1E-03 presented in Table 6 in chapter 0, the cause distributions presented in chapter 0, and the percentages of risk reductions given in Table 10.

	RCO 1	RCO 2	RCO 3	RCO 4	RCO 5	RCO 6	RCO 7
Human error							
Inadequate observation/ inattention	4.4E-05	6.3E-05	4.0E-05	5.1E-05	2.8E-05	3.1E-05	8.9E-05
Poor judgment of ship movement	3.6E-05	1.3E-05	1.8E-05	6.5E-06	3.5E-05	4.3E-06	3.5E-05
Fatigue/work overload	2.6E-05	3.3E-05	1.4E-05	4.2E-05	6.4E-06	2.2E-05	3.1E-05
Poor judgment of other factors	1.3E-05	1.4E-05	1.2E-05	1.3E-05	1.4E-05	1.4E-05	2.4E-05
Inadequate planning of voyage	2.4E-05	2.4E-06	7.7E-06	1.2E-06	Negligible	1.4E-05	4.1E-06
Intoxicated	2.1E-07	4.1E-07	Negligible	Negligible	Negligible	Negligible	Negligible
Failure to use navigational aids	5.0E-06	2.1E-06	4.8E-06	2.5E-06	1.4E-06	3.6E-06	6.1E-06
Failure to give way /high speed	4.5E-06	2.9E-06	3.0E-06	2.4E-06	2.4E-06	1.3E-06	6.9E-06
Lack of knowledge/skill/ training	6.4E-07	1.8E-06	4.6E-06	1.8E-06	1.4E-06	3.2E-07	2.6E-06
Communication problems	1.6E-06	1.1E-06	2.0E-06	4.1E-06	5.3E-07	2.4E-06	3.2E-06
Injury/sickness	Negligible	1.3E-07	Negligible	Negligible	Negligible	Negligible	Negligible
Use of defective equipment	5.1E-07	7.9E-07	1.1E-07	2.8E-08	8.2E-07	Negligible	3.7E-07
Technical failure							
Technical failure not related to main engine	1.3E-05	2.0E-05	2.6E-06	1.3E-06	2.1E-05	1.3E-06	3.9E-06
External factor							
Strong currents	3.7E-06	2.6E-07	7.9E-07	Negligible	4.7E-06	5.8E-06	2.9E-06
Severe heavy weather	6.9E-07	Negligible	2.3E-07	Negligible	2.1E-06	8.3E-06	2.5E-06
Sum	**1.7E-04**	**1.5E-04**	**1.1E-04**	**1.3E-04**	**1.2E-04**	**1.1E-04**	**2.1E-04**

Table 11: Estimated reduction potential of PLL per ship year

A ranking of the RCOs by total risk reducing potential in terms of PLL frequency reduction is given in Table 12.

Rank	RCO	PLL reduction	PLL reduction of total
1	RCO 7	2.1E-04	14%
2	RCO 1	1.7E-04	11%
3	RCO 2	1.5E-04	10%
4	RCO 4	1.3E-04	8%
5	RCO 5	1.2E-04	8%
6	RCO 3	1.1E-04	7%
7	RCO 6	1.1E-04	7%

Table 12: RCOs ranked by PLL reduction per ship year

Ship type	RCO 1	RCO 2	RCO 3	RCO 4	RCO 5	RCO 6	RCO 7
All chosen categories excluding tanker for oil	3.0E-05	2.7E-05	1.9E-05	2.2E-05	2.0E-05	1.9E-05	3.7E-05
Tanker for oil	1.0E-04	9.2E-05	6.6E-05	7.5E-05	7.0E-05	6.5E-05	1.3E-04

Table 13: Total estimated reduction potential of oil spill frequencies

Table 13 gives the total estimated oil spill frequency reduction following implementation of each RCO, based on the data given in Table 7: "Number of frequency of oil spills" and Table 10: "Workshop estimate of risk reducing potential". Further, the data presented in chapter 0 have been used to calculate values of tons of oil spill prevented and corresponding savings in clean-up costs, given in Table 14 and Table 15, respectively. Savings from reduced clean-up costs are yearly, and are thus depreciated over the lifetime of the ship according to Equation 1. The values in Table 15 represent the benefit (∆B) in Table 16 (NetCAF) in chapter 0.

Ship type	RCO 1	RCO 2	RCO 3	RCO 4	RCO 5	RCO 6	RCO 7
All chosen categories excluding tanker for oil	1.7E-03	1.6E-03	1.1E-03	1.3E-03	1.2E-03	1.1E-03	2.1E-03
Tanker for oil	1.2E-01	1.1E-01	7.7E-02	8.7E-02	8.1E-02	7.6E-02	1.5E-01

Table 14: Total estimated oil spill reduction potential [tons of oil spilled per ship year]

Ship type	RCO 1	RCO 2	RCO 3	RCO 4	RCO 5	RCO 6	RCO 7
All chosen categories excluding tanker for oil	$139	$125	$90	$101	$95	$88	$170
Tanker for oil	$9.565	$8.592	$6.176	$6.992	$6.518	$6.062	$11.737
Sum	**$9.704**	**$8.716**	**$6.266**	**$7.094**	**$6.613**	**$6.150**	**$11.907**

Table 15: Total estimated clean-up cost reduction potential [$ in clean-up cost per ship year]

8.4 Cost benefit assessment

There are several indices which express cost effectiveness in relation to safety of life such as Gross Cost of Averting a Fatality (GrossCAF) and Net Cost of Averting a Fatality (NetCAF), given in Equation 2 and Equation 3, respectively. Other indices based on damage to and the effect on property and environment may be used for a cost-benefit assessment relating to such matters, but this is not included in this report.

$$GrossCAF = \frac{\Delta C}{\Delta R}$$ **Equation 2**

$$NetCAF = \frac{\Delta C - \Delta B}{\Delta R}$$ **Equation 3**

where:

∆C is the cost per ship of implementing the Risk Control Option (Chapter 0).

∆B is the economic benefit per ship resulting from the implementation of the Risk Control Option, in terms of $ of clean-up cost saved depreciated over the lifetime of the ship (Table 15).

∆R is the risk reduction per ship, in terms of the number of fatalities averted implied by the Risk Control option (Table 11).

The criterion used for recommendations based on NetCAF and GrossCAF can be found in the consolidated version of the FSA Guidelines [26]. The criterion that has been used for all FSAs submitted to IMO so far has been at $3million/fatality [26]. However, it is stated in the FSA Guidelines that the proposed values for NetCAF and GrossCAF have been derived by considering societal indicators. They are provided for illustrative purposes only. The specific values selected as appropriate and used in an FSA study should be explicitly defined. This criterion is not static, but should be updated every year according to the average risk free rate of return (approximately 5%) or by use of the formula based on the Life Quality Index (LQI). By using the risk free rate of return of 5 per cent the criterion is calculated to $6.24 million/fatality and this value has been used as the criterion in this report. Indications from other reason studies are that by applying the LQI method the criterion would be even higher [27].

Table 16 sums up ΔC for each RCO for all RCOs split on initial cost and lifetime cost over the life time of the RCO. The initial cost is all costs related to the installation of a given RCO, while the lifetime costs are all costs (e.g. maintenance and running costs) needed in order to keep the RCOs operational for the full 25-year lifetime. The costs are also split on whether the cost will be taken by the shore or the ship. The values are calculated based on the input given in chapter 0 and 0 for a 25-year horizon.

Risk control options	**Ship**		**Shore**	
	Initial cost	**Lifetime cost**	**Initial cost**	**Lifetime cost**
RCO 1: Integration of navigation information and equipment including improved software quality assurance	$50,000	$74,909	$0	$0
RCO 2: Bridge alert management	$12,000	$37,259	$0	$0
RCO 3: Standardized mode(s) for navigation equipment	$0	$0	$0	$0
RCO 4: Automated and standardized ship-shore reporting	$0	$0	$7,443	$7,374
RCO 5: Improved reliability and resilience of onboard PNT systems	$10,500	$35,773	$0	$0
RCO 6: Improved shore-based services	$0	$65,960	$0	$0
RCO 7: Bridge and workstation layout standardization	$0	$0	$0	$0

Table 16: Cost for all RCOs given per ship year

In Table 17 the total cost of operating the RCOs are given taking a 25-year horizon. The values include all initial investment cost as well as all operational cost for the next 25 years in order to install the RCOs for all new ships built in that period. The cost again assumes that 4,000 ships are built each year for the next 25 years.

Risk control options	Ship		Shore	
	Initial cost	**Lifetime cost**	**Initial cost**	**Lifetime cost**
RCO 1: Integration of navigation information and equipment including improved software quality assurance	$2,959,728,359	$4,434,219,864	$0	$0
RCO 2: Bridge alert management	$710,334,806	$2,205,514,577	$0	$0
RCO 3: Standardized mode(s) for navigation equipment	$0	$0	$0	$0
RCO 4: Automated and standardized ship-shore reporting	$0	$0	$387,030,000	$383,470,383
RCO 5: Improved reliability and resilience of onboard PNT systems	$621,542,955	$2,117,539,368	$0	$0
RCO 6: Improved shore-based services	$0	$3,904,453,559	$0	$0
RCO 7: Bridge and workstation layout standardization	$0	$0	$0	$0

Table 17: Depreciated total cost for all RCOs based on 25 year horizon

In

Table 18 the benefits and risk reduction effects are given for the RCOs.

Risk control options	**ΔB**	**ΔR**
RCO 1: Integration of navigation information and equipment including improved software quality assurance	$136,765	4.3E-03
RCO 2: Bridge alert management	$122,848	3.9E-03
RCO 3: Standardized mode(s) for navigation equipment	$88,311	2.8E-03
RCO 4: Automated and standardized ship-shore reporting	$7,447	3.1E-03
RCO 5: Improved reliability and resilience of onboard PNT systems	$93,203	2.9E-03
RCO 6: Improved shore-based services	$86,683	2.7E-03
RCO 7: Bridge and workstation layout standardization	$167,816	5.3E-03

Table 18: Benefit and risk reduction for all RCOs given per ship year

Note that the risk reduction of the individual RCOs are not additive and thus implementing RCO 1 and RCO 2 would not necessarily yield a risk reduction of 4.3E-03 + 3.9E-03 = 8.2E-03. There might, however, be some synergies between the RCOs which would deem it prudent to implement several RCOs as package. This has however not been analysed here and all RCOs have been assessed as independent.

In Table 19 the resulting NetCAF and GrossCAF values are given based on the values in Table 16 and Table 18.

RCOs	NetCAF	GrossCAF
RCO 1: Integration of navigation information and equipment including improved software quality assurance	-$2,760,654	$29,084,428
RCO 2: Bridge alert management	-$19,076,077	$12,769,005
RCO 3: Standardized mode(s) for navigation equipment	-$31,845,082	$0
RCO 4: Automated and standardized ship-shore reporting	$2,347,553	$4,719,707
RCO 5: Improved reliability and resilience of onboard PNT systems	-$16,034,891	$15,810,192
RCO 6: Improved shore-based services	-$7,613,217	$24,231,866
RCO 7: Bridge and workstation layout standardization	-$31,845,082	$0

Table 19: NETCAF and GROSSCAF for all RCOs ($ per life saved)

As can be seen from the results, RCO 1, RCO 2, RCO 3, RCO 5, RCO 6 and RCO 7 have a negative NetCAF indicating that the RCOs are economically beneficial in itself, i.e. the costs of implementing the RCO is less than the economic benefit of implementing it, regardless of how many lives that are saved. A sensitivity analysis shows that all the RCOs except RCO 1 will have a negative NetCAF even if the cost was increased by 20 per cent and the benefit and the risk reduction was lowered by 20 per cent. For RCO 1 the NetCAF would be positive, and above the criterion of $6.24 million.

In addition RCO 4 have a GrossCAF of less than $6.24 million which indicates that the RCO should be implemented, according to the IMO criteria MSC 83/INF.2. A sensitivity analysis shows that RCO 4 will have a GrossCAF of less than the criterion even if the cost was increased by 20 per cent and the risk reducing effect was lowered by 20 per cent.

For RCO 4 it should here be noted that this is a shore based RCO with all cost and benefits taken by the society at large. The RCO has been implemented for new ships only and it could be envisioned that this would benefit existing ships as well. The total number of ship years in 2011 was over 107,000, i.e. about 26 times more than the yearly estimated number of new builds [21], thus representing a substantial potential for increased benefits in terms of risk to life as well as costs. It is believed that, including all ships would lower the risk per ship and as a result increases the risk reducing effect which could make the RCO cost beneficial; however, this has not been analysed for this report.

For RCO 4 it should also be noted that if only half of the 133 SOLAS countries currently without an electronic ship reporting system create new systems, i.e. some form of international cooperation, the GrossCAF will accordingly be cut in half and the NetCAF would be negative, which is another indication that the system should be implemented. Hence, the number of systems created (itself depending on the extent to which integrated systems covering multiple countries and regions are chosen) highly influences the outcome of the analysis.

9 Recommendations for decision-making

This study demonstrates that the RCOs listed in Table 20 are cost-effective according to the IMO criteria and should be considered for implementation at IMO.

RCOs recommended based on FSA
RCO 1: Integration of navigation information and equipment including improved software quality assurance
RCO 2: Bridge alert management
RCO 3: Standardized mode(s) for navigation equipment
RCO 4: Automated and standardized ship-shore reporting
RCO 5: Improved reliability and resilience of onboard PNT systems
RCO 6: Improved shore-based services
RCO 7: Bridge and workstation layout standardization

Table 20: RCOs recommended for further consideration at IMO

The FSA has demonstrated that there are improvements to the bridge systems including layout, integration and standardization which are cost-effective. RCO 1, RCO 2, RCO 3, RCO 5 and RCO 7 could be argued to also make familiarization and training easier for crew switching between ships and thus lower the associated costs for the ship owner.

In addition a standardized system for transfer of information and data between ship and shore and vice versa would potentially make RCO 4 and RCO 6 more cost-effective. The system should make transfer of broad datasets feasible and practical and there are at present several options for accomplishing this with the current communication channels.

It is also noted that the chosen RCOs do not cover and represent all the proposed solutions in the CG and that there might be other potential RCOs which are cost effective among the solutions not covered.

10 Annexes

10.1 Annex I: References

[1]	IMO (2008). Report of the Maritime Safety Committee on its eighty-fifth session (MSC 85/26/Add.2, annex 20)
[2]	IMO (2013). Revised Guidelines For Formal Safety Assessment (FSA) (MSC 91/22/Add.2, annex 34)
[3]	The Norwegian Coastal Administration (2012). E-Navigation; Enhanced safety of navigation and efficiency of shipping. Found at: http://www.e-nav.no/
[4]	IHS Fairplay Casualty Database (2012)
[5]	The Norwegian Maritime Authority (2012). Maritime Casualty Database
[6]	Parros, Skjong, Eide (2009). Under-reporting of maritime accidents
[7]	IMO (1974): International Convention for the Safety of Life at Sea (SOLAS)
[8]	IMO (2012). e-navigation – Report of the Working Group (NAV 58/WP.6/Rev.1, annex 2)
[9]	IMO (2007). Report of the Maritime Safety Committee on its eighty-third session (MSC 83/28)
[10]	IMO (2010). Adoption of performance standards for bridge alert management (MSC.302(87))
[11]	IMO (2012). Modular and open concept of Integrated PNT System (NAV 58/INF.5)
[12]	Risk acceptance criterion for tanker oil spill risk reduction measures Marine Pollution Bulletin 62 (2011), 116-127
[13]	Digital Ship magazine, August 2005, p.8
[14]	http://www.thedigitalship.com/powerpoints/athens2012/Day1/DS_Athens2012_Navarino.pdf
[15]	http://www.itopf.com/information-services/data-and-statistics/statistics/documents/StatsPack_001.pdf
[16]	Correspondence with Marine Cybernetics
[17]	Estimate by Knut Svein Ording, DNV
[18]	Correspondence with Jeppesen Norway AS
[19]	http://www.norges-bank.no/no/prisstabilitet/valutakurser/$/aar/
[20]	IMO (2011). Report from the Correspondence Group on e-navigation to NAV 57 (NAV 57/6)
[21]	DNV (2012) Effect of proposed CO_2 emission reduction scenarios on capital expenditure
[22]	Statistics Norway, www.ssb.no
[23]	www.mailasail.com
[24]	www.satworx.com
[25]	http://www.dnv.com/services/software/products/DNVNavigatorServices/
[26]	GUIDELINES FOR FORMAL SAFETY ASSESSMENT (FSA). MSC 83/INF.2.
[27]	IMO (2012): Review of the damage stability regulations for ro-ro passenger ships. SLF 55/INF.[3], annex 3
[28]	DNV (2005) Formal Safety Assessment of Electronic Chart Display and Information System (ECDIS)

10.2 Annex II: FSA team

Name	Title	Company
Harald Borgø		Norwegian Coastal Administration
Henrik Eikeland	Consultant	Det Norske Veritas AS
Jon Leon Ervik		Norwegian Coastal Administration
Peter Nyegaard Hoffmann	Discipline Leader	Det Norske Veritas AS
Ulrich A. K. Tagne		Norwegian Coastal Administration

Table 21: FSA project Team

Name	Company	Experience
Arve Lepsø	Det Norske Veritas AS	Arve Lepsøe has a master's degree in marine engineering and nautical science from 1997. He has been with DNV since 1998, and has extensive experience as a surveyor with nautical safety and communication systems. He currently works with verification, approval and inspection of marine operations. Previous work experience as Navigator on Norwegian Navy Ships and as deck officer on several chemical tankers in international trade.
Erik Sonne Ravn	Danish Maritime Authority	Erik Sonne Ravn has 15-year experience working on matters related to maritime risk analysis. The work has been done both at the Technical University of Denmark, the Danish Maritime Safety Administration and the Danish Maritime Administration.
Finn Spone	Det Norske Veritas AS	Work experience in DNV as Nautical Surveyor in Norway and Korea. Work experience as deck officer on several chemical tankers in international trade before joining DNV.
Jan van Tiggelen	Det Norske Veritas AS	Jan is educated as weapon engineering officer in the Netherlands Navy and holds an executive MBA in Shipping and Logistics from the Copenhagen Business School. Jan has 25 years' experience from the maritime industry. He has worked 2 years as Managing Director at Bentzen Electro (maritime electro), 3 years as Fleet Manager and Head of Department at Høegh Autoliners, 10 years as Project Manager at Kongsberg Maritime and 10 years as officer in the Netherlands Navy.
Kjetil Berg Hansen	Norwegian Coastal Administration	Maritime traffic manager at Fedje VTS since 2001. Master degree from Bergen. He has sailed in European trade as Chief Officer and Captain in the years 1995 to 2001.
Knut Svein Ording	Det Norske Veritas AS	Presently working as Business Development Manager for ISDS in Approval Center Ship and Offshore, DNV Norway. Was working as Maritime Manager and Area Production Support,SHE & Quality Manager for Malaysia and Brunei up until 1st August 2011. Previous experience in DNV include serving as Country Chair for Malaysia and Brunei, Managing the Admin Hub in Kuala Lumpur, Head of Section for Control Systems and Nautical Safety & Communication Systems in the previous MTP and working as a surveyor. Has 14 years of seagoing, project and management experience in the Norwegian Navy prior to joining DNV.
Omar Frits Eriksson	Danish Maritime Authority	Omar Frits Eriksson is currently head of Maritime Technology at the Danish Maritime Authority. He has 25 years of experience in maritime affairs, including 15+ years in public Aids to Navigation management. He is the chairman of the IALA Engineering committee as well as the chair of the IALA Risk Management Toolbox steering group. Omar has an MBA in Management of Innovation and Technology.
Stephen Sawhill	Det Norske Veritas AS	Offer 16 years of distinguished naval service with ship command and polar icebreaker experience, 14 years of international research experience in Arctic shipping, resources and environment, and 4 years DNV project management experience. Proven leadership and project management skills in multiple functional environments (commercial, military, field operations, academia and training).
Terje Alling	Norwegian Coastal Administration	Maritime traffic manager at Fedje VTS. Various VTS related positions in the Norwegian Coastal Administration since 1992. Educated as master from the Norwegian Naval Academy in 1984. Navigator and ship command experience in the period 1984-1992.

Table 22: Experts involved in the workshop on estimation of risk reducing effects

10.3 Annex III: Abbreviations

The following abbreviations are used in the report:

AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
ARPA	Automatic Radar Plotting Aids
DNV	Det Norske Veritas
ECDIS	Electronic Chart Display and Information System
FSA	Formal Safety Assessment
GROSSCAF	Gross Cost of Averting a Fatality
GMDSS	Global Maritime Distress Safety System
IBS	Integrated Bridge Systems
INS	Integrated Navigation Systems
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
IRPA	Individual Risk per Annum
LRIT	Long Range Identification and Tracking
LNG	Liquefied Natural Gas
MARPOL	International Convention for the Prevention of Pollution from Ships (MARPOL)
NCA	Norwegian Coastal Administration
NETCAF	Net Cost of Averting a Fatality
NMA	Norwegian Maritime Authority
Pax	Passenger
PLL	Potential Loss of Life
RCM	Risk Control Measure
RCO	Risk Control Option
RoPax	Roll-on Roll-off/passenger ship
SAR	International Convention on Maritime Search and Rescue (SAR)
SOLAS	International Convention for the Safety of Life at Sea (SOLAS), 1974
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978
VTS	Vessel Traffic Service

10.4 Annex IV: Basic terminology

The following definitions apply in the context of this study:

Accident:	An unintended event involving fatality, injury, ship loss or damage, other property loss or damage, or environmental damage.
Accident category:	A designation of accidents reported in statistical tables according to their nature, e.g. fire, collision, grounding, etc.
Accident scenario:	A sequence of events from the initiating event to one of the final stages.
Consequence:	The outcome of an accident.
Frequency:	The number of occurrences per unit time (e.g. per year).
Generic model:	A set of functions common to all ships or areas under consideration.
Hazard:	A potential to threaten human life, health, property or the environment.
Initiating event:	The first of a sequence of events leading to a hazardous situation or accident.
Risk:	The combination of the frequency and the severity of the consequence.
Risk contribution tree:	The combination of all fault trees and event trees that constitute the (RCT) risk model.
Risk control option (RCO):	A combination of risk control measures.
Risk evaluation criteria:	Criteria used to evaluate the acceptability/tolerability of risk.

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ANNEX 2

DETAILED SHIP AND SHORE ARCHITECTURE

1 EXAMPLE ON SINGLE WINDOW FOR MARITIME SAFETY INFORMATION

Importance of MSI

1 MSI is essential for enhancing, maritime safety. There is a particularly high expectation to improve the dissemination of MSI and its integration within bridge systems and shore systems.

2 In compliance with SOLAS V regulation 4 (navigational warning), each Contracting Government shall take all steps necessary to ensure that, when intelligence of any dangers is received from whatever reliable source, it shall be promptly brought to the knowledge of those concerned and communicated to other interested Governments.

3 In compliance with SOLAS V regulation 5 (Meteorological services and warnings), Contracting Governments undertake to encourage the collection of meteorological data by ships at sea and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation.

4 There are different onshore services involved in the production of MSI: NAVAREA and METAREA coordinators; Hydrographic Offices; Meteorological services; coastal and harbour VTS; MRCC (at least to inform the position of an accident); counter-piracy services and security harbor services. Consequently several MSP will be involved.

Formatting the MSI

5 It is important that the infrastructure has the capacity to use present communication systems in order to have a seamless introduction of new communication systems for digital safety information or other types of information and to consider the phasing out of equipment. Hence SafetyNet, NAVTEX and NBDP will be used by the infrastructure. But new radiocommunication technology may be used in dual either digital or telex mode.

6 To enhance MSI into digital messages, it is necessary to format MSI into a comprehensible and consistent language in order to secure the interoperability of data, the integration, the automation, the exchange and the interconnection of the systems. Hence an international nautical information exchange standard is necessary to:

- modernize MSI transmission from shore to ships (currently based on telex messages);
- integrate and display task oriented MSI on navigation and other bridge systems, and
- transmit and share data between onshore services involved in the collection and in the processing of nautical information as well as those interested by the knowledge of the nautical situation.

7 It is necessary to develop within IHO and WMO nautical and meteorological information within the IHO S-100 format in order to achieve the formatting of MSI.

Single Window for MSI

8 The goal of a national nautical information organization is to broadcast nautical information in different manners to navigators and other users: MSI, charts and publication updates. But first of all, this organization is based on the collection and the processing of information. This processing involves many national stakeholders and navigators as well. A single window for nautical information should facilitate the exchange of information between all stakeholders including Hydrographic Offices and MSI producers. The same process is necessary for meteorological information and involves the Meteorological services. This single window of nautical and meteorological information should integrate computerized flow management systems. Hence the IHO S-100 standard is necessary to convey and share nautical and meteorological information. It is obvious that the single window contains MSI for broadcasting.

9 This infrastructure is proposed for any Coastal State to achieve their SOLAS obligations seamlessly. In addition, the infrastructure is based on the IHO S-100 standard format which could help to modernize the IMO/WMO World-Wide Met-Ocean Information Warning Service (WWNWS), and in consequence the functional requirement of GMDSS dealing with transmitting and receiving MSI.

Transmission from shore to ship

10 Within the work of reviewing and modernizing the GMDSS it is important to identify which kind of new communications means could be used to transmit digital information in the IHO S-100 format: e.g. INMARSAT Fleet Broad Band, digital HF, NAVDAT, VDE. Through the ITU, additional spectrum is being reserved for specific maritime applications.

11 The infrastructure should integrate the formatting of MSI using the IHO S-100 format, a single window for MSI and a transmission network to broadcast MSI to ships. If NAVDAT is already a solution available by ITU to broadcast digital information, any other radio system identified by ITU compatible with GMDSS requirements should be tested and added to the infrastructure if found relevant.

12 The infrastructure should be able to bear the capacity to transmit messages, other than MSI by onshore centres to ships. MSI is already covering a large scope of operations as indicated in MSC.1/Circ.1288 including acts of piracy, tsunamis and other natural phenomena, WHO health advisory information and security related requirements. Exchange protocols between the single window for MSI and ships should then be developed.

Transmission from ship to shore

13 It should be possible for a ship to feedback to a competent authority ashore. SOLAS V/R31 requires all masters to transmit "danger messages" if they encounter any danger(s) to navigation. The single window for MSI should integrate standard messages from ships to consolidate a general overview of MSI. Hence standardized and automated reporting could be integrated in the single window for MSI.

Integration and display on bridge

14 MSI, using the IHO S-100 standard, transmitted to a ship should be task oriented, integrated and displayed on navigation and other relevant bridge systems to fulfil solution S1: Improved, harmonized and user-friendly bridge design.

Conclusion

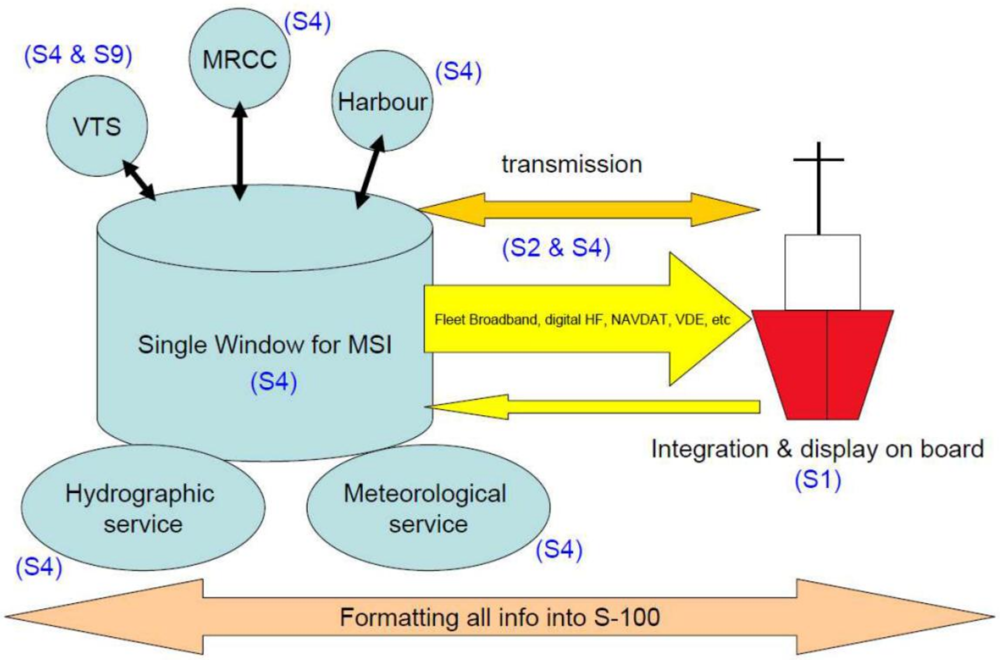
15 The single window for MSI infrastructure should meet the requirements of the revision of GMDSS and the three following solutions:

S2: means for standardized and automated reporting;
S3: improved reliability, resilience and integrity of bridge equipment and navigation information; and
S4: integration and presentation of available information in graphical displays received via communication equipment.

16 Meeting the above solutions would be aided through the application of the Human Centered Design framework as identified in Annex 4 to ensure usability requirements of the single window for MSI are met.

17 Solution S9, improved communication of VTS portfolio, can benefit from the MSI single window infrastructure. VTS should comprise at least an information service and may also include others such as a navigational assistance service or a traffic organization/management service or both. Transmission of the VTS traffic-picture for instance could help the user allowing a better overview of the surrounding traffic and aid spatial awareness. Mandatory reporting from ships to VTS could be automated to be processed by the same (MSI) single window.

General arrangement of the technical infrastructure of a Single Window for MSI



Prioritized main potential solutions by the Correspondence Group on e-Navigation:

S1: improved, harmonized and user-friendly bridge design;

S2: means for standardized and automated reporting;

S3: improved reliability, resilience and integrity of bridge equipment and navigation information;

S4: integration and presentation of available information in graphical displays received via communication equipment, and

S9: improved Communication of VTS Portfolio.

2 EXAMPLE OF A TECHNICAL INFRASTRUCTURE TO SUPPORT SEAMLESS INFORMATION EXCHANGE IN E-NAVIGATION

Basic concepts

1 CG proposes the establishment of a technical infrastructure denoted the Maritime Cloud – a communication framework, where the identity of all registered Maritime Actors are registered in a Maritime Identity Registry, and all information services available at the individual actors are registered in a Maritime Service Portfolio Registry.

2 Obtaining a Maritime Identity would resemble applying for a call sign or MMSI number, and each stakeholder would receive a digital certificate, which can be used to authenticate own information, and to establish a secure, encrypted communication link when sensitive or otherwise confidential information needs to communicated.

3 The Maritime Identity Registry would provide one or more Identity Brokers maintaining Identities, Attributes for identities and Certificates for identities. These Identities and their certificates would enable implementation of information security through public key infrastructures using security solutions well known in many other domains, e.g. the financial sector, this addresses security concerns such as authenticity, integrity and confidentiality.

4 The Maritime Service Portfolio Registry would contain a service specification catalogue and a service instance catalogue. The specification of a service is located in the product specification part of the IHO S-100 GI Registry. The Service Instance Catalogue is a register of provided services. The service instance catalogue links the Service with the Service provider Identity and the Area/leg/junction/point where this service is offered as well as metadata for the provided service (e.g. communication, quality, etc.). Service providers would maintain their own information on provided services in the instance catalogue. Service consumers could make queries for available services in the instance catalogue.

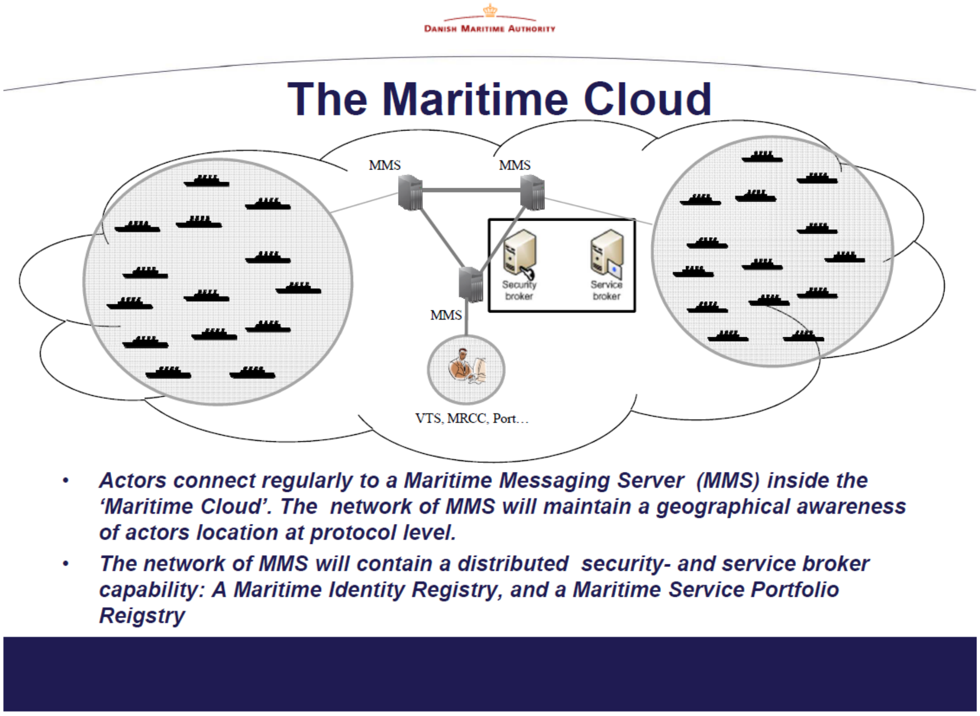


Figure 1

5 The MMS server network inside the Maritime Cloud is envisaged to be operated as a distributed server network by one or more trusted third parties – could be as national or regional data centers - exchanging data in a peer-to-peer network.

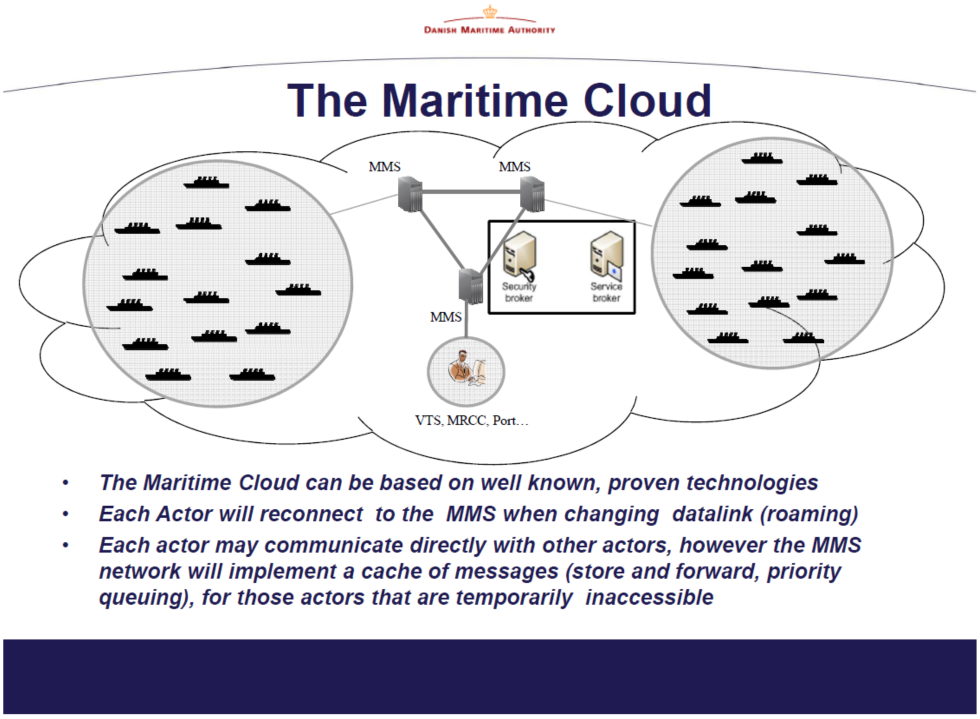


Figure 2

6 Actors would connect regularly to a Maritime Messaging Server (MMS) inside the Maritime Cloud. The network of MMS will at each connection update a geographical awareness of the position of each actor, at a protocol level. Shore based or Satellite AIS information or other sources of tracking data could supplement the update rate of the geographical awareness of the MMS network, at protocol level.

7 The current (or historic) geographical position(s) of each actor could be made available as a basic system information service inside the Maritime Cloud, available only to those actors authorized by the actor, or authorized based on rules contained in a data distribution plan similar to that developed under the LRIT agreement.

8 In the Maritime Cloud, actors can communicate automatically and seamlessly, regardless of the choice of communication link. Actors connected via a TCP/IP communication link can communicate directly, including the ability of acknowledging of information/data transfer. Actors temporarily disconnected, in a state of changing communication link, or not having a current TCP/IP based connection available, can be addressed via the MMS servers, which hold a priority queue of store and forward with acknowledgment of delivery capabilities, for Maritime Information Messages (MIM) – a data container for machine readable maritime information.

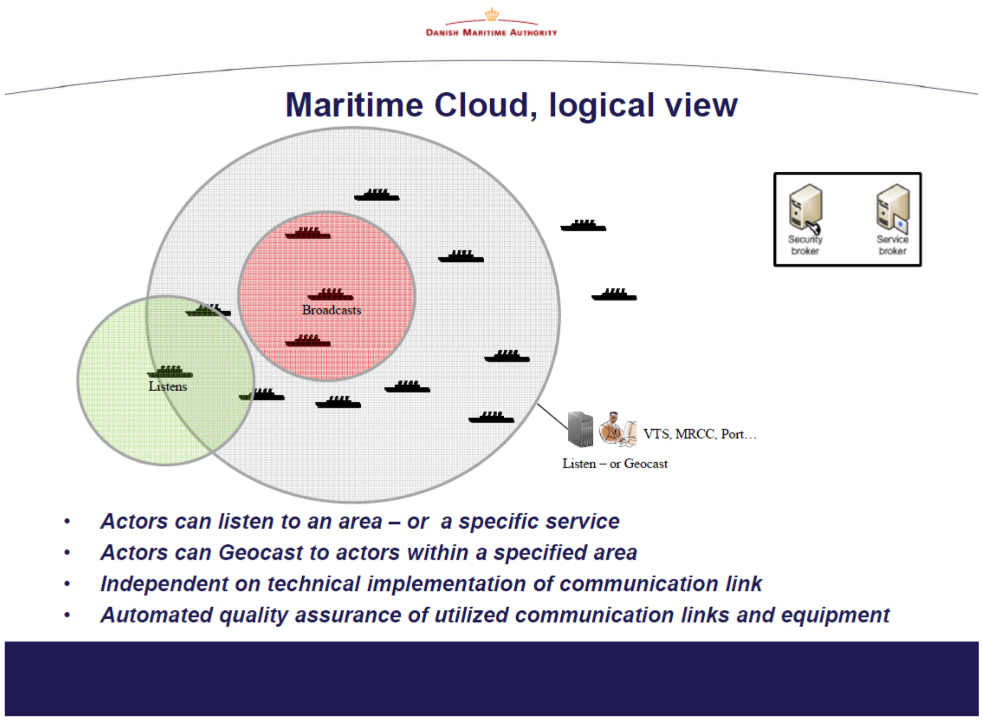


Figure 3

9 As an important concept, an actor can perform a Geocast to other actors, distributing a message to actors who listen to a certain geographical region or service, regardless of the communication link chosen by the individual actors.

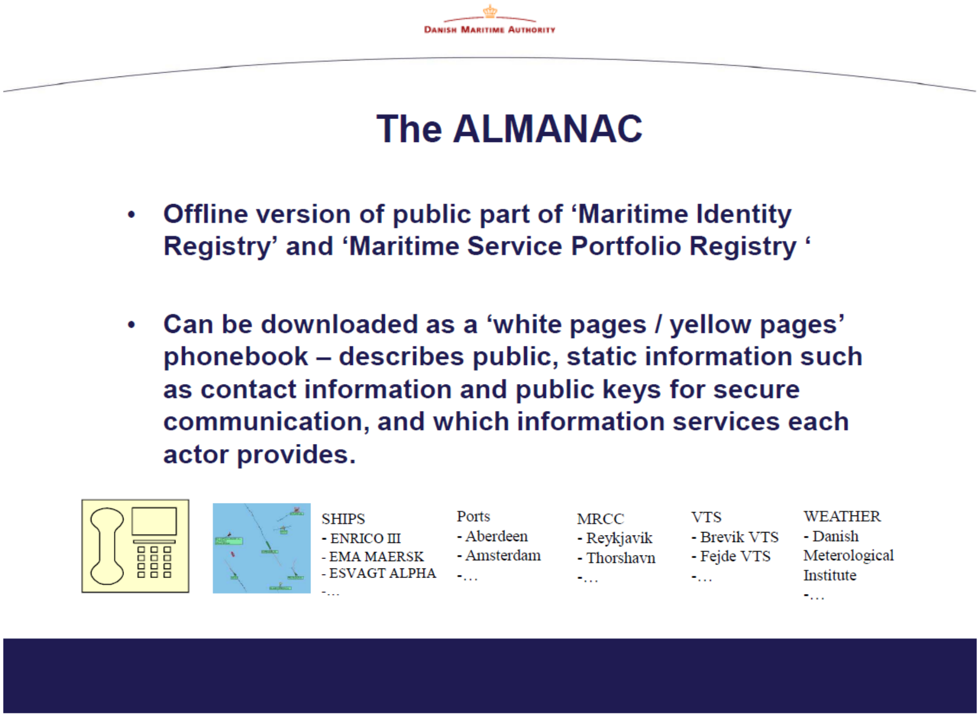


Figure 4

10 The ALMANAC (e.g. a directory or registry) would be an offline version of a public part of the Maritime Identity Registry and Maritime Service Portfolio Registry, which may be downloaded by actors. It would make available a "whitepages/yellowpages phonebook" describing public, static attributes of actors, including public keys for use in establishing secure communication, and a directory of which information services are available from particular actors in a particular area.

11 Using this Almanac, the identity and contact information of other actors, such as name, location and callsign of a VTS centre, or name, IMO number, MMSI number callsign of a ship, is available together with a list of which services this particular actor provides.

12 The Almanac may function as an advanced phonebook for contact information via a multitude of communication channels, for instance providing a specific ships name, callsign, MMSI number for DSC calling or AIS messaging, e-mail address, phone number(s), INMARSAT terminal number or other contact information to a VTS centre, Port or MRCC – or vice versa.

13 Furthermore, the Almanac would enable a VTS centre to see which ships in its area of responsibility support a certain automatic reporting service. A ship would be able to see which service providers can deliver Meteorological/Hydrographic data relevant to its intended route. A ship would be able to see which information services are provided by a particular port. Even if the only service provided by a port is just a link to the ports own existing webpage – outside the Maritime Cloud – the registration in the Almanac would provide a single point for locating professional maritime information services.

S2 Means for automated reporting

14 Automated reporting may be supported by this infrastructure. The Maritime Service Portfolio Registry may link to a service, describing the reporting requirements for entry to a particular port. Required reporting information may be delivered automatically to relevant actors.

15 Reporting may be performed from the ship – or by a trusted service provider ashore. That is a business decision for each vessel operator.

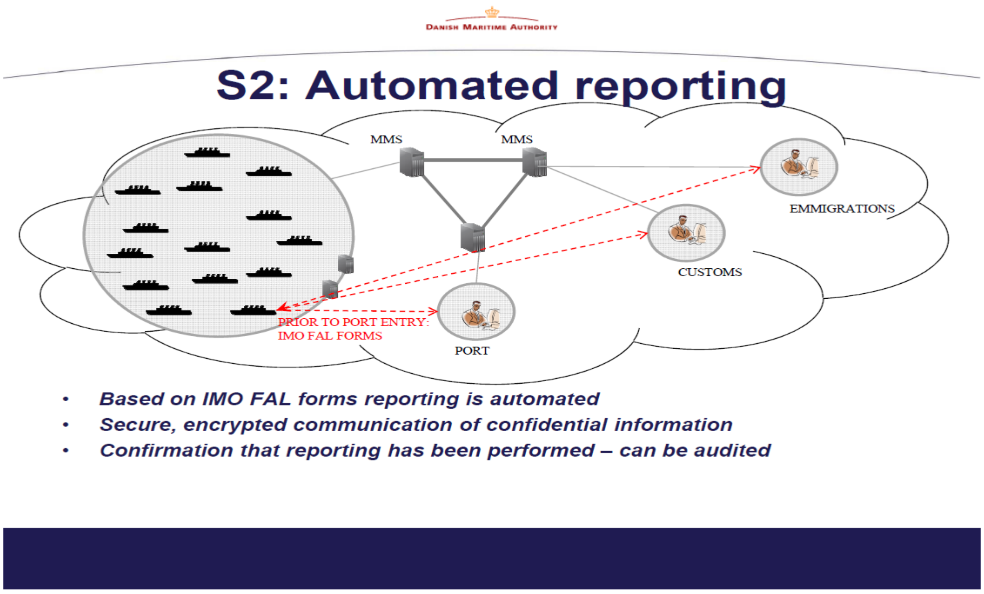


Figure 5

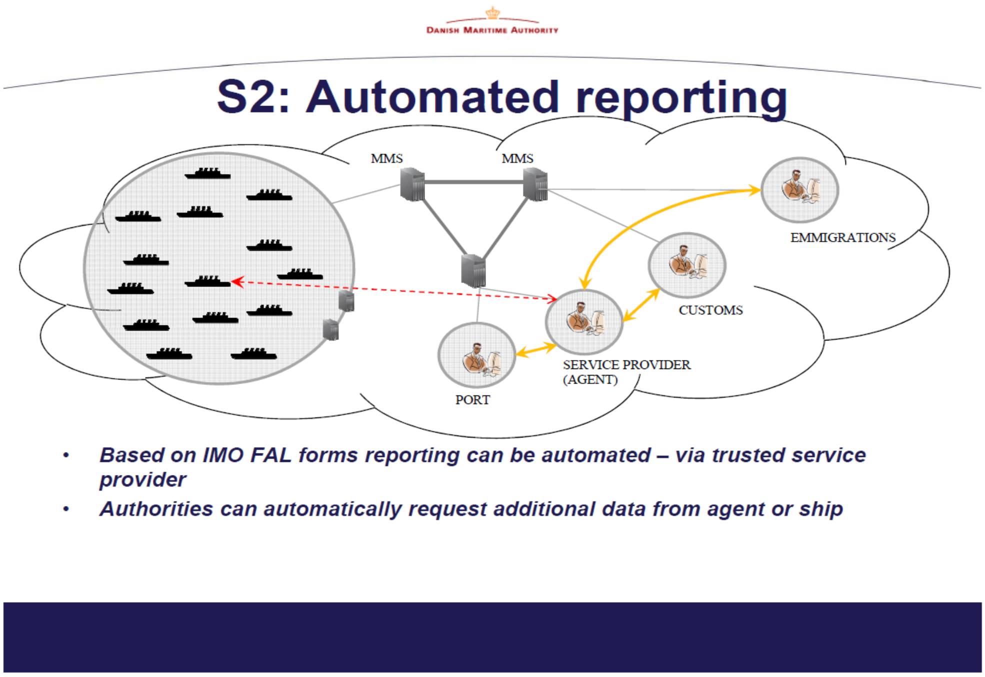


Figure 6

16 Reporting should be based on digital IMO FAL forms, or other harmonized reporting templates.

S4 Integration and graphical presentation

17 E-navigation is about getting ships safely, securely and efficiently from berth to berth in an environmentally friendly way, using globally enhanced systems for navigation, communication and related services – with the human element in focus. The expectations for e-navigation are given in MSC 85/26/Add.1.

18 The promulgation of MSI relevant to ships without causing information and task overload, plays a key role to solution S4, related to the integration and presentation of available information in graphical displays, received via communication equipment.

The current MSI promulgation regime applies NAVTEX and SafetyNet broadcast. The result is that ships may be outside coverage (A4 area), the broadcast information may be irrelevant to many recipients, and the output on the bridge is typically on a dedicated display or printer – not a graphical representation. Some quality assurance for navigational warnings is currently achieved through serial numbered messages and the issuing by NAVAREA Coordinators of weekly in-force bulletins. However, there remains a concern that bridge personnel may not notice the arrival of important information. The information flow cannot be fully quality assured.

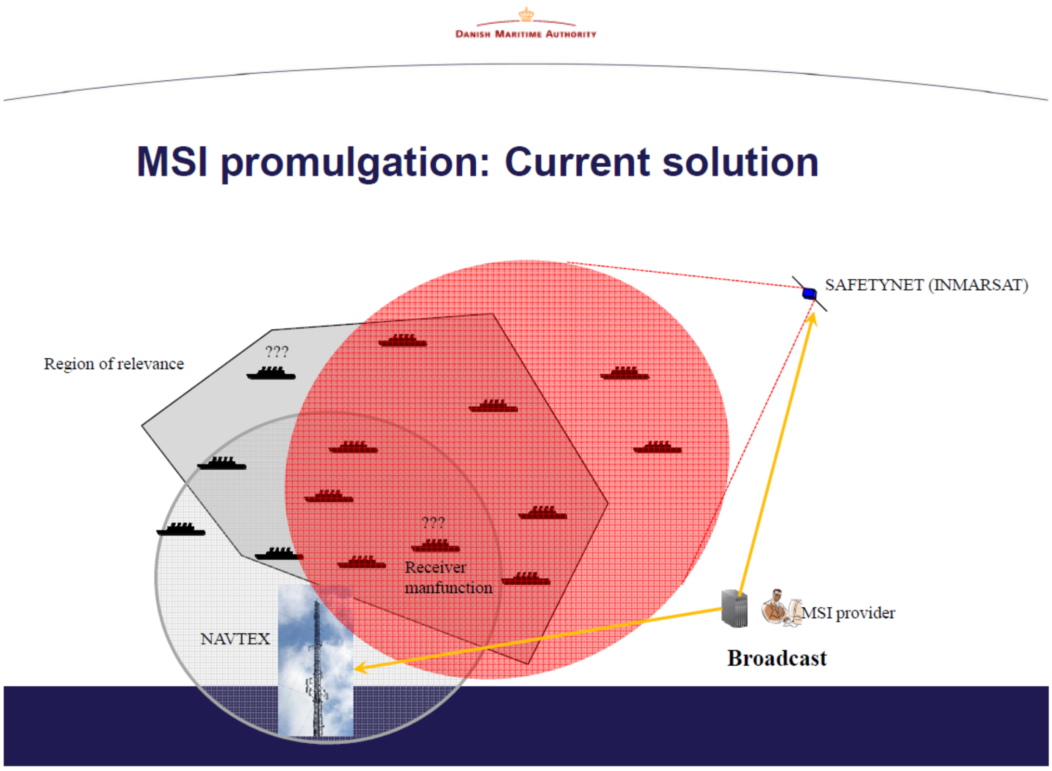


Figure 7

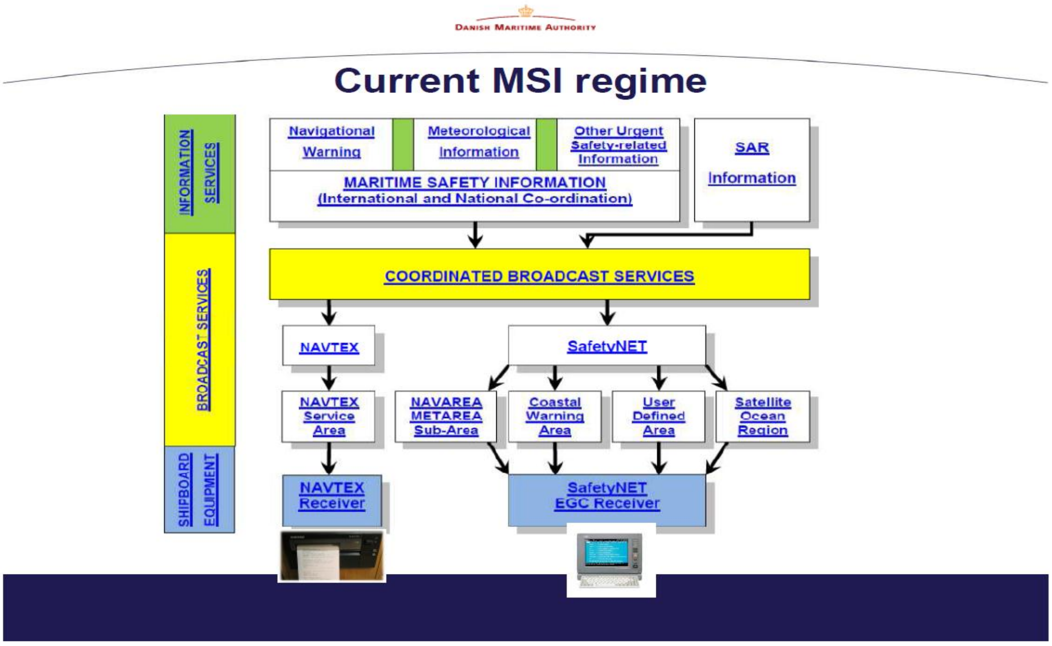


Figure 8

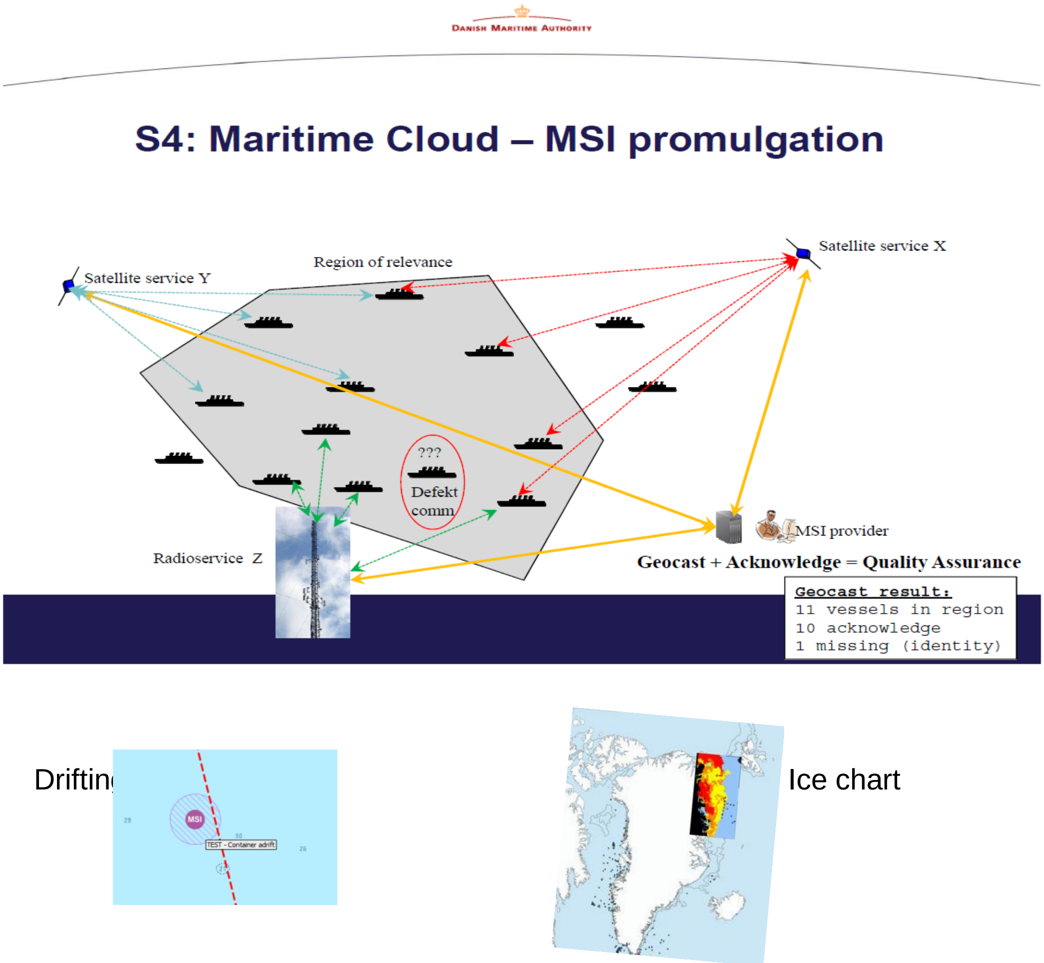


Figure 9

19 MSI, using the IHO S-100 standard, transmitted to a ship should be task oriented, integrated and displayed on navigation and other relevant bridge systems to fulfill solution S1: Improved, harmonized and user-friendly bridge design.

20 With the Maritime Cloud, only relevant recipients would receive the information regardless of the communication link chosen by the individual actor. Information overload could be avoided with appropriate information being graphically displayed. The lack of acknowledgments would reveal that recipients did not receive the information – the communication service provider, the radio link and the onboard communication equipment can be quality assured. The need for radio inspection may change dramatically. Additionally, the system should be developed in line with a HCD framework to ensure task and workload demands are optimal and the system is designed with the user needs as specified above.

21 It might also be beneficial to look into the traditional separation between MSI, Notice to Mariners and chart updates which are very much linked to the traditional ways of promulgating the information (often using old technology). A novel approach could be to handle what we call MSI and Preliminary and Temporary NM under one, since this encompasses temporary or dynamic information and bundle Permanent NM with ENC updates, since this encompasses less dynamic information. A significant increase in bandwidth might be required to support this novel approach which implies moving away from standardized text messages to combinations of text and graphic overlays for display on ECDIS or other equipment.

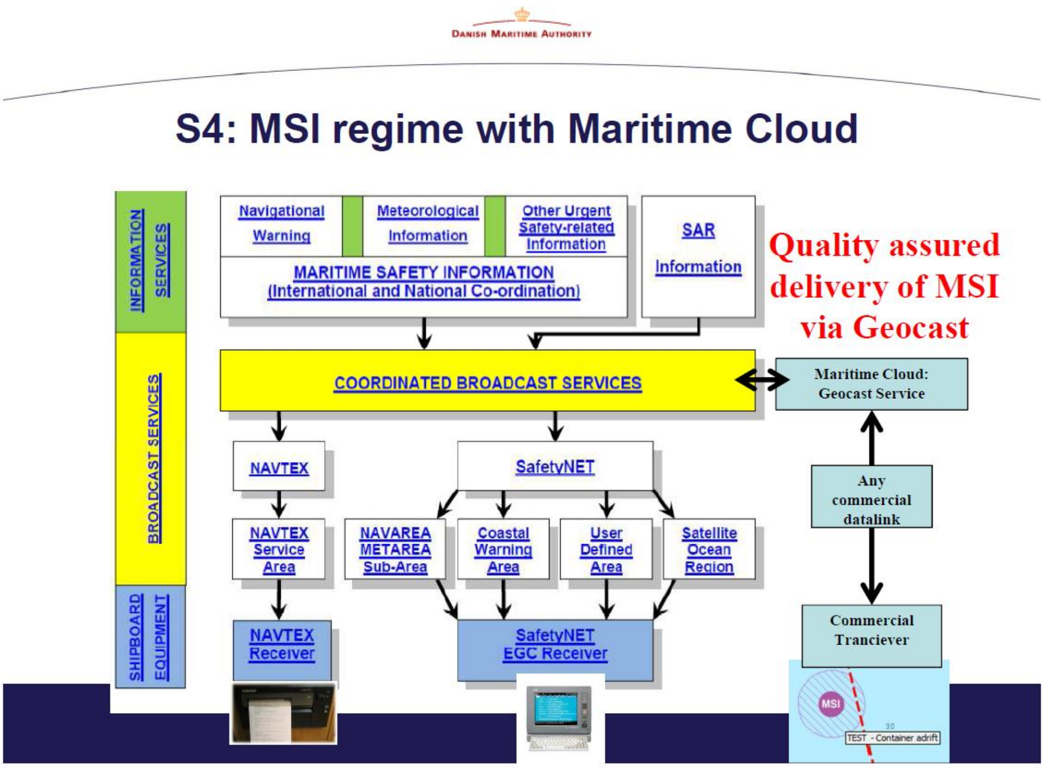


Figure 10

S9 Improved VTS communication

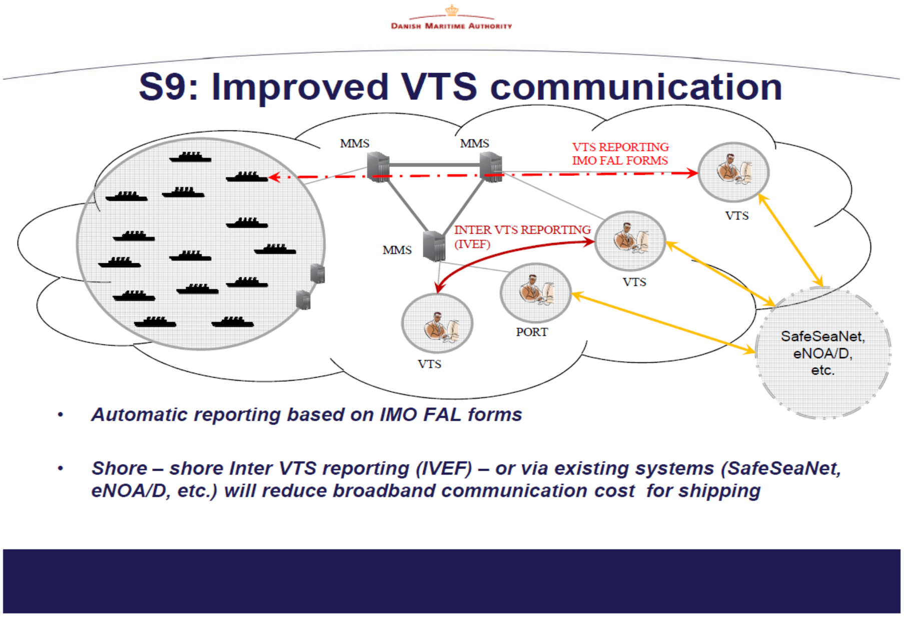


Figure 11

Other examples of how seamless information exchange could facilitate future e-navigation solutions.

22 The technical infrastructure under consideration may also facilitate the development of other advanced e-navigation services, in the next iteration of the e-navigation strategy. Examples are provided below.

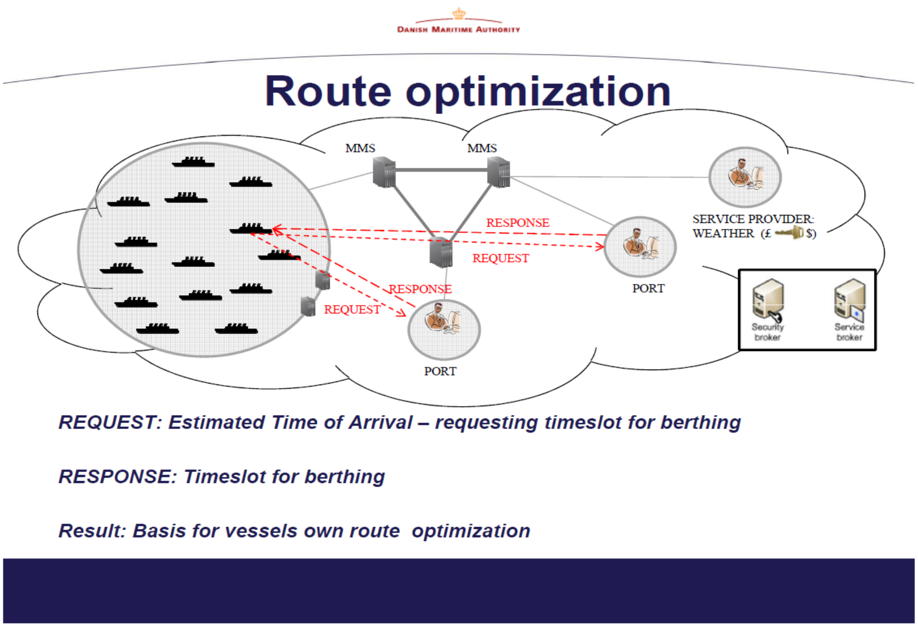


Figure 12

23 A ship may automatically request berthing timeslots in a particular port, based on an estimated time of arrival. This may facilitate the ship's own route optimization in terms of balancing speed/fuel efficiency.

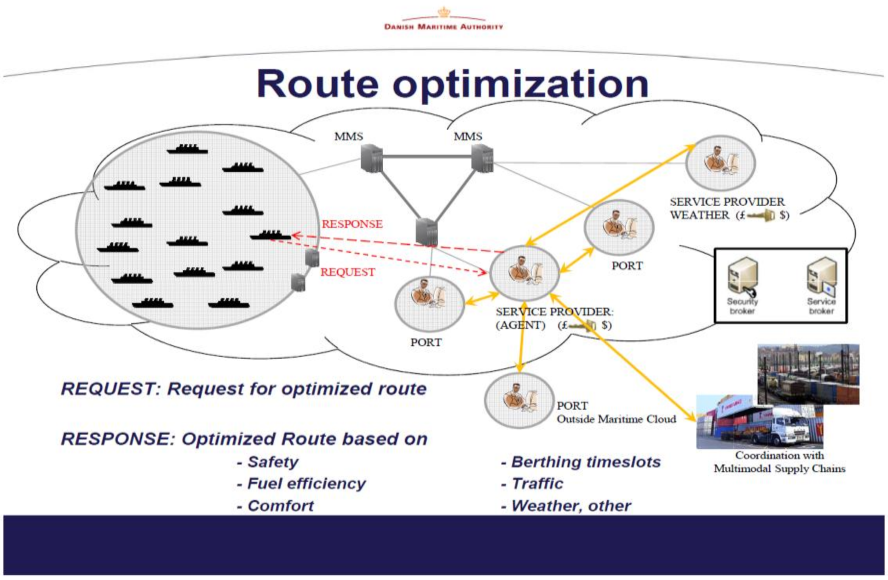


Figure 13

24 A ship could request an optimized route based on any number of parameters from a trusted service provider. Having the frequently updated geographical awareness available in the Maritime Cloud may facilitate multimodal transport and supply chain optimization.

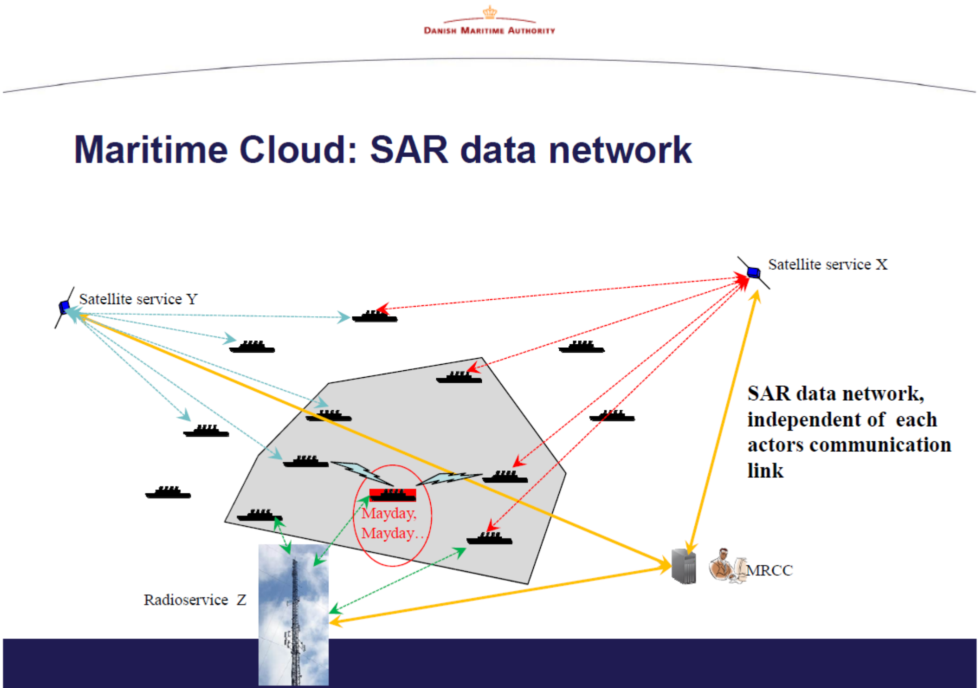


Figure 14

25 During a SAR operation, a MRCC could set up a data network amongst relevant selected actors, regardless of each actor's choice of communication service provider.

***

ANNEX 3

PRELIMINAY MARITIME SERVICE PORTFOLIOS

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP1	VTS Information Service (IS)	VTS Authority	The VTS IS is defined by IMO as **"**a service to ensure that essential information becomes available in time for on-board navigational decision making**"**. IS is provided by broadcasting information at fixed times and intervals or when deemed necessary by the VTS or at the request of a vessel. An Information Service involves maintaining a traffic image and allows interaction with traffic and response to developing traffic situations. An Information Service should provide essential and timely information to assist the onboard decision-making process, which may include but is not limited to: • The position, identity, intention and destination of vessels; • Amendments and changes in promulgated information concerning the VTS area such as boundaries, procedures, radio frequencies, reporting points; • The mandatory reporting of vessel traffic movements; • Meteorological and hydrological conditions, notices to mariners, status of aids to navigation; • Maneuverability limitations of vessels in the VTS area that may impose restrictions on the navigation of other vessels, or any other potential hindrances: or • Any information concerning the safe navigation of the vessel. The VTS IS is designed to improve the safety and efficiency of vessel traffic and to protect the environment. Among other, such services include catalogue such as: Routing, Channel info, Security level, Berthing, Anchorage, Time slot, Traffic monitoring and assessment, Waterway conditions, Weather, Navigational hazards, any other factors that may influence the vessel's transit, Reports on the position, Identity and intentions of other traffic.
MSP2	Navigational Assistance Service (NAS)	National Competent VTS Authority/ Coastal or Port Authority	The NAS is defined by IMO as **"**a service to assist on-board navigational decision-making and to monitor its effects**"**. NAS may be provided on request by a vessel in circumstances such as equipment failure or navigational unfamiliarity. Specific examples of developing situations where NAS may be provided by the VTS include: Risk of grounding; Vessel deviating from the recommended track or sailing plan; Vessel unsure of its position or unable to determine its position; Vessel unsure of the route to its destination; Assistance to a vessel to an anchoring position; Vessel navigational or maneuvering equipment casualty; Inclement conditions (e.g. low visibility, high winds); Potential collision between vessels; Potential collision with a fixed object or hazard; Assistance to a vessel to support the unexpected incapacity of a key member of the bridge team, on the request of the master.

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP3	Traffic Organization Service (TOS)	National Competent VTS Authority/ Coastal or Port Authority	The TOS is defined by IMO as **"**a service to prevent the development of dangerous maritime traffic situations and to provide for the safe and efficient movement of vessel traffic within the VTS area**"**. The purpose of the TOS is to prevent hazardous situations from developing and to ensure safe and efficient navigation through the VTS area. TOS should be provided when the VTS is authorized to provide services, such as when: • vessel movements need to be planned or prioritized to prevent congestion or dangerous situations; • special transports or vessels with hazardous or polluting cargo may affect the flow of other traffic and need to be organized; • an operating system of traffic clearances or sailing plans, or both, has been established; • the allocation of space needs to be organized; • mandatory reporting of movements in the VTS area has been established; • special routes should be followed; • speed limits should be observed; • the VTS observes a developing situation and deems it necessary to interact and coordinate vessel traffic; • nautical activities (e.g. sailing regattas) or marine works in-progress (such as dredging or submarine cable-laying) may interfere with the flow of vessel movement.

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP4	Local Port Service (LPS)	Local Port/Harbour Operator	LPS is applicable to those ports where it has been assessed that a VTS, as described above, is excessive or inappropriate. The main difference arising from the provision of LPS is that it does not interact with traffic, nor is it required to have the ability and/or the resources to respond to developing traffic situations and there is no requirement for a vessel traffic image to be maintained. Provision of LPS is designed to improve port safety and co-ordination of port services within the port community by dissemination of port information to vessels and berth or terminal operators. It is mainly concerned with the management of the port, by the supply of information on berth and port conditions. Provision of LPS can also act as a medium for liaison between vessels and allied services, as well as providing a basis for implementing port emergency plans. Examples of LPS may include: • berthing information; • availability of port services; • shipping schedules; • meteorological and hydrological data.
MSP5	Maritime Safety Information (MSI) service	National Competent Authority	The Global Maritime Distress and Safety System (GMDSS) as described in SOLAS Chapter IV defines the seventh functional requirement as: "Every ship, while at sea, shall be capable of transmitting and receiving maritime safety information". The MSI service is an internationally co-ordinated network of broadcasts of Maritime Safety Information from official information providers, such as: • National Hydrographic Offices, for navigational warnings and chart correction data; • National Meteorological Offices, for weather warnings and forecasts; • Rescue Co-ordination Centres (RCCs), for shore-to-ship distress alerts; • The International Ice Patrol, for Oceanic ice hazards.

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP6	Pilotage service	Pilot Authority/Pilot Organization	The aim of the pilotage service is to safeguard traffic at sea and protect the environment by ensuring that vessels operating in pilotage area have navigators with adequate qualifications for safe navigation. Each pilotage area needs highly specialized experience and local knowledge on the part of the pilot. Efficient pilotage depends, among other things, upon the effectiveness of the communications and information exchanges between the pilot, the master and the bridge personnel and upon the mutual understanding each has for the functions and duties of the other. The Pilot's Portable Unit (PPU) is a useful tool for safe navigation in clear and restricted visibility. Data accessible by the PPU should be made available in a structured, harmonized and reliable manner, and the interface for accessing such e-Navigation information should be standardized. Establishment of effective co-ordination between the pilot, the master and the bridge personnel, taking due account of the ship's systems and equipment available to the pilot, will aid a safe and expeditious passage.
MSP7	Tugs service	Port/Commercial Tug Organization	Efficient tug operations depend on, among other things, the effectiveness of the communications and information exchanges between relevant stakeholders. The aim of the tugs services is to safeguard traffic at sea and protect the environment by conducting operations such as: • Transportation (personnel and staff from port to anchorage) operations. • Ship assistance (ex: mooring) operations • Salvage (grounded ships or structures) operations • Shore operations • Towage (harbour/ocean) operations • Escort operations • Oil spill response Operations

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP8	Vessel shore reporting	National Competent Authority, Shipowner/ Operator/Master	The aim of vessel shore reporting is to safeguard traffic at sea, ensure personnel safety and security, ensure environmental protection and increase the efficiency of maritime operations. **Single-Window** is one of the most important solutions to reduce the Mariners workload (amount of time spent on preparing and submitting reports to shore-based authorities). To achieve this, reports should be automatically generated as much as possible from onboard systems. Some other important possibilities for vessel shore reporting system may include: • Single-entry of reportable information in single-window solution • Automated collection of internal ship data for reporting • All national reporting requirements to apply standardized digital reporting formats based on IMO FAL forms • Automated or semi-automated digital distribution/communication of required reportable information.
MSP9	Remote monitoring of ships systems	VTS Authority, Shipowner	The objective of the service for remote monitoring of vessel systems is to promote the safety of the vessel and personnel, protect the environment and improve and maintain the ships efficiency. The remote monitoring system can be combined with automated operation and control features as part of a fully integrated systems covering many aspects of the ship operation such as: • Propulsion (Main Engine) and Power Monitoring & Control • Auxiliary Machinery Monitoring and Control • Cargo & Ballast Monitoring & Control • Navigation equipment monitoring • Condition based monitoring • Mitigation of potential of fire and flood outbreaks and malfunctioning of necessary auxiliary systems and their supplies. • Managing critical vessels pares parts • Flood Prevention Systems • Fire Detection and Alarm System temperatures, pressure, level, viscosity, flow control, position of vessel, speed, torque control, voltage, current, machinery status (on/ off), and equipment status (open/ closed).

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP10	Telemedical Assistance Service (TMAS)	National health organization/ dedicated health organization	According to the IMO/ILO solution 164 the TMAS centre should provide medical advice for seafarers 24 h/day, 365 days/year. TMAS should be permanently staffed by physicians qualified in conducting remote consultations and who are well versed in the particular nature of treatment onboard ship. Within the maritime medicine the prevailing view has for a long time been that a standardization of the TMAS services is both necessary and wanted. This would firstly enhance the quality of the medical practice, and secondly, a standardization of reporting and registering of medical events will make a much better basis for advancement.
MSP11	Maritime Assistance Service (MAS)	Coastal/Port Authority/ Organizations	The primary mission of MAS is to handle communication between the coastal State, ship's officers requiring assistance, and other players in maritime community. These can be fleet owners, salvage companies, port authorities, brokers, etc. The MAS is on 24-hour alert to deploy rapid assistance and professional support for ships in connection with: Combating pollution, fire and explosions on board, collision, grounding, maritime security, terror mitigation, etc. The Ship Security Alert System enables a vessel to send a distress call if it is attacked by pirates, etc. On receiving such a call, the MAS is responsible for alerting the relevant authorities responsible for a response. The MAS is responsible only for receiving and transmitting communications and monitoring the situation. It serves as **a point of contact** between the master and the coastal State concerned if the ship's situation requires exchanges of information between the ship and the coastal State. Situations where the MAS apply are as follow: • Ship involve in an incident (loss of cargo, accidental discharge of oil, etc.) that does impair its seakeeping ability but nevertheless has to be reported. • Ship in need of assistance according to the master's assessment, but not in distress situation that requires the rescue of personnel on board. • Ship in distress situation and those on board have already been rescued, with the possible exception of those who have remained aboard or have been placed on board to attempt to deal with the ship's situation. The MAS entails the implementation of procedures and instructions enabling the forward of any given information to the competent organization and requiring the organizations concerned to go through the MAS in order to make contact with the ship.

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP12	Nautical Chart Service	National Hydrographic Authority/ Organization	The aim of the nautical chart service is to safeguard navigation at sea by providing information such as nature and form of the coast, water depth, tides table, obstructions and other dangers to navigation, location and type of aids to navigation. The Nautical Chart service also ensure the distribution, update and licensing of electronic chart to vessels and other maritime parties.
MSP13	Nautical publications service	National Hydrographic Authority/ Governmental Agencies	The aim of the nautical publication service is to promote navigation awareness and safe navigation of ships. The nature of waterways described by any given nautical publication changes regularly, and a mariner navigating by use of an old or uncorrected publication is courting disaster. Nautical publications includes: • Tidal currents, aids to navigation system, buoys and fog signals, radio aids to marine navigation, chart symbols, terms and abbreviations, sailing directions. • A Chart and Publication Correction Record Card system can be used to ensure that every publication is properly corrected prior use by mariners.
MSP14	Ice navigation service	National Competent Authority/ Organization	The ice navigation service is critical to safeguard the ship navigation in ice-infested waters, given how quickly the ice maps become outdated in the rapid changing conditions of the ice-covered navigational regions. Such services include: • Ice condition information and operational recommendations/advice • Ice condition around a vessel • Vessel routing • Vessel escort and ice breaking • Ice drift load and momentum, • Ice patrol
MSP15	Meteorological information service	National Meteorological Authority/WMO/ Public Institutions	The meteorological service is essential to safeguard the traffic at sea by providing weather, climate digital forecasts and related information to mariners who will use these types of information to support their decision making. Such information include: • Weather routing, Solar radiation, Precipitation, • Cold/hot durations, Warnings • Air temperature, Wind speed & Direction • Cloud cover, Barometric pressure

No.	Identified Services	Identified Responsible Service Provider	Short Description
MSP16	Real-time hydrographic and environmental information services	National Hydrographic and meteorological Authorities	The real time hydrographic and environmental information service is essential to safeguard navigation at sea and protect the environment. The service provided are such as: • Current speed and direction • Wave height • Marine habitat and bathymetry • Sailing Directions (or pilots): detailed descriptions of areas of the sea, shipping routes, harbours, aids to navigation, regulations, etc. • Lists of lights: descriptions of lighthouses and lightbouys • Tide surge prediction tables and tidal stream atlases • Ephemerides and nautical almanacs for celestial navigation • Notice to Mariners: periodical (often weekly) updates and corrections for nautical charts and publications
MSP17	Search and Rescue (SAR) Service	Search and Rescue Authorities	The SAR service is responsible for assisting, coordinating search and rescue operations at sea. In maintaining a state of full readiness the MRCC may perform the following rescue functions: • Survivors of any aircraft (not in an act of war) crashes or forced landings at sea; • The crew and passengers of vessels in distress; • Survivors of maritime accidents or incidents; • The SAR services must also coordinate the evacuation of seriously injured or ill person from a vessel at sea when the person requires medical treatment sooner than the vessel would be able to get him or her to a suitable medical facility. MRCC may also be pro-actively involved in activities such as: • Information collection, distribution, and coordination, • Monitoring towing operations, • Monitors and evaluates levels of risk from Maritime Safety Information (MSI) broadcasts to ensure an immediate response in case of life threatening situations developing; • Monitoring vessels not under command, • Pollution reports and vessels aground.

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ANNEX 4

PROPOSED DRAFT GUIDELINES ON HUMAN CENTRED DESIGN

Definitions

E-navigation: the harmonized collection, integration, exchange, presentation and analysis of marine information on board 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 [1]].

Human Centred Design: An approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge [2].

Life-cycle: The stages and activities spanning the life of the system from the definition of its requirements to the termination of its use covering its conception, design, operation, maintenance support and disposal [3].

Stakeholder: An individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations [2] (Likely stakeholders for e-navigation include mariners, marine pilots, equipment manufacturers, vessel traffic services (VTS), rescue coordination centres, recognized organizations, coastal States, port States and flag States, hydrographic offices, shipbuilders, shipowners, ship operators, ship charterers and training organizations [4]).

Usability: The extent to which a product can be used by specified users to achieve specified goals with safety, effectiveness, efficiency and satisfaction in a specified context of use [2].

User: Any party interacting (input into and/or extract information) with the system including operators and maintainers.

System: Combination of interacting elements organized to achieve one or more stated purposes (A system can consist of products, equipment, services and people) [5].

Introduction

1 E-navigation systems exemplifying essential usability principles will enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment. One of the important principles of usability as described within the International Standard Organization (ISO), other standards and research is that of HCD. HCD describes the methodology used to implement usability goals and to assess the result (It is interchangeably referred to as User Centred Design in some references). The basic premise of HCD is that designable components of a system need to be fitted to the characteristics of the intended user(s), rather than selecting and/or adapting humans to fit the system, product or service [p.5, [5]].

2 Addressing the needs of all users on board and ashore will support the harmonized collection, integration, exchange, presentation and analysis of marine information. Most importantly the system should support the user in low and high stress environments (such as low and high traffic situations and during challenging navigation and environmental conditions), and particularly whenever system are most susceptible. This will improve user

performance, decrease the time required for training, allow for error management and recovery, and the time and resources required for maintenance [6].

3 These guidelines outline a HCD framework for ensuring usability in e-navigation systems. It is intended to be used by most stakeholders involved in e-navigation (as defined above), however the primary users of the HCD framework will be those who develop and evaluate e-navigation systems: equipment manufacturers, system integrators, state approval authorities, shipbuilders, shipowners, ship operators, VTS/RCCs, International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and the Organization, including its member organizations. As these guidelines are based on system life-cycles, various stakeholders would be involved at different stages. The requirements within this HCD framework are meant to be goal-based and are not intended to specify or discourage the use of any particular design solution relevant to the development, design and manufacture of e-navigation systems. As such detailed and prescriptive design requirements which specify design solutions are not included.

4 While systems integration is not covered within these guidelines, it is important to note that the development of e-navigation systems must be undertaken within the broader context of systems integration (ship, other equipment, crew, shore, training, etc.) to ensure full consideration of usability issues.

HCD framework objectives

5 The guidelines present a HCD framework for the design and testing of e-navigation systems to achieve usability. It emphasizes the need to understand all users and their requirements and constraints [7]. The objective is to ensure that HCD requirements and criteria, from all user perspectives, have been met. This includes all users of the system (including maintainers). The improvement of usability within the development of e-navigation will be evolutionary and part of a continuous process as more understanding is gained over time [8].

6 This HCD framework was developed based on current usability standards, guidelines and research outcomes [2, 9, 10]. Annex 4.1 provides a brief overview of relevant, current international standards.

7 An important aspect that must be considered as part of these guidelines is software quality assurance. This is important as highlighted by a paper presented to the sub-committee on safety of navigation in 2012 (NAV 58/6/4) by the Republic of Korea [11]. This paper stressed the importance of ensuring that high-quality software that is both stable and complete will need to be installed to support e-navigation. The ISO/IES FCD 25010 standard provides further guidelines on systems and software product quality requirements and evaluation [12].

HCD framework process description

HCD framework requirements

8 The HCD framework process should as a minimum consist of these four activities:

Activity 1: Understand and specify the context of use (in which the system is/will be used);
Activity 2: Specify the user requirements;
Activity 3: Produce design solutions to meet user requirements; and
Activity 4: Evaluate the designs against requirements.

9 This framework will be required to be integrated into the "major" phases of e-navigation system life-cycles (i.e. concept development, planning and analysis, design and testing, implementation and operation). Figure 1 outlines the activities to be undertaken when applying the HCD framework. It illustrates the interdependence of each activity within the HCD process. It does not imply a strict linear process, rather it illustrates that each step in each activity uses outputs from other activities. Embedded within each is the requirement to conduct Testing Evaluation and Assessment (TEA) [10]. As part of the HCD framework, Activity 5 was added to cover the operational phase of the life-cycle. This should ensure that when navigation systems are being modified or new systems fitted, the human element issues are addressed and supported during the integration process into the operational environment. This will need to be aligned with ongoing crew training and maintenance support throughout the operational life, with the crew able to provide operational feedback that may lead to further refinements to the system and subsequently improved performance.[1]

10 The processes within the HCD framework should ensure that the following requirements are included:

- Establish a good understanding of any usability design shortfalls and strengths of previous generations of navigation systems (i.e. this may include conducting an early human element analysis (EHEA) to identify and document human element issues with current navigation systems). This is incorporated as a Pre-Activity phase within Figure 1 and is considered to be one of the starting points that feed into the HCD process activities. Results from this pre-activity can impact all future life cycle phases. As indicated, this EHEA is a continuous process with data collected during the operational phase providing feedback to the next generation of e-navigation systems.

11 Establish the context of use based upon an explicit and thorough understanding and assessment of users, tasks and environments (defined as Activity 1);

12 Ensure users are involved at each stage of activity during design and development;

13 Ensure the design addresses the whole user experience;

14 Ensure the design is driven and revised by user Testing, Evaluation and Assessment (TEA);

15 Ensure an iterative approach in the design process is adopted; and

16 Establish a design team that includes relevant multidisciplinary skills and perspectives.

Usability design principles

17 A central pillar within the current international standards is the "design usability principles" referred to as "dialogues" within the ISO standards [13]. These design principles consider some human limitations and provide a first step in establishing a core base for an understanding of good human centred design practice [10]. The design principles identified in the ISO standards complement previous work in this area by a number of "usability" researchers who identified important design usability principles (so called "usability heuristics" in the research community) which should be considered as part of the design of

[1] Please note that disposal of system has not been included at this stage. This is subject to further discussions.

systems [10-15]. As specified in the standards, these design principles are not strictly independent and they do overlap. It may be necessary to collaboratively interpret different principles in order to optimize usability for e-navigation.

18 The International Standard Organization (ISO 9421-110) identifies seven principles as being important for the design and evaluation of interactive systems. These can serve as a set of general subject areas for the design and evaluation of e-navigation systems and could be incorporated as performance standards forming part of the usability evaluation activity. Table 1 in annex 4.2 provides a definition and brief description of each of these seven design principles as highlighted in the ISO standards [13].

Testing Evaluation and Assessment (TEA)

19 In e-navigation the users play a crucial role and, hence the effectiveness of system usability evaluation is of particular importance. Therefore, the TEA is integrated within the HCD framework forming part of each phase of the system lifecycle and HCD activities. The TEA iterative process will ensure that human element issues are identified in the early stages of the design process and rectified accordingly. TEA covers a number of potential methods (i.e. heuristic evaluation, questionnaires, link analysis, walkthroughs and user tests) that could be used to evaluate system usability within each phase of the HCD process. As shown in Figure 1, the TEA circle becomes larger following each activity and each phase of the life-cycle process. This denotes the increasing intensity of the TEA process following each HCD activity [10]. There are a series of factors to be considered when selecting the appropriate TEA method within each activity. Often, in the early stages low-fidelity prototypes can be used to obtain feedback at a reduced cost. Annex 3 provides some examples of TEA methods that can be applied within each activity [2].

20 The TEA following activity 4 is conducted before a system is deployed operationally, ideally verifying and validating that usability requirements from all user perspectives have been met – this includes identified operational users as well as system maintainers. This TEA may involve the use of usability test beds with appropriate usability performance test methods and metrics[2] to ensure a system meets performance criteria and operational needs. In 2012, Japan presented a paper to the IMO's Safety of Navigation Sub-Committee meeting (NAV58) proposing one suitable methodology for usability evaluation of navigational equipment which can be used within Activity 4 [20]. An important component of TEA is to ensure that appropriate usability performance standards are used during the design and development of e-navigation systems.

21 A brief description of each activity within the HCD framework is provided below.

Pre-Activity – Conduct an early human element analysis (EHEA)

22 This pre-activity involves identifying human element strengths and weaknesses in the design of navigation systems during the operational phase. Such an analysis is intended to capture human element issues at the earliest stages, and a degree of iteration is usually required to clarify and evaluate these issues as the project develops. Early recognition of broad risks, concerns, constraints, assumptions, requirements and opportunities can provide initial direction to the HCD effort, and result in substantial gains. This activity involves the following steps:

[2] It is critical that appropriate usability metrics and test methodology are used at this stage of the TEA process to ensure usability.

.1 early analysis to capture lessons learned from operating similar or precursor systems;

.2 extraction, assessment and prioritization of human element issues and assumptions from all the information gathered, and their evaluation in terms of risk management;

.3 capture and compilation of the findings in a form that can be readily integrated into a Risk Register for future tracking and risk management before undertaking remaining activities.

Activity 1 – Understand and specify the context of use

23 This activity takes into account the overall environment in which the system will be used. It consists of the users' characteristics, their goals, tasks, physical environment, social and management environment and other factors that may have an impact on safety and performance of the whole system.

24 This activity involves identification of the following [2]:

.1 the users and other stakeholder groups;

.2 the characteristics of the users or groups of users (characteristics pertinent to design such as physical and cultural);

.3 the goals and tasks of the users; and

.4 the environment(s) of the system (organizational (i.e. stakeholder perspectives, applicable standards, assessment measures, etc.), technical and physical environment (i.e. task environment such as space, lighting, etc.).

25 The identification of context of use [28] is a "living" activity that is added to, modified, and updated as system development progresses. It provides the foundation for Activity 2 in the HCD framework.

Activity 2: – Identify user requirements

26 User requirements include user needs arising from human-system issues identified in the context of use related to the maritime environment. The objective is to develop a consistent set of user requirements (e.g. to achieving targets for performance, safety, maintenance, functionality, etc.) to reliably address human-system issues [9].

27 This activity involves the following [2]:

.1 clarification of system goals;
.2 analysis of stakeholders needs and expectations;
.3 analysis of user needs and expectations;
.4 resolving conflicts between different user requirements;
.5 assessment of health and safety risks;
.6 analysis of training needs;
.7 generation of operational concept, top-level system and mission requirements; and
.8 ensuring the quality of user requirements specifications.

Activity 3 – Produce and/or develop design solutions to meet user requirements

28 Activity 3 involves translating mission needs into top-level system functions which defines the operations and events that must be performed in order to meet the system requirements. Functions are then assigned between human and automation by comparing performance capabilities and limitations between humans and technology on a number of parameters (such as accuracy, speed, reliability, response flexibility, and strength). Cost factors and user cognitive and affective support needs are also considered.

29 This activity involves the following [2]:

.1 designing user tasks, user-system interaction and user interface to meet user and system requirements;

.2 applying design principles (see Table 1 in annex 4.2);

.3 allocation of functions;

.4 production of a task model;

.5 development of design solutions (and altering design solutions based on human centred design evaluation and feedback);

.6 specification of system and its use;

.7 development of prototypes;

.8 development of user training; and

.9 development of a maintenance regime and user support.

Activity 4 – Evaluate the design against criteria

30 Activity 4 represents the TEA before a system is deployed operationally to ensure that the design meets the requirements of particular usability performance standards. This TEA activity should involve a process that employs people as testing participants who are representative of the target audience to evaluate the degree to which a product meets its usability performance specifications [8] as highlighted in annexes 4.3 and 4.4.

31 This activity involves the following [2]:

.1 specifying the context of evaluation
.2 evaluation to improve design;
.3 evaluation against system requirements;
.4 evaluation against required practice; and
.5 evaluation in use.

Iterative process

32 During Activity 5 which is the operational phase of the system the user is trained, and throughout its operational life the user should be able to provide operational feedback that may lead to further refinements to the system and subsequently improved performance.

33 Each activity is to be revisited iteratively throughout system development, with feedback between each of the activities used for refinement to meet user and organizational goals. For example, increased definition of the context of use may impact on user requirements or, after initial prototyping and evaluation of a design solution, deficient user-requirements may be identified and amended.

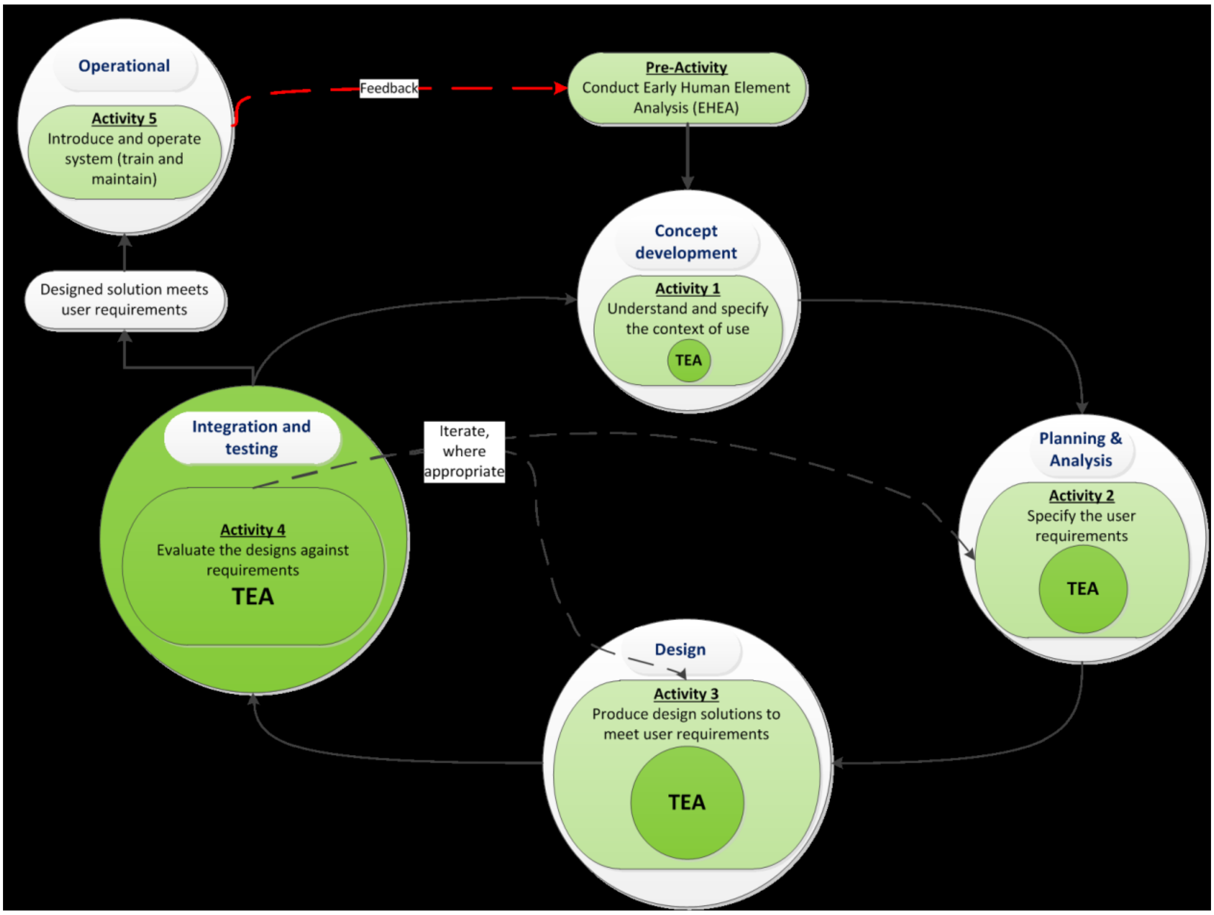

Figure 1: e-navigation Human Centred Design Framework

Bibliography

1 International Maritime Organization (2009). Report of the Maritime Safety Committee on its Eighty-Fifth Session. MSC 85/26/Add.1. London, IMO.

2 International Organization for Standardization (2010). ISO 9241-210: Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems. Geneva, Switzerland, ISO: 32.

3 International Organization for Standardization (2000). ISO/TR 18529 – Ergonomics: Ergonomics of Human System Interaction – Human centred lifecycle process descriptions. Geneva, Switzerland, ISO.

4 International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) (2011) e-Navigation: Frequently Asked Questions.

5 International Organization for Standardization (2011). ISO 26800: Ergonomics – General approach, principles and concepts. Geneva, Switzerland, ISO: 18.

6 Wickens, C., D. and C. Carswell, M. (1995). "The proximity compatibility principle: its psychological foundation and relevance to display design." Human Factors **37**(3): 473-494.
7 Nautical Institute (Swedish Branch) (2012). User Conference on e-navigation, Gotenburg, Sweden.
8 Nautical Institute (2012). e-navigation usability. London, International Maritime Organization.
9 Earthy, J. and B. Sherwood Jones (2011) Best practice for addressing human element issues in the shipping industry.
10 Peterson, E. S. (2012). Engineering Usability. Department of Shipping and Marine Technology. Gothenburg, Sweden, Chalmers University of Technology Doctor of Philosophy: 155.
11 Republic of South Korea (2012). Consideration of software quality assurance issues for e-navigation development. NAV58/6/4, International Maritime Organization.
12 International Organization for Standardization (2011). ISO/IEC 25010: Systems and software engineering - Systems and software requirements and evaluation (SQuaRE) - System and software quality models. Geneva, Switzerland, ISO: 34.
13 International Organization for Standardization (2006). ISO 9241-110: Ergonomics of human-system interaction - Part 110: Dialogue Principles. Geneva, Switzerland, ISO: 22.
14 Billings, C. E. (1997). Aviation automation: The search for a human-centered approach. Mahwah, NJ, Lawrence Erlbaum Associates, Inc.
15 Leveson, N. G. (1995). Safeware: System safety and computers: A Guide to preventing accidents and losses caused by technology. New York, Addison-Wesley.
16 Mahemoff, M., J. and L. Johnston, J. (1998). Principles for a usability-oriented pattern language. OZCHI 1998, IEEE Computer Society.
17 Nielsen, J. (1994). Heuristic evaluation. Usability Inspection Methods. J. Nielsen and R. L. Mack. New York, John Wiley & Sons.
18 Norman, D. A. (1988). The Design of Everyday Things. New York, Doubleday Publishing Group.
19 Schneiderman, B. and C. Plaisant (2004). Designing the User Interface - Strategies for Effective Human-Computer Interaction Addison Wesley.
20 Japan (2012). Draft Interim Guidelines for Usability Evaluation of Navigational Equipment in final form. NAV 58/INF.13. London, International Maritime Organization.
21 International Organization for Standardization (2008). ISO 9241-302: Ergonomics of human-system interaction – Part 302: Terminology for electronic visual displays. Geneva, Switzerland, ISO: 80.
22 International Organization for Standardization (2008). ISO 9241-300: Ergonomics of human-system interaction – Part 300: Introduction to electronic visual display requirements. Geneva, Switzerland, ISO: 9.
23 International Organization for Standardization (2009). ISO 9241-304: Ergonomics of human-system interaction – Part 304: User performance test methods for electronic visual displays. Geneva, Switzerland, ISO: 43.
24 International Organization for Standardization (2002). ISO/TR 16982: Ergonomics of human-system interaction – Usability methods supporting human-centred design. Geneva, Switzerland, ISO: 44.

25 Standards Australia (1994). SAA HB59 Ergonomics - the human factor. A practical approach to work systems design. Homebush, NSW Australia, Standards Association of Australia.

26 Department of Defence (2012). Design criteria standard. Human Engineering.

27 Hornbaek, K. (2006). "Current practice in measuring usability: Challenges to usability studies and research". International Journal of Human-Computer Studies 64(2): 79-102.

28 There are tools available for describing context of use (e.g. www.usabilitynet.org/tools/context.htm).

ANNEX 4.1

BASIS OF FRAMEWORK

This annex provides a brief overview of the international standards relevant to the design of e-navigation systems and consistent with ergonomics principles of human-system interaction. The intent is to provide a summary of the key principles and concepts, as well as an outline of how the standards link together to provide guidance for the different elements of human-centred design.

The e-navigation usability draft framework is developed based on the following standards:

- ISO 26800:2011(E) [5]
- ISO 9241 Series [2, 13, 21-23]
- ISO/TR18529 [3]
- ISO/TR 16982 [24]
- SAA HB59-1994 [25]
- MIL-STD-1472G [26]
- ISO/IEC 25010:2011(E) [12]

ISO 26800:2011(E) Ergonomics – General approach, principals and concepts

At the broadest level, **ISO 26800:2011(E)** identifies a general approach and broad principles and concepts relevant to the design and evaluation of interactive systems, "bringing together the basic principles and concepts of ergonomics in one document, and thus providing a high level view of the way in which ergonomics is applied".

ISO 9421 Series

The **ISO 9241** series of standards are the central set of documents for human centred design. ISO 9241 is a multi-part standard addressing the ergonomics of human system interaction. The series moves from broad principles to more specific requirements for aspects of system design such as world-wide-web interfaces or physical input devices. The majority of the series have some relevance to the detailed design of e-navigation equipment, however most important are the usability concept, the dialogue principles, the characteristics of presented information and the human-centred process model.

ISO/TR18529 Human-Centred Lifecycle Process Descriptions and ISO/TR 16982 Usability Methods

These handbooks will form the basis on which some of the e-navigation Human Centred Design (HCD) framework will be based. These handbooks described the human-centred lifecycle process model which has been developed in response to the need to improve the performance of the human-centred part of system development and support projects. The model is stand-alone, although it is naturally linked to models such as ISO/IEC 12207 due to the interaction between hardware and software within the design of interactive systems. The model uses the format common to process assessment models, describing the processes that ought to occur in order to achieve defined technical goals. The human-centred process category therefore contains processes, and processes contain key practices. The processes generate and use work products.

SAA HB59-1994 Ergonomics – The Human Factor: A practical approach to work system design

To some degree, the detailed methods are further supported by *SAA HB59-1994 Ergonomics – The Human Factor: A practical approach to work system design*. This handbook provides fundamental ergonomic information on human physical capabilities (such as anthropometry), physiological factors such as displays, controls, panel design, vision-related issues and other aspects of the broader environment that interactive systems might be designed within (lighting, noise, thermal environments, vibration and organizational issues like work pace, autonomy and time maximization).

MIL-STD-1472G - Design Criteria Standard – Human Engineering

This standard establishes general human engineering design criteria for military systems, subsystems, equipment and facilities for U.S. Department of Defence. Application of this guidance must be tailored to suit the context of use and the characteristics and needs of the end-users. These more or less follows the design principals set out in the ISO, however are more suited for defence applications.

ISO/IEC 25010:2011(E) – Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) – System and software quality models

This standard defines two sets of objectives required to achieve system and software quality as stated below:

.1 a quality in use model composed of five characteristics (some of which are further subdivided into sub-characteristics) that relate to the outcome of interaction when a product is used in a particular context of use. This system model is applicable to the complete human-computer system, including both computer systems in use and software products in use; and

.2 a product quality model composed of eight characteristics (which are further subdivided into sub-characteristics) that relate to static properties of software and dynamic properties of the computer system. The model is applicable to both computer systems and software products.

The characteristics defined by both models are relevant to all software products and computer systems. The characteristics and sub-characteristics provide consistent terminology for specifying, measuring and evaluating system and software product quality. They also provide a set of quality characteristics against which stated quality requirements can be compared for completeness. The aspect of software quality is critical and needs to be linked to usability.

ANNEX 4.2

USABILITY DESIGN PRINCIPLES

Table 1: This table provides a brief description of each of the nine design principles (based on ISO standards and research in this area)

Design Principle	**Brief Description**
Suitability for the task	Supports the user in the completion of the task.
Self-descriptiveness	At any time, it is obvious to the users which mode they are in, where they are within the mode, which actions can be taken and how they can be performed.
Conformity with user expectations	Conforms with user expectations, if it corresponds to predictable contextual needs of the user and to commonly accepted conventions.
Suitability for learning	Suitable for learning when it supports and guides the user in learning to use the system.
Controllability	System is controllable when the user is able to initiate and control the direction and pace of the interaction until the point at which the goal has been met.
Error Tolerance	A system is error-tolerant if, despite evident errors in input, the intended result may be achieved with either no, or minimal, corrective action by the user.
Suitability for individualization	A dialogue is capable of individualization when users can modify interaction and presentation of information to suit their individual capabilities and needs.

ANNEX 4.3

SOME EXAMPLES OF TESTING EVALUATION AND ASSESSMENT (TEA) METHODS

Table 2: Brief description of referenced methods than can be applied as part of TEA at various stages of the HCD framework.

Name of the Method	Direct involvement of users	Short description of method	HCD Stage
Observation of Users	Y	Collection in a precise and systematic way of information about the behaviour and the performance of users, in the context of specific tasks during user activity.	Activity 4[3]
Performance-related measurements	Y	Collection of quantifiable performance measurements in order to understand the impacts of usability issues.	Activity 4
Critical incident analysis	Y	Systematic collection of specific events (positive or negative).	Activity 1
Questionnaires	Y	Indirect evaluation methods which gather users' opinions about the user interface in predefined questionnaires.	Activity 1 and 2
Interviews	Y	Similar to questionnaires with greater flexibility involving face-to-face interaction with the interviewee.	Activity 2
Thinking aloud	Y	Involves having users continuously verbalize their ideas, beliefs, expectations, doubts, discoveries, etc., during their use of the system under test.	Activity 3 and 4
Collaborative design and evaluation	Y	Methods which allow different types of participants (users, product developers and human factors specialists, etc.) to collaborate in the evaluation or design of systems.	Any
Creativity methods	Y/N	Methods which involve the elicitation of new products and system features, usually extracted from group interactions. In the context of human-centred approaches, members of such groups are often users.	Activity 1 and 2
Document-based methods	N	Examination of existing documents by the usability specialist to form a professional judgement of the system.	Activity 1 and 2
Model-based approaches	N	Use of abstract representations of the evaluated product to allow the prediction of users' performance.	Activity 2 and 3
Expert evaluation	N	Evaluation based on the knowledge, expertise and practical experience in ergonomics of the usability specialist. **	Any
Automated evaluation	N	Algorithms focused on usability criteria or using ergonomic knowledge-based systems which diagnose the deficiencies of a product compared to predefined rules.	Activity 4
Simulation	N	Use of computer simulation modelling tools used for initial evaluations.	Activity 2 and 3

** The standard does not include expert users in this category but this could reasonably be considered another form of expert evaluation.

3 The usability evaluation methodology proposed by Japan fits into this activity area (16).

ANNEX 4.4

SOME EXAMPLES OF USABILITY ASSESSMENT CRITERIA

Table 3: Hornbaek Usability Performance Standards

Name	Short description
Accuracy	The number of errors users make in completing tasks.
Recall	How much information can users recall after using the interface?
Completeness	The extent to which tasks are solved.
Quality of outcome	Extensive measure of the outcome of tasks.
Measure of satisfaction	E.g. how satisfied were you with the use of the search engine?
Preference	Give users a choice of interfaces and see which they choose.
Content-dependent Questions	Users' satisfaction with specific features.
Satisfaction before use	Do users think they will be able to use the system?
Satisfaction during use	Satisfaction obtained while tasks are solved. Can be measured with heart rate variability, reflex responses and quantifications of negative comments.
Attitude towards content	How appealing was the subject matter?
Perceptions on outcome	Users' sense of success.
Other measures of satisfaction	Easy to make mistakes, the display is cluttered, meaningfulness.
Measuring specific attitudes	Annoyance, anxiety, complexity control, engagement, flexibility, fun, intuitive, learnability, liking, physical discomfort, want to use again.

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ANNEX 5

PRELIMINARY GUIDELINE ON E-NAVIGATION TESTBEDS

E-navigation testbeds

The term test bed is used across many disciplines to describe a platform that is used for research, development or testing. Such a platform can be protected from a live (or production) environment. However, in the maritime domain, it is often necessary to conduct live tests with appropriate safety precautions in place.

In the context of e-navigation, a test bed is used to demonstrate/evaluate a proof of concept of one or more of the e-navigation solutions, systems and services. These test beds may be established in a live or simulated test environment.

Harmonization of reporting of testbeds' results

It is important that the results of test beds are shared, as there will be outcomes and lessons learnt that will be useful to the maritime community.

In order to do this and to allow for ready comparison of all elements of test bed results (and map them to elements of the IMO e-Navigation Strategy Implementation Plan), reporting of test bed results should be harmonized.

A number of test beds are currently being established. However, at present, there is no guidance on how the results from test beds can be presented for sharing with the global maritime community.

Noting this and the IMO requirement above, it is necessary to harmonize the reporting of the results of testing of e-Navigation solutions, systems and services.

Benefits and scope of the guidelines
Harmonization of the reporting of results from test beds will allow the e-Navigation solutions being tested to be shared and compared.

This guidance includes, but is not limited to, the following:

- planning a test bed – initial considerations; and
- reporting results of a test bed

Consideration when planning a testbed

<u>Planning of test-beds</u>

- where possible, when planning test beds, e-Navigation applications selected should preferably be linked to the established user requirements and targeted towards the objectives of e-Navigation. Where possible, the applications should address identified gaps in the gap analysis;

- it is essential that tests meet an agreed standard which takes into account a structured, transparent, objective and repeatable methodology. Where the output is in the form of software tools, these should ideally be open-source, with arrangements in place for collaboration, user feedback and improvement.

Architecture

Where possible, and without stifling innovation, test beds should align with the technical and operational services in the Maritime Service Portfolio and the IMO e-Navigation architecture.

User and stakeholder involvement

Test beds should involve users and stakeholders at every stage – from planning to implementation and assessment of results.

Data Structures

E-navigation applications should fit within the baseline data model agreed for the development of e-Navigation – the IHO S-100 Data Registry.

Reference to the IMO Strategy Implementation Plan (SIP)

The details of the test bed, including the outcomes and lessons learnt (in the context of user needs, gap analysis and practical solutions of the IMO Strategy Implementation Plan (SIP)) must be recorded.

Is there a role for the Human Centered Design guideline here?

Sharing of information

Information on the progress of test bed trials, should, if possible, be provided on websites that can be accessed by all interested parties.

It is essential that tests meet an agreed standard which takes into account a structured, transparent, objective, valid and repeatable methodology. Where the output is in the form of software tools, these should be open-source, with arrangements in place for collaboration, user feedback and improvement.

All results should pass quality assurance checks and should be made widely available.

Testbed results

It is important that results from test beds are shared with the global maritime community. For test bed results to be useful to other parties, tests/simulations/trials must have scientific rigour (with regard to, for instance, set-up, collection of data and analysis).

Also:

- the results presented must be objective;
- trials must be reproducible;
- data gathered should be statistically sound and meet generally accepted "scientific standards";
- test results should be presented in acceptable scientific formats (i.e. they should suitable for publication in a peer-reviewed journal);

Harmonization also allows future meta-analyses of specific aspects. Other bodies can recreate trials both to verify results and alter various factors within the trials, in order to further develop the concepts being trailed.

It is proposed to develop a standard framework, such as template for reporting purposes.

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ANNEX 6

FRAMEWORK FOR THE STRATEGY IMPLEMENTATION PLAN

1 The implementation plan should identify responsibilities to the appropriate parties, IMO, other international organizations, States, users and industry, as well as timelines for implementation actions and reviews.

2 A stable and realistic implementation plan will create forward enthusiasm and momentum for e-navigation across the maritime sector. The implementation plan should identify responsibilities and appropriate methods of delivery. Implementation of the strategy will also need to take into account promotion of the e-navigation concept to key stakeholder and user groups.

3 A structured approach will be required to capture evolving user needs, making use of the existing agreed methodology, to incorporate any ensuing changes into the strategy and implementation plan.

4 The strategy implementation plan should include priorities for deliverables, resource management and a schedule for implementation and the continual assessment of user needs. The deployment of any new technologies should be based on a systematic assessment of how the technology can best meet defined and evolving user needs. Cooperation with relevant maritime test beds and other projects should be maintained throughout the implementation process in order to benefit from synergies.

5 The SIP should contain chapters detailing the work required to bring into being each of the identified e-navigation solutions and their corresponding RCOs. This will involve identification of regulatory and technical requirements to be undertaken. A further topic to cover will be the monitoring of any significant changes to training regimes.

6 Additional research tools that could be used for further and more detailed analyses on particular e-navigation solutions should be considered.

7 The SIP will also need to cover transition planning, taking into account the phasing needed to deliver early benefits and to make the optimum use of existing systems and services in the short term. The plan should be phased such that the first phase can be achieved by fully integrating and standardizing existing technology and systems and using a reduced concept of operations. Subsequent phases should develop and implement any new technology that is required to deliver the preferred architecture and implement the overall concept of operations.

8 Also needed within the SIP are processes for review and capturing lessons learned. e-navigation is not a static concept, and that development of logical implementation phases will be ongoing as user requirements evolve and also as technology develops enabling more efficient and effective systems. However, it is critical that this development takes place around a stable set of core systems and functions configured to allow extension over time.

9 The responsibilities that come with IMO ownership and control of the concept include:

.1 development and maintenance of the vision;

.2 definition of the services including their scope in terms of users and geography, and the concept of operations;

.3 identification of responsibilities for the design, implementation, operation and enforcement of e-navigation, acknowledging the rights, obligations and limitations of flag States, coastal States, port States and the various authorities within those States;

.4 defining the transition to e-navigation in a phased approach, enabling the realization of early benefits and the reuse of existing and emerging equipment, systems and services;

.5 taking the lead in setting the performance standards appropriate for e-navigation covering all the dimensions of the system: ship borne, ashore and communications. These standards should be based on user needs and should encourage technology neutrality and interoperability of system components;

.6 ensuring that the concept accommodates and builds on existing maritime systems and funding programs;

.7 facilitating access to funding from international agencies, such as the World Bank, the regional Development Banks as well as international development funding;

.8 assessing and defining the training requirements associated with e-navigation and assisting the relevant bodies in developing and delivering the necessary training programs;

.9 monitor the implementation of the concept to ensure that contracting States are fulfilling their obligations and ensuring that e-navigation users within their jurisdiction are also complying with requirements; and

.10 leading and coordinating the external communications effort necessary to support the case for e-navigation.

10 In sum, the SIP will be a phased implementation schedule, including roadmaps to clarify common understanding necessary for the implementation.

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