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Forschungsprojekt

Modulares und integriertes Schiffsbetriebs-, Navigations- und Kommunikationssystem

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Fraunhofer
FKIE

Modular, Integrated Navigation and Communication Bridge Concept

Report for the Federal Ministry of Transport
and Digital Infrastructure, Germany

Project 40.397/2016

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1 Introduction

The implementation of the International Maritime Organization's (IMO) e-navigation strategy is worked on with high political priority. This concept is supposed to increase the reliability of maritime transport. A core element is the enhanced exchange of safety relevant information between all parties involved at sea and ashore to improve the safety and efficiency of maritime transport through current information.

The intended and necessary harmonization and interoperability of maritime navigation systems and equipment will support the safe maritime transport. One essential element is the establishment and expansion of the integrated navigation system INS, which has been developed lead by Germany and implemented by the IMO, as a central element of the ships navigation.

An important part of the e-navigation strategy is the integration of additional, especially safety relevant, information received via communication systems into the navigation systems. For that purpose, the IMO integrated two main topics into its work program until 2018:

- Development of additional modules to complement the INS performance standards (MSC.252 (83)) concerning a harmonized bridge layout and presentation of information
- Development of guidelines for the harmonized display of navigation information received via communications equipment

Several key topics are to be developed, to support:

- A module that fits the e-navigation onboard architecture developed in Germany, which includes requirements to manage communication information to e.g. route, select, filter information, or choose the best communication system
- Requirements upon INS to integrate and display the information

Therefore, the IMO-approved integrated navigation system should be further established as a key component for ship navigation.

Besides e-Navigation, an increasing digitalization and integration of systems like e.g. navigation, communication, operation and safety systems can be noted as well as an enhanced information exchange in many areas (see figure 1).

Enhanced digitalization and information exchange also increases the risk of cyber-attacks. Therefore, current digital network- and device-technology has to be analyzed and critically examined as well as regulations for cyber risk management of the IMO or other international organizations. Cyber-attacks are a high risk nowadays and will threaten a safe maritime transport and management even more in the future.

These days, numerous IT-components can be found onboard. Among them, there are classical PC-architectures (e.g. bridge systems) as well as network systems (e.g. switches) and industrial automation systems.

Besides multiple advantages regarding efficiency as well as comfort, this also enables cyber-attacks on maritime systems. From a cyber-security point of view, the maritime IT-components are often classic architectures also known from other types of environment. Therefore, they are not only vulnerable for specialized but also for common attacks from the cybercriminal area. With growing digitalization and information exchange, the probability of cyber-attacks and the risks for the ships' infrastructure will further increase. Thus, the risks of such attacks ought to be analyzed and concepts for protection of the ships infrastructure have to be developed.

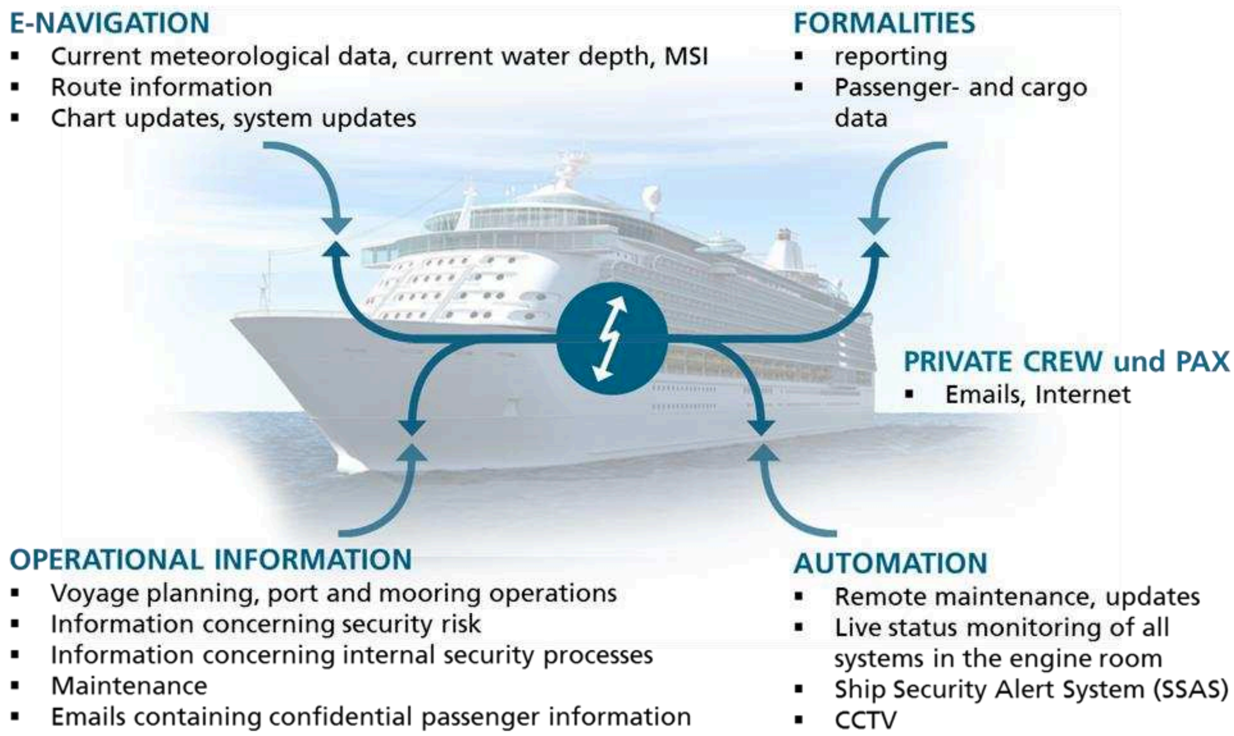


Figure 1: Digital data exchange

2 Objectives

The aim of this project is to develop requirements on a modular ship navigation and operation system which uses INS as a core element following the IMO strategy concerning the implementation of e-Navigation and to transform these requirements into IMO documents. The latter have to ensure the harmonized, task- and situation-dependent presentation of safety relevant information as well as the interoperability of ship navigation, operation and communication systems, and their sensor network. Based on the results of the German e-navigation demonstration project, requirements regarding cyber-security that guarantee a safe data transfer between ship and shore have to be developed.

Furthermore, innovative solutions to increase the safety of the ships' internal and external digital communication structure and its integrated devices will be evolved and lead to a concept to ensure a safe and efficient operation of the ships safety related systems.

Therefore, the focus is on the following sub-goals, which will be examined and worked out in propositions:

- integration of additional, especially safety relevant information, which are received via communication systems for the ship navigation and operation
- harmonization of user the interface design for navigation equipment
- expedite a bridge concept that uses INS as a core element and includes the communication systems
- determination of necessary amendments to the IMO resolution MSC.191(79) (performance standards for presentation of navigation related information on shipborne navigational displays (IMO, 2004a)) including SN/Circ.243 (guidelines for the presentation of navigation-related symbols, terms, and abbreviations, (IMO, 2004a)) with regard to its further developments since it has been introduced
- analysis of the risks that exist in terms of cyber-attacks when data is transferred from ship to shore and examine whether or not the current IMO interim guidelines on maritime cyber risk management guideline (MSC.1/Circ.1526, (IMO, 2016a)) ensure a safe and secure data exchange
- elaboration of a concept for internal digital infrastructure and external digital communication to guarantee a safe ship operation and navigation

The results are to be incorporated into the revised IMO performance standards for integrated navigation systems (MSC. 252 (83)), the IMO interim guidelines on maritime cyber risk management (IMO MSC.1/Circ.1526), the performance standards for presentation of navigation related information on shipborne navigational displays (MSC.191(79)), the guideline to be developed regarding a harmonized display of navigation information received via communication equipment, as well as into the IMO's work results on the subject of the integration of information from NAVTEX and Inmarsat SafetyNET receiver into INS. Furthermore, the work of the IMO regarding the PNT guideline, the revised documents for the ship reporting systems, and documents for maritime safety information (MSI) should be considered.

3 Approach

To achieve the objectives of the project, the following work packages were conducted. Due to decisions at IMO some work packages were adjusted by integrating new or revised work items and issues had to be earlier closed to be readdress in the future.

3.1 Harmonized data structure – harmonization of the format & structure of maritime services

Work package 1

In creating an e-navigation architecture, it is important to identify information and data flows, and the interactions between applications and user interfaces. Consequently, there is a need for a harmonized data structure to enable the use, interoperability, flow and accessibility of relevant information and data within the maritime domain (including both ship and shore aspects). Therefore, the FKIE participates in the framework of this work package in the established IMO/IHO Harmonization Group on Data Modeling (HGDM).

The focus of the work is to support the harmonized integration and presentation of information derived from communication systems onboard. The development of a harmonized format and structure of maritime services should enable the use of the maritime services onboard.

3.2 Harmonized presentation of information received via communication equipment – harmonization of user interface design

Work package 2

The Work package is formed by the requirements specification regarding the harmonized presentation of information received via communication equipment on the bridge. Therefore, when it comes to specify requirements to integrate the information received by communication systems, the provided information by onboard systems needs consideration. The work expands on the insights gained in the German e-navigation demonstration project. Furthermore, findings of the IMO correspondence group on *Guidelines for display of navigation information received via communication equipment* coordinated by Norway are considered.

The work is formed by the requirements specification regarding the harmonized presentation of information received via communication equipment on the bridge. Furthermore, when it comes to specify requirements to integrate the information received by communication systems, the provided information by onboard systems needs consideration. FKIE supported the international work and provided the specified requirements as well as a proposal for the structure of a guideline to the IMO correspondence group tasked with the issue.

Work package 4

In WP4, the appropriate IMO Instrument for regulating the harmonized display of navigation information received via communication equipment are determined, proposed and included in the international discussions. Therefore, the scope of the additions have to be validated and the usefulness to develop a new instrument in form of additional *Guidelines for display of navigation information received via communication equipment* have be evaluated in comparison to an inclusion of the requirements in an additional module for the IMO Resolution MSC.191(79). The issue will be discussed and evaluated in workshops of the national expert group for *integrated ship navigation and control systems* set up by the BMVI and coordinated by Fraunhofer FKIE. The workshops are to be prepared, coordinated, and evaluated.

Depending on the results, a recommendation for one of the following IMO instruments is made:

- revision of IMO Resolution MSC.191(79) including the assimilated SN/Circ.243 (guidelines for the presentation of navigation-related symbols, terms, and abbreviations) to integrate the latest results into an existing regulation
- draft of a new, separate guideline according to the IMO work program

Work package 5

In WP5, the results are transformed into IMO directives. The main part of the work serves to further develop an IMO instrument for the harmonized presentation of the additional information received via communication systems. Depending on the result of work package 4 as well as the direction of decisions and progress of the IMO, the following will be worked on:

- a proposition to revise IMO Resolution MSC 191(79), or
- a draft for a separate guideline.

For that purpose, a structure for either an additional module for IMO Resolution MSC 191(79) or for new IMO guidelines will be developed. Afterwards, the requirements that have been examined in WP2 with regard to harmonized display of information received via communication equipment are summarized and implemented into this structure. In WP5, the progress of the international work regarding the development of the IMO instruments is integrated (see WP8). Furthermore, the work package forms the basis to formulate the German contributions and submissions to IMO.

Work package 6

In WP6, the progress of the international work on guidelines on standardized modes of operation (S-Mode) is monitored and accompanied. Proposals and amendments for the draft guidelines on S-mode are developed and integrated in the international work on S-Mode lead by Australia. Conflicts with existing IMO instruments as IMO Resolution MSC 191(79) and SN/Circ.243 (guidelines for the presentation of navigation-related symbols, terms and abbreviations) are analyzed and taken into account for the development of the draft guidelines.

A set of additional symbols for SN/Circ.243 was determined and submitted to the IMO correspondence group on the development of *Guidelines on the standardized mode of operation of navigation equipment, S-Mode.*

To enable a harmonized presentation of information from multiple sensors on a single display (multi sensor display) amendments for IMO Resolution MSC 191(79) were developed and drafted.

To get an impression of the most recent status of the alarm management on bridges, investigations on a modern container ship were conducted.

3.3 Maritime cyber risk management and digital infrastructure

Work package 3

In WP 3, the risks deriving from data exchange between ship and shore as well as the data processing and storage on board are analyzed regarding cyber-security risks. The aim is to determine propositions to revise and amend IMO MSC-FAL.1/Circ.3 (*guidelines on maritime cyber risk management,* (IMO, (2017f)), the document superseding IMO MSC.1/Circ.1526 (interim guidelines on maritime cyber risk management), in order to guarantee a secure data exchange, processing, and storage. A status analysis of the current onboard infrastructure builds the foundation of WP3.

In particular, the following goals are pursued:

- Development of concrete threat scenarios based on abstract vulnerabilities derived from appendix 2.1 of IMO MSC.1/Circ.1526
- Based on the outlined scenarios, the systems listed in appendix 2.1.1 of IMO MSC.1/Circ.1526 will be classified as follows:
  - inevitably affected
  - possibly affected
  - not directly affected

The protection objectives are classified and prioritized according to the "BSI IT-Grundschutz" (BSI, 2017), which applies to the systems named in appendix 2.2.2 of IMO MSC-FAL.1/Circ.3. It has to be assessed whether or not an achievement of these goals is necessary to operate INS safely.

As approach a systematic risk analysis is followed. Therefore, relevant threat scenarios are chosen and substantiated, based on IMO MSC.1/Circ.1526 (interim guidelines on maritime cyber risk management) and IT basic protection. In this manner, the threat scenarios are described with respect to the aggressors' approach and means, the affected and vulnerable maritime systems, and an estimation of the probability and damage potential caused by the threat. Finally, with these threat scenarios, recommendations for safety measures and additions to IMO MSC.1/Circ.1526 (interim guidelines on maritime cyber risk management) are summarized.

Work package 7

In WP7, the requirements for the IT infrastructure on the bridge of ultra large vessels are analyzed. A concept for a secure ship-external as well as for ship-internal digital communication infrastructure is to be worked up. Modular and integrated technical devices, installations, and systems for the safe navigation of the ship, which shall be interconnected in this IT infrastructure (network), are regarded. The goal is to increase the safety, whereby the improvement of cyber-security is a vital component. The designed concept shall serve as a basis for the performance requirements that are to be derived from it.

Therefore, the research is focusing on onboard network technology. It is examined to which extent sensors can be integrated into a network instead of being separately wired. It is investigated which means (like e.g. redundancy) are necessary to ensure the reliability of such networks.

Regarding cyber security, beside classic protective measures for preventive protection and attack detection, ideas are developed considering the system's resilience in terms of emergency operating features in case of a cyber-attack. The WP is closely related to WP 3

3.4 Concept for IMO regulations for future ships

For the safe navigation, communication and operation of a ship, the IMO defines functional as well as hardware requirements. In light of advancing technology, technological and operational requirements, and the certification process the historically grown IMO regulations are to be analyzed. There is a need to assess how policies and IMO regulations should look like so that innovation is not constrained by specific device and performance requirements and increasingly complex cumulative regulatory frameworks.

To address this topic and specify a way ahead, Fraunhofer FKIE planned, organized, prepared, chaired and post-processed three workshops on behalf of the Federal Ministry of Transport and Digital Infrastructure.

3.5 Support of the BMVI concerning IMO subjects – amendments to international regulations

Work package 8

In WP 8, the BMVI is assisted and consulted regarding the IMO's international work. This includes the support of the actions concerning the IMO's subjects such as e-navigation and cyber-security as well as the collaboration in national and international working groups.

One part is the substantial preparation of national contributions to international working groups as well as the participation in the relevant meeting. These include:

- IMO Subcommittee for Navigation, Communication, Search and Rescue
- the IMO correspondence group for the development of Guidelines for the display of navigation information received via communications equipment (coordinated by Norway)
- International working group on S-mode coordinated by Australia
- IMO/IHO Harmonization Group on Data Modeling (HGDM)

Furthermore, WP8 includes the planning, preparation, and post-processing of meetings of the *BMVI's national expert group for integrated ship navigation and control systems* and the *DGON working group for maritime cyber risk management*.

In addition the BMVI was supported in the preparation of the national comments on the initial review of the regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS) in regard to

- SOLAS chapter IV (Radiocommunications)
- SOLAS chapter V (Safety of navigation)

- the Convention on the International Regulations for Preventing Collisions at Sea, 1972, as amended (COLREG 1972)
- the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code)

4 Harmonized presentation of information received via communication equipment

4.1 Requirements for harmonized presentation of information received via communication equipment

On the basis of the results of the projects SINFO and CE-INS carried out for the German Federal Ministry of Transport and Digital Infrastructure requirements for presentation of information received via communication equipment were determined and structured. They serve as the starting point for the development of an IMO regulation addressing the harmonized display of navigation information received via communication equipment. They consist of relevant issues regarding the functional requirements for the display of information e.g. for selection, routing and filtering. They describe how the various types of navigation information received via communication equipment e.g. Maritime Safety Information (MSI), alterations to own ship route, hydrographic and safe-depth information, and meteorological information should be presented. Furthermore, guidance is given how the information should be displayed on the various navigational systems or INS tasks.

The determined draft requirements were included in the guidelines for harmonized display of navigation information received via communication equipment (see chapter 4.3).

4.2 Determination of appropriate IMO Instrument for the harmonized display of navigation information received via communication equipment

To evaluate the appropriate IMO Instrument for regulating the harmonized display of navigation information received via communication equipment the various options were determined and then considered in workshops/guided deliberations. As input on these issues, the international discussion at the fourth session of the *IMO subcommittee on navigation communications and search and rescue (NCSR4)* and of the *IMO correspondence group on* guidelines for *Harmonized display of navigation information received from communication equipment* were taken into account.

The issue was addressed in

- guided deliberations at 2 meetings of the *national expert group for integrated ship navigation and control systems* set up by BMVI and coordinated by Fraunhofer FKIE
- and a meeting with department S3 of the Federal Maritime and Hydrographic Agency (BSH)

The content and issues of the workshop/guided deliberations were prepared, the workshops coordinated and finally the discussions analyzed.

The results highlight that the best way forward is to develop a separate guideline for the *harmonized display of navigation information received via communication equipment* with a reference to IMO resolution MSC.191 (79) including a clear specification of the application and the link to MSC.191 (79) in the introduction section of the guideline.

A separate guideline has the advantage that necessary changes and enhancements to the document due to future developments can be achieved without facing the difficulties to open the performance standards. The benefit to have flexibility to introduce future changes in an efficient manner has more advantages than to have all requirements included in MSC.191 (79) as a global document. The alignment of the guideline with MSC.191 (79) should be organized similar as the association of the SN/Circ. 243 *Guidelines for the presentation of navigation-related symbols* with MSC.191 (79) to ensure the endorsement of the document.

Additional symbols in regard to the presentation of navigation information received via communication equipment should be integrated and specified in SN/Circ. 243 to have all navigation related symbols in one document.

4.3 Guidelines for harmonized display of navigation information received via communication equipment

4.3.1 Development

Based on IMO resolution MSC.191 (79) and on the determined requirements for the presentation of information received via communication equipment a structure for the guidelines *for harmonized display of navigation information received via communication equipment* was developed by FKIE. The structure was presented to and discussed with the national expert group for *integrated ship navigation and control systems*. The results were submitted by FKIE to the IMO correspondence group on *harmonized display of navigation information received via communication equipment*.

The draft structure is divided in an introduction section with purpose, scope, application definitions, four sections with the guidance and as appendices details regarding definitions and references. In the guidance section in the general presentation part guidance regarding e.g. human centered design and display of information should be listed. In the section "Functional requirements for presentation of information" guidance related to selection of information, routing and filtering of information related to presentation should be given. The section "Presentation of navigation related information" should contain guidance on how the various kinds of information should be presented on the navigational displays. The operational display section should contain requirements for the integration on the various operational displays e.g. priority of presentation.

In the following a draft Structure for *Guidelines for harmonized display of navigation information received via communication equipment* is presented:

1. Purpose
2. Scope
3. Application
4. Definitions
5. General presentation requirements
    5.1. Human centered design
    5.2. Display of information
    …
6. Functional requirements for presentation of information
    6.1. General
    6.2 Routing
    6.3. Selection

6.4. Filtering

6.4. Prioritization

….

7. Presentation of navigation related information

   7.1. MSI or other geo-referenced locations impacting safety

   7.2. Alterations to own ship route

   7.3. Hydrographic, safe-depth information

   7.4. Collision Avoidance information

   7.5. Meteorological

   7.6. Dynamic air gap information

   7.7. …

8. Operational display

8.1. General

8.2. Collision avoidance – radar functions

   8.1.1. Overlay (permanent / non-permanent (toggling))

   8.1.2. Priority

   8.1.3. Integration

8.3. Route planning – ECDIS functions

   8.2.1. Overlay (permanent / non-permanent (toggling))

   8.2.2. Priority

   8.2.3. Integration

8.4. Route monitoring – ECDIS functions

   8.3.1. Overlay (permanent / non-permanent (toggling))

   8.3.2. Priority

   8.3.3. Integration

8.4. Additional display – INS task "status and data display" – or other means

Appendix 1 Definitions

Appendix 2 References

The correspondence group agreed on the suggested structure. The existing guidance based on document NCSR 4/8 (IMO, 2016b) was organized by FKIE according to the new structure.

Furthermore, additional requirements were provided by FKIE based on the results of WP1 (see 4.1) and integrated in the draft guidelines. The draft guidelines were further discussed in the IMO correspondence group. As the work of the IMO-IHO Harmonization Group on Data Modelling (HGDM) with respect to MSPs (Maritime Services) will affect the amount of information and what information has to be displayed onboard, the correspondence group felt that the guidelines for the *harmonized display of navigation information received via communications equipment* could not be completed until the work of the HGDM is more mature.

Taken into account the dependencies with the work of the HGDM a shortened guideline with reduced content was produced and submitted to NCSR 5. Given the amount of work required to finalize the draft guidelines and the value of coordinating this work with the amendments to the Revised Performance Standards for Integrated Navigation Systems (INS) (resolution MSC.252(83)), the correspondence group recommended to forward the attached draft guidelines to the Navigation Working Group, to be established at NCSR 5 to clarify the way forward.

The submitted guideline is attached as appendix 1.

4.3.2 Discussion at NCSR5 and adoption of interim guidelines

The Sub-Committee considered document NCSR 5/6 (IMO, 2018a) providing the report of the Correspondence Group and noted, in particular, the view of the Correspondence Group in respect to the overlap with other e-navigation related outputs (IMO, 2018b).

During the discussion on the guidelines in plenary the following issues were raised:

- the output associated with this agenda item should be extended so as to take into consideration developments related to MSPs,
- it was essential to make progress on e-navigation and show results and, thus, the guidelines should be finalized at this session as interim guidelines, and
- the Navigation Working Group should try to finalize the guidelines, leaving the flexibility to recommend a different approach other than approving interim guidelines.

The recommendations of the correspondence group regarding the progress for additional modules for the revised INS performance standards were postponed and discussed under agenda item 22 (any other business), see 5.2 and 5.2.2.

The navigation working group discussed the guidelines, revised and shortened it so that a finalization as interim guidelines was possible (IMO, 2018c). The Group expressed strong views on the need to facilitate the finalization of the guidelines after completion of the work on S-mode and MSPs and included some text to this effect in the cover sheet of the draft Interim Guidelines.

The Sub-Committee, agreed to the draft *Interim guidelines for the harmonized display of navigation information received via communications equipment*, and invited the Committee to approve it. MSC approved the interim guidelines at its 99th session as MSC circular MSC.1/Circ.1593 (IMO, 2018d).

Discussion in the navigation working group on additional displays to manage increasing amounts of information

Extensively, during the work on the guideline in the navigation working group the issue of an additional display in order to manage increasing amounts of information received by ships and to ensure segregation of information on different displays was discussed. Some delegations argued that this section could be construed as a new carriage requirement for additional displays requiring type-approval. Furthermore concerns were raised regarding the appropriateness of relying on additional displays for information management on the navigation bridge and the fundamental need to ensure that Maritime Services, when implemented, included a means of ensuring that only relevant information, in manageable volumes, was provided to ships by service providers. After some discussion the group modified the text and agreed that the purpose of raising the issue of additional displays was only an indication of future needs to manage large amount of data by providing additional displays and not intended to introduce a new carriage requirement.

Discussion and Recommendation

It should be noted that the approved interim guidelines for *harmonized presentation of information received via communication equipment* are not finalized. In this stage they can only be seen as preliminary guidance on how to deal with the integration and presentation of the information received via communication equipment. Many details are still unsolved and should be discussed together with the issue of the efficient distribution of relevant navigation related information from communications equipment to navigation displays.

The discussion on the additional displays shows that there are various views on the issue. Currently, we are far from a comprehensive solution that accounts for the distribution, integration and presentation, including requirements for a new bridge-architecture.

It is recommended, that when the agenda item with the maritime service portfolios is closed and it is clearer what information will be presented in the future on a navigation bridge, the issue for harmonized presentation should be reopened or newly included in the agenda of NCSR to develop an appropriate IMO instrument. This should be done together with *Guidance on the efficient distribution of relevant navigation related information from communications equipment to navigation displays* (see 5.2).

4.3.3 Discussion at NCSR6

During the discussion on the revision of the SN.1/Circ. 243 *Guidelines for the presentation of navigation-related symbols, terms and abbreviations* (see 6.4.3) in the navigation working group at NCSR 6, it was pointed out that the IHO S-100 working group is dealing with the harmonization of information product specifications (IMO, 2019e). It was recognized that several international organizations are developing information product specifications that will be available in the coming years. This work provides revised or new information on presentation issues related with the display of navigation information received via communication equipment. To progress the work on harmonized presentation of information on board, the group encouraged participation in the IHO S-100 working group.

Finally, it was recommended that after finalizing the work on maritime services (see 5.3), IMO should carry on with the work to harmonize the presentation of information received via communications equipment. In this framework the *Interim guidelines for the harmonized display of navigation information received via communications equipment (MSC./Circ.1593)* should be reopened and finalized.

As the development of maritime services is continuing after NCSR 6 (5.3.5 and 5.3.6), it has to be discussed and decided at what point in time it is appropriate to continue this work.

5 Integration of information received via communication equipment

5.1 Background - modules for onboard integration of information received via communication equipment

To allow the effective transfer and integration from information received via communication equipment to other onboard systems NCSR was tasked to develop additional modules to the revised performance standards for Integrated Navigation Systems INS (resolution MSC.252(83)).

Module F, as outlined in the report of IMO correspondence group coordinated by China (NCSR 4/7, (IMO, 2017d)), describes the standardized interfaces for data exchange to support transfer of information from communication equipment to an INS interface so that the information received via such equipment can be processed, filtered, routed and displayed on the navigational system. At NCSR 4 the progress of the work was discussed in the *navigation working group.*

Based on the results of the discussion the sub-committee decided to postpone the work concerning the future INS modules. As there is a strong link between the goals for module F and the *Guidelines for the harmonized display of navigation information received via communications equipment* it was decided to continue the discussion in the framework of the *IMO correspondence group on* guidelines for h*armonized display of navigation information received from communication equipment.*

Therefore, in coordination with the BMVI and the discussion in the national expert group for *integrated ship navigation and control systems*, it has been decided to accompany the discussion there. The aim is, to implement a proposal of FKIE to develop a separate guideline with functional requirements for the "Integrated Radio Communication" module of the onboard bridge architecture to allow the processing, filtering, routing of the information received via communication equipment onboard.

5.2 Suggestion for Guidelines for efficient distribution of information from communications equipment

5.2.1 Discussion before NCSR5

The *correspondence group on harmonized display of navigation information received via communication equipment* was tasked by NCSR4 (NCSR 4/29 (IMO, 2017a)) and confirmed by MSC 98 (MSC 98/23, (IMO, 2017e)) to identify the need and scope of issues relevant for the development of an additional module to the revised performance standards for Integrated Navigation Systems (INS) (resolution MSC.252(83)), related to display of information only, taking into account document NCSR 4/7 in relation to the additional module F.

Therefore, FKIE initiated the discussion in the correspondence group on the development of an additional module F to the revised performance standards for Integrated Navigation Systems (INS) (resolution MSC.252(83)) with the aim to develop missing guidance on how to functionally and physically enable the integration of the information received via communication equipment. As still the majority of bridge installations are not based on an INS the guidance should not be limited to ship bridges equipped with an INS, but drafted for all ship bridges. Requirements have to allow that the information received via communications equipment/systems is:

- processed, and filtered in accordance with the relevant requirements for interface and data
- stored with an indication to the operator that the new information has been received;
- selected according to the tasks and conditions;
- routed to appropriate tasks for INS, or navigation equipment on traditional bridge systems or other bridge equipment (safety, ...).

During the considerations of the correspondence group for the need and scope of issues relevant for the development of an additional module F to the *revised performance standards for Integrated Navigation Systems (INS) (resolution MSC.252(83))*, it has become clear that, in order to support the display of information received via communication equipment, the distribution to displays of safety information needs its own guidance - “Guidance on the efficient distribution of relevant navigation related information from communications equipment to navigation displays”. This guidance should furthermore not be limited to INS.

Therefore, the Correspondence Group concluded in their report NCSR 5/6 that an appropriate guideline should be drafted at a future date to support the attached guidelines (IMO, 2018a). These future guidelines should include the work already carried out for module F (NCSR 4/7) and they could be prepared in combination with the work on additional modules to the revised performance standards for integrated navigation systems (INS) (resolution MSC.252(83)) relating to the harmonization of bridge design and display of information in the post-biennial agenda of NCSR (MSC 98/23).

5.2.2 Discussion and decisions at NCSR5

The Sub-Committee considered document NCSR 5/22/10 by the Secretariat proposing a number of actions related to the status of the output on "Additional modules for the Revised Performance Standards for INS” relating to the harmonization of bridge design and display of information and noted, in particular, that:

- “the draft amendments to resolution MSC.252(83) approved by NCSR 4 (NCSR 4/29, paragraph 5.4 and annex 4) were not related to e-navigation, but to the output on "Interconnection of NAVTEX and Inmarsat SafetyNet receivers and their display on Integrated Navigation Display systems"
- MSC 98's decision might have been linked to the expectation that the outcome of the work on the Guidelines for the harmonized display of navigation information received via communications equipment would result in a proposal for an additional module for the INS performance standards, so that both sets of amendments could be adopted at the same time
- despite the good progress made by the Correspondence Group on the development of *Guidelines for the harmonized display of navigation information received via communications equipment*, the work had not resulted in concrete directions for the development of such a module. Instead, the Group had concluded that in order to support the display of information received via communications equipment, the distribution to displays of safety information needed its own guidance, for instance

to be named *Guidance on the efficient distribution of relevant navigation related information from communications equipment to navigation displays*, and should not be limited to INS; and

- due to the decision taken by MSC 98, the proposed unrelated amendments prepared under the output on the "Interconnection of NAVTEX and Inmarsat SafetyNet receivers and their display on Integrated Navigation Display systems" would be on hold for an unknown period of time."

After a brief consideration the Sub-Committee agreed to invite MSC to adopt the draft MSC resolution on Amendments to the Revised Performance standards for integrated navigation systems (INS) (resolution MSC.252(83)) and to delete the output on *Additional module to the Revised Performance Standards for Integrated Navigation Systems (INS) (resolution MSC.252(83)) relating to the harmonization of bridge design and display of information* from the post-biennial agenda.

5.2.3 Consequences

The suggestion of the Sub-Committee at NCSR5, which were approved by MSC 99, lead to the unsatisfactory situation that the only agenda item, allowing work in regard to a future onboard bridge architecture enabling processing, filtering, routing of the information received via communication equipment onboard is removed from the IMO agenda. To develop the necessary *Guidance on the efficient distribution of relevant navigation related information from communications equipment to navigation displays* a new work item needs to be proposed.

On a suggestion by Germany at NCSR5, the issue of the *Guidance on the efficient distribution of relevant navigation related information from communications equipment to navigation displays* is included as part of task 15 in the revised E-navigation Strategy Implementation Plan MSC.1/Circ.1595 (IMO, 2018e).

5.3 Harmonized data structure - Harmonization of the format & structure of maritime services

5.3.1 IMO/IHO Harmonization Group on Data Modelling (HGDM) - Background

Modern eNavigation tools could only be used in a consistent and safe manner across different navigational systems or equipment's on a ship bridge, if data objects and their presentation portrayals, which are provided by different services adhering to different standards, are harmonized. Thus, an internationally coordination is essential. The core element is a data structure to optimize the use, interoperability, flow and accessibility of relevant information and data within the maritime domain. Consequently, the compelling need for harmonization and coordination of all information objects through an internationally accepted organization involving all relevant parties was identified.

The Sub-Committee on Safety of Navigation at its 57 session had agreed that IHO's S-100 data model should be used as a baseline for creating a framework for data access and information services under the scope of SOLAS. Furthermore, it was agreed, that IMO, in consultation with other organizations, should consider the establishment of a Harmonization Group on creating a framework for data access and information services under the scope of

SOLAS, based on the example of the IMO/IHO Harmonization Group on ECDIS as well as the draft *Terms of Reference* for the IMO/IHO Harmonization Group on Data Modelling (HGDM) as prepared by the Sub-Committee (IMO, 2011).

This proposal was endorsed by the Maritime Safety Committee at its 90th session (IMO, 2012) and the Committee authorized the establishment of an IMO/IHO Harmonization Group on Data Modelling (HGDM) and approved its *Terms of Reference* as provided by NAV 57.

The HGDM was given the following tasks (Terms of Reference by MSC 90 (IMO, 2012)):

> 1 "In creating an e-navigation architecture, it is important to identify information and data flows, and the interactions between applications and user interfaces. Consequently, there needs to be a data structure to optimize the use, interoperability, flow and accessibility of relevant information and data within the maritime domain (including both ship and shore aspects). It is therefore important to harmonize efforts in data modeling, with the aim of creating and maintaining a robust and extendable maritime data structure. This maritime information and data structure will require some form of overarching coordination to ensure the ongoing management and maintenance of the structure.
>
> 2 There may be several management roles to be performed by such a coordinating body (for example, the maintenance of registries and the development and adoption of product specifications). This management role may be shared between relevant organizations. Therefore, the organizational structure of duties and responsibilities is a highly important element by which e-navigation can modernize the operational environment of the maritime industry and also fulfill the requirement of document MSC 85/26, annex 20.
>
> 3 The HGDM should be constituted of representatives of IMO and IHO Member States and Secretariats, and organizations with an official IMO/IHO observer status.
>
> 4 The HGDM should be chaired by an IMO Member State and supported by the Secretariat of the IMO.
>
> 5 The HGDM reports to the IMO Sub-Committee on Safety of Navigation (NAV) 1 (now NCSR), and to the IHO through the IHB Directing Committee2, as appropriate.
>
> 6 The HGDM should:
>
> .1 as requested by the IMO or the IHO, consider matters related to the framework for data access and information services under the scope of SOLAS, using as a baseline IHO's S-100 standard, with a view to harmonize and standardize:
>
> .2 formats for the collection, exchange and distribution of data;
>
> .3 processes and procedures for the collection; and
>
> .4 development of open standard interfaces; and
>
> .5 review the results of studies by the IMO, the IHO and other related organizations which address aspects of access to information services under the scope of SOLAS, and advise the IMO and the IHO as to whether they are compatible with the e-navigation concept taking into account the identified user needs as they exist at the time."

The establishment of the IMO/IHO HGDM

However, due to the fact that no Member State requested the activation of such an internationally accepted overarching coordinating group, the establishment of the group was postponed until MSC 98 reiterates this decision and agrees to activate the HGDM in the context of the discussion on Maritime Service Portfolios as requested by NCSR 4.

Following the decision of MSC 96 to include in the post-biennial agenda of the Committee, an output on "Develop guidance on definition and harmonization of the format and structure of Maritime Service Portfolios (MSPs)" at NCSR4 it was discussed, based on the document NCSR 4/27 (IHO et al.), to task the HGDM to commence the work on this output. Furthermore, a draft work plan was discussed at NCSR 4, but no agreement could be reached on the details about the work on specific MSPs. MSC 98 agreed to activate the HGDM based on the report of NCSR 4 (NCSR 4/29) and endorsed the first HGDM meeting.

Therefore, MSC 98 restricted the HGDM to work only on the output to "Develop guidance on definition and harmonization of the format and structure of Maritime Service Portfolios (MSPs)". Still unclear is the status of the primarily accepted list of Terms of Reference decided by MSC 90 as provided by NAV 57, which is still valid.

In this context, the FKIE supported the German Federal Ministry of Transport and digital Infrastructure in the process of developing a national position together with national stakeholder for the first HGDM meeting and supported the German delegation accordingly.

5.3.2 The course of the deliberation at the first HGDM meeting

As instructed by the Maritime Safety Committee (MSC 98) the IMO/IHO Harmonization Group on Data Modelling (HGDM) met from 16 to 20 October 2017 under the chairmanship of Mr. Sunbae Hong (Republic of Korea).

In line with instructions and restrictions given by MSC 98, to work only on the guidance on the definition and harmonization of the format and structure of Maritime Service Portfolios, the work focused on a *Guidance on the definition and harmonization of the format and structure of maritime services within the Maritime Service Portfolio (MSP)*. The current draft provides a template for Maritime Services, describes an overview of the structure, a three-level hierarchy of responsibilities and includes the definition of Maritime Services. Some delegations are in favor of drafting such guiding legal instruments as a resolution rather than using the form of an IMO circular.

In addition, there were some incoming papers, which were discussed intensively. A document HGDM 1/5/3 by BIMCO raised the question of harmonization of data elements which are also used and defined by other maritime stakeholder under the umbrella of the IMO FAL Convention, coordinated by the FAL Committee. Whereby, it was proposed to standardize data elements identity (ID). The group agreed that the harmonization of data element IDs was a key enabler to ensure inter-operability between services and to facilitate machine to machine communication. Hence there was strong support in the group for BIMCO's proposal.

In this respect, the group recalled that the FAL Committee was currently working on standard data sets for the FAL forms used by ships, in close cooperation with WCO, UN/CEFACT and ISO.

It was therefore the view of the group to inform the FAL Committee of the discussion in the group on this matter and the need to have harmonized data element IDs for the delivery of maritime services. The work should also cover data elements beyond those required by the FAL Convention. Consequenctly, the HGDM report requested action by the Sub-Committee, amongst others, to consider the proposal to establish a maritime registry, listing all maritime relevant data element IDs, for use in the provision of maritime services, with the Organization as possible host for such registry. It became evident, that the current work on maritime service portfolios has to be expanded and will also include maritime services and data elements not governed by SOLAS. Consequently, it is imperative to broaden the scope of the work to include services and data elements not mandated by SOLAS.

In the discussions during the meeting, all points were discussed which had clarification needs. The result of the discussions was that no point of the agreed results was in conflict with the prepared German position for this HGDM meeting. No negative impacts for the German Shipping industries are to be expected.

Results of guiding points in detail as agreed by the HGDM:

1 The Terms of Reference given by MSC for the HGDM provides a far-reaching legitimacy of the work.
2 The work of HGDM goes beyond the processing of MSPs, to make it clear that an MSP can consist of several Maritime Services,
3 The HGDM sees the harmonization of a permanent task, although the mandate of MSC 98 is limited in time.
4 S-100, IHO Standards as a frame of reference, represents a subset of the Common Maritime Data Structure (CMDS), although CMDS has not been sufficiently defined or described.
5 An IMO database should contain information about metadata for use in the maritime services.
6 The communication paths to be used are not the subject of harmonization.
7 It is not intended to set geographic areas for the maritime services where they are provided.

The mandate for the IMO/IHO harmonization Group on Data Modelling, HGDM goes at the moment until 2019 (NCSR6) only. Therefore, the group will submit an interim report to NCSR 5 requesting further regular meetings, which have to be approved by MSC99. Furthermore, the report recommends NCSR5 to invite other international organizations to identify the topics which require continued work to ensure the necessary harmonization on overarching standardization.

Summary

A first draft MSC Resolution on IMO guidance on the definition and harmonization of the format and structure of maritime services (data / information) within the maritime service portfolio was created to be submitted for approval to NCSR (IMO, 2017b). with the view of adoption by MSC after finalization at the next session of HGDM.

Furthermore, among other things the following actions by NCSR 5 were requested:

- note the first draft of the guidance on the definition and harmonization of the format and structure of MSPs within the Maritime Service Portfolio and consider the revised definition of MSP which is more concise and believed to capture the purpose and scope of MSPs better than the existing definition

- consider to invite international organizations which are domain coordinating bodies to use the template and to submit completed templates to the Organization as part of testing its purpose and suitability, and in order to be able to facilitate the completion of the draft Guidance
- note the HGDM's proposal to establish three levels of control and ownership
- note the view of the group on the need to harmonize data element IDs for marine services as a key enabler to ensure inter-operability between services
- consider to inform the FAL Committee on the ongoing discussion of the group on the harmonization of data element IDs for marine services and consider the proposal to establish a maritime registry, listing all maritime relevant data element IDs, for use in the provision of maritime services, with the Organization as possible host for such registry;
- consider to request coordination with the MSC and FAL Committee on this issue of establishing a maritime registry and note the group's concern in respect to the current terms of reference which limit the work to SOLAS-related maritime services
- invite the Committee to approve the holding of a second meeting of the HGDM

From a German perspective, the meeting was successful, because all issues as discussed and introduced by Germany were addressed as requested by the German Delegation. The establishment of the HGDM as a permanent working group was considered important, and therefore welcomed. A follow-up action of this first meeting may be required ensuring that the HGDM coordination group will be established on a permanent basis fulfilling all envisaged tasks under the umbrella of the IMO together with the IHO.

The cooperation within the German delegation (BSH and FKIE on behalf of the BMVI) was good. The expertise of the participants has complemented each other, and therefore Germany could make a significant contribution to the success of the meeting.

5.3.3 Discussion and progress at NCSR 5

At NCSR 5 the Sub-committee considered the report of the first meeting of the HGDM (IMO, 2018g) including the first draft of the Guidance on the definition and harmonization of the format and structure of maritime services within the MSP and a high-level template for maritime services. After a discussion of the documents, especially with the focus on the role of the organization, the sub-committee instructed the navigation working group to work on the input on detail with the focus on:

- the development of the draft Guidance on the definition and harmonization of the format and structure of maritime services within the Maritime Service Portfolio (MSP)
- the need for the template for maritime services
- the scope of the Organization's lead role on e-navigation, including what management and control functions the Organization should assume, and the consequences for the Organization

- the draft terms of reference for the second meeting of the Harmonization Group on Data Modelling

As a result of the work of the navigation working group the following was decided to further progress the work (IMO, 2018b):

- the progress on the development of the draft Guidance on the definition and harmonization of the format and structure of maritime services within the Maritime Service Portfolio (MSP) was noted and the template for maritime service descriptions was accepted and included in the draft Guidance.
- the IHO would act as domain coordinating body for maritime service No. 5 (Maritime Safety Information Service (MSI)), on behalf of IMO.
- the draft terms of reference for the second meeting of the HGDM were approved
- domain coordinating bodies were invited to submit the description of maritime services under their remit to HGDM 2, using the draft template
- the Group's discussion on establishing a future robust process for the review of the templates for maritime services descriptions were noted and it was decided that HGDM 2 should be instructed to consider the development of a sustainable continuous review process, without substantive involvement of organs of the Organization.

Discussion and Recommendation

The suggested process for the harmonization of maritime services was developed by the navigation working group, based on a proposal by the Netherlands. It included the involvement of the IMO secretariat simple as “post office” to receive the draft templates of maritime services and implement the HGDM as body to identify and harmonize the relevant data models based on the future suggested services. The flow chart is attached as annex 4 to the report of the navigational working group NCSR 5/WP.4 (IMO, 2018c). The chairman of NCSR, when discussing the report, suggested that the involvement of the IMO secretariat should be excluded from the process and that in general the process should not be further developed. After an intervention made by FKIE for Germany and the following discussion the development of the process was kept on the agenda of HGDM 2 including the discussion on the role of the organization.

A permanent process for the management of maritime services including a lead role for the IMO should be implemented. One solution for the evaluation of new maritime services would be to use a permanent installation of the HGDM or to include this permanently in the work program for NCSR similar to the agenda item Unified interpretation of provisions of IMO safety, security, and environment-related Conventions. In any case the IMO secretariat should function as “post office” for reception of new proposals.

Maritime register (database) containing data elements' identity (ID) for maritime services

Furthermore, the proposal of BIMCO (NCSR 5/8/2) on the establishment of a maritime register (database) containing data elements' identity (ID) for maritime services as part of the development of a harmonized e-navigation solution was discussed. As decided at the first meeting of the HGDM BIMCO submitted the document HGDM 1/5/3 again to NCSR 5. The HGDM has agreed that the harmonization of data element IDs was a key enabler to ensure inter-operability between services and to facilitate machine to machine communication (see 5.3.2). The Sub-Committee decided that the establishment of a maritime data element register was not within the scope of the current output "Develop guidance on definition and harmonization of the format and structure of Maritime Service Portfolios (MSPs)" (IMO, 2018b). As a relation between the proposal made by BIMCO and the ongoing work at the FAL Committee in regard to the harmonization and standardization of data formats for data elements for the FAL forms was seen, BIMCO and interested Member States were invited to propose a new output to FAL 42 for the development of a data model and the establishment of a maritime registry, in close cooperation with MSC, MEPC and their subsidiary bodies.

Discussion and Recommendation

According to the original terms of reference of the HGDM drafted by NAV (see 5.3.1), there is need for a data structure to optimize the use, interoperability, flow and accessibility of relevant information and data within the maritime domain. The issue of the harmonization of data element IDs is one major component to achieve this goal. To refer this work to another committee will have a delaying effect regarding the finalization of this aim. In any case the further work on *data elements' identity (ID) for maritime services* at the FAL committee should be accompanied and the submission of BIMCO to FAL should be supported.

5.3.4 The course of the deliberation at the second HGDM meeting

The second meeting of the IMO/IHO Harmonization Group on Data Modelling (HGDM), was held at IMO Headquarters from October 29th to November 1st, 2018.

At the beginning of the meeting IHO reported the innovations introduced within the S-100 Edition 4 (IMO, 2019a). In particular, attention was drawn to the incorporation of a new way of presenting products and the changed life cycle. Furthermore, the status of the completed S-100-based product specifications and of the IHO GI Registry was presented. It was assured that with the introduction of the S-101 product specifications for ENCs, in the future, ECDIS software updates will not be required in the case of a symbol change.

IHMA (International Harbor Master Association) addressed issues with the use of key terms and their lack of their definition. Various terms, such as "Maritime Service" or "Local Port Service" can be interpreted differently and their different use would lead to misunderstandings. These problems were acknowledged by the group, but it was decided not to change the titles. The correct explanation of the execution of a service can be further elaborated under its description. IHMA was invited to provide a description of Maritime Service 4 to NCSR 6, together with any concerns regarding the title of the Maritime Service.

The group reviewed the draft *Guidance on the definition and harmonization of the format and structure of Maritime Services*, based on document HGDM2/4/2, submitted by Norway. In this context, Germany initiated a discussion on the role of the IMO and the tasks of the HGDM. This proposal was well received.

The discussion and work on the guidance included:

- the purpose of the guidelines
- that appropriate draft resolutions and circulars should be submitted to MSC 101 for adoption

- revision of the guidance
- a recommended process of steps to be followed for the development of a new Maritime Service
- the role of IMO and HGDM in this context

The Group had a lengthy discussion on the future procedures for considering descriptions of Maritime Services to be submitted by Member States and/or international organizations acting as coordinating bodies. It was deliberated that the future need for the harmonization of descriptions of the Maritime Services could be addressed at NCSR under "Any other business" or under a revised output referring to the "Consideration of descriptions of Maritime Services".

A permanent establishment of HGDM working group was not favored to proceed with the development of maritime services. The developed template (see Appendix 2) describing Maritime Services was rated as adequate.

The course of action regarding the implementation of Maritime services was discussed, and as a result a two-step approach was defined to be suggested for NCSR6 (IMO, 2019a):

- a draft MSC resolution containing the draft *Guidance on the definition and harmonization of the format and structure of Maritime Services*, including the template for the submission of Maritime Services descriptions and guidance for the harmonized specification of technical services, and inviting Member States and international organizations, acting as domain coordinating bodies, to submit descriptions of Maritime Services to the Organization; and
- a draft MSC circular consolidating the descriptions of Maritime Services, which could be re-issued as revised versions, if Maritime Services were added or updated.

One major task of the meeting was, to evaluate the so far submitted descriptions of 15 Maritime Services. To avoid future misunderstandings, it was proposed to replace the term "Local Port Service" by "Port Logistics Service".

Surprisingly, the responsible organization (IALA) did not allow the editing of descriptions or highlighting of obvious mistakes provided by their maritime services. It was therefore agreed upon to only make editorial changes in the services, unless the responsible organization, in case of presence, itself proposes changes which would be then integrated. The procedure raises the question of how harmonization of services could be achieved, if content-related aspects are not documented.

From the point of view of the German delegation, the following point was not addressed:

- which quality criteria should be taken into account when assessing maritime services presented by Member States or coordinating bodies

IHO, when presenting the technical services for Nautical Chart Service and Nautical Publication Service, stated that internal mechanisms ensure that data can be transmitted in a quality-assured manner from the producing hydrographic service to the end user.

Summary

From a German point of view, the meeting was difficult, because the role and task of the IMO in harmonization of the services is not clear. This was especially true for finding a feasible solution for updating and evaluating the descriptions of the Maritime Services. Ultimately, a solution acceptable to all, was agreed upon - to discuss this in the future at NCSR. The, by Germany favored, solution regarding a constant implementation of the HGDM did not get sufficient support. The question is how an effective harmonization can be achieved at NCSR and the better of the two options would be to conduct this under a revised agenda item ("Consideration of descriptions of Maritime Services"). Furthermore, the task should include to discuss failures and open issues and not only editorial changes.

5.3.5 Discussion and Finalization of the guideline at NCSR 6

The report of the second HGDM meeting together with the documents NCSR 6/8/1 Requirement for telemedicine services submitted by the International Maritime Health Association (IMHA), NCSR 6/8/2 Input from IHMA on Maritime Service 4 submitted by the International Harbour Masters' Association (IHMA) and NCSR 6/8/3 comments on document NCSR 6/8 submitted by Japan, were considered.

NCSR 6/8 – Report of the second meeting of the IMO/IHO Harmonization Group on Data Modelling (HGDM) - Note by the Secretariat (IMO, 2019a)

The document provides the report of the second meeting of the IMO/IHO Harmonization Group on Data Modelling (HGDM). As major outcome the report contains:

1. An MSC resolution with the draft *Guidance on the definition and harmonization of the format and structure of Maritime Services*. The guidance includes the template for the submission of Maritime Services descriptions and guidance for the harmonized specification of technical services. Member States and international organizations acting as domain coordinating bodies are invited to submit descriptions of Maritime Services to the Organization;
2. A MSC circular consolidating the descriptions of Maritime Services, which could be re-issued, as revised versions, if Maritime Services were added or updated.

Furthermore, for the future, the report suggests a review of descriptions of Maritime Services based on the recommended process of steps to be followed for the development of a new Maritime Service to

1. rename the existing output for the development of Guidance to "Consideration of descriptions of Maritime Services"; or
2. consider the descriptions of Maritime Services, and relevant updates submitted by domain coordinating bodies and Member States involved in the preparation of Maritime Services under "Any other business".

NCSR 6/8/1 - International Maritime Health Association (IMHA) (IMO 2019b)

The document highlights the need of an up-to-date medical care at sea, as requested by ILO's Maritime Labour Convention. IMHA further ask to ensure that future broadband communication supports state-of-the-art telemedical assistance to ships at sea as real-time/live video-streaming/-conferencing in order to provide medical specialist consultation and guidance opportunity to onboard first-aiders as well as forwarding ashore pictures in as near as possible HD quality (already used by Navy ships).

NCSR 6/8/2 - International Harbour Masters' Association (IHMA) (IMO 2019c)

The document provides the template for the Maritime Service 4 (Port Call Support Service (PCSS)) and the suggestion to retitle "Local Port Services" as "Port Call Support Service" to avoid conflict with existing usage.

NCSR 6/8/3 – Japan (IMO 2019d)

The document provides comments on the report of the second meeting of the IMO/IHO Harmonization Group on Data Modelling (HGDM 2) NCSR 6/8. Japan suggest renaming the title of each maritime service that includes actual and physical services to avoid confusion. In document NCSR 6/8 Maritime service is defined as "the provision and exchange of maritime-related information and data in a harmonized, unified format". However, Japan outlines that the name Maritime Services is generally used and accepted as a combination of physical services and information or data services and not only as information service. Some examples are given. Furthermore, Japan suggests renaming the term "Maritime Service" itself as it lead to confusion with the general understanding of the term used in the maritime operation perspective.

Outcome

Based on the discussion in the plenary session and the discussion in the navigation working group reflected in their report NCSR 6/WP.4 (IMO, 2019e) the subcommittee came to the following conclusions (IMO, 2019f).

The Sub-Committee agreed with the proposed two-step approach recommended by second meeting of HGDM 2,

- to issue an MSC resolution containing guidance for the definition and harmonization of the format and structure of Maritime Services, and
- a MSC circular containing the descriptions of Maritime Services.

After consideration of the report of the navigation working group, the Sub-Committee approved the *Guidance on the definition and harmonization of the format and structure of Maritime Services in the context of e-navigation* including the new suggested title. The aim of the Guidance is to guarantee that the Maritime Services are implemented in a standardized and harmonized format (IMO, 2019g). Therefore, the guidance describes the various levels of responsibility regarding the implementation of maritime services. Within the guidance, the process for the development of a maritime service is described and illustrated with a flow chart. Important in this process is the template for the descriptions of MS in the context of e-navigation. This template should be used to describe a Maritime Service when developing a new MS according to the specified process. The template is attached as appendix 1 to the guidance. A description for the harmonized specification of technical services is listed in appendix 2. Furthermore, the relation between the different levels of service descriptions as well as the relation between MS and S-100 based product specification is outlined.

Furthermore, the draft MSC circular *on Initial descriptions of Maritime Services in the context of e-navigation* was approved (IMO, 2019g). The circular contains the descriptions of the following MS:

- MS 1 – VTS Information service (INS)
- MS 2 – VTS Navigational assistance service (NAS)
- MS 3 – Traffic organization service (TOS)
- MS 4 – Port support service (PSS)
- MS 5 – Maritime safety information (MSI) service
- MS 6 – Pilotage service
- MS 7 – Tug service
- MS 8 – Vessel shore reporting
- MS 9 – Telemedical assistance service (TMAS)
- MS 10 – Maritime assistance service (MAS)
- MS 11 – Nautical chart service
- MS 12 – Nautical publications service
- MS 13 – Ice navigation service
- MS 14 – Meteorological information service
- MS 15 – Real-time hydrographic and environmental information services
- MS 16 – Search and rescue (SAR) service

The descriptions are based on the template for draft descriptions of MS in the context of e-navigation. The template is part of the Guidance on the definition and harmonization of the format and structure of Maritime Services and attached as appendix 1 of the guidance (see above).

Having completed the work on the development of *guidance on definition and harmonization of the format and structure of Maritime Services in the context of e-navigation* and recognizing the need for a continuous review process of maritime service descriptions and the harmonization of related services, the Sub-Committee discussed the options for a continues review process of Maritime Services. Finally, it was agreed to invite the Committee to rename this output as "Consideration of descriptions of Maritime Services in the context of e-navigation" with a target completion year of 2021. It was decided that this was an interim measure and that the arrangements should be revisited in the future and revised according to the progress made in the development of descriptions of Maritime Services.

5.3.6 Conclusion

With the decisions at NCSR 6 so far the outcome regarding the agenda Item harmonization of the format and structure of Maritime Services is:

- guidance on how various organizations can develop Maritime Services that their format and structure is harmonized
- 16 initial descriptions of maritime services

- a preliminary procedure how to review future produced maritime service descriptions.

A continues agenda item for NCSR is proposed to accommodate future work related to the descriptions of Maritime Services. This future work on Maritime Services is not clearly defined. So far work regarding harmonization of Maritime services on IMO level was focusing more or less on editorial changes only. It has to be seen what will be discussed at the next two NCSR sessions on this issue. A more content related discussion with recommendations for changes, if obvious failures are listed in the descriptions of Maritime Services, might be more goal oriented.

At NCSR 5 it was decided to approve Interim guidelines for the harmonized display of navigation information received via communications equipment and to possibly reopen the issue after finalizing the work on maritime services. One reason was the workload of the Sub-Committee as well as the limited knowledge on which information should be received via communications equipment and how this information should be presented. At this point in time it seems that only few of the e.g. Maritime Services MS 1 (VTS Information service), MS 5 (Maritime safety information (MSI) service) are far enough developed to proceed with the development of guidance how to present this information on board. Therefore, it is recommended to delay the work on IMO level on the harmonized display of navigation information received via communications equipment for a couple more years to observe the future development.

6 Harmonization of user interface design for navigation equipment

6.1 IMO Correspondence group on S-Mode

6.1.1 Establishment of IMO Correspondence group on S-Mode at NCSR 5

At NCSR 5 the Sub-Committee discussed the issue of S-mode guidelines, which were included in the post-biennial agenda by MSC with a target completion date of 2019 (IMO, 2018b). It was recalled that the primary purpose of the guidelines was to provide for more standardization and a reduction in the time needed for seafarers to become familiar with a variety of electronic navigation equipment. The development of those guidelines is part of the IMO e-navigation Strategy Implementation Plan (SIP).

After discussion of the issue in the working group based on a first draft submitted by Australia et. Al (IMO, 2018f) the Sub-Committee established a correspondence group on the development of the draft guidelines on standardized modes of operation, S-Mode under the coordination of Australia.

Furthermore, the Sub-Committee noted that the completion of the S-mode guidelines would require a consequential revision of the amended guidelines for the presentation of navigational-related symbols, terms and abbreviations (SN.1/Circ.243/Rev.1).

Conclusion

The Sub-Committee is already aware of a possible revision of the amended guidelines for the presentation of navigational-related symbols, terms and abbreviations (SN.1/Circ.243/Rev.1). This is important in relation to the necessary inclusion of further navigational symbols in the guidelines, see 6.4.

6.1.2 Progress for NCSR 6

FKIE contributed to the work of IMO Correspondence Group on the development of the draft guidelines on standardized modes of operation (S-Mode) in regard to ICONS, abbreviations, default settings, grouping of information and functions activated via single or simple operator action. Submissions were prepared to six rounds in which the documents were circulated. To adapt the changed content of the guideline the correspondence group proposed that the name of the guidelines should be changed from guidelines on standardized modes of operation, S-Mode, to the Guidelines for the standardization of user interface design for navigation equipment. The comments of the *BMVI's national expert group for integrated ship navigation and control systems* were taken into account and included in the submissions. A national S-Mode workshop was organized to deliberate the issues related to S-mode in detail (see chapter 6.2). The details and the final outcome regarding the guidelines on S-mode is outlined in chapter 6.3.

6.2 National S-Mode Workshop

On May 7th and 8th, 2018 a German national expert group on integrated ship navigation and control systems (BMVI, BSH, FKIE and manufacturers) met to discuss the current *guideline for the standardization of functions and display of navigation equipment (s-mode) for NCSR 6 submission*. The workshop was planned, organized and chaired by FKIE.

6.2.1 Workshop preparations

In preparation of the workshop three ECDIS and radar systems (Raytheon Anschütz, Wärtsilä SAM Electronics, and TRANSAS) were investigated in the Federal Maritime and Hydrographic Agency's simulator in Hamburg on April 26th and 27th, 2018. In response to the draft guideline NCSR 5/INF. 13 *results of the S-Mode user preference test* conducted by the Republic of Korea (2017), the three ECDIS systems were analyzed in respect to their current conformity to the results of this survey regarding information grouping and accessibility of functions. This research was to shed light on the magnitude and implications for the systems of the manufacturers of appendices 3 and 4 of the s-mode guideline.

To compare the grouping of information (own ship information, navigational information, cursor, route monitoring, target information, and hot keys) as proposed by Republic of Korea (2017; see appendix 4.A of this report) and the groups of information displayed on the systems, each system was photographed and analyzed in regard to consistent grouping, missing information within groups, information added to a group, and whether the information is displayed at all times or in a flexible field. The results showed that manufacturers already largely group the information as proposed by the Republic of Korea (2017). Only own ship information was not consistently grouped by two systems. However, own ship information in Appendix 3 of the s-mode guideline contains less information and this information group was grouped consistently by all manufacturers. Regarding the target information group all three systems grouped consistently. Two pieces of information were not included in this group by two manufacturers. However, again this is not in conflict with the current Appendix 3 of the s-mode guideline. Only for route information would manufacturers have to add information according to the current guideline. More information was added by manufacturers for the groups: own ship, cursor, route, and target information. These results showed that Appendix 3 would not have a large effect on manufacturers. (See appendix 4.B of this report for more detailed results.)

To analyze whether Appendix 4 of the s-mode guideline would have any effect on the systems of the manufacturers, it was investigated whether 101 functions listed in Appendix 4 were accessible by a single or simple operator action. Whereas a single operator action is defined as "A procedure achieved by no more than one hard-key or soft-key action, excluding any necessary cursor movements, or voice actuation using programmed codes." and a simple operator action is defined as "a procedure achieved by no more than two hard-key or soft-key actions, excluding any necessary cursor movements, or voice actuation using programmed codes" (IMO, (2007). Results were documented in an Excel table with single, simple, na for not available or "…" for functions that could not be investigated thoroughly due to time constraints. Due to the number of functions, if functions were not found within two minutes, the search was cut off and viewed as "not available". The accessibility of functions of each system was compared to the current s-mode guideline. Additionally, a questionnaire was prepared in which the attendees of the workshop were to cross whether the functions should be accessible via single or simple operator action. This was to objectively review any strong differences between the attendees, the systems and the current guideline. (See appendix 4.C of this report for detailed results.) The results showed that attendees (N = 9; six with nautical experience, three without nautical experience) felt 21 functions should be accessible via single operator action while the s-mode guideline currently states simple. Vice versa the s-mode guideline lists ten functions as "single" where the attendees found these functions to be tolerable as a simple operator action. Furthermore, 63 times the systems offered functions via a single operator action while deviating from the s-mode guideline –simple. Twenty-seven times the functions were accessible via simple operator action or more whilst deviating from the s-mode guideline-single. Overall, the results here show that the current systems and attendees find that certain functions should be accessible quicker than the s-mode guideline currently requests. However, there were also functions providing discussion points for the workshop as systems and attendees found that certain functions could be less quickly accessible than the s-mode guideline currently stated. It should be noted that for some systems, functions were accessible via single, simple and more operator actions depending on the cursor function. These results provided a basis for the discussion in the workshop and showed that the cursor should be included in the future s-mode guideline and its discussions. A study with a large group of participants with nautical experience could obtain more objective results on the issue.

6.2.2 Workshop discussion and results

During the course of the meeting the following was discussed:

- the need to establish a formal intersessional correspondence group to coordinate the further development, including testing, and finalization of a guideline on S-Mode
- general comments to the Annex of the S-mode guidelines and then Appendix 1 – Human Factors research supporting design principles for standardized modes
- appendix 2[1]- Navigation-related terminology and icons of functions (hot keys and shortcuts)
- appendix 3- Essential grouping of information; and in correspondence with this discussion: a survey investigating conformity of three different ECDIS systems with the draft guideline NCSR 5/INF. 13 results of the S-Mode user preference test conducted by the Republic of Korea (2017) to assess the magnitude and implications of appendix 3 for manufacturers
- appendix 4 – List of functions that must be accessible by single or simple operator action. In correspondence with this discussion, a short survey was completed by members of the meeting (with the exception of FKIE members), assessing their opinion on which functions should be accessible by single simple operator action, and a comparison of three ECDIS and radar systems and their conformity with suggestions in Appendix 4, again, to assess its magnitude and implications for manufacturers.
- appendix 5 – standard and user settings for ECDIS and radar.
- current conflicting symbols in addition to SN/Circ. 243 "Guidelines for the presentation of navigation-related symbols, terms and abbreviations."

The general discussion established and solidified a general need for a standard- especially in regards to terminology. This was underlined by the general consensus of the group to stress that the annex of the guideline should not only apply to INS, ECDIS and radar, but be stricter in its wording, to also include other electronic navigation equipment, if applicable. Nonetheless, the group agreed that informative information should be a matter for appendix 1 which should be reflected in its title. During the discussion of Appendix 2, the group was

[1] On May 7th – 8th, appendices 2-5 were numbered Appendix 1-4. For readability, these are referred to as Appendix 2-5, to not confuse Appendix 1 – Human Factors research supporting design principles for standardized modes and Appendix 1 – Navigation related terminology and icons of functions.

of the opinion to leave no room for interpretation, thus, eliminated all alternative suggestions for icons, whilst making sure that the wording is in line with IEC 61174. After discussing the implications for manufacturers, the group had no major issues with appendices 3 and 4. The discussion of Appendix 5 revealed that there are different mental models when referring to "standard user settings". As such, it was agreed upon that Appendix 5 should be referred to as "default and user settings for ECDIS and radar throughout the entire appendix. Furthermore, it was agreed that users should know what to expect when returning to a default mode, thus parameters should be the same for ECDIS and radar systems. Regarding the issues with additional symbols for IMO SN/Circ.243, the group decided the symbols introduced by FKIE should be included to avoid further misunderstandings of the symbols (see 6.4).

6.3 Finalization of guidelines for S-mode at NCSR 6

The guidelines on S-mode were discussed and finalized at NCSR 6. According to the content the guidelines were renamed to *guidelines for the standardization of user interface design for navigation equipment*. The guidelines consist of a general outline of user interface standardization design principles and five appendices (IMO, 2019f).

Appendix 1 of the guidelines is an informative appendix on human factors research supporting standardization design principles. It outlines the application of human factors and cognitive science during the design of navigation systems and is providing information on how human factors and human error is related to system design.

In Appendix 2 of the guidelines, navigation-related terminology and icons of functions (hot keys and shortcuts) for commonly-used functions on navigation equipment are listed. Associated terminology, abbreviation and an icon (if useful) are described for each function. Where icons, terms and/or abbreviations are used on navigation equipment, they should meet the requirements. Where icons, terms and/or abbreviations are not available the developed solutions should not conflict with those listed in Appendix 2 of the guideline. It was decided that where appropriate and practical, a brief explanation of the purpose of an icon should be easily obtainable by the user. This functionality should be easily turned off to allow flexibility to meet user needs.

Appendix 3 of the guidelines (logical grouping of information) specifies groups of related essential navigational information that should be displayed together on the user interfaces of the navigational systems. The aim is to allow a quick localization of the related navigational information to support the usability of the systems and a consistent presentation across navigational equipment. The appendix applies to Radar, ECDIS and minimum INS functions as defined in resolution MSC.252(83) (IMO, 2007). To improve standardization and usability the appendix may be applied to other electronic navigation equipment and navigation sensors.

In Appendix 4 of the guidelines a list of functions which should be accessible by single or simple operator action are listed, to support fast access to essential functionality. Single or simple operator action are defined in the guidelines according to resolution MSC.252(83) (IMO, 2007) as follows:

- Single operator action is defined as "A procedure achieved by no more than one hard-key or soft-key action, excluding any necessary cursor movements, or voice actuation using programmed codes."

- Simple operator action is defined as "A procedure achieved by no more than two hard-key or soft-key actions, excluding any necessary cursor movements, or voice actuation using programmed codes."

Appendix 5 of the guidelines specifies default settings for radar and ECDIS. Default settings are specified to allow the user to select a familiar default state of the system. Default settings can be activated with a single operator action. Furthermore, in Appendix 5 of the guidelines, guidance is provided on the use of user settings. On systems, a facility should be provided to store and recall user-specific settings. The system should offer the possibility to store and recall at least two user configurations. The selection for recalling a stored configuration should be followed by an action to confirm the selection.

Two of the appendices of the guideline are referenced in the revised resolution MSC.191(79), see chapter (6.5).

6.4 Additional symbols for IMO SN/Circ.243

6.4.1 Background and approach

Together with the performance standards for presentation of navigation related information on shipborne navigational displays resolution (MSC.191(79)) *guidelines for the presentation of navigation-related symbols, terms and abbreviations* (IMO SN/Circ.243) were adopted by MSC in 2004. The purpose of the guideline is to provide guidance on the appropriate use of navigation-related symbols to achieve a harmonized and consistent presentation. Within the guidelines symbols are listed e.g. regarding the presentation of own-ship information, radar target information, AIS target information, route information. Following the adoption of these guidelines *IEC test-standards (IEC 62288) for presentation of navigation-related information on shipborne navigational displays* (IEC, 2014) were developed which go beyond what was already listed in the IMO circular regarding the symbology. This lead in the last years to the fact, that certain symbols were unknown to the mariners onboard, as these symbols are not included in training programs according to STCW.

The lack of knowledge of the 2nd officer of the vessel Pacific Orca of a specific AIS symbol which was only listed in the IEC test standard could have been one of many reasons for the accident of the vessels Pacific Orca and the Jurie van den Berg (BSU, 2014). It was recommended by the accident investigators of the Federal Bureau of Maritime Casualty Investigation to include the symbol in the appropriate IMO standards.

Therefore, an analysis was conducted which new symbols were introduced with the IEC test-standards 62288 and should be included in the IMO guidelines for SN/Circ.243. Furthermore, the identified symbols were analyzed, in regard to design and color conflicts with the existing symbols. In a second step the results were included in the agenda of S-Mode workshop held at the Federal Maritime and Hydrographic Agency. They were discussed and a final set was developed for inclusion in the IMO circular.

These symbols were submitted to the IMO correspondence group *on the development of Guidelines on the standardized mode of operation of navigation equipment, S-Mode* with the aim of an inclusion of these symbols in the report of the correspondence group to NCSR 6. The report should recommend an inclusion of the symbols in the IMO circular. The addition of the symbols to the report was discussed related to the terms of reference of the group. The majority of the correspondence group was supporting the inclusion of the symbols in the report.

6.4.2 Recommended symbols

In the following the recommended symbols for inclusion in the IMO SN/Circ.243 are listed and explained. Most of the symbols and corresponding texts are kept unchanged from the IEC test standards 62288 (IEC, 2014) for consistency reasons.

Functional requirements from IEC 62288 regarding presentation issues for certain navigational information related to the symbols are listed in appendix 3. As in the IMO SN/Circ.243 only requirements regarding the layout of symbols are listed, the functional requirements should not be included. This information should be taken into account when the interim guidelines for the harmonized display of navigation information received via communications equipment, MSC.1/Circ.1593 (IMO, 2018d) will be reopened and revised:

- Sleeping (activated) AIS target with neither reported heading nor COG
  Sleeping (activated) AIS target with neither reported heading nor COG should be presented as acute isosceles triangle oriented toward the top of the operational display area with one line crossed through the symbol.

  Note: This recommendation differs from the symbol listed in IEC 62228. A change of the test standard will be necessary.

- *Alternative presentation for associated targets*.
  IMO SN/Circ.243 requires the presentation of associate targets (i.e. activated AIS targets associated with tracked radar targets) as either activated AIS target symbols or tracked radar target symbols.
  Alternatively, activated AIS target symbols representing associated targets may be modified by circumscribing a circle around the symbols isosceles triangle.

  Tracked radar target symbols representing associated targets may be presented with larger diameter circles modified by inscribing an isosceles triangle inside the symbols' circle.

- *Selected AIS ATON*
  Selected target symbols should be presented as broken squares indicated by their corners, centered on the selected target symbol.

- *Selected AIS-SART*
  Selected target symbols should be presented as broken squares indicated by their corners, centered on the selected target symbol.

- *Lost AIS ATON*
  Lost target symbols should be presented as crossed lines centered on the target symbol. The lines should be drawn using a solid line style and should flash with the required color red until acknowledged by the user.

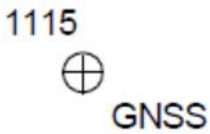
- *Lost AIS-SART*
  Lost target symbols should be presented as crossed lines centered on the target symbol. The lines should be drawn using a solid line style and should flash with the required color red until acknowledged by the user.

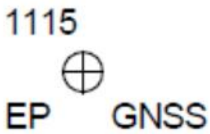
- *AIS SAR aircraft*
  An AIS SAR aircraft should be drawn with a thin solid outline with the same basic color as used for target symbols. The symbol should be oriented in the direction of

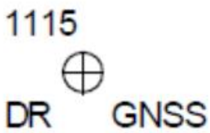
the COG.

- *AIS SAR vessel*
  If provided, a search and rescue vessel should be presented by having a circle with cross drawn with a solid line inside the standard activated AIS vessel symbol.

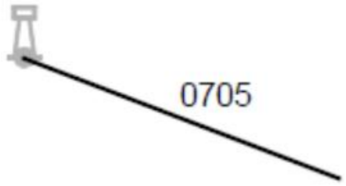
- *Plotted position*
  A plotted position (Fix, EP, and DR) should be presented as a circle with crossed lines centered at the position. The length of the crossed lines should be the diameter of the circle. The circle and crossed lines should be drawn using a thin solid line style. The position should be labelled with time and an indication of its source for example GNSS, L (Loran), R (Radar range), V (Visual bearing), VR (Visual bearing and Radar range). If the position is an estimated position, it should also be labelled with the letters "EP". If the position is a dead reckoned position, it should also be labelled with the letters "DR". Alphanumeric text used to label the position should be the same basic color as the symbol.

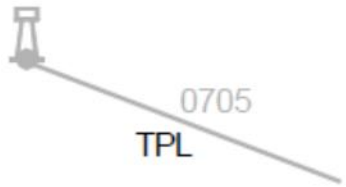






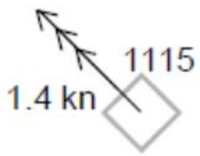
- *Line of position*
  A line of position (LOP) should be presented as a single line originating from a charted object and extending towards own ship. The bearing of the LOP should be referenced to the CCRP. The LOP should be drawn using a thin solid line style. The LOP should be labelled with time. If the LOP is transferred, it may also be labelled with the letters "TPL" for transferred position line. Alphanumeric text used to label LOP should be the same basic color as the line. A LOP range observation will be an arc.

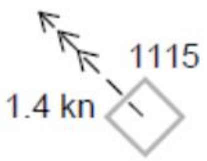




Examples show the default symbol for a water tower.

- *Tidal stream*
  A tidal stream should be presented as a single line with three arrowheads. The line should originate from the charted position for which a tidal stream table (or tidal stream data) is available. The line for an actual tidal stream should be drawn using a thin solid line style. The line for a predicted tidal stream should be drawn using a thin long dashed line style. The arrowheads for a tidal stream should be drawn using a thin solid line style. The tidal stream should be labelled adjacent to the line with the effective strength and time, ideally on opposite sides. Alphanumeric text used to label the tidal stream should be the same basic color as the line.





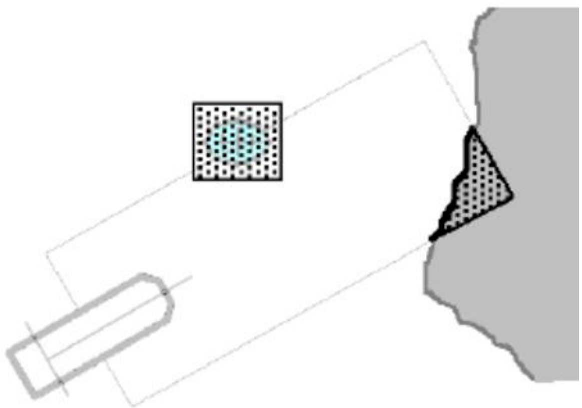
Examples show the default symbol for a point or area for which a tidal stream table is available.

- *Mariner danger highlight*
  A danger highlight should be presented as a polygon bounding a geographic area designated as dangerous to navigation, or as a poly-line creating a boundary around such an area. The boundary of the polygon, or poly-line, should be drawn using a thick solid line style. Recommended color: red.

  The polygon, or bounded area should be filled with a transparent fill using the same color as the polygon or poly-line.

Examples show the default symbol for a mariner entered danger highlight of a dangerous wreck at an unknown depth bounded by a rectangular danger highlight and an outcropping of land bounded by a user-entered danger highlight.

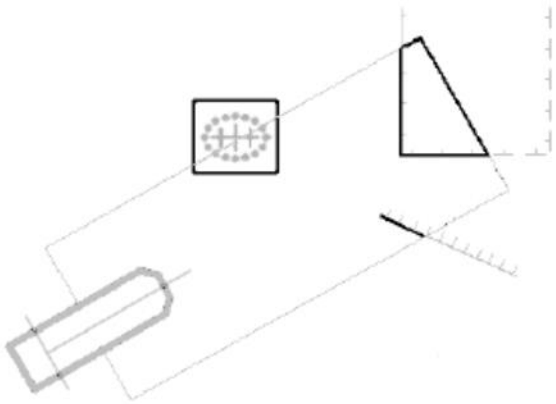
- *Alarm highlight*
  The graphical indication in the chart area of an alarm condition (see MSC.232(82)/A 11.4.4 and 11.4.6) should be presented as a polygon or poly-line on the boundary of the area or point object causing the condition. The polygon or poly-line should be drawn using a thick solid line style with recommended color red. The bounded area should have a transparent fill of the same color.



The example shows a depth area more shallow than safety contour and a dangerous wreck within the look-ahead safety check area.

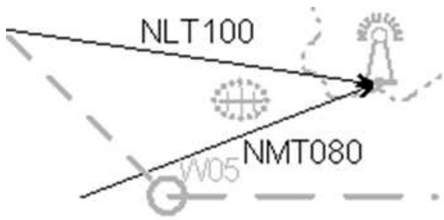
- *Caution highlight*
  The graphical indication in the chart area of warning or caution conditions (see MSC.232(82)/A 11.4.4 and 11.4.6) should be presented as a polygon or poly-line on the boundary of the area or point object causing the condition. The polygon or poly-line should be drawn using a thick solid line style with recommended color yellow and

adjacent thin lines of black on either side for visibility against a white (day) background. The bounded area should not be filled.



Examples show point (wreck), restricted area and line (fish stakes).

- *Danger bearing*
  A danger bearing or clearing line should be presented as a single line with an arrowhead directed at the base of a charted object. The line should be drawn using a thin solid line style with the required color red. A danger bearing should be labelled with its bearing. The letters "NMT" should be used to indicate "not more than". The letters "NLT" to indicate "not less than". Alphanumeric text used to label the danger bearing should be the same basic color as the line.



The drawing is not to scale. The example shows the default symbols for a light and a dangerous wreck at an unknown depth.

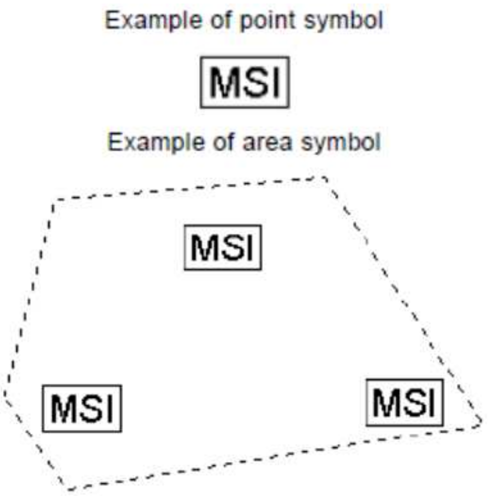
- *Radar test target*
  When an internally generated test target is enabled, it should be indicated by the presentation of the large letter "X" adjacent to the target with the basic color used for the target symbol.

  In addition, a bold "X" should be shown in a conspicuous location in the operational display area.

- *Maritime Safety Information, MSI*
  MSI point symbol should be presented as box with the "MSI" inscribed inside it. The box should be centered at the position derived from MSI message. The box should be drawn using a thick solid line style.

  MSI area symbol should be presented as a series of lines bounding a geographic area designated as "caution" to navigation. Connecting lines should be drawn using a thin dashed line style and using the basic color of the symbol. The area should be filled with a sparse pattern of MSI point symbols.

  Note that the source of MSI maybe NAVTEX, AIS ASM function identifier 22 or 23 (SN.1/Circ. 289), etc.

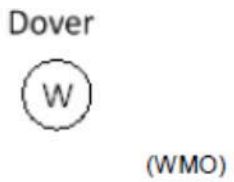


- *Meteorological information*
  Meteorological information symbols consist of two parts: the weather station symbol or reference point and the wind shaft. The weather station symbol should be presented as a circle with "W" inscribed inside it. The circle should be centered at the position derived from the site location report binary message. The circle should not be more than 6 mm in diameter, drawn using a thin solid line style and using the same basic color as AIS AtoN. The reference point symbol should be presented as a dot. The dot should be more drawn using a thin solid line style and using the same basic color as AIS AtoN. Alphanumeric text may be used to label the weather station.

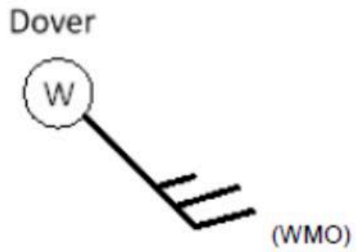
  The optional wind shaft should be used to represent wind force and direction as defined by WMO No.485, Appendix II-4, the surface plotting model. If wind force and direction is not available, then there should be no environmental symbol. The wind shaft should be not more than 3 times the diameter of the weather station symbol. The length of barbs and pennants should not exceed the diameter of the weather station symbol. The wind shaft should be drawn using a thick solid line style and using the same basic color as AIS AtoN. The wind shaft is directed along the axis of the wind towards the center of the station circle and stops at its circumference. Wind is represented by barbs and solid pennants. The full barbs representing 5 m/s or 10 kn, The half barbs representing 2,5 m/s or 5 kn and the solid pennant representing 25 m/s or 50 kn. All pennants and barbs lie to the left (clockwise) of the wind shaft in the northern hemisphere and to the right (counter clockwise) of the wind shaft in the southern hemisphere. Barbs are at an angle of 110° to 130° from the wind shaft. Pennants are triangles with their bases on the wind shaft.

A calm should be indicated by a circle drawn around the weather station circle: Missing wind speed should be indicated by placing an “x” at the end of the wind shaft in lieu of the wind barbs.

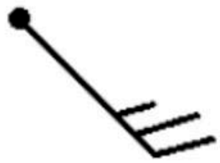
Note that the source of meteorological information may be AIS ASM function identifier 26 or 31 (SN.1/Circ. 289), etc.



Example of weather station



Example of weather station with optional wind shaft in southern hemisphere



Example of reference point with optional wind shaft in southern hemisphere

- *Tidal and water level information*
  Tidal and water level information symbol consist of three parts: the tidal symbol, tidal flow symbol and the tidal gauge symbol.

  The tidal symbol should be presented as a diamond with “T” inscribed inside it. The diamond should be centered at the position derived from the site location report binary message. The diamond should be drawn using a thin solid line style and using the same basic color as AIS AtoN.

  The optional tidal flow part of the symbol should be used to represent tidal speed and direction. If tidal speed and direction is not available then there should be no tidal flow symbol. The tidal flow symbol should be drawn to the direction of the tidal current and using the same basic colour as AIS AtoN.

  The optional tidal gauge part of the symbol should be used to represent availability of water level information. If water level is not available then there should be no tidal gauge symbol. The tidal gauge symbol should be drawn using a thick solid line style, transparent fill and using the same basic colour as AIS AtoN.

  Note that the source of tidal information may be AIS ASM function identifier 31 (SN.1/Circ. 289), etc.

- *Signal station*

  Signal station should be presented as a diamond centered at the reported position of the signal station. The sides of the diamond should be the same basic color as the AIS AtoN symbol.

  The symbol should be labelled with text "SS" centered in the diamond and the color of the label should be the same color as the symbol.

  Note that a signal station is a station capable of transmitting marine traffic signals. The source of signal station may be AIS ASM function identifier 19 (SN.1/Circ. 289), etc.

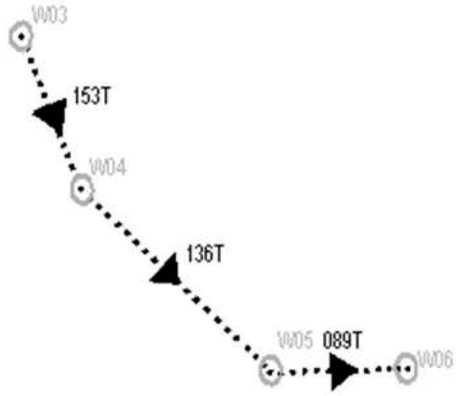
- *Route information broadcast*

  Route information is as a series of waypoints connected by one or more legs. Leg lines on the route information should be drawn using a thin dotted line style. They should have a centered solid triangle with equal length of each side and should be the same basic color as the AIS AtoN symbol. Solid triangle is centered on visible part of each leg.

  Leg lines on the route information may be labelled adjacent to their line with their course. The label should not interfere with text used to label the waypoint. Alphanumeric text used to label a leg line should be the same color as the leg line.

  The color of route type "mandatory route" should be different from other route types.

  Note that the source of route information may be AIS ASM function identifier 27 or 28 (SN.1/Circ. 289), etc.



- *Berthing data*

  Berthing assignment should be presented as a box with the "BERTH" inscribed inside it. The box should be centered at the position derived from the berthing data message. The box should be drawn using a thick solid line style and should be the same basic color as the AIS AtoN symbol.

  Note that the source of berthing data may be AIS ASM function identifier 20 (SN.1/Circ. 289), etc.

- *Clearance time to enter port*

  Clearance time to enter port should be presented as a box with the "CTE" inscribed inside it. The box should be centered at the position derived from clearance time to enter port data message. The box should be drawn using a thick solid line style and should be the same basic colour as the AIS AtoN symbol.

  Note that the source of clearance to enter port may be AIS ASM function identifier 18 (SN.1/Circ. 289), etc.

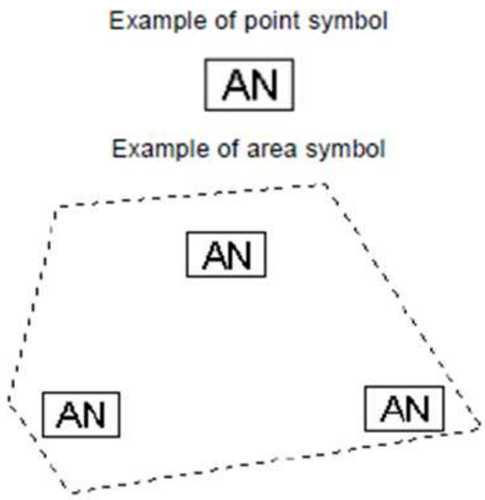
- *Area notice*

  Area notice point symbol should be presented as box with the "AN" inscribed inside it. The box should be centered at the position derived from Area notice message. The box should be drawn using a thick solid line style and should be the same basic color as the AIS AtoN symbol.

  Area notice area symbol should be presented as a series of lines bounding a geographic area. Connecting lines should be drawn using the thin dashed line style and using the same basic color as the symbol itself. The area should be filled with a sparse pattern of area notice point symbols. Drawing priority of area notice symbol is below Maritime Safety Information MSI.

  Note that the source of the area notice may be AIS ASM function identifier 22 or 23

(SN.1/Circ. 289), etc.

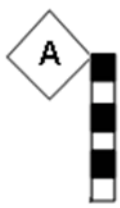


- *Air gap*

  Air gap symbols consist of two parts: the air gap symbol and the air gap gauge symbol. The air gap symbol should be presented as a diamond with "A" inscribed inside it. The diamond should be centered at the position derived from the site location report binary message. The diamond should be drawn using a thin solid line style and using the same basic color as AIS AtoN.

  The air gap gauge part of the symbol should be used to represent availability of air gap information. If air gap is not available then there should be no air gap gauge symbol. The air gap gauge symbol should be drawn using a thick solid line style, transparent fill and using the same basic color as AIS AtoN.

  Note that the source of the air gap/air draught information may be AIS ASM function identifier 26 (SN.1/Circ. 289), etc.



- *Environmental report*

  The environmental report symbol should be presented as a diamond with "ENV" inscribed inside it. The diamond should be centered at the position derived from the site location report binary message. The diamond should be drawn using a thin solid line style and using the same basic color as AIS AtoN.

  Note that the source of environmental information may be AIS ASM function identifier 26 or 31 (SN.1/Circ. 289), etc.

6.4.3 Discussion and approval of revised IMO SN/Circ.243 at NCSR6

The IMO correspondence group on S-mode submitted with its report the proposed revision of SN.1/Circ.243/Rev.1 to NCSR 6 (IMO, 2019h). The suggested revision of the navigational symbols followed the proposal made by Germany (see 6.4.1 and 6.4.2). The symbols were discussed in the navigation working group and agreed upon. The symbols and Annex 2 of the guidelines "navigation-related terms and abbreviations" were revised (IMO, 2019e).

The Sub-Committee agreed on the revised draft SN circular. The revised guidelines will come into force as SN/Circ.243/Rev.2 and will be applicable for radar equipment, ECDIS and INS on January 1st, 2024 and for all other navigational displays on the bridge, on July 1st, 2025.

6.5 Amendments to resolution MSC.191(79)

To progress the application of the guidance given in the *guidelines for the standardization of user interface design for navigation equipment* amendments to resolution MSC.191(79) *performance standards for presentation of navigation related information on shipborne navigational displays* (IMO, 2004a) were considered. It was agreed to include references to Appendix 2 and Appendix 3 of the *guidelines for the standardization of user interface design for navigation equipment* in the resolution. The reference to Appendix 3 (logical grouping of information) of the guideline is included in chapter *5.1 arrangement of information* of MSC.191(79) whereas the reference for Appendix 2 *navigation related terminology of icons and of functions* is included in chapter *5.2 readability* of the resolution.

Both appendices of the guideline will be mandatory due to the integration of the references in MSC.191 (79). The revised MSC.191 resolution including the mandatory application of the two appendices with the related SN/Circ.243/Rev.2 will come into force for radar equipment, ECDIS and INS on January 1st, 2024 and for all other navigational displays on the bridge on July 1st, 2025.

6.6 Conclusions

The *guidelines for the standardization of user interface design for navigation equipment,* specifying aspects to improve the usability and standardization of navigational equipment are another step in regard to a harmonized presentation of navigational information. The guidelines achieve this goal without over-specifying and restricting the design of navigational systems. Due to a reference of the appendices 2 and 3 of the guideline in MSC.191(79) a mandatory application is ensured and the guideline will be recognized and followed.

Furthermore, the revision of SN/Circ.243 is another important step for the introduction of presentation requirements for navigational displays on IMO level.

Nonetheless, issues regarding a user-friendly design and operation of navigational systems are unsolved. Especially in regard to information overload. The systems provide too much functionality deviating from the original purpose of the navigational systems. Therefore, a more task-oriented approach for the design of navigational systems in the future is required to enhance the safety of navigation. A new concept for IMO regulations is necessary, describing the minimum and maximum functionality necessary for each task.

7 Multi sensor displays - IMO Resolution MSC.191(79)

To enable a harmonized presentation of information from multiple sensors on a single display (multi-sensor display) amendments for IMO Resolution MSC.191(79) were developed and drafted. The aim is to allow the presentation of more than one sensor on a multi-sensor display. Therefore, the developed amendments to MSC.191(79) contain requirements for a user-friendly presentation of sensor related information and describe the possibility to replace the display units of the sensors by multi-sensor displays.

Description

A multi-sensor display presents information from more than one sensor. A multi-sensor displays may be part of a multifunction display, presenting and combining sensor and operational information. On an INS, sensor information from multiple sensors could be presented e.g. on the tasks "navigation control data" and "status and data display". A multi-sensor display could replace display units of the individual sensors.

If sensor information is presented on a multi-sensor display, at least a second display should have the possibility for presentation of the sensor information for back-up purposes. This display should be independent to the first display. A failure of the first display including network failures should not degrade the performance of the back-up display.

Submission to NCSR6

The amendments were developed together with the BMVI, DNV GL and BSH and discussed in a meeting of the BMVI's national expert group for integrated ship navigation and control systems.

The document was submitted to NCSR6 (NCSR 6/11/16) by Germany (IMO, 2018h). At the discussion at NCSR 6 the amendments were not approved. The major arguments against the inclusion of the amendments were that MSC.191(79) were not the appropriate document, as the added requirements were not restricted to presentation matters only. Furthermore, it was mentioned in the discussion that the requirements could lead to additional carriage requirements.

8 Alarm management on ship bridges

Much has been done to reduce alarms on the bridge, e.g. performance standards for bridge alert management were introduced by IMO (Resolution MSC.302(87), 2010b). However, recent feedback from mariners has brought attention to the many apparent alarms on the bridge. This has spiked interest in the current bridge alarm management. Thus, an investigation of a container ship on the passage from Hamburg to Bremerhaven was set up to get an idea whether more research in this area is necessary. The goal of this investigation was to get an impression of the current alarm management system used on the bridge and determine the need for a reduction of alarms.

8.1 Approach

To get an impression of the most recent status of the alarm management on bridges, investigations on a modern container ship were conducted. The types of equipment used on the vessel were recorded. To determine whether ECDIS and radar settings are the core of frequent alerts, the selected settings were determined. Types and number of alarms were documented during navigation of the ship. Furthermore, semi-structured interviews with the master and 1st officer of the ship were to give insight on current issues regarding alarm occurrences and presentation. At no point was the investigation to hinder the crew while navigating the ship or risk the safety of the passengers.

8.2 Setting

8.2.1 Vessel and voyage

A container ship built in the year of 2017, was selected for its young age, convenience of the route, and partnership. The vessel left the port of Hamburg to set anchorage off the coast of Germany. The vessel left the anchorage area a day later and docked the port of Bremerhaven. Alerts were recorded during a time period of 14 hours and 45 minutes between 6:56 am -15:38 pm and between 4:23 am and 10:26 am.

8.2.2 Equipment

Amongst others, the bridge was equipped with two ECDIS, 2 x-band radars and one s-band radar, an alert management system (AMS) displayed in the conning monitor unit, two echo sounders, a minimum keyboard and display (MKD), NAVTEX printer combined display unit, engine alarm indicators (no.1-4), pilot door unit, bow thruster controllers. The mentioned equipment caused alarms at one point during the recording. The AMS is designed according to the IMO performance standards for bridge alert management.

8.2.3 General Alarm Settings

Alarm settings of the individual systems could not be thoroughly investigated, as it was a priority to not disturb the crew. However ECDIS, AMS, and radar systems were all used in silent mode. Safety contour was set to 10 meters to see any water level differences on the ECDIS chart during navigation in confined waters e.g. Elbe River. CPA/TCPA option for AIS/radar targets were switched off, and is used in more open sea area only. On ELBE, AIS target presentation was solely in use for ECDIS. Outside of ELBE AIS targets presentation was in use for both radar and ECDIS systems.

8.3 Background - presentation of alarm information on installed Furuno systems

The presentation of alarm information of the installed Furuno systems correspond to the IMO resolution for bridge alert management (MSC.302(87)/2010b). According to these standards the term "alert" is used as an umbrella term for emergency alerts, alarms, warnings and cautions.

Emergency alerts present immediate danger to human life or to the ship. Alarms represent the most urgent priority for navigational alerts which demands immediate attention to avoid any hazardous situations. Furuno displays these visually as a blinking alarm in red, additionally, a buzzer is sounded until the alarm is acknowledged. Warnings are representative of situations which demand immediate attention for precautionary reasons. On Furuno, a blinking warning is presented in yellow-orange with an acoustic sound, which -if not acknowledged- can become an alarm. Cautions represent conditions which demand attention to out of the ordinary situations or to the given information. On Furuno, these cautions are presented in yellow. Cautions do not blink and have no acoustic presentation.

Alerts are furthermore divided amongst two alert categories: Category A and B (IMO, 2010b):

> "Category A alerts are specified as alerts where information at a task station directly assigned to the function generating the alert is necessary, as decision support for the evaluation of the alert-related condition, e.g.: danger of collision; and danger of grounding. Therefore category A alerts cannot be acknowledged at AMS of Furuno and have to be acknowledged at the system initiating the alarm. This fact indicated to the user on the AMS of Furuno.
>
> Category B alerts are specified as alerts where no additional information for decision support is necessary besides the information which can be acknowledged at the AMS of Furuno."

8.4 Results

8.4.1 Quantitative Results

Alerts displayed on the AMS and acoustic alarms caused by systems not connected to AMS were recorded. A camera was used to photograph alerts displayed on the AMS to avoid any disturbances for the crew during the navigation of the vessel. A total of 105 alerts (71 cautions, 20 warnings and 14 alarms)[2] were recorded, of which 98 were presented visually and seven acoustically. Of the 98 visually presented alerts, 29 alerts were intended as alarms or warnings. Of the seven acoustic alerts not displayed by AMS, four alerts can be categorized as alarms (e.g. open pilot door; engine alarm) and three alerts as cautions (e.g. 'BAM COM error'; 'thruster control').

In general, alerts from each individual system were listed as its own separate alert. This means that some alerts (e.g. 'crossing safety contour') were displayed up to five times (radar systems no.1- no. 3 and ECDIS no.1 & no.2). The same type of alerts received the same prioritization.

[2] The investigation makes no claims of factual completeness for several reasons. First, alerts could not be recorded at all times due personnel resources. But more importantly alerts displayed on the AMS did not receive a specific id. Thus, alerts could not be fully recognized as new alerts or old alerts displayed anew.

However, this did not apply to alert 'restricted area'. This alert was presented as a warning on AMS with ECDIS no. 2 as a source and as a caution with ECDIS no.1 as the source. Furthermore, the 'BAM COM error' caution was not integrated on the AMS and only displayed on the MKD.

Table 1
Occurrence of Alerts* (N=105 alerts)

Type of Alerts	Number of Alerts
Navtex related alerts	13
Crossing special area	11
Restricted area	11
Echo sounder 2 com error	11
Crossing safety contour	9
Depth (stern) not available	9
Sensor COM related errors	9
UKC Limit	6
Anchorage area	5
Other alerts* (e.g. off track, AIS cautions, out of paper)	21

Note: at most other alerts appeared three times

Table 2
System Source of Alerts* (N= 105 alerts)

System	Number of Alerts
AMS +	19
AMS/ ECDIS no.1	18
AMS/ ECDIS no.2	18
AMS/ chart radar no.2	13
AMS/ chart radar no.1	10
AMS/ chart radar no.3	9
Systems disconnected from AMS	8
AMS/ Navtex	6
AMS/ HCS	2
AMS/ AIS Transponder	2

8.4.2 Interview

A semi-structured interview was completed by one crew member to assess what the main problems are with alarm occurrences and presentation. Some questions were also answered by other crew members in conversation.

The interviewee finds that the major problem regarding alarm occurrence and presentation is the workload the current setup demands. The interviewee reported that, more often than not, a single person is responsible on the bridge for acknowledging alerts which need to be acknowledged at different stations- even when the same alert is presented. Examples mentioned were NAVTEX related alerts and distress alerts which have to be acknowledged at the corresponding device -located in the back. Also, ECDIS alerts have to be acknowledged at up to three devices which are separated by a mid-panel. This was found very frustrating. Furthermore, the interviewee finds that a major problem with the presentation is that, it is hard to place the device which causes the alerts. Due to the fact that most alerts are presented by the AMS, it is no longer possible to acoustically locate which device causes the alert. Although the AMS displays this information visually, the interviewee points out, that it is too hard to distinguish the text.

When asked which alarms cause most of the problems, the interviewee reported that in difficult scenarios, such as navigating in China with many fishing boats around, there are many unnecessary alerts regarding CPA/TCPA. But that AIS and distress alerts, or in general communication alerts are the most annoying alerts, due to the fact that these need to be acknowledged at the specific devices.

Correspondingly, the interviewee would prefer a single work station at which all alerts can be acknowledged. Furthermore, the interviewee finds that a prioritization and harmonization of alarms needs to be optimized. The interviewee and a crew member report that some alerts such as anchorage area warnings are entirely unnecessary and restricted area warnings do not need an acoustic presentation. ("We are smart we don't need some of the alarms" and "I don't feel like making a course for every system. But, if I haven't used the system for a long time, I won't remember…It's about safety, no?")

8.5 Conclusions

Due to the silence mode and alert settings the bridge was relatively quiet with very few acoustic alerts. However, this status should not be the normal state. The chosen silent mode shows that there are still problems with the alarm management, both in occurrence and prioritization. It became very clear from the interview and conversations that having to acknowledge alerts at many different stations (ECDIS no.1 & no. 2, NAVTEX, GMDSS etc.), when sometimes there is only one staff member on the bridge, is still a problem. At this point it should be noted that some of these alerts have to be acknowledged at the system providing the alert, e.g. a collision alarm on the radar system, where all information related to the alert is available. This is according to the concept described in the IMO resolution MSC.302(87) (IMO, 2010b).

Furthermore, the vessel was equipped with individual systems. Issues such as having to acknowledge certain alerts at both ECDIS systems, would not be an issue, if an integrated navigation system (INS) were implemented. Additionally, some alerts (warnings and cautions such as: caution area, restricted area etc.) caused by ECDIS, can potentially be deselected. However, a deselection of alerts was not chosen for liability reasons. The chosen settings result in an additional increase of alerts at several work stations. Nonetheless, it should be considered to incorporate all alerts belonging to category B into the AMS including all GMDSS alerts to address the issue of too many work stations.

The feedback about too many alerts, mostly regards NAVTEX and GMDSS alerts, but in general no increase in alerts in comparison to the last years has been perceived by the crew. This is reflected by the results of the quantitative study which show that NAVTEX related alerts occurred most often.

To improve the issue with locating the alerts to its source, changes to the HMI of the AMS, especially when presented as a small portion of the conning display, should be considered. While the AMS also represents all alerts in an alert list and has reduced a number of acoustic alerts, which have been major issues in the past, it appears that currently it is not possible to efficiently assess the source causing the alert. Graphical representation or representing the AMS as a larger section of the conning display could be a solution and should receive further research. Acoustic announcement at individual systems in not a solution as it was one of the major problems with the alert representation in the past.

In general, the investigation to receive first impressions revealed that a prioritization of alerts and presentation of alerts should receive a more thorough investigation. Longer investigations which also assess the state at open sea are necessary. Also more different vessels should be investigated as equipment differs from vessel to vessel and settings will differ from crew to crew which will cause differences in the occurrence and handling of alarms. A possible reduction might be achieved by the integration of GMDSS alerts into the AMS and by installing an integrated navigation system (INS). In general, the concept of bridge alert management according to the IMO standards appears to reduce the workload of the crew regarding the handling (acknowledgement, silencing, etc.) of alerts in comparison with vessel without an AMS.

9 Network technology and risks

9.1 Introduction

Communication networks serve the purpose to enable the communication between devices. These communication networks usually consist of several layer of communication which might be overwhelming when viewed as one. The OSI (Open Systems Interconnection) model reduces the complexity by separating the communication in different layer which are individually interchangeable by alternative protocols to adapt to requirements.

This document describes the different encounters on different layers of the OSI model with their risks and possibilities to mitigate them.

The first chapter (9.2) describes different network topologies and their risks or implementation-depended requirements. The following chapter (9.3) lays out the different attack vectors and problems. The following chapters are based on the OSI model. Chapter 9.4 is about the physical layer (layer one in the OSI model), and describes the base of this layer as the physical communication as bit stream. The following chapter 9.5 covers the data link layer which has basic routing functionality, and thus is the first networking layer. Whereas the physical layer is not reduced to point-to-point, the first addressing usually occurs in the data link layer. The third layer, the network layer, allows routing over network borders and is described in chapter 9.6. The addresses which are used in the data link layer are limited to them (like MAC (Media Access Control) addresses, CAN-bus IDs (Controller Area Network)) but the addresses in the network layer are (in general) worldwide (IP (Internet Protocol) addresses). The transport layer or layer four is described in chapter 9.7, followed by chapter 7.8 in which the application layer is described- which is actually layer seven, but to ease the examination the layers five to seven are considered as one layer. This also includes the network layers which are run by the operating system and the user land software.

9.2 Network Basics

A computer network can be implemented in different ways. The implementation which is used has some pros and cons which have to be accounted for.

The first network type which is considered is not yet a network but a point-to-point connection between two nodes. These connections usually connect a data source or sink to a concentrator using a communication protocol, for example like RS-232. The cons of this protocol are that all networking has to be done by the concentrator, there is no real networking protocol which routes the data. The pro is that a device can be addressed directly and no further protocol is required to contact the recipient. If the device should be directly contacted remotely, it is required that the data cable must be at full length.

Another network type is a network bus. All network devices are connected to a common data link where all data is sent over. This network type requires that exactly one device is currently using the bus. If a second device starts communicating, that bus gets jammed and typically no data can be decoded. To avoid such a collision there are usually three different types of multiple access established:

The first method is called CSMA/CD (carrier sense multiple access/collision detection) which is used by Ethernet. If a sender wants to send a data unit it senses the bus, if it is currently in use. If not it sends its data unit. If it detects a collision, it cancels the current communication and yields for a random time until it senses the bus again.

The second method is CSMA/CA (carrier sense multiple access/collision avoidance) which is used by wireless networks, like wireless Ethernets. It operates similar to CSMA/CD: It checks the communication channel for availability. If it detects a free channel, it waits a random time before it sends its data. This is necessary because wireless networking devices are not necessarily full-duplex-capable, therefore it can't listen and send at the same time. Another problem can result from the hidden station problem, where two senders are not in range of each other, but a common receiver receives both data units which would result in a collision with CSMA/CD.

The third method is called CSMA/CR (carrier sense multiple access/collision resolution) which is used by the CAN-bus. Because the CAN-bus is the common usage in maritime networks this explanation focusses on this. This communication method requires a common clock and unique ID device IDs. The common clock is synchronized between the devices from recessive bits (passively set voltage by the bus resistor) to dominant bits (actively set to a voltage by a device). During the arbitration phase all sending devices listen to the bus for all messages. The arbitration phase starts with the transmission of the IDs of the senders. The first time any sender receives a collision (in this case one sender sends a recessive bit, but receives a dominant bit) it yields the transmission. With unique IDs at the end of the arbitration phase only one sender will be left and sends its message without delay.

With network buses sharing a common media, their transmission is always limited to one sender which reduces the possible transmission rate on the bus. With collision control the transmission rate is also limited. The main pro of bus networks are the low cost of required cabling because only the bus is required for all connected devices where with serial communications an own cable is required per device.

The last communication network is a star topology, which may be in general a tree topology. This topology requires a central device to which all nodes are connected to (or in general all devices in a subtree of the device are connected to). This central node receives all data from the devices and sends it either to a receiver, if it is connected to the device itself, to another layer or broadcasts it, if the recipient is unknown. The non-leaf nodes may hold a recipient table, to reduce network load by not needing to broadcast all traffic. This network has the advantage that traffic is only sent to nodes which should receive the traffic, so the load of all nodes is reduced. Furthermore, traffic may be separated into virtual subsets of the tree for traffic separation. The main disadvantage of this topology is that, if one non-leaf node is lost the network gets separated. This can be avoided, if the network consists of two separate central nodes. However further network protocols are required to ensure that only one path between two nodes exist. A loop may lead to broadcast storms, where all data units circle through the network.

The direct connections are usually used to contact valves or the rudder or as last-line-connections from a network protocol changer, like Ethernet-to-RS232-bridge. After the network bridge they usually are used for GPS (Global Positioning System), logging, sonar, anemometer, AIS (Automatic Identification System) or the auto pilot. Bus networks are typically for navigation systems or control. Star topology Ethernet connects most of them to the control terminals.

9.3 General Attack Vectors

This section lists the various types of attack which could be carried out on the communication system in a ship. Sometimes an attack could be of multiple types, i.e. if an abuse of systems occurs there is also at least a partial denial of service ongoing, because the affected system is not usable during the attack.

9.3.1 Denial of Service

A DoS (denial of service) attack is an attack where some or at least a relevant number of systems of a network are currently not usable during the attack. This could lead to an economic impact, e.g. when a ship could not leave the harbor. A DoS can also effect subsystems only, e.g. if the public internet access on a cruise ship is not available due to a DoS attack.

9.3.2 Compromise

Another type of attack is the compromise of systems. Systems could be abused for a type of usage they are not designed for. Recent threats are crypto miners which use systems to dig crypto currencies. These attacks might lead to a faster aging of hardware and possibly to a DoS attack because the system is overloaded with the mining.

Furthermore, an attack could lead to wrong navigational data or abusive commands to the control of the ship which may direct the ship in a collision with other vessels.

9.3.3 Data Exfiltration

The last threat which might occur is the exfiltration of data. This might be the least relevant risk, because the ship's systems should not contain critical data but it may have an economic impact.

9.4 Physical

The physical access to a network port is the entry point to a network. Therefore, it is the first level where an unauthorized access can be prohibited. It is necessary to use tools to reach the network access port. Like Ethernet network ports, USB-ports (Universal Serial Bus) are entry points to a network. If these are required, i.e. for software updates, these ports should only be available in secure environments like the bridge.

If wireless network access is possible, it's hard to limit the range of the devices. Furthermore, it's not possible to limit the access like a wired network port. Relevant systems must never be accessible through wireless network.

If a network access could not be prevented by hardware, it is advisable that critical systems should be connected to a switch with multiple ASICs (Application-Specific Integrated Circuit), so a surge could only damage some network ports not all of them.

9.5 Data Link

The next layer where an attack could occur is the data link layer. If it could be prevented that an attacker could establish a data link then a further impact is unlikely.

9.5.1 Limiting Access

The first objective is to prevent establishing a data link by limiting the accessibility to well-known devices. This can be achieved using a MAC filter in Ethernet-based networks or USB-security in bus-based networks. A cryptography-based approach is advisable, because MAC filters or USB security can be bypassed using MAC or USB-ID spoofing. A strong cryptographic method based on IEEE 802.1x is harder to bypass, but increases the complexity and requires a RADIUS-server (Remote Authentication Dial-In User Service) as security backend. The standard IEC61162-460 requires a MAC filter.

9.5.2 Structural Parameters

The structure of the data link layer defines the stability of the network sub-segment against errors. A bus-based system can easily get interrupted, if the bus is saturated with erroneous data or just jamming. A star or better double-star topology may limit the impact to the sub-tree of the network.

If a double star topology is used, it is required to use a form of loop-prevention like the STP (Spanning Tree Protocol, IEEE 802.1d). However, STP is outdated by RSTP (IEEE 802.1w), further possibilities are provided by VLAN-support (Virtual Local Area Network) and MSTP (Multiple Spanning Tree Protocol, IEEE 802.1s).

Most importantly, critically required systems should always be redundant or multi-homed, i.e. connected to two distinct sub-trees of the network.

9.5.3 Reducing Impact

To reduce a possible network-wide impact, a separation of data into several virtual segments is advisable. With this separation it is possible to limit the data transfer between sub-trees of the network and create multiple layers of sub-networks over a physically single network. In Ethernet-based networks this could be achieved using VLANs (IEEE 802.1q). An example for such separation is the separation of system data, sensor data, radar data, compass data, outbound network connections, application networks into each separate VLAN.

With VLAN-separation, it is required that the edge ports do not allow introduction of VLAN-tagged Ethernet frames into the network, because this may lead to VLAN-traversal, where an Ethernet frame is introduced in a foreign VLAN.

In the same way it's advised that separate busses should be used for separate systems- one bus for control and one bus for navigation- so an intrusion into the navigation bus could not lead into abusive commands to the control bus.

If a STP is used the protocol itself could be attacked. Therefore, a form of protection against these attacks must be established. Here, are at least two forms of protection are mandatory:

At least one device should be elected as a root bridge. This is usually the root of a star topology. This device must have the highest STP priority. If a double star topology is used the other root switch should have the second highest priority.

All edge ports should be configured with either BPDU[3] (bridge protocol data unit) guard or BPDU filtering. The first method shuts the port down, if it received a STP data unit where the last method only filters it. An alert should be sent, if any BPDU is received on an edge port.

To limit the impact network wide either by error or by malicious infiltration of data, a form of storm control should be established. This storm control should limit the rate of incoming packets.

9.6 Network Layer

The network layer is the composition of several networks into a larger scale networks. It includes, if connected, the Internet.

The network layer requires, because of its possible worldwide character, a limitation of communication relations between local networks and other networks. These limits are implemented using firewalls which are required in IEC 61162-460.

These firewalls can be distinct between stateful and stateless firewalls. Stateless firewalls are easier to implement and have lower possibility of impact due to bad implementation. Stateful packet filtering can limit the direction of connection which is per se not possible in stateless firewalls. (It is possible to mimic stateful filtering by only allowing connection-related packets and limiting the non-related packets in one direction, but this is limited to stateful Layer-4-protocols like TCP (Transmission Control Protocol).)

If an Internet-access is required, e.g. for map updates, this connection must always be outbound. Inbound connections must never be allowed. In general, all network zones should have a security level to distinct the severity of impact between these networks. A network with a lower security level must never be allowed to access a higher security level network.

Each permitted network path between networks should be limited to the absolute minimum.

9.7 Transport Layer

The transport layer is used to multiplex network devices to work with different applications. The transport layer is also used to connect different serial connected network devices using a single serial-over-UDP-bridge (User Datagram Protocol, IEC 61162-1).

The transport layer also allows using multicast connections where one sender creates a message which has multiple receivers. Another use of the transport layer is to create reliable connections over unreliable networks using TCP.

Whereas firewalls are usually a part of the network layer, a stateful firewall is established in the transport layer by filtering based on the transport layer protocol.

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[3]Bridge Protocol Data Unit, the frames which are used by the STP to exchange data between network bridges

9.8 Application

The top layers of the network stack are the software part of the networking infrastructure. The first layer of communication may be a software tunnel, like Transport Layer Security (TLS).

This layer establishes a session between the communication partners, and by using TLS this could also be encrypted. The usage of a cryptographically secured connection ensures that the data is not altered and the communication partners can be validated, so it is generally advisable to use it. The drawback is that this needs a Public Key Infrastructure (PKI) which represents the trust anchor.

Also the design of the layer depends on the design of the whole software infrastructure. If used in a client-server-infrastructure, the server is the single point of failure and needs special protection. The client has less relevance in this design, but the input from the client must also be treated as it may be tainted, so input validation is always necessary.

When using a decentralized peer-to-peer infrastructure all parts are equal, so there may not be a single point of failure, but some peers could have different roles, like multiple sensors could send the data to multiple receivers. Thus, this infrastructure needs some form of sender validation.

9.8.1 Internet Access

If a system needs connection with the internet, these devices are more vulnerable to crafted data from a man in the middle. Therefore, a TLS-secured (Transport Layer Security) connection is crucial for the data security. Even with a TLS-secured connection, there should always be a form of validation of the data which is received from the internet, e.g. with signatures.

An example is here the encryption and validation of ENC (electronic navigational chart) data using the S-63 standard.

9.8.2 Operating System

The software which communicates always runs on an operation system (OS). Therefore the OS could alter the data before it is sent out. It is important that the integrity of the OS is ensured at the earliest point in the boot process. The Unified Extensible Firmware Interface (UEFI) secure boot is one approach for that which should be used.

Further points are the reduction of attack vectors on the OS and its user-land software. The software set should be reduced to the absolute minimum required to use the terminal. Furthermore, automatons which might allow an attacker to execute software in the background, like USB auto start must be disabled.

The usage of a role-based authorization system can reduce the impact of a compromise and a program should never be executed as a superuser.

An anti-virus program could be used, but a reduced software set without the possibility of installing further software renders this almost useless, with no internet access to update its databases the installation of this software even may reduce the security of the system by opening another attack vector.

9.8.3 Data Validation

As mentioned the data should always be validated. It is also recommended that failures of validation of data are necessarily an attack. The data transmitted by a network may be altered by environmental effects, if their transmission is not secured by a network layer, like TCP. Therefore, the evaluation of the alerts should account for the transmission of the data. High false positive rates, where alerts are emitted which are no real threats, may lead to users ignoring real threats (cry-wolf-effect).

A central monitoring system should watch over the network and monitor the health of the system so errors could be evaluated (MSC.302(87), IEC61924-2). High-risk data, like actuator commands must always be monitored and validated. Alerts should always be logged.

The fusion of sensor data allow a validation of the data for their coherence: If one sensor input is off the bounds of fusion of the other sensors, this single data should be considered wrong and might be dropped. A high error-rate may present a defective system, even if the data which it generates is syntactically correct.

9.9 Summary

In conclusion there are several threats which a maritime network is exposed to. Amongst these threats are the denial of service, the compromise and data exfiltration.

The OSI model has several layers where these threats can be mitigated: First, the physical layer -where physical access can be limited or redundancies can be established; the data link layer -where address-based access control can limit the impact or structural parameters of the network and can reduce the possible range of an attack or lead to automatic recovery; the network layer –where firewalls can reduce the affected area; the transport layer -where the limitation of reachable applications or the usage of broadcasts can reduce the network load; and the application layers -which have a wide range of possibilities to mitigate or limit an attack. Data encryption and validation are some basic methods which can ensure the validity of the data. The operating system can use role-based access control to limit the access to the network.

In conclusion, there are a wide range of possible methods which can strengthen the maritime network against attacks. If one of these systems are configured correctly, a possible attack can be stopped at this point. If an attacker could bypass this first layer of defense, there are more which could limit the impact or yield the attack completely. It is strongly recommended to use as much defense layers as possible to strengthen the network against attacks and technical defects.

10 Analysis of Maritime Cyber Risks

10.1 Background

Today's maritime navigation systems support officers onboard with a huge amount of information. A modern INS gathers data from sensors (e.g. GPS, depth sensor, and radar) and automation (e.g. propeller, rudder), integrates and processes this data and displays it in a human comprehensible form. The shipmaster can then make decisions based on the presented information. Due to this data-centric process it is not surprising that many modules in a modern INS consist of information technology (IT) systems and that the boundary between the physical world and these IT systems is hardly noticeable.

The use of digital technologies does offer many opportunities for safety and efficiency in navigation, but also demands more responsibility for the security against cyber threats. Indeed many deployed cyber systems onboard derive from standard IT systems which makes them vulnerable to common cyber-attacks e.g. well-known attacks in the internet domain. In fact a modern malware, e.g. the ransomware NotPetya, can disable a modern ship if it can intrude the ships network as certain as it can intermit a running business for weeks. In the past, navigational equipment was isolated from other onboard systems and did not have any connection to external networks. But due to the huge potential of today's digital technology for future navigation the solution of strictly separated systems is not applicable anymore. An integration of external communication in navigation systems is not only an enhancement for routing and safety through up-to-date weather information or charts but can also simplify and optimize processes in logistics and compliance through automated reporting. Future goals for the maritime sector may be remotely controlled or autonomous ships which need a communication to navigational equipment as well.

Before integrating onboard systems in external networks, it is necessary to analyze todays and future critical systems, identify possible cyber threats and implement measures to harden them against cyber-attacks.

To face cyber risks and implement cyber security the maritime industry came up with several standards, guidelines and recommendations. We briefly discuss some of them and give an outline of missing aspects with this report.

Following, we introduce a possible modern ship's network and identify navigational critical components. Among these systems is an INS which we analyzed further. In workshops with industry partners (Raytheon and Veinland) we identified the architecture and components of a modern INS. This architecture will be a basis for the cyber risk analysis in the last section.

10.2 Standards, guidelines and recommendations

Cyber risk management and cyber security has finally moved into the focus of the maritime industry. To face the risks arising with new digital technologies, the maritime domain came up with several standards, guidelines and recommendations on different levels of abstraction. They range from high level management guidelines to specifications addressing technical staff members. We make a cross-section through current documents, discuss them and give an outline about some missing points and opportunities to cover them.

The IMO approved its "*Guidelines on Maritime Cyber Risk Management*" (IMO, 2017f) in July 2017 which were firstly published as interim guidelines in June 2016. These guidelines provide a high-level overview and recommendations on cyber risk management with the aim to safeguard shipping. They give a first hint which technologies on a vessel may be affected by cyber threats and explain broadly and with examples how these threats arise before they state cyber security to be a crucial aspect for safe shipping. A brief outline of cyber risk management and its main process follows. The guidelines refer to other guidelines and standards for more detailed or more concrete information both from the shipping domain and standard IT domain. Among them is the well-known ISO/IEC 27001 on information security management systems (ISO, 2013).

One document referred to is the IMO Guideline "*The Guidelines on Cyber Security Onboard Ships*" (BIMCO, 2017), published in July 2017 by a joint group of maritime industry partners. A first edition has already been published in February 2016. These guidelines provide a description on how to implement a cyber risk management process in a maritime enterprise based on the NIST framework (NIST, 2014). After a first outline of their cyber security approach and the defense-in-depth principle the guidelines describe the consecutive steps in their approach in regard to maritime domain specific characteristics. They give guidance on how to identify vulnerabilities, assess cyber risk and develop counter measures to prevent, detect and react to cyber incidents. All steps are filled with examples and suggestions which are comprehensible for non-specialists. The annex provides a list of cyber systems which are usually present on a vessel to support the identification of relevant digital assets for a cyber security assessment. A notable feature of these guidelines are clarifications of contingency, response and recovery plans to prepare a fast return to normal business procedures in case of successful cyber incidents. A well-organized and trained recovery from cyber-attacks is a key factor to ensure resilience and functional continuity of operational technology and hence a requirement for safe shipping.

The "*Recommended Practice on Cyber Resilience Management*" (DNV, 2016) was published by DNV GL in September 2016. This document provides technical guidance on realizing a cyber risk assessment on three levels of abstraction. Besides a high-level assessment for a coarse overview of the risk situation, the authors propose focused assessments for individual critical systems via Bow-Tie analysis and a comprehensive, in depth assessment for a detailed overview with references to "BSI IT-Grundschutz" (see: BSI, 2017). More technical guidance for staff members familiar with information security assessment is given in the appendix where results of familiar process steps in the assessment of standard systems are transferred to the maritime domain. A notable feature of this document is a description of verification and validation of cyber security mechanisms in technical equipment via testing setups.

The standard IEC 61162-460 (IEC, 2015) was approved in August 2015 and is meant to extend the family of IEC 61162-standards on digital interfaces for navigational equipment with requirements for the safe and secure operation of networks. The document relates well-known technical requirements for standard IT network systems with typical needs and demands of maritime navigational networks. It provides requirements on network architecture, coupling systems and components to ensure a safe and secure communication between services and gives further description an how the fulfillment of these requirements can be tested.

10.2.1 Some missing aspects

The presented documents show that guidance to implement maritime cyber security is given at all business levels of an enterprise. The maritime domain benefits from the progress in cyber security of other domains (like standard office or industrial automation) and has already transferred their key concepts for controlling cyber risks. However, there are some aspects which have to be considered and developed in this domain.

The development and implementation of general technical measures to face cyber threats work well. Indeed most techniques from other domains in which the digital progress is more advanced can be adjusted to fit into the maritime domain. However, a comprehensive cyber security cannot persist without the establishment of secure processes and the consideration of humans as users of digital systems. To deploy measures which integrate these two factors, the maritime industry has to examine and presumably rework its own business processes and offer cyber security trainings for crew members.

The implementation of generic measures to face cyber threats provides a moderate security level but there are still situations in which these measures do not fulfill all security requirements or are hardly acceptable. One example may be a periodical password authentication for crew members using steering systems. Although the security requirements for these systems are high it is not acceptable that the system locks itself in a critical navigational situation just because the navigator mistypes his password three times in a row. Hence domain-specific security measures that take into account contextual requirements have to be developed. This includes the processing of sensor data onboard to deduce specific indicators for cyber-attacks targeting navigational systems.

The detection of cyber incidents needs a substantial understanding of the system in place. An effective Intrusion Detection System (IDS) for maritime systems has to reflect domain specific rules and processes to understand normal system procedures and identify malicious behavior. Encountered cyber incidents have to be automatically preprocessed and enriched with contextual information to present a comprehensive cyber situation to the ship-side crew based on which it can evaluate the risk and possible opportunities for action. In the medium run the objective has to be supporting a crew without cyber experts on board to make decent decisions on actions concerning IT systems.

A special characteristic of shipping is its dependency on reliable and safe cooperation with other entities. For example navigation and especially collision avoidance can only work, if the used onboard data and the provided information via maritime services have high reliability and integrity. The corruption or failure of just one vessel's systems may have far-reaching consequences even for not directly involved entities. Therefore an adequate standard for cyber security onboard and corresponding regulations to ensure these standards throughout the whole industry have to be formulated and approved. The standard IEC 61162-460 for navigational networks is a first step to ensure cyber security onboard and should be extended to a standard for all cyber systems which are part of a vessel's network.

The benefits of collaboration in case of cyber security in the maritime domain are extremely high. In fact business processes and models in the maritime domain are often based on a reliable cooperation with different (international) players. Thus the impact of a successful cyber-attack to one company may impair many partners throughout the domain and the company’s own cyber risk depends on a solid risk management of others. Through the sharing of developed cyber security measures, incident information and experience in reaction to cyber-attacks, the whole domain can improve risk handling. To support this exchange a platform has to be established to publicly report and classify cyber incidents for research and transparency on this topic.

10.3 Network infrastructure onboard

There are several cyber and IT systems onboard a modern vessel performing different tasks, e.g. GPS receivers for positioning, rudder controllers for steering, satellite gateways for communication, office PCs for managing cargo, and Wi-Fi routers for public access points.

To reflect this diversity we broadly differentiate between five categories of cyber systems onboard ships:

1. Navigation systems
2. Automation systems
3. Communication systems
4. Administrative/Office systems
5. Public network systems

The communication technology between these systems may vary from serial bus systems with proprietary protocols to Ethernet systems using open and standardized IP-based protocols. There are several reasons why proprietary communication protocols were preferred in the past and can still often be found onboard especially in automation networks, but for convenience, and to ensure a high compatibility with other systems, most of today's ship-intern communication is carried out via IP-based protocols.

Depending on the onboard network topology, systems are often clustered in (sub-) networks with only akin systems. Therefore we use the term navigation network for all navigation systems together with their communication infrastructure. The terms automation network, communication network, administrative/office network and public network are used accordingly. Sometimes these networks are physically isolated from one another (air gap) but this is not usually the case. For example administrative systems often make use of communication systems to send and receive messages from shore. Thus, a cyber risk analysis of one of these networks always has to take into account systems of other networks, even if they are virtually separated (VLAN) or interaction is regulated by a security gateway or firewall.

Onboard systems have a different criticality regarding safety and hence different requirements for cyber security. Cyber-attacks targeting systems of one of the above networks may have an impact on navigational safety and we classify them by the probable extent of this impact.

The impact of cyber-attacks on navigation and automation networks highly affects safe navigation as these systems are directly integrated into the process of choosing a route and steering the vessel. For example, a failure of the radar may cause a collision with another ship in situations with poor sight or an evasion maneuver may not be performed correctly, if the rudder controller does not react.

The impact of cyber-attacks on communication systems moderately affects safe navigation as a manipulation or non-availability may have an indirect implication on navigational decisions. For example missing or manipulated navigational or meteorological warnings influence navigational decisions, but may be compensated to a moderate level by other onboard systems or the master himself. Communication systems may become more critical for navigation in the future, because remotely controlled or autonomous ships are influenced directly by messages from other (shore-based) entities.

The impact of cyber-attacks on administrative/office systems or the public network does not directly affect safe navigation. However, a cyber-attack on these systems may spread through gateways, and thus compromise systems which are more important for safe navigation. For example, an attacker may login to an office computer with spied credentials and use a known vulnerability of the firewall to get access to the propeller control unit in the automation network.

10.4 Integrated Navigation System (INS)

Almost all important systems for safe navigation are situated in the navigation network which we assume to be a modern INS. In the following we want to describe such an INS with its components and discuss how to classify them by means of the cyber security protection goals availability, integrity and confidentiality. The reference system is a Raytheon Synapsis integrated bridge which is generalized for this presentation.

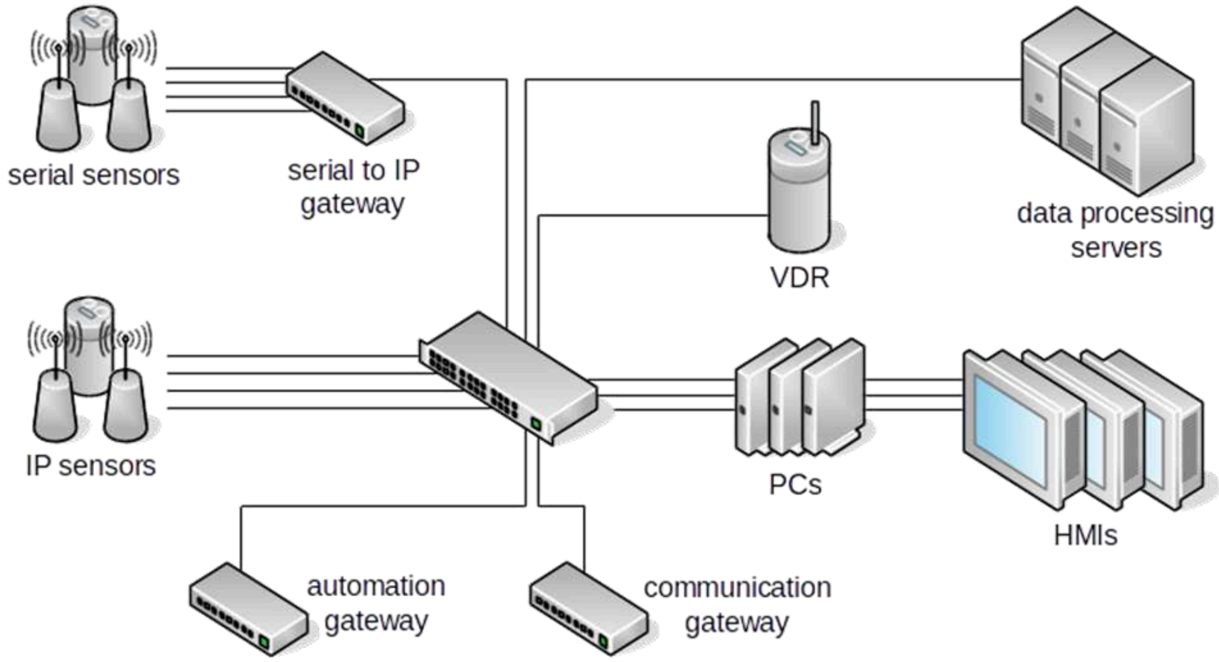

Figure 2: Schematic structure of a navigational network.

10.4.1 Network infrastructure

There is a switch as a central node for Ethernet/IP-based communication. This technically allows any two systems to communicate bidirectional, though access and permission is usually granted by net separation technologies such as firewalls or VLAN. Legacy devices which support serial communication (e.g. NMEA), but do not offer an IP interface are integrated via serial-to-IP gateways.

A safe and secure network infrastructure is necessary for frictionless cooperation between all navigational systems. Availability of the infrastructure must be ensured to enable the transfer of data between sensors and navigation systems (INS tasks). A disabled or disturbed infrastructure would make digital support for navigation impossible and it is therefore a highly prioritized goal to keep the network infrastructure running and fast responding, e.g. via redundancy. Integrity of delivered messages must be ensured to enable a veridical situational awareness, proper navigational decisions and unchanged passing of commands to automation machinery (as steering). On the one hand unnoticed modification of sensor messages may cause integrated chart display modules to display an incorrect situation and may be the main root for false navigational decisions or missing collision avoidance alerts. On the other hand the delivery of incorrect commands to automation machinery (e.g. rudder or propulsion) during a complicated situation can cause an accident of the vessel. Confidentiality of the network is usually a less important goal as most navigational data delivered by the network is public anyway and a leakage of messages does not influence the safety of navigation.

10.4.2 Gateways to external networks

Connection to other systems for automation or communication is handled via gateways. These gateways may facilitate external systems to seamlessly integrate into the network (e.g. via VPN) or only allow restrictive exchange of normalized data packets (e.g. firewalls, data exchange service).

Security requirements for these components partially depend upon the connected peer network. Gateways to automation have to be highly reliable, when exchanging commands for steering or sensor data arising from machinery (e.g. propeller speed, rudder position). They have to be available for exchanging data in near real-time to avoid lags in course adjustment. Prevention and detection of unauthorized modification has to be ensured especially for outgoing commands to machinery, but also for incoming sensor data. However, the latter may be harmonized with internal sensor data to detect modifications or inaccuracies. A loss of confidentiality of information exchanged with the automation network has no direct effect on safe navigation, and hence is of minor interest.

Gateways to communication exchange data with external entities, e.g. other vessels, weather information services or shore-based operation centers. The need for availability of communication data in the navigation network depends upon the degree of automation with which the vessel is navigating. For example a vessel navigated via remote control highly depends upon data exchange with a fleet operation center while autonomous ships or manually controlled ships may spare a continuous connection with a third party. Integrity for incoming messages has to be ensured since this data influences navigational decisions or even directly modifies steering via remote control. The impact of losing confidentiality of communicated information with external entities individually depends upon the specific data, but usually this does not affect safe navigation directly.

It has to be noted that in general gateways to external entities or networks provide an ample surface for cyber-attacks since they form the last line of defense to insecure networks. Therefore, it is important to define strict rules for information exchange and continuous monitoring upon these components.

10.4.3 Sensors

Sensors are the most important data acquisition devices when it comes to navigation of a ship. They form the ship's interface to the physical world and feed other systems with geospatial and situational data. Examples for navigational sensors are GPS, radar, depth sensor, compass and AIS. Here, we consider AIS to be a sensor to complement radar for collision avoidance, but it could also be classified as a communication device since it relies on received messages from other vessels.

In general the demands for availability and integrity of sensors are very high. A disabled radar system directly impacts collision avoidance mechanisms onboard whereas missing compass information may be extracted from GPS data. Unnoticed manipulation of sensor systems can have a huge impact in navigational decisions, but thanks to the integration of sensors it may be possible to detect faults via validation of data. In general, confidentiality of sensor data is not a highly prioritized goal.

10.4.4 Voyage Data Recorder (VDR)

The Voyage Data Recorder (VDR) gathers sensor data and steering commands and persists this information in a protective storage which can be recovered after an incident to analyze causes that let to that incident.

In general, an unavailable or manipulated VDR has only an indirect impact on safe navigation since its main purpose is supporting investigation when safe navigation mechanisms have already failed. Therefore, availability of the gathering and integrity of data may be classified as minor goals in the first place. However, gathered data helps improving security mechanisms in the long run which makes securing the VDR an important process. The information leakage of the VDR depends on gathered data, but is in general not critical in relation to direct consequences for the safety of navigation.

10.4.5 Data processing servers

Data processing servers (or services) form the heart of the INS and necessary for safe navigation. They gather, harmonize and check sensor data for consistency and are hence the main source for all alerts associated with the current navigational situation. Furthermore they prepare information for presentation on a HMI. Depending on which INS architecture is considered the structure of data processing servers may highly vary. For example there may be a whole server farm with each machine specialized in performing a different subtask on the data or there may be just one server doing all the work. It may even be practical to pass on dedicated data processing servers and do all computation directly on PCs directly controlling HMIs. Data processing servers provide functionality for a consistent common reference system (CCRS).

Due to their central role in the INS architecture the services provided by data processing servers must be well secured. Unavailable or disturbed services can not only result in the inability to navigate and average, but may also affect the alert management so that failures are not propagated to the crew. A manipulation of the system can have a vast impact on navigational safety since its results are presented to the crew normally without further automatic check for integrity. Thus, securing availability and integrity of data processing servers takes a high priority. Confidentiality of data processing servers are not a necessary aspect for ensuring safe navigation.

10.4.6 PCs and HMI

The purpose of human machine interfaces (HMIs) and their controlling PCs is usually just displaying processed data to a crew member for supporting navigational decisions, but they can also be used to control sensors or even send commands to automation systems. They are normally chosen to be lightweight systems, if data processing is done by separate servers.

Displaying processed data to the crew is necessary for safe navigation, and hence HMIs. Users PCs have to be available and they have to show a reliable view of the data received. Manipulated or hidden markings on an ECDIS display can confuse the shipmaster and cause accidents. If all HMIs crash at once, e.g. due to a ransomware attack, ship services may still be available but interaction with the crew is no longer possible. Individual configuration of display views by crewmembers may be another asset to protect. Since HMIs are used to authenticate crew members against present navigation services, they have to be secured against manipulation of hardware and software to keep passwords and tokens secret. For the same reason the confidentiality of HMI systems has to be ensured.

10.5 Cyber risks to a modern INS

In this section we describe some concrete and exemplary cyber threats to which an INS is exposed. Starting point for the analysis is the navigation process as the main functionality an INS has to provide. At the end of the section we discuss some countermeasures to avoid these threats and integrate them into the context of present standards and guidelines.

10.5.1 Scope

The scope of this analysis defines which attacks and threats to the INS may be possible by describing what capacities an attacker may draw on and what goals and motivation may be behind his or her attack.

In this analysis we assume a possible attacker to be either an outsider or an insider. Outsiders are people who do not belong to the organization and do not have an authorized direct access to the INS. This implies that outsiders have put in the effort to obtain (physical or digital) access to manipulate the INS, and that their knowledge about system internals is humble. For a successful attack, they need a considerable preparation time. Examples for outsiders in the IT context are cyber criminals, terrorists, or hacktivists. In the maritime domain there may also be intruders from different companies or even other maritime traffic participants.

An attacker may also be an insider who belongs to the organization itself or contributes to its supply chain. Insiders may gain access to the INS (or one of its components) without taking a noticeable effort and have knowledge about system internals. In contrast to outsiders they may perform more sophisticated attacks with less preparation time. Examples for insiders are crew members, service engineers, manufacturers or employed software developers.

We assume that it is the objective of the attacker (outsider or insider) to impede the navigation process of the ship. A successful navigation process presents the navigator an overview of the current navigational situation and provides sufficient information so that he can make the best possible navigational decision. This decision then leads to a navigational action which is performed by the navigator. In this analysis we assume that the attacker may not interfere with the last part of the process where the action is performed. Hence our navigational process ends with the presentation of the processed data.

We divide the navigation process into the following steps (or sub-processes).

1. Acquisition of navigational data (from local sensors)
2. Acquisition of external data (AIS, chart updates, …)
3. Processing of data
4. Presentation of the navigational situation (processed data)

Between these steps, data is communicated between the involved systems, i.e. the IT infrastructure is used for the exchange of messages.

The *acquisition of navigational data* provides the INS with data from local (ship-side) sensors. Prominent sensors are the GNSS receiver, compass, radar and echo sounder. The result of this process is raw data records, which may be later integrated by other systems. By *acquisition of external data* a gathering of data provided by external systems (not ship-side) is understood. Among this data may be AIS records from another ship, current weather conditions and chart updates. This data is received and provided for processing systems. The *processing of data* integrates available navigational and external data to produce an overview of the situation. The result of this step is, amongst others, the current position, speed and course, but also tracked targets, the ship's route information and safety alarms. The last step in the process is the *presentation of the navigational situation*. The information is displayed to the navigator on screens or he is informed by acoustic signals if there is a need for action. After this step the navigator should be capable to make a sound navigational decision.

To achieve an attack, an attacker may interfere with the navigational process at or between these described steps. We focus on four kinds of attack classes which assume that the attacker has different capabilities and access to the INS. We classified by attacks which need or make use of *access from outside*, *social engineering*, *access to the INS network* and a *malware in an INS system*. The following image connects these attack classes with critical target points in the navigational process.

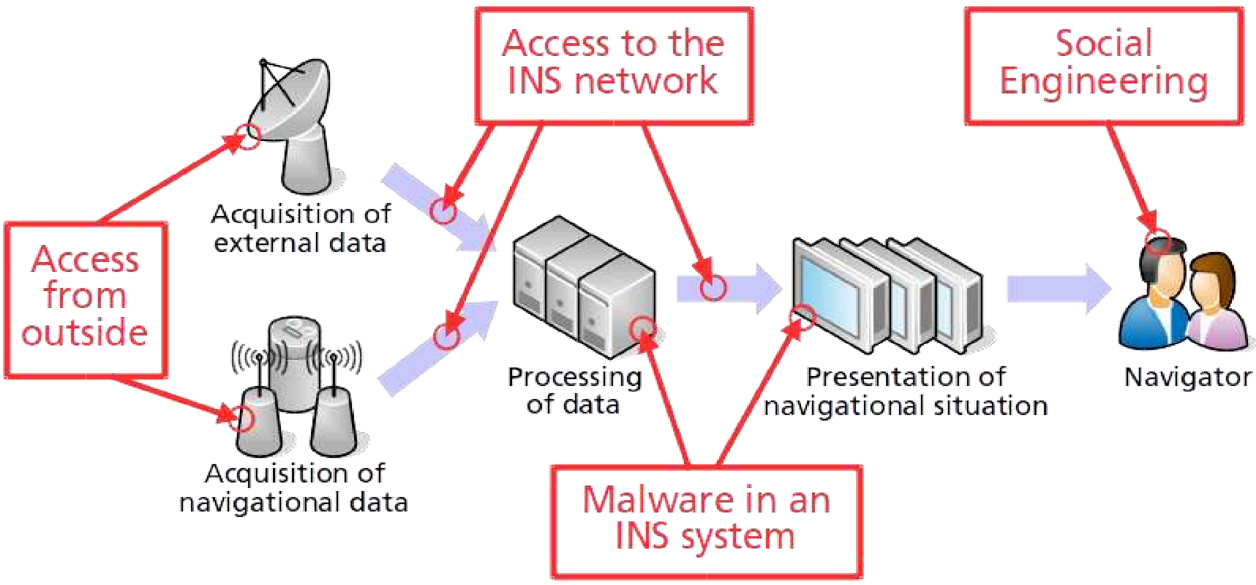

Figure 3: Navigation process with attack surfaces.

In the following section every attack class is briefly described. We provide information about necessary requirements and the context in which attacks of the given class can be performed. To every class we give examples for attacks targeting the INS and impeding the navigational process.

10.5.2 Access from outside

The objective of attacks in this class is to influence the system (INS) remotely from an external source. So the attacker has no physical interaction with the system or direct access to it at any point. Attacks in this class use manipulation of incoming data to impede the navigation process. Examples for incoming data in this context are AIS datagrams from other ships, chart updates or remote route optimizations. Depending on remote services used by the INS, it could be possible for the attacker to get direct control over one of the INS systems which may have an interface to a public network (e.g. the internet).

Requirements and Context

To perform attacks in this class the attacker needs access to some external interface of the INS. This may be a system placed in another network on board or an exchange interface towards the internet for route exchange, optimization or chart updates. Another important interface for exchanging data is the AIS. Theoretically, all shipside sensors represent an external interface, but data may be hard to manipulate.

The effort of manipulating incoming data depends on the chosen interface. Manipulated AIS data is relatively easy to implant since the protocol is open and does not yet provide security mechanisms. For manipulation of public network related communication the attacker has to either get into the middle of an established communication channel or pretend to be a known communication partner. The necessary effort depends on established security policies for the communication. Manipulation of sensors (e.g. GPS spoofing) needs a solid technical background of the attacker and may only be performed using special equipment.

Examples

The AIS infrastructure with its open protocol may be used by the attacker to implant manipulated information about other ships or general maritime objects. The attacker can craft AIS messages for maritime objects in the area of the attacked ship which then are displayed to the navigator. It may also be possible to move or even erase objects from the screen by sending AIS updates to given object IDs.

The attacker may inject manipulated chart updates into the INS. Depending on the update process, he may pretend to be a certified publishing organization announcing a chart update to be downloaded from a manipulated website. If the attack is successful, then his manipulated chart update will be installed in the INS. The impact may have two effects. On the one hand the attacker may place, erase or move objects in the INS chart which does confuse the navigator. On the other hand his chart updates may also contain a corrupt data structure which can lead to a system failure or the installation of malicious software.

The INS (or more general the ship) may have a communication interface which can be accessed by a remote system to exchange route and machine information or give navigational advice. Such services are often implemented by a publicly available web interface (or frontend) which may be accessed by the attacker as well. It is no secret that secure authentication to publicly available web services is often neglected and the attacker could easily circumvent this mechanism to send manipulated information. With these capabilities, it may be possible for him to implant a manipulated route or get direct access to components of the INS.

Manipulation of incoming GPS data (GPS spoofing) is another attack which fits into the class of attacks from outside. The GPS receiver calculates its own position, based on incoming datagrams from GPS satellites whose communication protocol is publicly known. An attacker may send crafted datagrams and pretend to be one or more GPS satellites with chosen positions. This may induce the calculation of a manipulated position on the GPS receiver which is then presented to the navigator.

10.5.3 Social Engineering

For an attacker, it is often very expensive to find and make use of security weaknesses in IT systems. Therefore he may try to circumvent security mechanisms by getting access from authorized employees who are often easier to manipulate. He may use social interactions to gather passwords or even let an unaware user grant a connection to a malicious service of the attacker by clicking on an interesting link in a malicious email.

This kind of attack is known as Social Engineering. It is often used as a first step to enter a system and perform more sophisticated attacks like network based attacks or placing a malware in a system.

Requirements and Context

There is hardly any effort for the attacker to perform Social Engineering. Simple attacks can be executed via well-crafted emails. The difficulty comes with the connection of several information sources to produce highly authentic messages to convince the user that the received mail is not tampered with and trustworthy.

For some attacks, the attacker may need access to the ship during operation. He can, for example, pretend to be a service engineer to get physical access to INS systems or to legitimately ask for credentials to open an installed service tool.

The consequence of Social Engineering can be the bypassing of nearly all technical security mechanisms, and should therefore not be underestimated. The impact depends on follow-up attacks which make use of the overcome security hurdle.

Examples

A lot of business processes make use of email-based communication. The attacker can craft a malicious email which looks like the notification of some governmental authority to download and fill out an urgent digital form which is necessary to get into the next port. A distracted crew member may follow the link to download the document, and is redirected to a malicious website which automatically installs malware on the user's system. The attacker has achieved his goal and has placed himself directly in the INS system.

For some tasks HMI systems have to be unlocked by crew members. This is usually done via username and password. After this authentication crew members can interact with the system and alter navigational routes, if they have appropriate rights. With some modification of the system, an attacker could record keystrokes during a login process on the machine and use gathered credentials at a later time to illegally change the system. The recording can either be done through software or hardware modifications. A software keystroke logger may be installed by plugging an USB device in the target machine which executes malicious code. Hardware keystroke loggers are usually directly implemented in keyboards or in the interface of the system, and are therefore not detectable by software, but depending on the architecture more difficult to install.

The attacker may also watch crew members while they type in their passwords or even ask them to unlock some service for them. In many situations people are not aware how important their credentials may be for a possible attacker, and what impact a leakage may have. Some passwords could allow an attacker to establish a remote connection to the INS which is not detected by any security mechanism, because legitimate credentials are used.

In a sophisticated version of Social Engineering the attacker may pretend to be a service engineer and get a granted physical access to the INS. It is not unusual for engineers to open locked ports and install new hardware on the bridge. Hence, he may place his malicious device right into the system to perform attacks from there. In most cases the crew does not notice any difference to the system at all.

10.5.4 Access to the INS network

The INS is by definition a distributed system. There are many specialized vendors who produce different components which are integrated into one system. To orchestrate these components a modern INS uses IT communication technologies (mostly IP-based networks) which become critical to the safe and correct operation of the bridge. An attacker with access to the INS network may perform attacks which have a crucial impact on the system.

In the context of an INS one may distinguish between two levels of communication with different characteristics. First, there is communication of standardized data as input and output to and from the INS (e.g. to and from data processing servers). Examples for this kind of communication are most navigational data encodings, as AIS-, NMEA- and IEC 61162-450-packets. They make use of known protocols in an open architecture to allow interoperability with systems from other vendors. Without further security mechanisms (e.g. message authentication) they are easy to read, to craft or to manipulate by a possible attacker on their way of communication. Also since these protocols are widely spread in the maritime domain, an attacker may reuse developed malicious programs to a variety of other targets.

Second, there is INS internal communication, defined by the vendor or integrator of the system. It is used to synchronize INS internal services like redundant systems, the alarm management and chart displaying devices. Protocols and encodings used for internal messages are often proprietary, and therefore more difficult to decode or even manipulate by an attacker. He may have to invest more time or get more system knowledge to successfully perform an attack, and it is likely that he cannot reuse his developed tools to other systems. But reversing and impeding a proprietary protocol is not impossible and depending on the context can be simpler than expected (Security by obscurity).

Requirements and Context

To perform this kind of attack, the attacker has to get access to communication interfaces of the INS network with devices which are controlled by the attacker. The most obvious way to do so, would be by accessing the bridge and connecting a mobile computer to a network switch. While pretending to be a service engineer, he may place a small computing device in the bridge network which he may access from outside the ship (social engineering). It is also possible to use already installed bridge components either by implanting malware through an USB device or by installing a backdoor on these components before integration.

Attacks with access to the INS network do not always require a remote communication channel to the attacker. In fact, attacks may be performed automatically by a malicious program which has been placed in the network before. These malicious programs are sometimes called logical bombs, and may execute if a condition applies, e.g. some special route is taken or a certain maritime object is passed.

Examples

With access to the INS network the attacker may implant crafted navigational data which is then interpreted by processing components. There are different objectives that the attacker may follow. For instance the attacker could try to manipulate navigational data so that the navigational situation presented to the navigator is distorted, but plausible. This may imply bad navigational decisions with fatal consequences. The attacker may also just send out random navigational messages with a high frequency to override the system display, and thus make instruments unusable. The navigator has to drive the ship blindly. Polluting the network with fragments of messages containing incomplete encodings may also simply crash the INS.

One special case of tampering with navigational systems through network access is manipulation of AIS data. The AIS transceiver works as a bidirectional channel for gathering information from other ships or maritime objects nearby and publishing information of the own ship to other maritime players. Data shared this way consists of position, size and course, but also contains route information. The linkage to an INS is ordinarily implemented via standardized protocols which do not provide security mechanisms. So the attacker may almost freely implant incoming and outgoing AIS data. In consequence, the attacker may inject or move maritime objects in the digital chart. The attacker may also manipulate the sent AIS position data, so that other ships locate the targeted ship elsewhere. Indirectly, this may also be used to trigger alarms and distract the crew.

BAM and BNWAS on a modern bridge are provided as distributed services, and hence need internal communication. In fact alerts and alarms may occur and be acknowledged on different systems. The attacker could therefore reverse the used protocols to synchronize these services, and not only trigger arbitrary alarms, but also acknowledge upcoming alerts automatically, before a crew member takes notice. This abrogates a key functionality of a modern bridge on which many navigators rely to avoid hazards.

A device performing a DoS attack floods the network or individual systems with a huge amount of (random) messages and overloads communication interfaces this way. In consequence the network or system and its services are temporary unavailable which can have a fatal impact for time-critical processes. A DoS attack targeting and disabling the radar during a crucial maneuver in an unclear situation can cause false navigational decisions and hence provoke an accident.

There are many other functionalities in a modern INS which depend on communication and synchronization between different devices. Without comprehensible and reliable security mechanisms all of these functionalities may be manipulated by an attacker with either more or less effort. For instance the autopilot, route exchange and tracking maritime objects belong to this category.

10.5.5 Malware in an INS System

Malware can be used by an attacker to change the behavior of a system itself. The severity of the attack may be comparable to an attacker who is logged in on an INS system with privileged access (e.g. administrator access). The attacker can execute and close arbitrary programs, read and manipulate data and communicate to other INS components. If the attacker got as far as to install and run the malware on an INS system, the attacker basically has the whole control over this system.

There are sophisticated attacks which require an attacker to have a communication channel to the compromised system. For instance the attacker needs a remote channel, if the attacker wants to exfiltrate data, explore the system or react to current situations intelligently. But attacks with a high impact on the system can also be performed automatically without interaction. A nowadays common example for an automatic attack is ransomware whose objective is simply to make the infected system unusable unless a certain amount of money is transferred to the attacker.

Attacks through malware are often too fast for a human to react properly, and may only be encountered effectively by a hardened system with several security layers and anti-virus solutions.

Requirements and Context

Although malware in an INS system may have a fatal impact, it still has to be placed there somehow. In the lifecycle of an INS system there are many opportunities where this may happen. For instance the malware could be implanted by the manufacturer himself as an undocumented backdoor to access his systems. The malware could also be installed by a corrupt service engineer during a maintenance procedure (see Social Engineering) or even brought into the system by a careless crew member via an USB-device.

The effort that an attacker has to take to develop a suitable malware has to be taken in consideration as well. Depending on which technical layer the attacker wants to attack, and what objectives the attacker has, the preparation of the attack may take a long time. If the attacker wanted to attack a common operating system (e.g. Windows) just to make the target machine unusable, then the attacker could draw on a huge amount of already existing malware families on which the attack can be based. An automatic attack on special INS services with a view of fabricating a distorted navigational situation for the navigator comes with expensive development costs.

Examples

A malware in a data processing system may open a backdoor for a remote communication channel to the attacker (e.g. a remote shell). This allows the attacker the execution of attacks over a vast distance. Without any security mechanisms the attacker could shut down the machine or particular services to disrupt bridge functionalities. A remote execution on HMI machines would allow the attacker to freeze the display in delicate navigational situations.

More subtle attacks on INS systems may directly manipulate the electronic charts, change the current active route and activate the autopilot to provoke an average. They may also hide specific targets on the screen and block the alert system. An attacker might even install own navigation software on the system and exchange the current one.

There is a large variety of attacks which can be performed from this point, if no security mechanisms are rolled out on the system and execution is not structured in security layers. The surveillance and validation of integrated systems is another process which has to be enrolled to ensure sane system applications.

10.5.6 Countermeasures

To encounter cyber security incidents and reduce the cyber risk, it is necessary to implement holistic countermeasures in the INS and its adjoining systems and maritime services. Following the common IT security classification, an effective minimization of cyber risk consists of measures to prevent and detect cyber security incidents as well as measures to react to successful attacks (see Figure 4). These measures may also be divided into those which are based on secure (business) processes, the implementation of secure technologies and those who improve cyber security through trained user awareness and behavior (human factor).

There are general IT-security countermeasures which are also applicable to a modern INS. Many cyber problems that we face in the maritime environment have already been solved in other domains and can be transferred easily. However, the maritime domain has its own characteristics and regulations. Security measures have to be developed that comply with special characteristics of the maritime domain. For instance forensic mechanisms, which rely heavily on a stable connection to an external security operations center, are inconvenient for an INS since a broadband connection cannot be guaranteed in many situations.

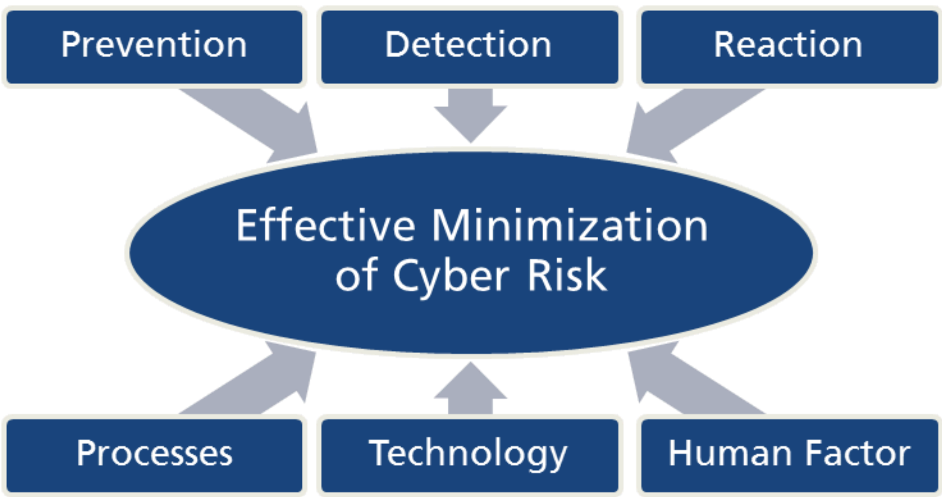

Figure 4: Countermeasures

To avoid the attack classes mentioned in the previous sections, appropriate actions have to be taken and measures have to be implemented. Attacks through access from outside can be encountered through technical hardening and processes to monitor and evaluate connection attempts. The success of Social Engineering is decreased by teaching the crew how cyber-attacks can happen and how to recognize a scam, or through business processes which complicate the access to core systems even for the navigator.

The risk of attacks which make use of the INS network can be diminished by implementing well-known security measures from the internet domain. For instance the access to the network has to be technically governed and supervised with state-of-the-art techniques. The likelihood and impact of malware in INS systems can be decreased by hardening and monitoring of these systems. This can only be done effectively, if processes to detect and measure attack surfaces are elaborated in the industry. The domain also needs trained IT experts to monitor and react to cyber incidents.

10.5.7 Proof of Concept: Cyber-Attacks on a bridge network

To show the impact of cyber-attacks targeting a bridge network, we have chosen an attack vector described in the concept earlier in this section and implemented a proof of concept for cyber-attacks in collaboration with Raytheon Anschütz. The attacks assume that an attacker has access to the bridge network. For instance this assumption may be the consequence of weak security measures at the communication infrastructure or a system manipulation realized by a corrupted service technician. Since the results of the security experiments are security relevant and therefore confidential, we can only give a rough outline of their impact in this report.

The experiments using the proof of concept implementation under the named assumptions were realized in a simulation environment provided by and located in the Federal Maritime and Hydrographic Agency (BSH) in Hamburg. They show that the bridge system under test is heavily affected by cyber-attacks. State of the art bridge systems strongly depend on a reliable internal communication infrastructure to exchange navigational data from specialized systems and expect the communicated data to be authentic. Introducing an "evil component" into the communication infrastructure which can inject manipulated data can therefore lead to a massively corrupted overview of the navigational situation. This may influence navigators to make wrong navigational decisions which cause averages or collisions with maritime objects.

For instance the experimental results show that it is possible to manipulate the overview of the navigational situation presented by the ECDIS and Radar applications. It was possible to inject fake targets in both applications as well as erasing targets from the displaying screen in a subtly way. Furthermore, the availability of both applications could be influenced leading to controlled failure of instruments triggered by an attacker. These impacts do not only influence the local navigational instruments but also propagate to surrounding maritime objects which depend on reliable data from the bridge's AIS components.

Countermeasures for the described scenarios are being developed as part of the ACTRESS project funded by the Federal Ministry for Economic Affairs and Energy (BMWI)[4].

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[4] See https://www.emaritime.de/projects/actress/

10.5.8 DGON Working Group „Maritime Cyber Risk Management“

To inform and coordinate the German maritime industry regarding maritime cyber risks and cyber security, the German Institute of Navigation (DGON) initiated the working group "Maritime Cyber Risk Management". The working group is coordinated by FKIE together with Raytheon Anschütz and afEfa. Its goals are the following:

1. Providing a national active exchange platform for the topics concerning "Cyber Risk Management" and "Cyber Security" for the maritime domain. This includes an overview of current national and international activities for these topics, the clarification of implicated requirements on current systems and responsibilities for maritime stakeholders as well as the identification of missing aspects of cyber security in upcoming standards and regulations.
2. Providing concrete measures and mechanisms to evaluate and reduce the cyber risk for the maritime domain with a focus on cyber risks which arise as a result of the digitalization in maritime navigation (e.g. e-Navigation). This includes the identification of threats to maritime cyber systems, provision of tools and guidelines to assess and evaluate cyber risks as well as the development of technical, personnel and organizational measures to mitigate and reduce cyber risks.

Since November 2017 the working groups meetings take place quarterly in Bremen and Hamburg with additional meetings for special topics. There were in average about 12 participants on each meeting, they include manufacturers of maritime technical devices, law offices, classification societies, ship owners and research institutes.

Results of the working group include a gathering of relevant cyber security documents, a comparison of requirements formulated in these documents, a stakeholder analysis for cyber risk management in the maritime domain and a gathering of bridge systems which are exposed to cyber risks. At the moment the produced documents are only available for members of the working group but they will be used as a basis and guideline for future publications. One of these publications will be a central platform to share maritime cyber security documents and their content in a structured way among maritime stakeholders.

The gathering of IT-systems in bridge systems will be used in accordance with the Federal Office of Information Security (BSI) to provide a template and guideline for the implementation of information security management systems for ship owners. A first version covering ashore cyber systems for ship owners was already published[5] and a second version including onboard systems will follow by the end of 2019.

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[5] See https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Grundschutz/Hilfsmittel/Profile/Profil_Reedereien.html

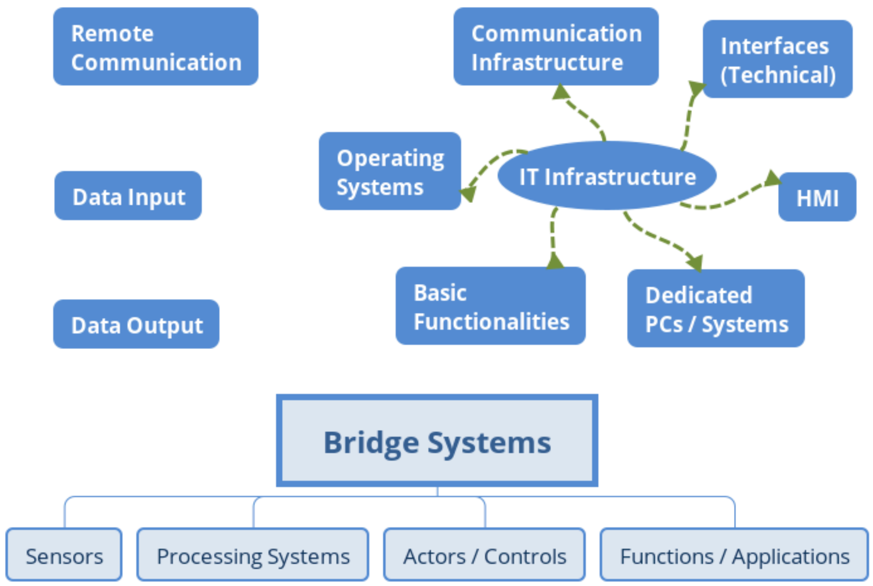

Figure 5: Bridge systems which are exposed to cyber risks (outline).

The participants of the working group identified a lack of standards and regulations regarding the human factor in maritime cyber security. The working group will elaborate this aspect in future sessions in collaboration with ship owners to collect cyber security training material and give an overview of current obligatory trainings.

11 Workshops on a concept for IMO regulation for future ships

For the safe navigation, communication and operation of a ship, the IMO defines functional as well as hardware requirements. In light of advancing technology, technological and operational requirements, and the certification process the historically grown IMO regulations are to be analyzed. There is a need to assess how policies and IMO regulations should look like so that innovation is not constrained by specific device and performance requirements and increasingly complex cumulative regulatory frameworks.

To address this topic and specify a way ahead, Fraunhofer FKIE planned, organized, prepared, chaired and post-processed three workshops on behalf of the Federal Ministry of Transport and Digital Infrastructure.

On February 12th and 13th the *BMVI's national expert group for integrated ship navigation and control systems* was invited to a one-and-a-half day kick off workshop on "modular concept for bridges"[6], and two subsequent workshops on April 10th and 11th and on July 9th, 2019 in Hamburg, Germany at DNV GL and BSH.

For the kick-off workshop on February 12th and 13th FKIE analyzed needs for the agenda to cover topics such as:

- introduction and background to the purpose and need for the workshops
- discussion and analysis of current situation on IMO instruments of regulation – resolutions, performance standards, circulars, guidelines …
- discussion and analysis of current situation on relationship between IMO resolutions and IEC test standards
- discussion and analysis of current situation on certification and compliance process
- discussion and analysis of current situation on situation on board – current bridge / navigation / communication equipment and systems
- discussion and analysis of current situation on future challenges
- discussion and analysis of current situation on interfaces / migration
- definition of goals – what are our aims and objectives?
- brainstorming regarding solutions and improvements – for a holistic future-oriented approach and for individual issues
- strategy for document submission at IMO
- lessons learned from recent document submissions at IMO
- future procedure
- final discussion and course of action

In addition FKIE prepared several moderation methods to support the group in the achievement of their workshop goals. Fourteen attendees of the workshop from BMVI, BSH, DLR, DNV-GL, Fraunhofer CML and Fraunhofer FKIE, German ship owners association (VDR), as well as manufacturers from Raytheon Anschütz GmbH and Wärtsilä showed a large and

[6] The workshop was prematurely named "modular concept for bridges" as members of the NCSR 5 group had met in advance to discuss the need for this meeting and the mental model of these members was inflicted on this work item. The chapter will speak of an IMO concept for bridges as the group has not collectively decided on how to implement their future plans. However, the Workshops that were invited to were named "modular concept for bridges".

lively participation from the very beginning. Thus the moderator initiated an expectations round, in which all participants received time to express their concerns, hopes, and visions. Overall the expectations documented can be allotted to three categories: expectations regarding hopes of increased efficiency of the IMO processes (six mentions), expectations to follow a certain approach (four mentions, approaches differ), and expectations that certain topics would be discussed in the round to create more understanding within this group (six mentions).

Following the expectation round, individual participants discussed whether there truly is a need for a modular approach. This discussion showed that a common understanding of goal-based and modular approach has to be created. While a goal-based approach describes a function with a goal rather than a specific (device) requirement, the "modular" approach is more far-reaching. A goal-based approach would require a substantive revision, while a "modular" approach would also require a structural change. The approaches are not meant to be exclusive, but complementary. Furthermore the heatedness of the discussion revealed the need for open communication between manufacturers and ship-owners after a recent unsuccessful submission to NCSR (NCSR 6/11/6).

Furthermore, the workshop provided its participants with a common understanding of the IMO and its structures and most importantly the need for change regarding the IMO regulations. It was pointed out that IMO regulations make use of task-based language, instead of goal-based language. Thus, the regulations contain a mixture of requirements and functions. To achieve change, participants reported their goals and means to achieve their goals. Participants assessed which work items would be required. Some work items such as framework conditions were worked out during the workshop others were documented in an action plan. Participants were assigned to work items which were to be prepared for the next meeting.

The workshop also covered difficulties regarding the IMO and its regulations and future challenges. It was collectively agreed upon that a change in the IMO regulations, due to overlaps, duplicate descriptions and specific device requirements, is also necessary in terms of content. First ideas, such as the use of "or other means" or to create a functional "performance standard" for each (main) function, were considered. Participants stressed that in order to ensure success of their goals, they feel that legal competencies are a necessity as well as financially sustainable plan for all involved.

The workshop was analyzed and evaluated by FKIE. A second workshop was prepared and organized with the goal to assess the current situation for bridge systems from different viewpoints, present the assigned work items and discuss further plans. The workshop was attended by thirteen representatives of BMVI, BSH, DNV-GL, DLR, Fraunhofer CML and FKIE, German ship owners association (VDR), and manufactures such as Raytheon Anschütz GmbH and Wärstilä. The assigned work items covered:

- the identification of passages in SOLAS V that need revision or adaptation
- the identification of SOLAS chapters outside chapter V relevant for navigation, communication, automation
- an overview of the structure for functions
- a comparison of target and current functions
- the gathering of human-machine-interface requirements

The status of bridge systems and future development as well as of the current certification process were presented on flip charts.

Status Bridge:

- approximately 5% of the ships are equipped with an INS and approx. 95% with 10-15 individual systems
- individual systems cause many alarms that need to be acknowledged on individual devices
- challenging to master the 10-15 individual systems
- training on e.g. ECDIS is impossible. "There is training on a specific ECDIS system and in practice there are 15 different ECDIS systems"
- overburdening of navigators
- uncertainty concerning cyber security
- compatibility of the Maritime Communication Platform (former Maritime Cloud) and cyber security is a challenge. Shipping companies' IT departments do not prefer the Maritime Communication Platform as a connection from ship to land
- shipping companies consider a connection to the Maritime Communication Platform as undesirable
- desire to exchange existing data, but no requirements are defined that state how and on what frequency etc. these requirements must be met
- communication between individual components without a standardized interface
- variety of navigation information on individual devices is a challenge when navigating in areas of high traffic density, coastal proximity and pilotage
- the corset of IMO regulations hinders technological development as well as modular and system approvals
- missing "reporting culture"- Sources are only documented by traffic control centers, such as "System Maritime Verkehrstechnik". Near misses - of which there are quite a few - are not reported

Goals:

- desire for e-Navigation revival - harmonization, simplification, integration of navigation & communication.
- a desire to implement INS in perfection (standard displays, a standard alarm management system, plug-ins with sensors)
- MASS light is the result of e-Navigation & INS, which enables watch-free navigation of the ship on a bridge
- goal: harmonized information processing

Future development:

- increasing network (NAV, automation, communication). This results in an increasing number of functions all the while education levels decrease. However, systems are increasing in complexity (e.g., condensation of functions on ECDIS)

- forecast of shipping companies: In the next 10 years, an improvement of communications on the high seas is not to be expected. Too many obsolete systems are available for equipment and communication
- higher networking will be available. Tasks that are currently exclusively on board will be moved ashore "Traffic Management (route exchange)"
- increasing offer of integration of external services without clear definition of data paths, data structure (where and who has access to the data) and preparation of data integrity
- request for data pool, which is processed by a third party, so that, if desired, with an authorized access, you can get the data you need

Certification status:

- example: How should an INS type approval be carried out according to SOLAS V / 18.1?
- momentarily, sensors are included in INS, whose type approval are actually described for single devices
- an INS on board does not correspond to 99% of the tested type
- how to perform an on board type approval? ("Safety or Safety Equipment")
- when replacing individual components of complex systems, the assessment of the impact of that replacement becomes more difficult as integration increases
- interfaces should be inspected

The project SAFEDOR conducted by Abreu (2008) which dedicated its work to analyzing features on the bridge that are likely to have the most significant effect in terms of navigation safety, was presented by a member of the workshop. In light of this project an overview of existing functional requirements regarding navigation was presented.

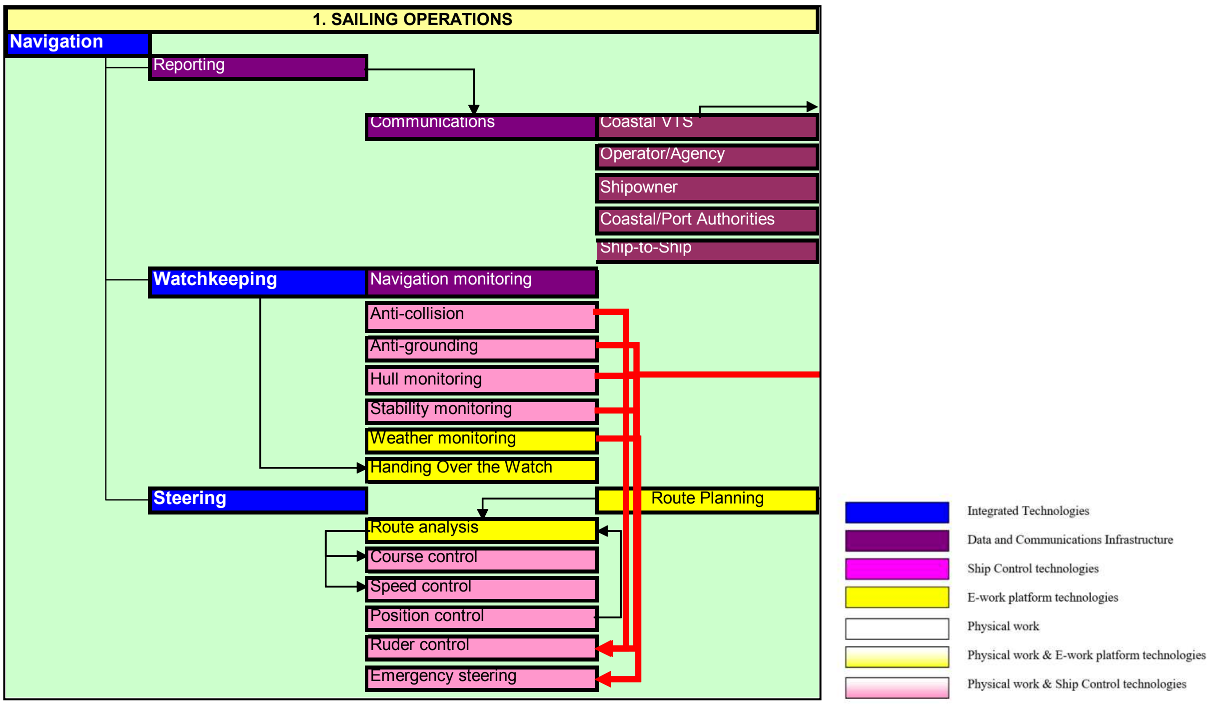

Figure 6: Functional requirements model related to Navigation (Abreu, 2008)

Adapted from Design, Operation and Regulation for Safety: User Requirements/ Current Practices, by J.P. de Abreu, 2008, Final report for project SAFEDOR no. IP-516278, p. 16. Copyright 2005 by The SAFEDOR Consortium. Reprinted with permission.

Safe Navigation	Communications	Reporting	VTS reporting
Safe Navigation	Communications	Reporting	Pilots
Safe Navigation	Communications	Reporting	Operator / Agency reporting
Safe Navigation	Communications	Reporting	Shipping Company reporting
Safe Navigation	Communications	Reporting	Port Authorities reporting
Safe Navigation	Communications	Anti-collision	Ship-to-Ship
Safe Navigation	Watchkeeping	Navigation monitoring	Follow route
Safe Navigation	Watchkeeping	Anti-collision	Traffic surveillance
Safe Navigation	Watchkeeping	Anti-grounding	Detected dangers to navigation
Safe Navigation	Watchkeeping	Hull monitoring	Monitor ship's safety state
Safe Navigation	Watchkeeping	Stability monitoring	Monitor ship's safety state
Safe Navigation	Watchkeeping	Weather monitoring	Monitor Weather condition forecast
Safe Navigation	Watchkeeping	Safety systems	Monitor Safety Systems
Safe Navigation	Steering	Route planning	Alter route plan to avoid heavy weather
Safe Navigation	Steering	Route planning	Assisting ships in distress
Safe Navigation	Steering	Course control	Return to route
Safe Navigation	Steering	Speed control	Alter speed to avoid collision
Safe Navigation	Steering	Position control	Positioning in chart
Safe Navigation	Steering	Position control	Adjusting course
Safe Navigation	Steering	Ruder control	Deviated to avoid collision
Safe Navigation	Steering	Ruder control	Emergency steering

Figure 7: Functional requirements related with Navigation (Abreu, 2008)

Adapted from Design, Operation and Regulation for Safety: User Requirements/ Current Practices, by J.P. de Abreu, 2008, Final report for project SAFEDOR no. IP-516278, p. 17. Copyright 2005 by The SAFEDOR Consortium. Reprinted with permission.

Furthermore, an example of what a function should look like was presented for the echo sounder. In its most generic form a function is the task that an object shall fulfill. Along with form, material and structure, a function provides an essential characteristic of an object which is used in some type of form. In the case of echo sounding equipment this means: specify under keel clearance (UKC), visualize depth, save data, and provide data to other devices. Participants were of the opinion that it is fundamental that a function is solely there to provide information on what, when, where, why, how, and who is involved in its most generic form. Thus, coming to the conclusion that an IMO requirement has the purpose of describing which task a function has. In discussion, the group assessed that device standards would allow all information to be displayed on a centralized display and control device (HMI), but the equipment regulations (SOLAS V) are a problem as “display” in requirement "to measure and display" is understood as “a device is needed” by certifiers. Manufacturers reported of the tremendous difficulty of figuring out what to pay attention to while certifiers reported their difficulties in deciding what to approve.

Furthermore, the workshop covered an overview of HMI requirements and SOLAS Chapters II, III, IV and V which should be considered for a revision or adaptation. Here, by means of SOLAS V regulations 1, 15, 18 and 19 the variation of information in regards to e.g. ship size (weight vs. gross tonnage) vs. length (m). Rule 19 illustrated that a new "wording” or more functional wording as well as a technological revision is necessary. Shipping companies should be responsible for determining whether certain regulations are still desired or should be revised. In respect to chapters II, III, and IV it was pointed out that a worldwide discussion is necessary when considering MASS: "How Can an autonomous ship rescue at sea?" a requirement from SOLAS Chapter III, and "What security requirements for data transfer capabilities should exist?" a question resulting from SOLAS chapter IV.

A final discussion concluded that:

- SOLAS should only be a framework
- ECDIS regulations must be described in general terms. This concerns several places in SOLAS
- generic content belongs in SOLAS and goal-based descriptions belong in a performance standard. (e.g. ECDIS implementation deadlines are not part of a generic description and can be taken out)
- certain "wordings" are used technically incorrect (e.g. "anti-grounding is actually performed by the navigator and not ECDIS")
- solutions must be found for a modular approach which support both conventional equipment and modular alternatives for a longer migration period

The workshop closed with the assessment of "Lessons Learned" from the failed attempt to integrate multiple sensor displays into the resolution MSC.191 (79). Participants considered the following to be valuable lessons:

- too little time
- goals were not clearly defined and communicated with IMO members
- feedback from IMO: "Not the right instrument to place MSD"
- certain organizations (ICS, CIRM) have to be included in the process
- better, clearer documents are needed
- people were caught by surprise, intentions should be addressed beforehand

The workshop results and documents were prepared and distributed by FKIE. A third workshop was prepared and organized with the goal to determine the group’s common goals, identify necessary work packages and a work plan. In contrast to the first workshop, goals were now to be agreed upon collectively instead of a collection of individual goals. Furthermore, the members of the group were given the opportunity to address and discuss topics in the interest of the group. The workshop was attended by eleven representatives of BMVI, BSH, DNV-GL, Fraunhofer CML and FKIE, German ship owners association (VDR), and manufactures such as Raytheon Anschütz GmbH and B&M Marine Construction.

On a proposal of two participants a discussion on functional safety was included in the agenda. Here, the group was asked whether the subject of functional safety should be a current concern of the group and how urgent this topic is. After a discussion on this matter, it was decided that IMO should set specifications, then the distribution of tasks can be derived. IEC should give an input stating their support for the IMO proposition. Thus, ISO should be given feedback not take on any tasks and await IMO specifications as there are already IMO activities concerning this matter (C 122/3(a)/2; IMO, 2019i) - where ISO is welcome to provide input. On that note-to address the second matter on the agenda- workshop participants were asked to provide their comments to the document C 122/3(a)/2 (IMO, 2019i) in the near future and informed that Germany’s course of action is to support this proposition.

The workshop continued with a recap of the last two workshops by FKIE, presenting the collected individual goals, general framework, previous action plan, results and status of on board situation, and to do's. In the course of this recap and in the light of the discussion on the functional safety matters, participants agreed to replace wordings concerning "redundancy" with "functional safety". The group then defined as preliminary overall goal the e-navigation definition, specific goals and related work items.

Preliminary overall goal: E-navigation is defined according to MSC 85/26 Add.1 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.*" M (IMO, n.d. a)

Specific goals:

(1) Ships must be prepared for future challenges (Maritime 4.0, MASS, cyber security, etc.) as well as applicable and affordable.
   - eNavigation revival - harmonization, simplification, integration of NAV & COM
   - Develop the INS concept (uniform information presentation, standard alarm management, slide-in modules with sensors)
   - MASS light: eNavigation + INS, (enables wake-free operation on bridge)

(2) IMO regulations must be expandable and goal-oriented (technology independent formulations and structure as stated in MSC.1/Circ.1394 *Generic Guidelines for Developing IMO Goal based standards* (IMO, 2015).
   - Flexibly respond to equipment (IMO functional equipment requirements), redundancy and availability requirements (IMO)
   - Future IMO-instruments shall be conducted in a manner consistent with "the highest practicable standards of maritime safety, efficiency of navigation and prevention, and control of maritime pollution from ships." (IMO, 2019i)

(3) To ensure a defined level of quality of on-board systems through suitable processes (testing, certification, monitoring / assessment, change management)

(4) Define an approval process (on an IMO level)

(5) Stick to MSC.1/Circ.1394 (IMO, 2015) as in:
   - E.g. Resolution MSC.287 (87) (IMO, 2010a)
   - Tier 1-3 corresponds to SOLAS, Tier 4 and higher the performance standards, Tier 4 IMO regulations
   - other documents and specifications found on the IMO website on IMO Goal-based standards (IMO, n.d. b)

(6) IMO regulations should define the "what"- the "how" must be sharply separated.

Identified work packages:

Work package 1: Expandable and goal-oriented IMO-goal-based-standards (GBS) and regulations with modular concept

a. Design structure and formulate independently of technology (SOLAS IV / V and PS (Tier I - IV))
   - Analysis of MSC / Circ.1394, Rev.1 (IMO, 2015) for a basis

- Analysis of MSC / Res. 287 (87) (IMO; 2010a) (GBS Bulker, Tanker) for an example of an implementation of goal-based standards.
- Analyze SSE6 / WP ?, GBS for SOLAS III (LSA) can serve as an example
  - Identification of the objectives and functions needed for joint revision of SOLAS IV and V (vertical and horizontal functions)

b. New design: GBS Tier I - IV (and V for examples)
   - Step 1: run through for a simple example (Echosounder or SDME)
   - Step 2: validate by running through a complex example (Collision Avoidance of the INS)

c. Note to MSC with new draft (examples)
d. Consider migration

Work package 2: Prepare ship navigation and communication for future challenges (applicable and affordable)

a. Analysis of the current state of the navigation and communication systems on the ship
   - Extract list of requirements from SOLAS IV / V
   - Derive functions from the current situation (first vertical / specific and then horizontal / overarching)
   - Prepare according to a modular concept

b. Consider future (foreseeable) developments / functions (e.g. MASS, Maritime 4.0)

Work package 3: Definition of an Approval Process (on IMO level)

The discussion on contingencies of the work packages were moved to the next meeting which was arranged for September 11th, 2019 at BSH in Hamburg, Germany. The workshop results and documents were prepared and distributed by FKIE.

Conclusion

In conclusion during the first workshop the group determined that there is a need of a revision of IMO regulations. This was based on the fact that advancing technology is hindered by historically grown IMO regulations, its technological and operational requirements, and certification processes. Furthermore a common understanding of the IMO structures and regulations was established. The group expressed their individual concerns, goals and visions. During the second workshop a deeper understanding and awareness of the current situation on bridges, future development, and certification processes, was created. Along with the determination of goals, the group was informed on matters such as existing navigational functional requirements, revision-worthy chapters in SOLAS based on navigational issues, exemplary functional requirements. Furthermore, during the third workshop the group specified goals and identified necessary work items.

12 Support of the BMVI concerning IMO subjects

12.1 Work Items

To assist the BMVI and consult in matters regarding the integration of the project results in the international work of the IMO is a major objective. This includes the support of the actions concerning the IMO's subjects such as e-navigation and cyber-security as well as the collaboration in national and international working groups.

This includes the substantial preparation of national contributions to international working groups as well as the participation in relevant meetings. Such as:

- the IMO Subcommittee for Navigation, Communication, Search and Rescue, NCSR
- the IMO correspondence group for the development of Guidelines for the display of navigation information received via communications equipment (coordinated by Norway)
- the international working group on S-mode coordinated by Australia (until NCSR 5)
- the IMO correspondence group on the development of the draft guidelines on standardized modes of operation (S-Mode), coordinated by Australia (after NCSR 5)
- the IMO/IHO Harmonization Group on Data Modeling (HGDM)

To support the international activities with a wide expert knowledge, the *BMVI's national expert group for integrated ship navigation and control systems* is coordinated by FKIE. This includes the planning, organization, preparation, chairing and post-processing of the meetings.

In addition the BMVI was supported in the preparation of the national comments on the initial review of the regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS) in regard to

- SOLAS chapter IV (Radio communications)
- SOLAS chapter V (Safety of navigation)
- the Convention on the International Regulations for Preventing Collisions at Sea, 1972, as amended (COLREG 1972)
- the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code)

During the duration of the project the following was conducted:

- the IMO subcommittee meetings NCSR 4, 5,6 were prepared for the topics related to the objectives of the project and accompanied by one or two staff members as part of the German delegation (see chapter 4, 5, 6 and 7)
- the two meetings of the IMO/IHO Harmonization Group on Data Modeling were prepared and one person form FKIE participated (see chapter 5)
- FKIE contributed to the work of IMO Correspondence Group on guidelines for harmonized display of navigation information received from communication equipment (coordinated by Norway (see chapter 4 and 5)
- the Australian-guided international working group on the subject of S-mode was convoyed

- FKIE contributed to the work of IMO Correspondence Group on the development of the draft guidelines on standardized modes of operation (S-Mode) in regard to ICONS, abbreviations, default settings, grouping of information, functions activated via single or simple operator action (see chapter 6)
- Elaborations – respectively statements – in regard to the status of the "*Guidelines for maritime cyber risk management"* as well as to the IMO/IHO Harmonization Group on Data Modelling (HGDM) were prepared and made available to the BMVI (see chapter 5.3)
- seven meetings of the *BMVI's national expert group for integrated ship navigation and control systems* were planned, organized, prepared, chaired and post-processed
- a National S-Mode workshop was planned organized and chaired by FKIE (see chapter 6.2)
- three workshops on a concept for IMO regulation for future ships were planned, organized, prepared, chaired and post-processed by FKIE (see chapter 11)
- the DGON working group on cyber risk management were coordinated together with Raytheon and afEfa.
- drafting of a national input for MSC 98 on comments on the proposed amendments to resolution MSC 252 (83) (Performance standards for integrated navigation systems (INS))
- one meeting was prepared and organized to coordinate the submission of the national comments on the initial review of the regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS) related to the safety of navigation (see chapter 12.2)

The assignments of this work immediately integrate and materialize the results of all work packages of this project.

12.2 Regulatory scoping exercise for the use of Maritime Autonomous Surface Ships

In addition the BMVI was supported in the preparation of the national comments on the initial review of the regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS) in regard to

- SOLAS chapter IV (Radio communications)
- SOLAS chapter V (Safety of navigation)
- the Convention on the International Regulations for Preventing Collisions at Sea, 1972, as amended (COLREG 1972)
- the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code)

An Excel sheet was prepared containing the initial review of the IMO member states. The Excel sheet was distributed to the members of the BMVI's national expert group for integrated ship navigation and control systems for collection of comments. A workshop was organized and the comments were collected, validated and finally consolidated in the Excel sheet. Together with the BMVI the comments were recorded in the IMO GISIS system.

12.3 Conclusions and recommended actions

Guidelines for harmonized display of navigation information received via communication equipment, and

- At NCSR 5 it was decided to approve Interim guidelines for the harmonized display of navigation information received via communications equipment and to possibly reopen the issue after finalizing the work on maritime services. The approved interim guidelines for harmonized display of navigation information received via communication equipment are not finalized in any way. In this stage they can only be seen in giving preliminary guidance how to deal with the integration and presentation of the information received via communication equipment. Many details are still unsolved and have to be discussed together with the issue of the efficient distribution of relevant navigation related information from communications equipment to navigation displays.
- The work for harmonized display of navigation information received via communication equipment should be further progressed when it is clearer what information will be presented in the future on a navigation bridge. The issue for harmonized presentation should then be reopened or newly included in the agenda of NCSR. This approach should be combined with the development of *Guidance on the efficient distribution of relevant navigation related information from communications equipment to navigation displays*. The work on the development of guidance on definition and harmonization of the format and structure of Maritime Services in the context of e-navigation is now completed, but a preliminary review process of future Maritime Services is implemented at NCSR (see chapter 5.3). At this point in time it seems that only few of the e.g. Maritime Services MS 1 (VTS Information service), MS 5 (Maritime safety information (MSI) service) are far enough developed to proceed with the development of guidance on how to present this information on board.
- Therefore, it is recommended to delay the work on IMO level on the harmonized display of navigation information received via communications equipment for a couple of years to observe the future development.

Guidance for efficient distribution of information from communications equipment

- *Guidance on the efficient distribution of relevant navigation related information from communications equipment to navigation displays* should functionally and physically enable the integration of the information received via communication equipment. The guidance should not be limited to INS as the majority of bridge installations are not based on an INS. Therefore, the guidance should not be integrated in the revised performance standards for Integrated Navigation Systems (INS) (resolution MSC.252(83)). This would hinder the dissemination of INS onboard as this would result in restricting requirements only for INS.
- The output on additional modules to the Revised Performance Standards for Integrated Navigation Systems (INS) (resolution MSC.252(83)) relating to the harmonization of bridge design and display of information was deleted from the post-biennial agenda. Therefore, the only agenda item, allowing work on *guidance for efficient distribution of information from communications equipment* is removed from the IMO agenda (see 5.2). To develop the necessary guidance a new work item needs to

be proposed based on task 15 of the revised E-navigation Strategy Implementation Plan MSC.1/Circ.1595 (IMO, 2018e).

- Currently, a comprehensive solution that accounts for the distribution, integration and presentation, of information received via communication equipment is not in sight. As there is too much functionality on many navigational displays already, a new modular, task-oriented concept should be developed for navigation systems. This should include the design of the systems as well as a new modular structure for IMO regulations.

Common Maritime Data Structure - Harmonization of the format & structure of MSs

- With the decisions at NCSR 6 the work on the development of guidance on definition and harmonization of the format and structure of Maritime Services in the context of e-navigation is completed. So far the outcome regarding the agenda Item harmonization of the format and structure of Maritime Services is:
    - guidance on how various organizations can develop Maritime Services that their format and structure is harmonized
    - 16 initial descriptions of maritime services
    - a preliminary procedure how to review future produced maritime service descriptions.
- A permanent process for the management of maritime services including a lead role for the IMO must be implemented. One solution for the evaluation of new maritime services would be to use a permanent installation of the HGDM or to include this permanently in the work program for NCSR, similar to the agenda item *Unified interpretation of provisions of IMO safety, security, and environment-related Conventions*.
- It is now decided to rename the output on Maritime Services as "Consideration of descriptions of Maritime Services in the context of e-navigation" with a target completion year of 2021. This is implemented as an interim measure and that the arrangements will be revisited in the future and revised according to the progress made in the development of descriptions of Maritime Services.
- This future work on Maritime Services is not clearly defined. So far work regarding harmonization of Maritime Services on IMO level was focusing more or less on editorial changes only. It has to be seen what will be discussed at the next two NCSR sessions on this issue. A more content related discussion with recommendations for changes, if obvious failures are listed in the descriptions of Maritime Services, might be more goal oriented.

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Harmonization of user interface design for navigation equipment

- The guidelines for the standardization of user interface design for navigation equipment, specifying aspects to improve the usability and standardization of navigational equipment are another step in regard to a harmonized presentation of navigational information. The guidelines achieve this goal without over-specifying and restricting the design of navigational systems. Due to the mandatory application of two appendices of the guideline by a reference in MSC.191(79) the guideline will be recognized and followed.

- The revision of SN/Circ.243 is an import step for the introduction of presentation requirements for navigational displays on IMO level, especially as the revision is closing the gap between IMO requirements and details specified only on IEC level.
- Nonetheless, issues regarding a user-friendly design and operation of navigational systems are unsolved. Especially in regard to information overload. The systems are filled with too much functionality deviating from the original purpose of the navigational systems. Therefore, a more task-oriented approach for the design of navigational systems in the future is required to enhance the safety of navigation. A new concept for IMO regulations is necessary, describing the minimum and maximum functionality necessary for each task.

13 Summary

The project was bringing issues together regarding the way ahead for a future modular integrated navigation and communication bridge concept and to support the BMVI to move these issues forward at IMO. Due to decisions at IMO some work packages were adjusted by integrating new or revised work items and issues had to be earlier closed to be readdress in the future.

13.1 Introduction

The implementation of the IMO's e-navigation strategy is continued with high political priority. This concept is to increase the reliability of maritime transport. A core element is the enhanced exchange of safety relevant information between all parties involved at sea and ashore. An important part is the integration of additional, especially safety relevant, information received via communication systems into the navigation systems. An essential element is the establishment and expansion of the integrated navigation system, as a central element of the ships navigation. Therefore, the IMO integrated agenda items into its work program: for the development of additional modules for INS performance standards, for the development of guidelines for the harmonized display of navigation information received via communications equipment, for guidelines on standardized modes of operation and to progress the development of maritime services.

Besides e-Navigation, there is an increasing digitalization and integration of systems like e.g. navigation, communication, operation and safety as well as an enhanced information exchange in many areas. Enhanced digitalization and information exchange also increases the risk of cyber-attacks. Therefore, current digital network- and device-technology should be analyzed as well as regulations for cyber risk management of the IMO or other international organizations. Concepts for protection of the ships infrastructure should be developed.

13.2 Objectives

The aim of this project was to develop requirements on a modular ship navigation and operation system, which uses INS as a core element following the IMO strategy concerning the implementation of e-Navigation, and to transform these requirements into IMO documents. The latter are to ensure the harmonized, task- and situation-dependent presentation of safety relevant information as well as the interoperability of ship navigation, operation and communication systems, and their sensor network. Furthermore, solutions to reduce cyber risks were evolved to increase the safety of the ships' internal and external digital communication structure and its integrated devices.

Therefore, the focus was on the following sub-goals:

- integration of additional, especially safety relevant information, which are received via communication systems for the ship navigation and operation
- harmonization of user interface design for navigation equipment
- expedite a bridge concept that uses INS as a core element and includes communication systems
- determination of necessary amendments to the IMO performance standards for presentation of navigation related information on shipborne navigational displays

- analysis of the risks that exist in terms of cyber-attacks and elaboration of a concept for internal digital infrastructure and external digital communication to guarantee a safe ship operation and navigation
- the results were to be incorporated into the appropriate IMO resolutions

13.3 Method

To achieve the objectives of the project the following approaches were followed:

Harmonized data structure – harmonization of the format & structure of maritime services

In creating an e-navigation architecture, it is important to identify information and data flows, and the interactions between applications and user interfaces. Consequently, there is a need for a harmonized data structure to enable the use, interoperability, flow and accessibility of relevant information and data within the maritime domain (including both ship and shore aspects). Therefore, the Fraunhofer FKIE participated in the framework of this work package in the established IMO/IHO Harmonization Group on Data Modeling (HGDM). The focus of the work was to support the harmonized integration and presentation of information derived from communication systems onboard. The development of a harmonized format and structure of maritime services should enable the use of the maritime services onboard.

Harmonized presentation of information received via communication equipment – harmonization of user interface design

The work was formed by the requirements specification regarding the harmonized presentation of information received via communication equipment on the bridge. Furthermore, when it comes to specify requirements to integrate the information received by communication systems, the provided information by onboard systems needs consideration. FKIE supported the international work and provided the specified requirements as well as a proposal for the structure of a guideline to the IMO correspondence group tasked with the issue.

Furthermore, the progress of the international work on guidelines on standardized modes of operation (S-Mode) is monitored and accompanied. Proposals and amendments for the draft guidelines on S-mode are developed and integrated in the international work. Conflicts with existing IMO instruments as IMO Resolution MSC 191(79) and SN/Circ.243 were analyzed and taken into account for the development of the draft guidelines. A set of additional navigation-related symbols for SN/Circ.243 was determined and submitted to the IMO correspondence group on *S-Mode.* To enable a harmonized presentation of information from multiple sensors on a single display (multi sensor display) amendments for IMO Resolution MSC 191(79) were developed.

To get an impression of the most recent status of the alarm management on bridges, investigations on a modern container ship were conducted.

Maritime cyber risk management and digital infrastructure

In these work packages, the risks deriving from data exchange between ship and shore as well as the data processing and storage on board were analyzed regarding cyber-security risks. A model for onboard navigational IT network infrastructure based on literature and interviews has been developed. The attack surface of that model was deduced together with its threats which were identified and described in their context with realistic examples. Furthermore, countermeasures to these threats were developed and compared to those proposed by current guidelines and technical standards. A proof of concept proving the feasibility of exploitation of some identified threats and the lack of countermeasures implemented in modern bridge systems has been developed and tested with real-world systems.

To inform and coordinate the German maritime industry regarding maritime cyber risks and cyber security, the German Institute of Navigation (DGON) initiated the working group "Maritime Cyber Risk Management". Fraunhofer FKIE coordinated the working group together with industry partners.

Concept for IMO regulations for future ships

To assess how policies and IMO regulations should look like so that innovation is not constrained by specific device and performance requirements and increasingly complex cumulative regulatory frameworks, Fraunhofer FKIE planned, organized, prepared, chaired and post-processed three workshops on behalf of the Federal Ministry of Transport and Digital Infrastructure (BMVI).

Support of the BMVI concerning IMO subjects – amendments to international regulations

The BMVI was assisted and consulted regarding the IMO's international work. Based on the international approach to realize the IMO e-navigation strategy, the regulative implementation was substantially accompanied. One part was the substantial preparation of national contributions to international working groups as well as the participation in the relevant meetings. Furthermore, the results of the project were transformed into IMO regulations.

13.4 Results

Harmonized data structure – harmonization of the format & structure of maritime services

Based on the results produced by IMO/IHO Harmonization Group on Data Modeling and the work at NCSR a two-step approach was developed to proceed with the harmonization of maritime services. Firstly to issue a MSC resolution on *Guidance on the definition and harmonization of the format and structure of Maritime Services in the context of e-navigation*. The aim of the Guidance is to guarantee that the Maritime Services (MS) are implemented in a standardized and harmonized format. Therefore, the guidance describes the various levels of responsibility regarding the implementation of maritime services. Within the guidance, the process for the development of a maritime service is described and illustrated with a flow chart. Important in this process is the template for the descriptions of MS in the context of e-navigation. This template should be used to describe a Maritime Service when developing a new MS according to the specified process. A description for the harmonized specification of technical services is listed in the appendix. Secondly, a MSC circular *on Initial descriptions of Maritime Services in the context of e-navigation* was finalized. The circular contains the descriptions of the so far described 16 Maritime Services.

Harmonized presentation of information received via communication equipment – harmonization of user interface design

Guidelines on the harmonized presentation of information received via communication equipment were developed and discussed at IMO. Due to the status of the guideline and the necessity to take into account the development of maritime services regarding the presented information onboard, the guidelines were revised, shortened, and finalized as interim guidelines (MSC.1/Circ.1593). It is planned to finalize the guidelines after completion of the work on S-mode and maritime services.

The guidelines on S-mode were finalized renamed to *guidelines for the standardization of user interface design for navigation equipment*. The guidelines consist of a general outline of user interface standardization design principles and five appendices. The appendices standardize navigation-related terminology and icons of functions for commonly-used functions on navigation equipment, define logical grouping of information of related essential navigational information that should be displayed together on the user interfaces, list functions which should be accessible by single or simple operator action to support fast access to essential functionality and specify default settings for radar and ECDIS. Two Appendices are mandatory due to an integration of references in resolution MSC.191 (79).

The IMO correspondence group on S-mode submitted with its report the proposed revision of SN.1/Circ.243/Rev.1. The suggested revision of the navigational symbols, which followed the proposal made by Germany, were approved and will be enforced as SN/Circ.243/Rev.2. They will be applicable for radar equipment, ECDIS and INS on January 1st, 2024 and for all other navigational displays on the bridge, on July 1st, 2025.

Maritime cyber risk management and digital infrastructure

The digitalization onboard introduces cyber risks for maritime navigational equipment. As a result of our work we outlined how cyber risks impact the navigation process for state-of-the-art bridge systems (e.g. Integrated Navigation Systems). A theoretical study shows how the attack surface of a bridge system looks like and which attack vectors exist to influence bridge systems. A proof of concept in collaboration with Raytheon Anschütz underlines the feasibility of cyber attacks on bridge systems. Together with the German Institute for Navigation (DGON) a working group was established to face cyber risks for the maritime domain.

Concept for IMO regulations for future ships

As a result of the three workshops a need of a revision of IMO regulations was identified based on the fact that advancing technology is hindered by historically grown IMO regulations, its technological and operational requirements, and certification processes. Furthermore, a common understanding of the IMO structures and regulations was established. A deeper understanding and awareness of the current situation on bridges, future development, and certification processes, was created. Finally, goals and identified necessary work items for the way ahead were specified.

13.5 Practical outcome

Harmonized data structure – harmonization of the format & structure of maritime services

So far the outcome regarding the agenda Item *harmonization of the format and structure of Maritime Services* is guidance on how various organizations can develop Maritime Services that their format and structure is harmonized, 16 initial descriptions of maritime services and a preliminary procedure how to review future produced maritime service descriptions. An agenda item for NCSR for two sessions is decided to accommodate future work related to the descriptions of Maritime Services. Unfortunately, this future work on Maritime Services is not clearly defined. So far, work regarding harmonization of Maritime services on IMO level has focused more on editorial changes. A more content related discussion with recommendations for changes, if obvious failures are listed in the descriptions of Maritime Services, will be more goal-oriented.

Harmonized presentation of information received via communication equipment – harmonization of user interface design

It should be noted that the approved interim guidelines for *harmonized presentation of information received via communication equipment* are not finalized. In this stage they can only be seen as preliminary guidance on how to deal with the integration and presentation of the information received via communication equipment. Many details are still unsolved and should be discussed together with the issue of the efficient distribution of relevant navigation related information from communications equipment to navigation displays.

The *guidelines for the standardization of user interface design for navigation equipment,* specifying aspects to improve the usability and standardization of navigational equipment are another step in regard to a harmonized presentation of navigational information. The guidelines achieve this goal without over-specifying and restricting the design of navigational systems. Due to a reference of the appendices 2 and 3 of the guideline in MSC.191(79) a mandatory application is ensured and the guideline will be recognized and followed.

Furthermore, the revision of SN/Circ.243 is another important step for the introduction of presentation requirements for navigational displays on IMO level.

Nonetheless, issues regarding a user-friendly design and operation of navigational systems are unsolved. Especially in regard to information overload. The systems provide too much functionality deviating from the original purpose of the navigational systems. Therefore, a more task-oriented approach for the design of navigational systems in the future is required to enhance the safety of navigation. A new concept for IMO regulations is necessary, describing the minimum and maximum functionality necessary for each task.

Maritime cyber risk management and digital infrastructure

The results show that maritime industry is merely in the beginning of facing cyber risks to onboard systems. The industry has to rethink their safety and security measures concerning an ever-present IT infrastructure. A first step towards securing onboard IT infrastructure has to be the transfer of cyber security measures from classical IT systems to specialized maritime systems if applicable. The next step will be eradicating security flaws, which arise from domain specific context. Some challenging technical aspects will be the development and implementation of sound Intrusion Detection Systems (IDS) which consider maritime application data and the establishment of standards to ensure secure and reliable cyber systems.

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15 Abbreviations

AIS	Automatic Identification System
AtoN	Aids to Navigation
CCRS	Consistent Common Reference System
CG	Correspondence Group
CIRM	Comite' International Radio-Maritime
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea
ECDIS	Electronic Chart Display and Information System
e-NAV	e-Navigation
ENC	Electronic Navigational Chart
FKIE	Fraunhofer Institute for Communication, Information Processing and Ergonomics
GMDSS	Global Maritime Distress and Safety System
GBS	Goal based standards
GPS	Global Positioning System
GUI	Graphical User Interface
HCD	Human-Centered Design
HEAP	Human Element Analyzing Process
HGDM	Harmonization Group on Data Modelling
HMI	Human Machine Interface
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IBS	Integrated Bridge System
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organization
IMO	International Maritime Organization
INS	Integrated Navigation System
MS	Maritime service
MSC	Maritime Safety Committee of the International Maritime Organization
MSI	Maritime Safety Information
MSP	Maritime Service Portfolio
NAVTEX	Navigational Warnings by Telex
NCSR	Subcommittee on Navigation, Communications and Search and Rescue of the International Maritime Organization
OOW	Officer Of the Watch

S-100	Universal Hydrographic Data Model
SAR	Search and Rescue
SENC	System Electronic Navigation Chart
SOLAS	International Convention for the Safety of Life at Sea
VTM	Vessel Traffic Management
VTS	Vessel Traffic Services
WMO	World Meteorological Organization

Appendix 1 Draft Guidelines for the harmonized display of navigation information received via communications equipment (submitted to NCSR 5)

1 Purpose

1.1 This document provides guidance on the display of navigation-related information received by communications equipment. It aims to ensure that information is displayed in an efficient, reliable and consistent format, in a manner that is easily interpreted to support decision-making.

1.2 These guidelines supplement the Resolution MSC.191(79) "Performance standards for the presentation of navigation- related information on shipborne navigational displays" in regard to the presentation of navigation information received via communication equipment.

1.3 The use of these Guidelines will ensure that navigation information received via communications equipment is displayed in a harmonized manner on the ships' navigational bridge.

2 Scope

2.1 The availability of electronic data that enhances the safe and efficient navigation of ships necessitates that shipborne systems capable of presenting this information to the user should do so in a harmonized and readily assimilated way.

2.2 This information will be presented to shipborne users through a combination of primary navigational displays, such as ECDIS, Radar and INS, together with any additional display facilities that may be considered appropriate to assist the safe and efficient navigation of the vessel.

2.3 Reception of Maritime Safety Information (MSI) by means of direct printing has always been an important part of the GMDSS. However, it is clear from user requirements, such as those gathered during the user needs analysis of e-navigation, that there is a need to portray such information in a harmonized way on appropriate navigation displays.

2.4 To ensure effective decision making and safe navigation, the proper integration and presentation of information received via communication equipment is essential.

3 Application

3.1 This Guideline is applicable to the information obtained from, but not limited to, communications equipment defined in SOLAS.

4 Definitions

4.1 Definitions found in this guideline are specified in Appendix 1

5 General presentation requirements

5.1 Human Centered Design (HCD)

.1 The type and volume of information displayed should be appropriate to the voyage phase and should not overload the user. Therefore this Guideline should be read in conjunction with MSC.1/Circ.1512 in order to ensure that measures to prevent information overload take into account relevant human centered design principles.

.2 The type and level of information displayed should complement the user's capabilities, and should take into consideration human factors principles as specified in section 5 (see MSC.1/Circ.1512, paragraph 6). Higher levels of integration mean that systems should be carefully evaluated to ensure that complexity and workload are compatible with the ability of the user (OOW).

.3 In designing systems and equipment that will incorporate navigation information received via communications equipment, due consideration should be given for the ability of the operator to manage information. Any information received requires careful prioritization based on human centered design principles.

.4 The receipt, display and use of navigation information received via communications equipment should be tested by the user and incorporated into the HCD process.

.5 Navigation information received via communications equipment should be manageable through the application of user preferences. The system should assist the user in reducing clutter and in enhancing situational awareness.

.6 The integration of navigation information received via communications equipment should not distract from the user's primary task of maintaining the safe navigation of the ship.

5.2 Display of information

.1 Navigation information received via communications equipment should be displayed in a timely, unambiguous and harmonized manner.

.2 Navigation information received via communications equipment should be displayed according to Resolution MSC.191(79) and, if applicable, based on the relevant S-100 based Product Specification.

.3 Where there are no appropriate symbols defined for display in the relevant S-100 based Product Specification, additional new symbols need to be added to SN.1/Circ.243/Rev.1, as shown in the appendix.

.4 Information should, where applicable, be geo-located and integrated with other navigation and charted information. Where possible, the graphical geo-located display of areas, points, lines and other information received via communications equipment should assist the user in developing situational awareness.

.5 The additional display of information from communications equipment must not degrade the primary information on a particular display but contribute to the overall navigational safety of the vessel.

.6 Data should be appropriately filtered according to the selected scale/display range of the display. Only critical information should be displayed at all ranges, if practicable.

.7 The source of the received information should be readily identifiable.

.8 Where navigation information poses a direct risk to the vessels planned route and or movement, the information should be indicated as an alert. This may be determined based on the safety settings available within the electronic navigation equipment such as ECDIS, Radar or INS.

6 Functional requirements for presentation of information

6.1 General

.1 Information that has been received by onboard communication equipment should include an integrity testing process.

6.2 Routing

.1 The user should be able to route information to another display if fitted,

.2 There should be a clear indication of the routing in use.

.3 Routing should allow the user to route the information according to the navigational situation and task.

6.3 Selection and filtering

.1 Navigation information should be displayed in such a manner that information overload is prevented. Selectable functions should be included to allow for display of only the required information necessary for safe navigation and the task at hand.

.2 It should be possible to select and filter (categorize) of Information and data received on board in accordance with urgency and sea area.

.3 Information relevant to planned route and situation should be identified using adequate filtering processes.

.4 Means should be available enabling the user to select the information needed for the current operational task and situation.

.5 There should be a clear indication of the selection and filtering parameters in use.

.6 It should be possible to manually select the information for automatic presentation on the navigational displays.

.7 Information that presents a danger to safe navigation and requires an alert should be identified.

6.4 Prioritization

.1 It should be possible to prioritize information and data received on board. This should be prioritized in accordance with urgency and sea area.

6.5 Indication of new information

.1 An alert or indication should draw attention to the presence of new and/or relevant information related to the vessels movements or operating area.

7 Presentation of navigation related information

7.1 MSI or other geo-referenced locations impacting safety

.1 New information should be indicated on a route planning, route monitoring or collision avoidance display by an icon or symbol and an alert should be given.

.2 It should possible to present additional information upon selection (request) via pick-report functionality on ECDIS and radar displays or INS tasks route monitoring, route planning and collision avoidance.

[7.2 Alterations to own ship route

.1 Graphical presentation of alterations received from external source should be clearly displayed and differentiate from the monitored route.

.2 It should be possible to display additional information of the alterations received from an external source on demand. (At least the source of the alterations received).]

8 Operational display

8.1 General

.1 Information received from communications equipment should not obscure the primary information of an operational display.

.2 The [overlaid information] received from communications equipment should be clearly distinguishable as being additional information that has been added to the display.

8.5 Additional display – INS task "status and data display" – or other means

.1 The increasing amount of data received from communications equipment may require an additional display on board

.2 HMI for displaying and evaluating received information as well as for specifying filtering, routing, and presentation parameters (selection for presentation) should be provided.

.3 The user should be able to view information items and their filtering, routing, and selection (presentation) properties.

.4 The user should be able to edit the filtering, routing, and selection (presentation) properties of information items.

[Appendix 1 Definitions *[to be checked to ensure that it references definitions in the document only]*

Maritime Safety Information (MSI)

Maritime Services (MS)

Selection of Information – Selection is a method which specifies which information should be displayed on the navigational systems and INS tasks.

Routing - Routing is a technical method to distribute data for navigation equipment.

Filtering of information– Filtering is a technical method which categorizes and extract the information according to certain parameters, e.g. relevance for navigation, relevance for route, distance to own ship.

Filter parameters - parameters which present the filter settings. The filter parameters are presented to and set by the user to be used by the technical process.]

Appendix 2 References [*check these references are cited in the document and renumber at completion*]

The following references should be noted:

1 Resolution MSC.191(79) "Performance standards for the presentation of navigation-related information on shipborne navigational displays1"

2 Resolution MSC.232(82) "Revised performance standards for electronic chart display and information systems (ECDIS)"

3 Resolution MSC.252(83) "Revised performance standards for Integrated navigation systems (INS)2"

4 Resolution MSC.302(87) "Performance standards for bridge alert management (BAM)"

5 Resolution A.694(17) "General requirements for shipborne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids."

6 Resolution A.706(17) "World-Wide Navigational Warning Service"

8 Resolution A.811(19) "Performance standards for a shipborne integrated radiocommunication system (IRCS) when used in the GMDSS"

9 Resolution A.817(19) "Performance standards for electronic chart display and information systems (ECDIS)"

11 SN.1/Circ.243/Rev.1 "Amended guidelines for the presentation of navigation-related symbols, terms and abbreviations"

12 MSC.1/Circ.1512 "Guideline on Software Quality Assurance and Human-Centred Design for e-navigation"

14 IHO S-100 "Universal Hydrographic Data Model"

16 Joint IMO/IHO/WMO Manual on Maritime Safety Information (2015 edition),

[MSC.1/Circ.1310/Rev.1]

Appendix 2 Template for a maritime service NCSR 5/8 (IMO, 2017)

This template should be used by international organizations to describe the maritime services that are within their remit. Descriptions of maritime services provided to IMO using this template will enable IMO to exercise, leadership and overarching oversight and to provide a globally harmonized list of maritime services.

To ensure a standardized approach in the development and implementation of maritime services, the content should include a general description of the operational services, and a reference to associated technical services that will enable the exchange of information in digital format.

1. Title of the maritime service (Maritime Service number)

2. Submitting Organization

3. Description of the maritime service

Stating the exact nature and scope of the maritime service in accordance, if applicable, with existing IMO instruments. Additional details might be added for clarity as required.

4. Purpose

What is the purpose of the maritime service?

What value does it bring to its intended stakeholders?

Is the maritime service compliant with regulatory requirements, if applicable?

In the case that the maritime service covers existing services, a description of the steps required to transition from analogue to digital information promulgation must be included.

5. Operational approach

How is the purpose of the maritime service achieved, taking into account existing guidance of the Organization and other international bodies?

6. User needs

Describe the user needs the maritime service addresses. In so doing make reference to any relevant IMO instruments and, where applicable, include one or more use cases.

7. Information to be provided

List the information elements the maritime service provides. The information elements will be the starting point for data modelling, as part of the technical services to access, promulgate or exchange the information.

8. Associated technical services

Using the table below list existing or potential technical services associated with this maritime service.

Name	ID (MRN)	Description	Architect(s)	Standardization body

9. Relation to other maritime services

Describe any relationships between this and other maritime services such as interdependencies or areas of overlap. This section should clarify the nature of interdependencies, overlaps and provide recommendations for their resolution. � Maritime

Appendix 3 Functional requirements from IEC 62288 for presentation of navigational information

In this appendix functional requirements from IEC 62288 regarding presentation issues for certain navigational information are listed. The requirements are related to the identified symbols for inclusion in IMO SN/Circ.243, see 6.4.2. This information should be taken into account when the interim guidelines for the harmonized display of navigation information received via communications equipment, MSC.1/Circ.1593 (IMO, 2018d) will be reopened and revised.

- Maritime Safety Information, MSI
  MSI symbols should be in a separate user selectable layer or group, removable by single operator action. The removal may be connected to generic removal functionality of non-chart object layers.

  The user dialog area should have an indication if MSI notices are available in the area currently displayed, but the MSI layer is not automatically selected for display.

  MSI symbols may be connected to a date range and in such case each MSI notice symbol should be displayed only when user selected date is within data range.

  It should be possible to cursor pick an MSI symbol for further details.

  When presentation of MSI point and area symbols are provided as overlay on chart or radar, then means should be provided for cursor pick of the symbol to provide further information in the user dialog area of the display.

- Meteorological information
  Other meteorological or hydrographic information such as visibility, temperature, salinity, etc., if available, should be available on demand.

- Tidal and water level information
  The optional tidal flow part of the symbol should be used to represent tidal speed and direction. If selected, the details of tidal flow should be presented in the associated AIS object dialog using one decimal.

  The optional tidal gauge part of the symbol should be used to represent availability of water level information. If selected, the details of water level should be presented in the associated AIS object dialog relative to vertical datum of ENC using one decimal.

- Signal station
  Other information from signal station, if available, should be available on demand.

- Berthing data
  Other information from berthing data, if available, should be available on demand.

- Clearance time to enter port

  Other information from clearance time to enter, if available, should be available on demand.

- Area notice

  Area notice symbols should be in a separate user selectable layer, which is removable by single operator action. The removal may be connected to generic removal functionality of non-chart object layers.

  The user dialog area should have an indication if area notices are available in the area currently displayed, but the area notice layer is not selected for display.

  Area notice symbols may be connected to a date range and in such case each area notice symbol should be displayed only when user selected date is within data range.

  It should be possible to cursor pick an Area notice symbol for further details.

- Air gap

  Air gap relative to the water surface in meters with one decimal and other Air gap information, if available, should be available on demand.

- Environmental report

  All available details of environmental information should be displayable on demand.

Appendix 4 S-Mode Workshop Material

A. Excerpt of NCSR5/INF:13 Guidelines on standardized modes of operations- Results of the S-mode user preference test

The following table shows information selected by participants from items displayable on the ECDIS information window.

Items		Details	Number of selection
Own ship information	HDG	Heading	319 (95.8%)
	STW	Speed	309 (92.8%)
	COG	Course Over Ground	320 (96.1%)
	SOG	Speed Over Ground	317 (95.2%)
	Position	Present position	309 (92.8%)
	Propulsion	Engine RPM	162 (48.6%)
	Rudder	Rudder angle	164 (49.2%)
	UKC	Under Keel Clearance	249 (74.8%)
Route monitoring	Name	Route name	277 (83.2%)
	To WPT No	Next waypoint number	280 (84.1%)
	Distance	Distance to next waypoint	294 (88.3%)
	Bearing	Bearing to next waypoint	280 (84.1%)
	TTG	Total Time To Go	278 (83.5%)
	ETA	Estimated Time to Arrival	280 (84.1%)
	Next Course	Next course	283 (85.0%)
Cursor	LAT	Latitude of present cursor position	286 (85.9%)
	LONG	Longitude of present cursor position	289 (86.8%)
	Distance	Distance from own ship	305 (91.6%)
	Bearing	Bearing from own ship	300 (90.1%)
Target	Name	Name of target ship	289 (86.8%)
	BRG	Bearing from target ship	285 (85.6%)
	RNG	Range from target ship	283 (85.0%)
	COG	Course Over Ground of target ship	283 (85.0%)
	SOG	Speed Over Ground of target ship	285 (85.6%)
	CPA	Closest Point of Approach	288 (86.5%)
	TCPA	Time to Closest Point of Approach	284 (85.3%)
	BCR	Bow Cross Range	240 (72.2%)
	BCT	Bow Cross Time	234 (70.3%)
Nav. info	Wind	Present wind direction and speed	263 (79.0%)
	Current	Present current direction and speed	256 (76.9%)
	Navigational Info.	Navigation information from other equipment	205 (61.6%)
Scale		Present scale of electronic chart	243 (73.0%)
Alert		Present alert information	256 (76.9%)

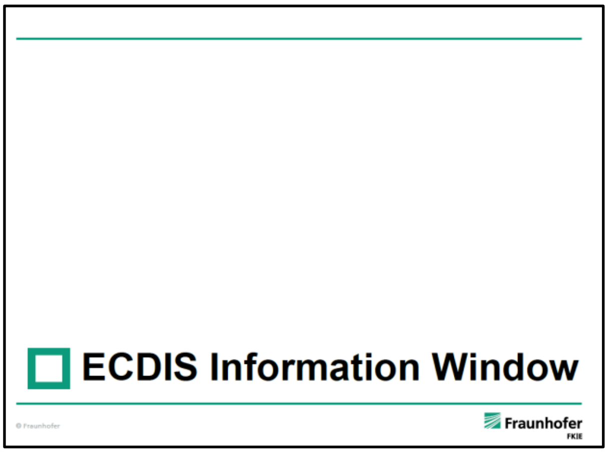
The following table shows functions selected by participants from items displayable on the ECDIS menu bar.

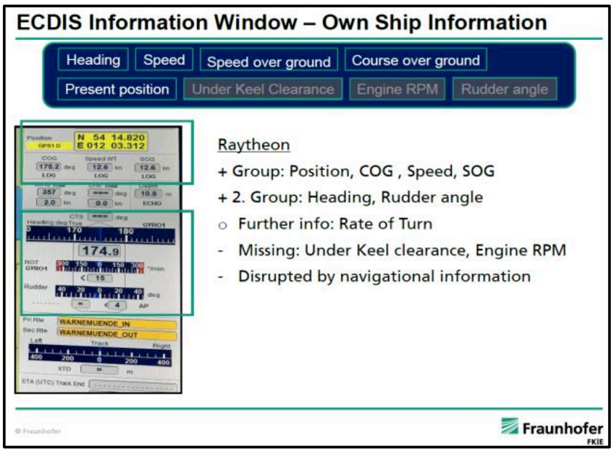
Items		Details	Number of selection
Alert	Anchor Watch	Dredging alarm	277 (83.2%)
	Approach	Safety contour, specified area	250 (75.1%)
	CPA/.TCPA	Information concern with collision danger	283 (85.0%)
	Sensor	Monitoring of connected sensor	268 (80.5%)
	Off track	deviation alarm	272 (81.7%)
	ENC ref	No ENC, non-HO	220 (66.1%)
	Lost target	Setting the alarm for lost target	210 (63.1%)
	Datum	Standard position from geographic surveying	223 (67.0%)
	Anti-grounding	Alarm against grounding	245 (73.6%)
Chart	Display mode	Base, Standard, Other	270 (81.1%)
	Layer	Detail layer selection	249 (74.8%)
	North up	Chart orientation	274 (82.3%)
	RCDS mode	Raster chart setting	208 (62.5%)
	Safety Contour	Safety Contour setting	281 (84.4%)
	Safety Depth	Depth check	279 (83.8%)
	Chart converter	Chart installation	210 (63.1%)
	AIO	Admiralty Info. Overlay	223 (67.0%)
	Find	Chart find	212 (63.7%)
	Manual Update	Chart editing by user	224 (67.3%)
Logbook	Logbook	Record of navigation information	199 (59.8%)
	Track	Track check	217 (65.2%)
Route	Planning	Route plan	272 (81.7%)
	Monitoring	Route monitoring	274 (82.3%)
	Check	Check any danger on route	253 (76.0%)
	Export	Export route data	230 (69.1%)
	Import	Import route data	228 (68.5%)
	Setting	Route setting	234 (70.3%)
Setting	Profile	ECDIS setting memorization	234 (70.3%)
	Sensor	Interface with other equipment	245 (73.6%)
	Time	Time setting	225 (67.6%)
	Interface	Setting of sensor	206 (61.9%)
Target	Activation zone	Target activation value setting	232 (69.7%)
	Filtering	Target filtering	230 (69.1%)
	Information display	Target data setting	249 (74.8%)
	Outline	Outline	216 (64.9%)
	Find	Find target	202 (60.7%)
	History	History of targets	193 (58.0%)
	Setting	Setting for target menu	210 (63.1%)
Measurement	EBL, VRM	Check of range, bearing	271 (81.4%)
LOP		Verification of ship position	227 (68.2%)

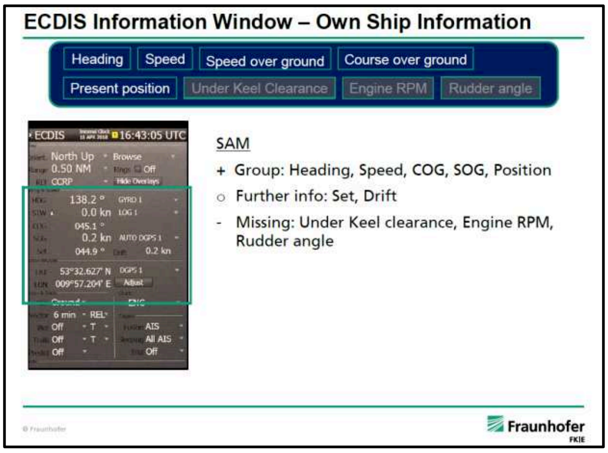
The following table shows functions selected by participants from items displayable on the ECDIS shortcut key.

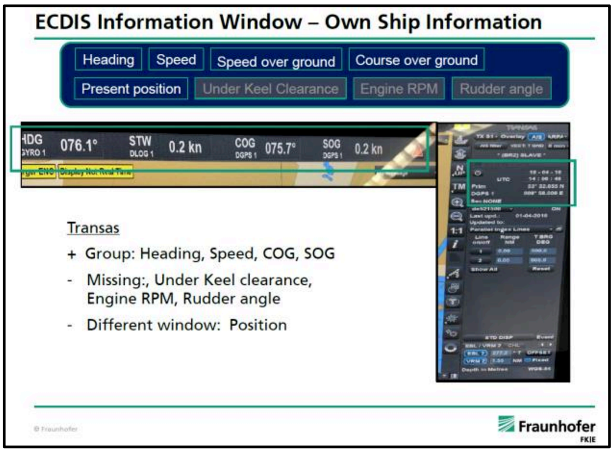
Items	Details	Number of selection
Standard Mode	Change to Standard mode	230 (69.1%)
Own ship	Display own ship on center	272 (81.7%)
Canceling of Data	Display only Chart	153 (45.9%)
MOB	Man Over Board	242 (72.7%)
North up	Chart Orientation	220 (66.1%)

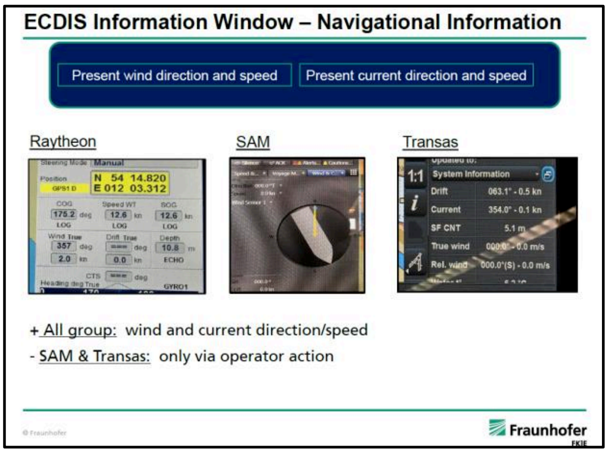
B. Excerpt of PPT Presentation of Workshop Results (read left to right, then top to bottom)

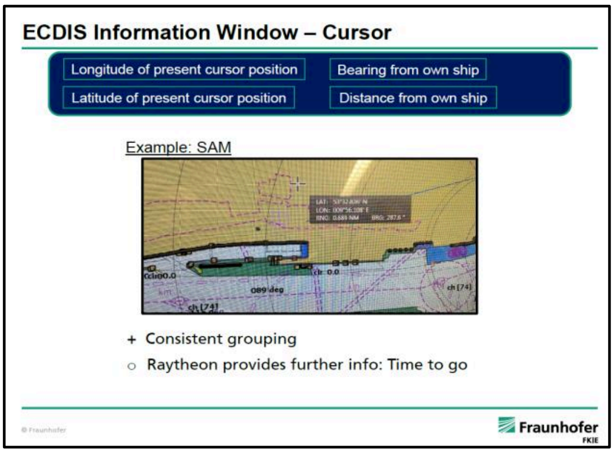








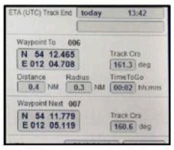




ECDIS Information Window – Route Monitoring

Route name | Next WP | Distance to next WP | Bearing to next WP

Next course | Total time to go | Estimated time to arrival



Raytheon
- Further info: Track distance, WP after next WP
- Missing: bearing to next WP

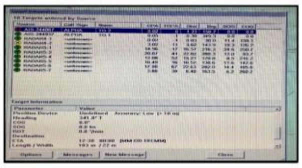
SAM
- Flexible field

Transas
- Further info: track distance
- Wheel overline instead of waypoint
- Flexible field

ECDIS Information Window – Target information

Name of TS | Bearing to TS | Range to TS | Bow cross time

COG of TS | SOG of TS | CPA | TCPA | Bow cross range



Raytheon
- Further info: ship type, call sign, ETA, RoT, destination, width, length
- Missing: bow cross range, bow cross time
- Not available in ECDIS information window

ECDIS Information Window – Target information

Name of TS | Bearing to TS | Range to TS | Bow cross time

COG of TS | SOG of TS | CPA | TCPA | Bow cross range

SAM
- scrolling necessary to view all information

ECDIS Information Window – Target information

Name of TS | Bearing to TS | Range to TS | Bow cross time

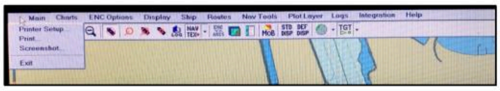
COG of TS | SOG of TS | CPA | TCPA | Bow cross range

Transas
- Further info: Heading, RoT etc.
- Missing: Bow cross range, Bow cross time
- Available with mouse over as overlay

ECDIS Menu Bar – Hot Keys

Standard mode | Chart only | North up

Center own ship | Man over board

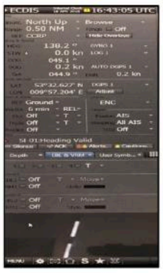


Raytheon
- North up only available in radar

ECDIS Menu Bar – Hot Keys

Standard mode | Chart only | North up

Center own ship | Man over board



Sam
+ Group: Standard mode, Chart only, Man over board
- Missing: Center own ship, North up

ECDIS Menu Bar – Hot Keys

Standard mode | Chart only | North up

Center own ship | Man over board

Transas
+ in Radar mode „Hot key"
- in ECDIS mode not as „Hot Key" available

C. Results of Single and Simple Operator Research and Questionnaire

The Column "function" offers a description of the functions. Column "equipment" states the system to which this function refers. Column "norm" describes the status in the current s-mode guideline in numerical form: zero is a single operator action, one is a simple operator action. Column "results" is the average (N=9) of the answers received via the questionnaire. Whereas a red coloration was given when the attendees felt that the function should be available via single operator action (< .50) and the guideline stated simple. A green coloration was given for those fields that the attendees felt the function should be accessible via a simple operator action (> .5) and the s-mode guideline currently states single operator action. The next "norm" column repeats the s-modes guideline current status in text form. The next three columns shows the deviation from the norm of each system.

Function	Equip ment	Norm	Result	Norm	System 1	System 2	System 3
1. Select ECDIS Standard Display	ECDIS	0	0,22	**single**	single	simple	single
2. Remove radar (image and tracked target), AIS and other navigational information overlaid over the ENC chart.	ECDIS	0	0,11	**single**	single	single	single
3. Select route monitoring display covering own ship's position	ECDIS	0	0,22	**single**	single	single	simple
4. Select default ECDIS settings *followed by an action to confirm the selection	ECDIS	0	0,22	**single**	single	single	simple (not followed by confirmation)
5. Present AIS filter criteria	ECDIS	0	1,00	**single**	single	single	single
6. Present excluded MSI coverage areas and message categories	ECDIS	0	0,83	**single**	single	na	>2 Klicks
7. Present date (or date range) of date dependent ENC objects	ECDIS	0	1,00	**single**	single	simple	simple
8. Select AIS target information	ECDIS	1	0,78	**simple**	single	single	single
9. Remove chart data	Radar	0	0,22	**single**	single	single	single
10. Reset VRM origin to the CCRP position	ECDIS	1	0,89	**simple**	na	na	single
	Radar	1	0,56	**simple**	na	na	single
11. Reset EBL origin to the CCRP position	ECDIS	1	0,89	**simple**	na	na	single
	Radar	1	0,56	**simple**	na	simple	single
12. Reset ERBL origin	Radar	1	0,56	**simple**	…	simple	…
13. Reset Parallel Index line to own ship's heading	Radar	1	0,89	**simple**	…	simple	na
14. Remove user defined maps	Radar	0	0,56	**single**	…	na	single
15. Select default radar settings	Radar	1	0,33	**simple**	…	simple	simple
	ECDIS	0	0,44	**single**	na	single	single

Function	Equip ment	Norm	Result	Norm	System 1	System 2	System 3
16. Select presentation mode (radar, chart and other navigation information)	Radar	0	0,50	**single**	na	single	single
17. Remove AIS Area Notice	ECDIS	1	0,83	**simple**	…	na	na
	Radar	1	0,83	**simple**	…	na	na
18. Remove additional information (including information for route planning, route monitoring, information overlays and supplementary navigation tasks	ECDIS	1	0,67	**simple**	na	simple	single
19. Set panel illumination	ECDIS	1	0,75	**simple**	single	simple	na
	Radar	1	0,63	**simple**	single	simple	na
20. Set display brilliance / Toggle Day /Night mode	ECDIS	1	0,67	**simple**	single	single	simple
	Radar	1	0,56	**simple**	single	single	3 klicks
21. Select ECDIS mode	INS	1	0,56	**simple**	single	na	na
22. Select Radar mode	INS	1	0,44	**simple**	single	na	na
23. Select Conning display mode	INS	1	0,56	**simple**	single	na	na
24. Select CAM-HMI as defined in Bridge Alert Management (BAM) (for example as required by INS)	INS	1	0,67	**simple**	single	na	na
25. Select North UP display	ECDIS	1	0,33	**simple**	na	single	simple
	Radar	1	0,22	**simple**	1-3 Klicks	single	single
26. Select ship's Head Up display	ECDIS	1	0,38	**simple**	na	single	simple
	Radar	1	0,25	**simple**	1-3 Klicks	single	single
27. Select ship's Course Up display	ECDIS	1	0,67	**simple**	na	single	simple
	Radar	1	0,44	**simple**	1-3 Klicks	single	single
28. Select True Motion mode	ECDIS	0	0,78	**single**	na	single	simple - if cursor is placed in center single
	Radar	0	0,67	**single**	1-3 Klicks	single	single
29. Select Relative Motion mode	ECDIS	0	0,67	**single**	na	single	simple -if cursor is placed in center single
	Radar	0	0,50	**single**	1-3 Klicks	single	simple
30. Select Ship centred mode	ECDIS	0	0,22	**single**	single	simple	simple
	Radar	0	0,25	**single**	na	simple	single
	ECDIS	1	0,75	**simple**	…	simple	simple

Function	Equip ment	Norm	Result	Norm	System 1	System 2	System 3
31. Select Shipp off centred mode	Radar	1	0,75	**simple**	single	simple	single
32. Perform True Motion reset	ECDIS	0	0,63	**single**	…	simple	…
	Radar	0	0,63	**single**	single	simple	…
33. Select range	ECDIS	0	0,44	**single**	single	single	na
	Radar	1	0,38	**simple**	single	single	simple
34. Perform Range up	ECDIS	1	0,33	**simple**	single	single	single
	Radar	0	0,22	**single**	single	single	na
35. Perform Range down	ECDIS	0	0,33	**single**	single	single	single
	Radar	0	0,22	**single**	single	single	na
36. Temporarily suppress the “heading line”	Radar	0	0,33	**single**	single	…	single
37. Toggle Range Rings on and off	ECDIS	1	0,75	**simple**	…	single	na
	Radar	1	0,44	**simple**	single	single	single
38. Start Variable Range Marker adjustment	ECDIS	1	0,89	**simple**	…	single	simple
	Radar	1	0,89	**simple**	single	single	simple
39. Start Electronic Bearing Line adjustment	ECDIS	1	1,00	**simple**	…	single	simple
	Radar	1	1,00	**simple**	single	single	simple
40. Start Electronic Range and Bearing Line adjustment	ECDIS	1	0,78	**simple**	na	single	…
	Radar	1	0,78	**simple**	na	single	…
41. Perform Target Acquire	Radar	1	0,33	**simple**	simple - associa-tion on; single -as-sociation off	single	single
42. Select tracked target	ECDIS	1	0,44	**simple**	…	single	simple - je nach cursor-Ein-stellung auch single
	Radar	1	0,22	**simple**	single	…	simple- je nach cursor- Ein-stellung auch single
43. Call up the information asso-ciated with an object by cursor pick on its symbol	ECDIS	1	0,33	**simple**	single	simple	1-3 Klicks je nach cur-sor-Einstel-lung
44. Perform target cancella-tion(or to put an AIS target to sleep)	ECDIS	1	0,67	**simple**	single	simple	single/sim-ple
	Radar	1	0,67	**simple**	…	simple	single/sim-ple

Function	Equip ment	Norm	Result	Norm	System 1	System 2	System 3
45. Perform cancellation of all targets (or to put all AIS targets to sleep)	ECDIS	1	1,00	**simple**	…	simple	single/simple
	Radar	1	0,88	**simple**	…	simple	single/simple
46. Acknowledge an Alert	ECDIS	0	0,11	**single**	…	single	simple
	Radar	0	0,11	**single**	single	single	simple
47. Silence alerts	ECDIS	0	0,22	**single**	…	single	simple
	Radar	0	0,22	**single**	single	single	simple
48. Record an event	ECDIS	1	0,75	**simple**	…	…	single
49. Set Trial Manoeuvre on	Radar	1	0,88	**simple**	single	single	…