Summary: In the paper the author presents advances in e-Navigation concept. The paper deals with the problem of the formal safety assessment on e-Navigation, especially risk control options. The IMO Correspondence Group on e-Navigation (the Author is a member of this group since 2006) has reviewed the preliminary list of potential e-Navigation solutions and prioritized five potential main solutions, presented the finalized Cost Benefit and Risk Analysis, considered the further development of the detailed ship and shore architecture, further developed the concept of Maritime Service Portfolios and considered the issue of Software Quality Assurance. The solutions have served as the basis for the creation of Risk Control Options (RCOs) that were believed to be tangible and manageable in terms of quantifying the risk reducing effect and the related costs.

Keywords: e-Navigation, Risk Control Options (RCO), Risk Analysis, Formal Safety Assessment (FSA)

1. INTRODUCTION

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

In particular, a preliminary list of nine main categories and practical e-Navigation solutions (shown below) was obtained from NAV 58/WP.6/Rev.1 Annex 2 [7], and formed a reference point for undertaking the FSA:
S1: Improved, harmonized and user-friendly bridge design;
S2: Means for standardized and automated reporting;
S3: Improved reliability, resilience and integrity of bridge equipment and navigation information;
S4: Integration and presentation of available information in graphical displays received via communication equipment;
S5: Information management;
S6: Improved access to relevant information for Search and Rescue (SAR);
S7: Improved reliability, resilience and integrity of bridge equipment and navigation information for shore-based users;
S8: Improved and harmonized shore-based systems and services;
S9: Improved communication of VTS service portfolio.

Regarding the scope of the e-Navigation project and defined as “the harmonised collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment”, and due to the limited timeframe of the project, the IMO Correspondence Group (CG) members were tasked to propose a list of five out of the nine predefined categories of e-Navigation solutions based on three main criteria 12. The criteria for the selection process were described as follow:

1. Seamless transfer of data between various equipment on board;
2. Seamless transfer of electronic exchange of information/data between ship-shore, shore-ship, inter-shore, intra-shore communications, and ship-ship;
3. The work should be based on systems that are already in place (according to the already adopted IMO’s e-Navigation strategy [4]) and development of potential futuristic carriage requirements should therefore be strictly limited.

The result of the exercise is presented in Table 1. “X” marks the categories of solutions chosen by the different countries.

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Based on the majority principle the following categories of solutions were thus retained for the FSA [9]:

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

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

Based on the sub-solutions from these five retained categories of solutions, seven Risk Control Options for the FSA were created by the FSA team [1]. Sub-solutions where combined serving as the basis for the final seven RCOs, irrespective of the solution categories from which they originated. In other words, sub-solutions from different solution categories have been joined into the same RCO where appropriate with regards to the FSA, and not all aspects of all sub-solutions are necessarily covered as part of a RCO. The solutions served as the basis for the creation of RCOs that were believed to be tangible and manageable in terms of quantifying the risk reducing effect and the related costs.

All Risk Control Options are created and assessed with regards to new builds only. Additional positive consequences for the existing fleet are thus not quantified in this report. The process resulting in the final seven RCOs is illustrated in Fig. 1.

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

2. DESCRIPTION OF RISK CONTROL OPTIONS

Based on the scope of e-Navigation, the five main prioritized categories of solutions in Table 1, the prioritized sub-solutions (NAV 58/WP.6/Rev.1 Annex 2) [7], and the
solution’s relevance towards identified risks, the following risk control options (RCOs) are defined. Please note that even though the RCOs are based on the 5 prioritized categorise of solutions, not all sub solutions as per [7], are necessarily covered by the RCOs. The RCOs have been defined with the core of e-Navigation in mind and RCOs: 1, 2, 3, 5 and 7 addresses the workability and practical use of information/data on board and therefore improves the navigators’ ability to safely navigate the ship. RCOs: 4 and 6 addresses the efficient transfer of marine information/data between appropriate users and thus lowering the burden of reporting and making relevant information for navigation available.

2.1. INTEGRATION OF NAVIGATION INFORMATION AND EQUIPMENT INCLUDING IMPROVED SOFTWARE QUALITY ASSURANCE

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

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

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

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

RCO as used for basis for cost / benefit assessment
The purpose of integrating navigation information and equipment is to provide integrated and augmented functions to the navigator, i.e. an improved basis for navigational decision-making. In order to assess effects and costs, RCO 1 is made tangible by basing it on Integrated Navigation Systems (INS) as described in IMO resolution MSC.252(83) in [3]. Other technologies and solutions that fulfil the RCO are thus not excluded, but are not quantified in terms of costs and effects. The following elements (taken from the INS standard) have been chosen to represent RCO 1:
• **Task: Route planning and monitoring**
  - The INS should provide the route planning and monitoring functions and data as specified in Module A and B in the ECDIS performance standards;
  - Having the route check against hazards based on the planned minimum under keel clearance as specified by the mariner;
  - Overlaying radar video data on the chart to indicate navigational objects, restraints and hazards to own ship in order to allow position monitoring evaluation and object identification;
  - Determination of deviations between set values and actual values for measured under-keel clearance;
  - The alphanumeric display to present values of Latitude, Longitude, heading, COG, SOG, STW, under-keel clearance, ROT (measured or derived from change of heading);

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

• **Task: Navigation control data**
  For manual control of the ship’s primary movement the INS navigation control display should allow at least to display the following information:
  - under keel clearance (UKC) and UKC profile, STW, SOG, COG, position, heading, ROT (measured or derived from change of heading), rudder angle, propulsion data,
  - set and drift, wind direction and speed (true and/or relative selectable by the operator), if available,
  - the active mode of steering or speed control,
  - time and distance to wheel-over or to the next waypoint,
  - safety related messages e.g., AIS safety-related and binary messages, Navtex, SafetyNet or other GMDSS information. Binary messages or other machine readable data received via communication equipment should be presented in its relevant geographical context using standard symbology;

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

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

- **Redundancy of important equipment**
  - Adequate back-up arrangements should be provided to ensure safe navigation in case of a failure within the INS;
  - The failure of a single task station should not result in the loss of a function mandated by the carriage requirements of SOLAS;
  - In case of a breakdown of one task station, at least one task station should be able to take over the tasks;
  - The failure or loss of one hardware component of the INS should not result in the loss of any one of the INS tasks;

- **Software testing**
  - It is believed that increased focus and requirements to software testing will increase the reliability of the INS bridge system;
  - The following elements are included:
    - follow up of software development during system design at manufacturer by 3rd party in order to ensure quality in software development;
    - extensive testing of INS system with testing of error modes and failures of single components to ensure performance.

As a basis for comparison, vessels are thus assumed to have either a bridge including the above mentioned, or a bridge complying only with the minimum requirements in SOLAS chapter 5. This obviously differs from the situation on board most vessels today, where the extent of integration will be somewhere in between this. However, in the context of this report and the e-Navigation project, the results are believed to be indicative.

### 2.2. BRIDGE ALERT MANAGEMENT

**Background driving force**

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

**Current situation**

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

**RCO as used for basis for cost / benefit assessment**

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

It is suggested to implement an alert management system as described in [5]. A central alert management Human Machine Interface (HMI) is envisaged to support the bridge team in the immediate identification of any abnormal situation, of the source and reason for the abnormal situation and support the bridge team in its decisions for the necessary actions to be taken.

The performance standards in IMO resolution MSC.252(83) [3] specify a central alert management HMI to support the bridge team in the immediate identification of any abnormal situation, of the source and reason for the abnormal situation and support the bridge team in its decisions for the necessary actions to be taken. The alert management architecture and the acknowledgement concept specified, avoid unnecessary distraction of the bridge team by redundant and superfluous audible and visual alarm announcements and reduces the cognitive load on the operator by minimizing the information presented to which is necessary to assess the situation.

For this system to be effective at reducing distractions to the safe navigation of the ship, all audible alarms on the bridge, regardless of system it is associated with, should be included. The base for comparison is a bridge system with no form of alert management between systems, and the specific requirements for the alert management system is:

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

2.3. STANDARDISED MODE(S) FOR NAVIGATION EQUIPMENT

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

**Background driving force**

Safe navigation relies on the ability of key personnel to easily operate navigational equipment as well as comprehend the information that is presented to them. This will not always be the case when someone is new to a particular setup. Lack of familiarity with bridge equipment and/or slow response due to not finding correct information/control/alarm is thus considered to adversely affect safe navigation. Standard modes or default display configurations are envisaged for relevant navigational equipment. Such standard modes should be selectable at the task station and would reset presentation and settings of
information to provide a standardized and common display familiar to all stakeholders. The standard mode should be accessible by a simple operator action.

**Current situation**

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

**RCO as used for basis for cost / benefit assessment**

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

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

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

It is recognized that the terms S-mode and default mode have certain meanings and implications from earlier discussions concerning the same theme [6]. For the purposes of this RCO standard mode is limited to the points described above.

### 2.4. AUTOMATED AND STANDARDISED SHIP-SHORE REPORTING

**Background driving force**

A potential for reducing workload due to filling out and delivering reportable information is identified. Forms are usually manually filled out and sent individually to each authority requesting the information. Compliance with IMO FAL forms normally takes about 2 hours to fill. Thus a significant potential for reduction in paper work exists.

**Current situation**

An investigation undertaken by the MarNIS project [1] of 15 European ports found that around 25 documents had to be sent from the ship, or the ship’s agent, in conjunction with a port call. This does not include documents related to services in port such as cargo on- and off-loading, waste disposal and ordering of supplies, nor documents related to customs clearance of the cargo [11].

The data requested in many of these documents are fully or almost identical. As an example, in one port, four different documents with identical content had to be sent to four different parties. The problem is further increased by different reporting requirements in different countries, and even between ports in the same country. Documents are also often in paper or other non-computer-compatible formats. This requires shore organizations to manually enter the data into their data systems, which is a time-consuming and costly affair [11].

Electronic port clearance of ships is in the process of being a reality [2]. The US has implemented their system (eNOA/D), which all ships above 300 GRT have to use for
in/out clearance in the US [2]. In Europe SafeSeaNet (SSN) is developed as an internet based system. This system is mainly used for exchange of information between different authorities (countries) [2]. The establishment in 2005 of SafeSeaNet Norway as a national ship reporting system was the first step towards simplifying reporting and information flow between ships and shore-based facilities in Norway [1].

**RCO as used for basis for cost / benefit assessment**

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

- The system envisaged would allow bridge crew to edit all reportable information in one interface. The system would integrate relevant on board systems enabling collection of information and data needed for reporting;
- The system should allow for automated digital distribution of required reportable information (single window solution), including both static, dynamic, voyage related and SAR information to authorized authorities, with the least possible intervention required by the ship during and/or before navigation;
- Secure ship-shore data communication would be a prerequisite for an automated reporting solution. In order to reduce the amount of ship-shore data communication, a system for shore distribution to stakeholders is envisaged;
- The system should facilitate information to be entered only once.

### 2.5. IMPROVED RELIABILITY AND RESILIENCE OF ON BOARD PNT SYSTEMS

**Background driving force**

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

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

**Current situation**

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

**RCO as used for basis for cost / benefit assessment**

Provision of resilient PNT data relies on the exploitation of existing, modernized and future radio navigation systems, sensors and services. The proposed PNT concept (NAV 58/INF.5) [8] is an on board system that supports the exploitation of the modernization processes in radio navigation systems (space-based and terrestrial), ship-side sensors and
shore-side services. In order to improve reliability and resilience of position, navigation, and timing data (PNT) an integration of PNT related systems and services is envisioned. PNT data encompasses position, velocity, and time data (PVT) and ship's parameters describing ship's current movement and attitude (e.g. heading, rate of turn).

The PNT concept [13] is an open framework supporting the usage of any sensors, services and data sources improving the accuracy or assessing the integrity of provided PNT data and applied components.

2.6. IMPROVED SHORE-BASED SERVICES

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

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

Background driving force

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

There are several examples on accidents where broadcasted navigational warnings are either missed or disregarding, e.g. the “Tricolor” accident in the English Channel. Because of the location of the sunken vessel, at a point where two lanes combine in the Traffic Separation Scheme (TSS) of the English Channel/Southern part of the North Sea and the fact that “Tricolor” was just completely submerged under water, the wreck was considered as a hazard to navigation. Despite standard radio warnings, three guard ships, and a lighted buoy, the Dutch vessel “Nicola” struck the wreck the next night, and had to be towed free. After this, two additional patrol ships and six more buoys were installed, including one with a Racon warning transponder. However, on 1 January 2003 the loaded Turkish-registered fuel carrier Vicky struck the same wreck; she was later freed by the rising tide.
Secondly, Notice to Mariners (correction of nautical charts) should be received electronically without any delays in the delivery. Distribution via post is time consuming and the ships risk to sail in waters, for which the nautical charts are not up-to-date.

**Current situation**

Shore-based authorities gather and hold a lot of information regarding navigational warnings, incidents, operations, tide, AIS, traffic regulations, chart corrections, meteorological conditions, ice conditions, etc. In Norway, the Norwegian Coastal Administration (NCA) coordinates and sends out approximately 600 navigational warnings within Norwegian waters each year [4].

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

**RCO as used for basis for cost / benefit assessment**

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

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

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

### 2.7. BRIDGE AND WORKSTATION LAYOUT STANDARDISATION

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

**Background driving force**

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

**Current situation**

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

**RCO as used for basis for cost / benefit assessment**

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

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

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

### 3. CONCLUSIONS

The IMO CG prioritized the following five main potential e-navigation solutions: S1: Improved, harmonized and user-friendly bridge design; S2: Means for standardized and automated reporting; S3: Improved reliability, resilience and integrity of bridge equipment and navigation information; S4: Integration and presentation of available information in graphical displays received via communication equipment; and S9: Improved Communication of VTS Service Portfolio.

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

The prioritization should not be seen as a reduction in the ambition level for e-navigation. Remaining solutions will be assigned to a roadmap for future iterations of the e-navigation Strategy Implementation Plan [10].

The solutions have served as the basis for the creation of Risk Control Options (RCOs) that were believed to be tangible and manageable in terms of quantifying the risk reducing effect and the related costs.

The RCOs listed below demonstrate cost-effectiveness according to the IMO FSA criteria: RCO1: Integration of navigation information and equipment including improved software quality assurance; RCO2: Bridge alert management; RCO3: Standardised mode(s) for navigation equipment; RCO4: Automated and standardised ship-shore reporting; RCO5: Improved reliability and resilience of PNT systems; RCO6: Improved shore-based services; RCO7: Bridge and workstation layout standardisation.

Bibliography


ROZWÓJ KONCEPCJI E-NAVIGATION – OPCJE KONTROLI RYZYKA

dokonała wstępnej oceny listy potencjalnych rozwiązań koncepcji e-Navigation i wytypowała priorytetowych pięć potencjalnych rozwiązań głównych, i przedstawiła analizę ryzyka. Rozwiązania te posłużyły jako podstawa do stworzenia opcji kontroli ryzyka (RCOs), które uważa się za namiętne i konkretne w zakresie ilościowego ograniczenia ryzyka i związanych z tym kosztów.

**Słowa kluczowe:** e-Navigation, formalna ocena bezpieczeństwa FSA, ocena ryzyka i zarządzanie bezpieczeństwem, opcje kontroli ryzyka