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Polish Approach to e-Navigation Concept

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ABSTRACT: The advantage of the latest technical development in the field of automation, electronics, telecommunications, informatics, telematics, geomatics and global position fixing techniques, achievement in data storing, processing, analysing, transferring and visualisation should be taken into account and applied to the maritime technology. We should build new E-Navigation era using those new technologies. In the paper the Authors try to discuss the main tasks of the maritime community for the near future in the field of E-Navigation.
The authors believe it is now appropriate to develop a broad strategic vision for incorporating the use of new technologies in a structured way and ensuring that their use is compliant with the various electronic navigational and communication technologies and services that are already available.
The aim is to develop an overarching accurate, safe, secure and cost-effective system with the potential to provide global coverage for vessels of all sizes. Implementation of this new strategic vision might require modifications to working methods and navigational tools, such as inner ship's computer net, charts, bridge display equipment, electronic aids to navigation, communications and shore infrastructure. At this stage, it is difficult to be precise about the full extent of the changes that might be necessary to fully deliver this vision. However, there might need to be changes to a number of regulatory instruments, including the appropriate chapters in the SOLAS Convention (chapters IV and V mainly). This proposal is not in any way intended to conflict with the clear principle, as confirmed in the SOLAS Convention, of the master's authority for the operational safety of the vessel, and in UNCLOS, of freedom of navigation rights.

1 INTRODUCTION

The common objective shared by all the Member States of IMO (International Maritime Organization) is a commitment to deliver safe, secure and efficient shipping on clean oceans. The co-sponsors of this submission believe that IMO now has an opportunity to develop and map out a clear strategic vision for one common integrating and utilizing all the navigational technological tools at our disposal to secure a greater level of safety and incident prevention which will, at the same time, deliver substantial operating efficiencies with resulting commercial benefits, whilst also continuing to respect the freedom of navigation rights.

It is decide to add a new item on E-Navigation to the work programme of the IMO Sub-Committee on Safety of Navigation (NAV) and also to that on Radio-communications and Search and Rescue (COMSAR). The aim should be to develop a strategic vision for the utilization of existing and new navigational tools, in particular electronic and radio-communication tools, in a holistic and systematic manner.

E-Navigation would help reduce navigational accidents, errors and failures by developing standards for an accurate and cost effective system that would make a major contribution to the IMO's agenda.

2 SCOPE OF THE PROPOSAL

The aim is to develop an overarching accurate, secure and cost-effective system with the potential to provide global coverage for vessels of all sizes.

Implementation of this new strategic vision might require modifications to working methods and navigational tools, such as charts, integration of bridge equipment, electronic aids to navigation, communications and shore infrastructure. At this stage, it is difficult to be precise about the full extent of the changes that might be necessary to fully deliver this vision. However, there might need to be changes to a number of regulatory instruments, including the appropriate chapters in the SOLAS Convention. This would therefore entail consideration of the various strands of this policy in the Sub-Committees on Safety of Navigation (NAV) and Radiocommunications and Search and Rescue (COMSAR). This proposal is not in any way intended to conflict with the clear principle, as confirmed in the SOLAS Convention, of the master's authority for the operational safety of the vessel, and in UNCLOS, of freedom of navigation rights.

3 DEFINITION

The E-Navigation Committee of IALA's proposes the following working definition of E-Navigation as a starting point: "E-Navigation is the collection, integration and display of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, safety and security at sea and protection of the marine environment."

Similar point of view is presented by others Authors. According to Basker [Basker, 2005] E-Navigation is the transmission, manipulation and display of navigational information in electronic formats to support port-to-port operations. Its main components will be:

- electronic navigation charts,
- positioning – combined use satellite and terrestrial radionavigation services,
- vessel information – route, heading, manoeuvring parameters and other status items,
- communication – ship to shore, shore to ship and ship to ship,
- integrated displays – on board ship and shore,
- information prioritization and alert capability.

4 AN INITIAL APPROACH TO E-NAVIGATION

E-Navigation is intended to make safe navigation easier and cheaper.

It is needed:

- to minimise navigational errors, incidents and accidents;
- to protect people, vessels, cargoes, marine environment and resources;
- to improve safety and security;
- to reduce costs for shipping and coastal states; and
- to deliver benefits for the commercial shipping industry;
- It can be delivered:
- by using satellite positioning and radio-communication systems;
- by introducing INS/IBS and computer technology on ships;
- by introducing common format for automatic data exchange with shore-based monitoring and intervention capability.

The aim is to develop a strategic vision for E-navigation, to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing system that will contribute to enhanced navigational safety (with all the positive repercussions this will have on maritime safety overall and environmental protection) while simultaneously reducing the burden on the navigator. As the basic technology for such an innovative step is already available, the challenge lies in ensuring the availability of all the other components of the system, including electronic navigational charts, and in using it effectively in order to simplify, to the benefit of the mariner, the display of the occasional local navigational environment. E-navigation would thus incorporate new technologies in a structured way and ensure that their use is compliant with the various navigational communication technologies and services that are already available, providing an overarching, accurate, secure and cost-effective system with the potential to provide global coverage for ships of all sizes.

5 HUMAN ELEMENT

Some observations were made on the human element issues that need to be addressed when developing an E-Navigation strategy:

- man/machine interface (i.e., balance between standardisation and allowing for innovation and development);
- modes of information display/portrayal;

- appropriate communication of situation awareness; and
- equipment should be designed to engage both the bridge team, pilot and VTS operator, maintaining high levels of attention and motivation without causing distraction.

6 KEY ISSUES AND PRIORITIES

Considering the wide range of options and benefits that could become part of E-Navigation, the primary value of E-Navigation is to join the ship's bridge team and sea traffic monitoring teams to create a unified navigation team that would achieve safer navigation through shared information. For full implementation of such a system it would need to be mandatory for SOLAS vessels and scaleable to all users.

It was suggested that before the primary benefits and value-added services could be realised, an architecture comprising three fundamental elements should first be in place. These are:

- Electronic Navigation Chart (ENC) coverage of all navigational areas (WEND - Worldwide Electronic Navigational Chart Database);
- a robust electronic position-fixing system (EPFS), with redundancy; and
- an agreed infrastructure of communications to link ship and shore.

Specifications for these fundamental elements are contained as follow.

6.1 *Hydrographic Data (ENCs)*

A full coverage of ENCs for navigational waters will require considerable effort from the world's hydrographic community. It has further been noted that the existence of proprietary updating software in many ECDIS systems has become a key cost issue when implementing ENC data. It is thought that if, through IMO, an open architecture system could be agreed, this would allow a more competitive environment in the purchase, and maintenance of ECDIS systems thus reducing the overall costs of ENC's and increasing the global rate of acceptance. From the seaman's point of view there is unsolved question of responsibility for correction of information presented by ECDIS and ENC updating.

6.2 *Position Fixing*

Electronic position-fixing systems, which could be integrated into e-navigation, can be divided into Global Navigation Satellite Systems (GNSS), GNSS augmentations, terrestrial radio-navigation systems and non-radio positioning systems. There are two operational GNSS at present (GPS & GLONASS) and two more planned: European - GALILEO and The People's Republic of China - COMPASS. It has long been recognized that GNSS require augmentation to achieve the required integrity for safety of life applications and the accuracy needed for specialized navigation and positioning. Augmentation systems fall into two broad categories: Ground Based (GBAS) and Satellite Based (SBAS). GBAS (IALA) maritime beacon system has been the standard GNSS augmentation system for maritime applications. SBAS is based on two operational (WAAS, EGNOS) and two planned public service (MSAS, GAGAN).

There are many high accuracy, local terrestrial radio-positioning systems provided, mostly on a commercial basis, for specialized applications. However, the only terrestrial radio-navigation system with widespread, regional coverage is Loran-C. The Far East Radio-Navigation System (FERNS) is provided under an international agreement between PRC, Russia, Korea and Japan and extends from the Bering Straits to the South China Sea. Saudi Arabia also has a system, covering its own territory and the Arabian Gulf. Non-Radio Positioning Systems is the Inertial Measuring Unit (IMU), usually integrated with GNSS to enhance it and cope with outages.

The problem of fixing position coordinates for navigational needs considered only in terms of measurement error seems to have already been solved in a global scale. Its realization with higher or lower precision is only a function of the technical solution adopted. Therefore, other, equally important, although often omitted, exploitation parameters of navigation systems become crucial. These are: availability, integrity, continuity and also reliability.

The following is a list of key elements required for e-Navigation position fixing:

- appropriate accuracy, availability, continuity, and integrity (alert limit, time to alarm, integrity risk), already included in IMO Resolution A.915(22);
- adequate redundancy;
- compatibility between systems; and
- appropriate datums (vertical and horizontal).

There is also necessity to develop a unified theory of the some navigational criteria (availability, reliability, continuity, and integrity) under consideration and to determine the relations between them, because [Specht, 2003]:

- reliability and availability refers to different functional structures,
- definition of continuity is ambiguous,

– lack of mathematical connection between availability, reliability and continuity,
– vague procedures and methods of determining each of the criteria,
– measurement of the criteria is based only on statistic analysis of empirical measurement data.

These and others methodological problems should be solving as soon as possible, because all fixing systems characteristics have to be considerate in the same standardized way. The next important problems in implementation position systems to E-navigation are:

– identification of the service provider responsibility (especially for global and wide area positioning systems) for accidents caused by non-operation status,
– to establish international cooperation between GNSS service providers related to others than positioning services (Safety of Live, Commercial, Search and Rescue,…),
– to solve responsibility problem for core navigational system provider and augmentation signal deliverer.

Current GNSS has a common weakness in that they are all subject to accidental or intentional interference. Hence, alternative and independent position fixing capabilities need to be considered. Consideration should be given to independent non-GNSS Electronic Position Fixing System and sensors as a potential component of E-Navigation.

E-Navigation systems should enable the electronic capture of radar ranges, radar and visual bearings, etc. for position fixing.

6.3 *Communications*

The following is a list of key communication aspects required for e-Navigation, relating to both technical and content:

– autonomous acquisition and mode switching (i.e., minimal mariner involvement needed);
– common messaging formats;
– sufficiently robust (e.g., signal strength, resistance to interference);
– adequate security (e.g., encryption);
– sufficient bandwidth (data capacity);
– growth potential;
– automated report generation;
– global coverage (could be achieved with more than one technology); and
– the use of a single language (English), perhaps with other languages permitted as options.

The following communications issues are among those that will require resolution to achieve the above:

– it seems likely that a satellite broadband link will be required to achieve the above requirements, and consideration must be given to how this will be achieved; and
– the question of cost and who pays for the provision of a satellite broadband link must be resolved early in development of E-Navigation.

The standardization and unambiguous interpretation of information plays an essential role in the appropriate accomplishment of navigational information acquisition and exchange processes in the E-Navigation System. The definition of relevant standards will enable unequivocal interpretation of the information. Measures taken to unify the above mentioned standards are aimed at the development of the navigational information ontology. The starting point for the creation of this ontology is an analysis and classification of navigational information accounting for its kind and range. This will allow to sort out the structure of navigational information, thus the availability and exchange of information will be extended.

7 NEED OR COMPELLING NEED

There is a clear need to equip the master of a vessel and those responsible for the safety of shipping ashore with modern proven tools to make marine navigation and communications more reliable and thereby reduce errors - especially those with a potential for loss of life, injury, environmental damage and undue commercial costs. More substantial and widespread benefits for states, shipowners and seafarers can be expected to arise from the increased safety at sea which is the core objective of E-Navigation. According to the United Kingdom’s Marine Accident Investigation Branch, navigational errors and failures have been a significant element in over half of the incidents meriting a full investigation in the last four years.

There are already a great many electronic navigational and communication technologies and services available or in development - such as Automatic Identification System (AIS), Electronic Chart Display and Information Systems (ECDIS), Integrated Bridge Systems/Integrated Navigation Systems (IBS/ INS), Automatic Radar Plotting Aids (ARPA), radio navigation, Long Range Identification and Tracking (LRIT) systems, Vessel Traffic Services (VTS) and the next modified generation of Global Maritime Distress and Safety System (GMDSS) - which can provide automatically the master and those ashore with the necessary information they require.

In addition to reducing navigational errors and failures, these technologies can deliver benefits in areas such as search and rescue, pollution incident response, security and the protection of critical marine resources, such as fishing grounds. They can also offer operational benefits by enabling the capture of advance information on cargo arrival and increased throughput capacity in congested ports, fairways, and waterways, or in poor visibility conditions.

However, if such technological advancement remains uncoordinated, there is a risk that the future development of the global shipping industry will be hampered through lack of standardization on board and on land, incompatibility between vessels, and an increased and unnecessary level of complexity.

By taking a pro-active lead through the development of a strategic vision, IMO also has the opportunity to contribute to improvements in the international organizational structure overseeing marine navigation, improve international co-operation and give guidance to other organizations involved, such as the IHO and IALA and key stakeholders such as equipment designers, suppliers, navigation practitioners, shipowners and the port industry.

Furthermore, the strategy has the potential to contribute positively to the reduction of the burden on all countries, including developing countries, in having to maintain physical aids to navigation. It should also assist separate initiatives such as those currently under consideration in the Facilitation (FAL) Committee e.g. the development of electronic means for the clearance of ships and the submission of information to a single point (the 'Single Window' concept), which are aimed at reducing the range of reporting obligations on the ship-owner and ship master.

8 AN INTEGRATED E-NAVIGATION ACTION PLAN

The co-sponsors of this submission believe that the time is right to develop a coherent E-Navigation policy to embrace the ever-growing and complex set of technological aids which already exist. Delivery of this vision requires a clear, global commitment, articulated through a viable and coherent framework which sets out a migration plan (from where we are to where we want to go) for Governments and industry to achieve a common and consistent format for the use of electronic technologies.

The challenge for IMO is to develop a framework which accommodates and builds on existing systems already furthering the concept of E-Navigation, such as the World Bank-funded Marine Electronic Highway project in the Malacca Straits and the European Union's projects:

ATOMOS IV (Advanced Technology to Optimize Maritime Operational Safety - Intelligent Vessel) and MarNIS (Maritime Navigation and Information Services). The framework must deliver improved navigational safety for maritime Authorities, coastal States and the master of a vessel, without imposing unnecessary burdens on them.

The development of E-Navigation system can include following steps:

1 Identification of the system and theirs subsystems (Integrated Navigation System INS, Integrated Bridge System IBS, shore centers with their specificity), particularly:
   - identification of system architecture and their structures,
   - requirements for defined subsystems and structure,
   - defining the kind and range of navigational information and subsystems interfaces.
2 Developing models of integrated navigation subsystems (INS) and alert management.
3 Developing models of integrated bridge subsystem (IBS).
4 Developing models of shore-based centers subsystems.
5 Developing a model of automated information acquisition and exchange subsystem:
   - elaboration of the concept of automated information acquisition and exchange subsystem,
   - developing of navigational information ontology for the information acquisition and exchange in projected E-Navigation System,
   - analysis and choice of specific formal language for navigational information ontology recording,
   - requirement specification for data security.
6 Integration of modeled subsystems into E-Navigation System.

9 PRACTICAL REALISATION OF E-NAVIGATION SYSTEM

The most important problem during creation of e-navigation concept is concerned with answer to following important questions:

- the communication platform and technical means used for communication, transmission protocols and data encryption;

– structure and basic equipment of shore data navigation support and data processing centre;
– technical structure of ships data exchange system and the presentation format of data within the integrated bridge system.

Due to problems of IBS definition an affords should be made to standardise and define minimal subsystems and modules of Integrated Bridge Systems and such definition will be base for further e-navigation system definition and creation. The IBS system is nowadays the integration of following subsystems: Radar/ARPA, ECDIS/ENC, VDR/S-VDR, Systems of control HAP/CSAAP, Gyrocompass, Autopilot/Trackpilot, Logs, Echo-sounder, GMDSS, SSAS (Ship Security Alert System), External communication, AIS, DGNSS and Inertial and mooring support systems. So many integrated electronic systems and devices under one system will lead to several problems unknown yet on the base of experience with less integrated systems. The following research problems should be then resolved:

– ensuring reliable and redundant communication between marine subsystems with use of fast networks (Ethernet, RS485, CANs) with possible errors considerations;
– definition of models and algorithms of techno-logical used by e-navigation with permission of proper level of navigational safety;
– creating the model of navigational information circulation and presentation on the integrated bridge and shore navigation support centre with use of proposed system;
– definition of model of navigation information exchange with use of satellite communication, VHF, WiFi, Internet or GPRS;
– definition of minimal information set, sufficient for reliable e-navigation system functioning;
– creation of the model of optimal information in all e-navigation subsystems;
– creation of optimal visualization model of naviga-tional data on ship equipped with IBS and for data exchange within e-navigation;
– definition and creation of control and protection model of e-navigation system.

The prediction of possible development of e-navigation system is very difficult but it could be anticipated that the system will be developing in two main directions:

1 integrated system – where information from ships will be send to shore data processing centres and the main decisions about the ship navigation assist will be made onshore;
2 distributed system – based on development of ship intelligent self-organising systems which will be able to exchange the information between the other ships and will be able to process the information and to support the decision of navigators.

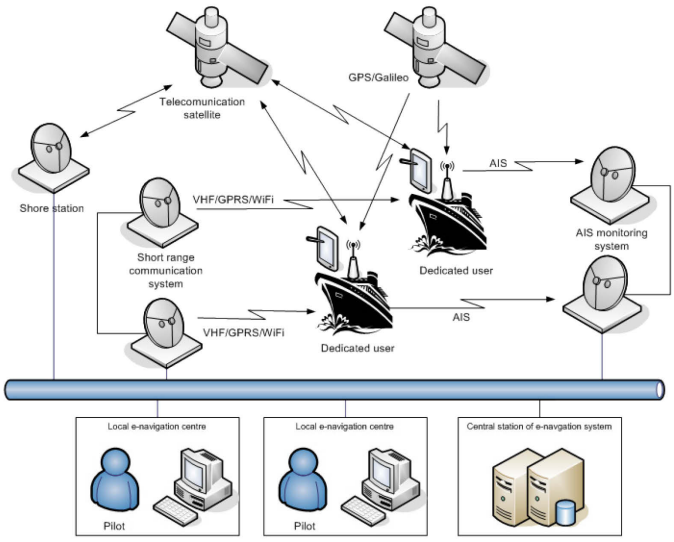

Fig. 1. Final development of E-Navigation system

Most likely the final versions of the e-navigation system will be the combination or above solutions. In more near future the system will be most likely developed in two stages:

1 first stage which will be totally based on existing bridge and communication systems (AIS, ECDIS and voice VHF) only development of shore navigation support centres will be necessary;
2 final stage with dedicated system based on created ship e-navigation support platform where satellite communication will be applied (Fig. 1).

10 ANALYSIS OF THE ISSUES INVOLVED

The key structural components of a safe and comprehensive E-Navigation policy are:

– accurate, comprehensive and regularly up-to-dated Electronic Navigational Charts (ENCs), covering the entire geographical area of a vessel's operation;
– accurate and reliable electronic positioning signals, with "fail-safe" Performance (probably provided through multiple redundancy, e.g. GPS, Galileo, differential transmitters, Loran C and defaulting receivers or onboard inertial navigation devices);
– provision of information on vessel route, course, manoeuvring parameters and other status items (hydrographic data, ship identification data, passenger details, cargo type, security status etc), in electronic format;
– transmission of positional and navigational information: ship-to-shore, shore-to-ship (e.g. by

VTS, Coastguard centres, hydrographic offices) and ship-to-ship;
- accurate, clear, integrated, user friendly display of the above information onboard and ashore (e.g. using IBS or INS);
- information prioritisation and alert capability in risk situations (collision, grounding etc), both onboard and ashore; and
- reliable transmission of distress alerts and maritime safety and security information with reduction of current GMDSS requirements by utilizing newly emerged communication technologies.

11 ISSUES TO BE CONSIDERED

Contemporary technologies already provide the capability to deliver much of the envisaged E-Navigation strategy. The co-sponsors of this document propose that the MSC, and its subsidiary bodies, should focus on creating the right environment to realize the full potential of these navigational technologies. This new work programme item will also need to tackle a wide range of issues (extending beyond what is already being done at IMO), including:

1 increasing the production, coverage and interfaces of ENCs; as well as accelerating the distribution and promotion of commercially viable and globally accepted protocols for ENC production and updating;
2 agreeing standardized controls and common performance standards of bridge E-Navigation systems (including the consideration of such issues as what information needs to be captured, how it should be displayed, how it should be laid out and what should be shared with other vessels and shore-based navigation support centres);
3 agreeing protocols to provide more information to professional and authorized users, whilst preventing unauthorized access to, dissemination of, or intervention in safety or security-critical, real-time data transmissions;
4 developing a shared understanding of the potential benefits and mechanics of shore support and oversight, leading to the design and implementation of shore-based marine E-Navigation support centres covering coastal and, potentially, international waters; and
5 setting out an orderly and safe migration plan for E-Navigation which takes into account the future role of existing navigational tools, in different locations and situations.

12 DO THE BENEFITS JUSTIFY THIS PROPOSED ACTION?

Considerable sums of money are expended by shipowners and operators, on top of the substantial resources deployed by flag, port and coastal State regulators, in seeking to make marine navigation easier and to reduce navigational errors and failures. The E-Navigation strategy would enable the industry to benefit from reducing these costs in the long-term. The co-sponsors of this submission are convinced that if action is not taken soon, the disadvantages of pursuing uncoordinated individual technologies will outweigh the potential benefits that together they could deliver. Focusing resources on the co-ordination of improvements to navigational and communication tools will bring substantial overall safety, security, environmental protection and commercial benefits.

Full analysis of costs will be needed, if and where these occur over and above those that have already been considered by IMO for the range of existing required navigational and communication systems. The co-sponsors recognize that any such new costs may include those related to the administrative burden on contracting States as a consequence of any changes to current national regulations that may be necessary.

Coastal and port States incur substantial expenditure in providing physical aids to navigation, whether funded by the public purse or met by the shipowner through dues levied on port traffic. Although a great deal has been done by coastal and port States in reducing such costs - by automation, by the application of low-maintenance equipment and by the use of renewable energy sources - there will be continued upwards pressure on the cost of servicing aids to navigation networks, given the dependence on skilled labour and fuel. For developing countries especially, the establishment costs for physical aids to navigation or the costs to affect a transfer to the use of renewable energy sources or increased automation can be considerable. A comprehensive and integrated E-Navigation strategy would provide the opportunity for reducing overall costs whilst fully meeting obligations for the safety of navigation.

13 THE CORE OBJECTIVES OF AN INTEGRATED E-NAVIGATION SYSTEM

Using electronic data capture, communication, manipulation and display, to [NAV 53/13/…, 2007]:

Using electronic data capture, communication, processing and presentation, to:

1 facilitate safe and secure navigation of vessels having regard to hydrographic and navigational information and risks (e.g. coastline, seabed topography, fixed and floating structures, meteorological conditions and vessel movements).
2 facilitate vessel traffic observation and management from shore/coastal facilities where appropriate, for example in harbours and approaches.
3 facilitate ship to ship, ship to shore, shore to ship and shore to shore communications, including data exchange as needed to achieve (i and ii).
4 provide opportunities for improving the efficiency of transport and logistics.
5 facilitate the effective operation of distress assistance, search and rescue services and the storage and later use of data for the purposes of traffic and risk analysis and accident investigation.
6 integrate and present information onboard and ashore in a format which, when supported by appropriate training for users, maximises navigational safety benefits and minimises risks of confusion or misinterpretation.
7 facilitate global coverage, consistent standards and mutual compatibility and interoperability of equipment, fitment, systems, operational procedures and symbology, so as to avoid potential conflicts between vessels or between vessels and navigation/traffic management agencies.
8 facilitate (subject to a local risk assessment) a phased migration to e-navigation while maintaining physical aids to navigation and systems where required to ensure continued navigational safety, and having regard to legacy systems, the varying state of development of aids to navigation and systems in different parts of the world and the likely timescales for adoption.
9 demonstrate levels of accuracy, integrity and continuity appropriate to a safety-critical system (under all operating conditions and having regard to risks of malicious or inadvertent interference).
10 be viable as a safety-critical system on a stand-alone basis having regard to both the onboard and ashore applications of e-navigation
11 integrate data and communications systems mandated for other purposes (e.g. security), as far as practicable, so as to minimise the number of 'stand-alone' systems onboard and ashore
12 be scalable, to facilitate fitment and use, by smaller vessels (e.g. fishing, leisure vessels).
13 be capable of development/adaptation to integrate other, value-added functionality, while avoiding any interference with or degradation of core safety-related functions.
14 be capable of development/adaptation to facilitate low cost generational change as new capabilities and functionality are developed.
15 facilitate effective waterway use for different classes of vessels.

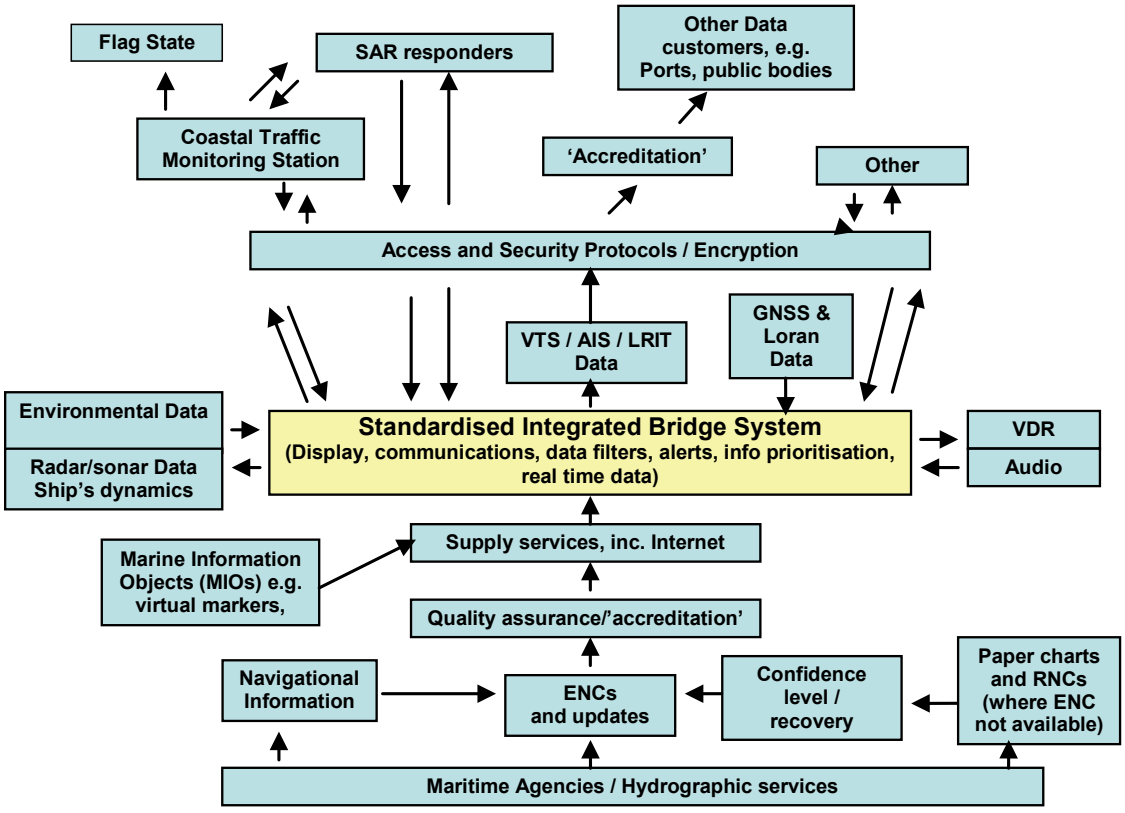

Fig. 2. E-Navigation system architecture [NAV 53/13/…]

14 CONCLUSIONS

The co-sponsors of this submission believe that the time is right to develop a coherent E-Navigation policy to embrace the ever-growing and complex set of technological aids which already exist. Delivery of this vision requires a clear, global commitment, articulated through a viable and coherent framework which sets out a migration plan (from where we are to where we want to go) for Governments and industry to achieve a common and consistent format for the use of electronic technologies.

The challenge for IMO is to develop a framework which accommodates and builds on existing systems already furthering the concept of E-Navigation, such as the World Bank-funded Marine Electronic Highway project in the Malacca Straits and the European Union's projects ATOMOS IV (Advanced Technology to Optimize Maritime Operational Safety - Intelligent Vessel) and MarNIS (Maritime Navigation and Information Services). The frame-work must deliver improved navigational safety for maritime Authorities, coastal States and the master of a vessel, without imposing unnecessary burdens on them.

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