A contribution to IALA's continued development of e-navigation

Results of Australian E-Nav Workshop

Contents

Introduction

The agenda for IALA E-NAV 2 lists the review of the definition of e-navigation (Item 6.1) and the development of a working paper on an "IALA e-navigation vision" (Item 6.4). The aim of this paper is to provide the Committee with potentially helpful information, collected from key Australian maritime stakeholder groups, on the subject of e-navigation.

It is hoped that this information may assist IALA bring increased clarity to the vision and definition of e-navigation. In particular, this paper provides several conclusions that largely stem from the Australian e-navigation workshop, and three key recommendations that are designed to provide achievable milestones leading towards the realisation of e-navigation.

Australian e-navigation workshop

On 22 November the Australian Maritime Safety Authority (AMSA) convened a workshop at which 56 delegates, representing a wide range of maritime organisations and stakeholders from across Australia, considered the topic of e-navigation.

To set the scene and bring delegates up to date on e-navigation and relevant background issues, presentations were given by representatives from AMSA, the Australian Defence Science and Technology Organisation, Airservices Australia, the Royal Australian Navy and several maritime training organisations. Presentation topics included:

- The history and development of e-navigation to date,
- Human factors and situation awareness,
- Modern aviation navigation,
- Navigation in the Royal Australian Navy,
- Navigation training and simulation, and
- Under keel clearance management systems.

Delegates were informed of the potential problem faced by e-navigation surrounding the provision of Electronic Nautical Charts (ENCs). Consequently, the supply of sufficient ENCs to underpin the implementation of e-navigation was not raised as a new challenge for e-navigation, rather it was accepted as one of the already known and understood challenges.

Through syndicate work delegates were asked to consider three focus questions:

Q1. Human Factors and e-navigation. What are the main challenges that you think will need to be faced with regard to Human Factors in the development of e-navigation?

Q2. Technology and e-navigation. With a wide range of existing electronic navigational aids already in use, where do you feel the main challenges lie with regard to ensuring 'standardised and integrated' technology?

Q3. What are the key benefits for the mariner, and the marine industry, that can be gained from developing e-navigation?

This paper provides details of the findings in response to the three focus questions. However, it is worth mentioning at the outset, that the majority of delegates felt that even after discussing e-navigation for a full day the definition of e-navigation lacked clarity. This lack of clarity makes meaningful discussion difficult, and hence it is proposed that improving the definition of e-navigation must be given high priority within IALA and also the IMO e-navigation Correspondence Group. Only when a clear definition of e-navigation is available will strategies be able to be devised to make e-navigation a reality.

Using information collected during the workshop AMSA subsequently created three diagrams, which may assist with the further development of an e-navigation definition and vision (see Annex 5). These diagrams have been provided to the IMO e-navigation Correspondence Group and have been submitted to IMO COMSAR 11.

It is hoped that the Committee might be able to use the information contained in this paper to help further its work on e-navigation.

Human Factors Challenges

Key points stemming from presentations given by the Australian Defence Science and Technology Organisation and Airservices Australia with regard to human factors issues for marine and aviation navigation, and the broader topic of 'situation awareness', were:

- limited ship crew sizes present workload and workflow problems,
- in merchant ships there is often no independent check on actions taken by those with navigation responsibility (unlike aviation),
- in several instances it has been shown that the inappropriate use (or over reliance without checking) of electronic navigation devices has resulted in accidents,
- layers of redundancy are required with electronic navigation systems,
- procedures for use and dealing with abnormal conditions are essential,
- in aviation, after using a route based approach for the past decade or so, there is now a move toward area based navigation, in which pilots define intended routes and navigation is executed with pilot input and ground based air traffic control management,
- there is a need to include 'low end' users (eg. smaller non-SOLAS vessels) as e-navigation is developed,
- for light aircraft in Australia it will be possible to provide future aviation 'e-navigation' equipment on a subsidised basis through a combination of economies of scale in equipment manufacture and cost savings stemming from not recapitalising ground systems such as radar, and it was felt there could maritime parallels for the implementation of e-navigation,
- in the aviation world there are some problems with the process of equipment certification, in that it is inherently expensive and can result in instances where 'round-about' and less than satisfactory solutions are developed to fix problems so as to avoid re-certification processes (again, parallels with the certification of marine navigation systems were seen).

A full list of issues in response to focus question one is at annex 1.

Technology and e-navigation

Key points stemming from presentations made on technology and e-navigation by AMSA, the Royal Australian Navy, OMC International, Pivot Maritime International and the Western Australian Maritime Training Centre were:

- The role of VTS will be affected by e-navigation and VTS will also influence the development of e-navigation,
- The development and adoption by the world's Navies of new technology with applications for enhancing spatial and situational awareness may have benefits for the wider maritime community (eg. night vision and the use of lasers for range finding),
- The Australian Navy's ECDIS equipment has the capability to manually input observed bearings, ranges, horizontal sextant angles and astronomically determined positions, thus enabling navigation without GNSS,
- The Australian Navy has noted that adequate and effective training was essential for the proper use of ECDIS,
- Traditionally, marine navigation has focussed on the problem of horizontal position determination, but the vertical element (draught, tide, depth, soundings, squat, settlement, heave, pitch and roll) is becoming

increasingly important and its management has the potential to realise significant financial benefits,
- E-navigation may be able to take from work undertaken in the development of real-time under keel clearance management systems since these systems often involve the fusion of navigation systems, shore support organisations and real-time communication and exchange of data,
- The role of simulation as a training tool is becoming more important as systems onboard ships become more complex and hi-tech,
- There is an emerging problem in that as more advanced electronic systems are brought into use, many simulation systems are comparatively less able to emulate them,
- Work is needed to ensure simulation systems are fit for purpose, and it may be that standards should be developed for simulation equipment,
- Simulation offers a method of identifying and analysing human factor issues so as to resolve them before navigation systems are installed in ships,
- A holistic approach is needed to introducing technology, including the development of "abnormal condition" procedures and ensuring there is regular training for the handling for "abnormal conditions".

A full list of issues in response to focus question two is at annex 2.

Benefits relating to e-navigation

Workshop delegates saw the following as being the key benefits to be gained from developing e-navigation:

- Increased traffic efficiency, safety, security and reliability
- Standardised procedures, practices, and training
- More efficient vessel reporting
- Overall cost savings
- Access at sea to relevant and real-time information to assist navigation
- To encourage good ergonomic bridge design and a reduction in human factor problems onboard
- Coordinated worldwide cultural change in marine navigation practice
- Environmental benefits
- Improved communication
- Reduction in the number of errors and resulting incidents

This list of benefits aligns well with statements that have been made previously at IALA and IMO in relation to e-navigation.

A full list of identified benefits is contained in annex 3.

Challenges relating to e-navigation

Workshop delegates provided the following comments in relation to some of the challenges perceived to be facing the development of e-navigation:

- Adequate training, both initial and long-term ongoing training, will be very important to the successful implementation of e-navigation.
- It is important that an agreed list of benefits, which will demonstrably outweigh the cost of implementation, is established early on.
- A simple ‘minimum’ requirement for an e-navigation wheelhouse layout will need to be identified and agreed.
- It may be difficult to identify a compelling case for e-navigation, however in the future it will be important to enable choice for mariners [sic. implementation needs to be scalable and based on a minimum standard].
- E-navigation is here today and we don’t need more rules but instead more training (standardised training) is needed. Also, the mariner must be ‘on-side’. Standardisation of bridge layouts and navigation equipment needs to be promoted. Also, e-navigation will need to deliver improved information and communications services.
- The development of e-navigation must be progressed using a holistic approach. It is likely to result in major changes to navigation practice, but there should be commensurate changes in the corresponding underpinning regulations. Marine navigation training organisations will require more information about abnormal e-navigation system conditions (via a database) in order to properly train for all likely abnormal scenarios. Further, onboard e-navigation system procedures will be required [sic. similar to the use of procedures in aviation].
- As technology matures there is a form of automatic or natural standardisation. Present day computers are an example of this phenomenon. This natural process may occur with onboard marine navigation systems. The IMO should consider incorporating an open architecture approach to equipment standards to allow for innovation.
- E-navigation could become the means of navigation, rather than the use of AtoN.
- If e-navigation delivers standardised equipment for mariners, then that is very good and is justification for proceeding with e-navigation. However, there will also need to be an advantage for ship owners, since at present it seems there is not much incentive for ship owners to embrace e-navigation.
- Potential improvements in logistics efficiencies could be a key benefit for ship owners. Another benefit may be reduced insurance premiums. Yet another benefit may be that money saved in the provision of traditional AtoN may be able to be directed to funding installation of onboard e-navigation systems (as was outlined in the case of aviation).
- The basic fundamental inputs for an e-navigation system must be clearly identified.
- An emerging problem is that as the technical complexity of equipment increases there is often no technical/engineering expertise onboard to provide for ongoing operation in the event of system failures. As a result, the development of e-navigation equipment must proceed on the basis that the equipment will be simple to use, maintain and be robust and inherently reliable.

It was noted that standardisation is a double-edged sword in that it is good for ensuring commonality in functionality and layout, but it can also prevent innovation and technological development.

Using a summary of the key human factors and technical challenges facing e-navigation (distilled from annexes 1 and 2), delegates were asked to rank these challenges in order of priority and importance. The results of this exercise are tabulated in annex 4.

From the table in annex 4 it can be seen that training, standards and engaging mariners and meeting their needs were considered the most important challenges. This outcome reflected that although there were few practising mariners at the workshop, the majority had a practical maritime background and so held in high regard the interests and concerns of mariners.

Next came cost of development and also the cost of redesign and retrofitting of equipment, along with issues pertaining to the use of simulation for the training of mariners.

In the middle of the list of challenges are the human factor problems of standardisation and intuitive controls (“knobology”). Next in order of importance are personnel related problems, such as prevailing cultures and the will, or lack of will, to embrace change.

Lower in perceived importance were the issues of scalable application, human factors aspects of automation, backup arrangements, redundancy and cost.

At the very end of the list there is an item on “levels of technical expertise at sea”. This is a peculiarity, since this item could just as easily sit next to training at the top of the list, or maybe alongside the personnel issues in the middle of the list. However, it is more likely that the intent of this item is that poor “levels of technical expertise” was seen as a fact of life, and that it could be adequately mitigated against through regulatory mechanisms, the use of procedures and the provision of appropriate levels of redundancy and system integrity.

e-navigation architecture

Taking into account the comments and information collected at the Australian e-navigation workshop, AMSA subsequently developed a diagram that captures the inputs and outputs of e-navigation (annex 5). To accompany this diagram two further diagrams were created to help explain in more detail the ship and shore e-navigation systems (also in annex 5).

Conclusions

There are several key conclusions that can be drawn from Australia's e-navigation workshop (listed in no particular order):

- (C1). The current definition of e-navigation lacks clarity, without which it is difficult to hold meaningful discussions and the development of strategies to realise e-navigation is problematic. Bringing clarity to the e-navigation vision and its definition will not be an easy task, but it is hoped the diagrams in annex 5 can be of some assistance.

- (C2). Even with the current definition of e-navigation it is clear that a majority support the initiative and can identify tangible benefits that e-navigation has the potential to deliver.

- (C3). Some of the more important issues and problems to solve when developing e-navigation will be in the area of agreeing on standards, providing training, engaging mariners and making sure mariner's needs are addressed.

- (C4). Human factor issues should be a major focus in the development of e-navigation, in terms of solving existing human factors problems, improving navigation situational awareness, and also to help avoid unintentional new human factors problems.

Recommendations

At this early stage the definition and vision of e-navigation are a little unclear, which should not be surprising given the breadth and complexity of e-navigation and all its component parts. Nonetheless, it is important to the ultimate success of e-navigation that some clear, definite and achievable milestones be agreed and worked towards. These milestones should be part of an e-navigation "road map". With this in mind, the following three objectives are recommended to the Committee for consideration, whether to be undertaken by IALA or to be recommended by IALA to either the IMO or IHO, as appropriate:

R1. Communications

Recognising the ever increasing reliance on communications at sea, work should be commenced to define and develop performance standards for "digital global maritime communications" to support the need for communications and data transfer between ships, between ship and shore and between shore maritime organisations. IALA might recommend this initiative to IMO via the IMO e-navigation Correspondence Group.

R2. ECDIS and ENCs

At the centre of shipboard requirements for e-navigation is a capability to use electronic means for position determination, presentation, and for route planning and monitoring. The current e-navigation definition and vision provides sufficient detail to conclude that

ECDIS fuelled with ENCs is the logical tool for these functions. It is therefore recommended that several appropriate and achievable milestones be set with respect to ECDIS and ENCs:

- A mandated ECDIS carriage requirement which is on the agenda for IMO NAV 53, and
- Establish a list of ports for which ENCs should be created covering both the ports and their immediate approaches.

R3. Financial Rationale

Further study should be carried out on the potential economic benefits of e-navigation. Aspects that should be included in this study are: multi-modal transport logistics (i.e. supply chain efficiencies), possible savings in the provision of AtoN, reduction of ship-sourced pollution (due to better scheduling), reduced maritime incidents (including possible insurance premium reductions), and the reduced costs of responding to such incidents. Currently, the economic driver for proceeding with e-navigation appears to be based on intuition, or "gut feel", which in all likelihood is correct. However, some credible study in this area will make advancing e-navigation significantly easier.

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Annex 1

Focus Question 1

Human Factors and e-navigation. What are the main challenges that you think will need to be faced with regards to Human Factors in the development of e-navigation?

- Fully engage mariners in the development of e-navigation concept and solution
- Training/re-training of mariners-emphasis on systems being tools to aid navigation and mariners always need to 'look out the window'
- Cost of re-design/integration of bridge systems
- Ensuring the potential benefits drive the technology solution not vice versa
- Shared authority/control requires shared responsibility being accepted
- Agreement on standards (technical) may take considerable time
- Current big gap in level and extent of technology onboard different types of vessels – should there be a minimum level?
- Caution should be exercised in adopting/mirroring aviation navigation approaches
- Relevance and applicability to the mariner. Produces information that mariners require
- Continuity between mariners. Variation in needs due to; generation, capability, motivation and attitude
- Human resources available to be recruited into the commercial marine industry
- The untrained (recreational) mariner
- Ergonomics standards in bridge design
- The need to keep the individual as the 'master' of the navigation process
- The ability of technology to monitor and raise alarms, as necessary
- The fact that most of the time there is a single navigator and thus there is no 'challenge or response'
- No standard for equipment layout
- Cultural differences where people will not accept data output and thus not act
- Will mariners have required levels of psychometric aptitude/suitability to use the systems?
- Will mariners be conversant/familiar with advanced technologies?
- Requirements for standardised and international training syllabuses
- Need to define/regulate currency and competency levels
- Need to consider type training/systems certification
- Need to maintain certain levels of standardised equipment/procedures/interfaces
- Organisational issues
- Increased demands on finite resources/fatigue
- Increased automation causes reduced job satisfaction and skill levels
- Attitudinal barriers to change i.e. old salts
- Culture of maritime industry, training in the maritime industry, and the long history of maritime industry brings excessive baggage (unlike the aviation industry)
- No integrated/holistic approach to equipment building and equipment installation: this occurs without real regard to end user needs

- Perception (real or otherwise) that aviation driver for human factor management is not relevant to maritime industry because immediate impact on human life not as obvious
- Industry culture/perception
- Multiple suppliers
- How do we achieve standardisation in a reasonable/useful timeframe
- How do the systems actually fit in with the mariner and his/her needs?
- Training – maintaining competency over time
- Training/education
- Presentation of data – uniformity
- Standardisation of equipment
- Procedures – to assist situational awareness
- Indemnity – financial limitations
- Electronic equipment back up - the human being isn't [presently backed up]
- Design, including bridge design
- E-navigation to provide real life use of alternate (back up) layers of systems e.g. manual observation of bearings/ranges and they have to correlate/check automatic position systems
- Utilise a HFI [Human Factors Integration] approach to identify and eliminate HF issues. This will lead to an appropriate training regime that needs to be established. Range of responsibilities managed from the bridge can be large – prioritisation is required.
- Automation feedback is poor. Need to design with a more user-focused approach. Need to test systems to monitor whether they meet expectations. The system needs to provide the right feedback to the mariner – when the mariner needs it. Also, feedback needs to be provided on how the automation is doing.

Focus Question 2

Technology and e-navigation. With a wide range of existing electronic navigational aids already in use, where do you feel the main challenges lie with regards to ensuring ‘standardised and integrated’ technology?

- There is no “push” in Industry to achieve a standard approach to systems and technology.
- To achieve standardisation it must be Government initiated and led.
- It is essential to determine what are the requirements for e-navigation right now, and going forward.
- Probably more difficult is to determine what is dropped.
- E-navigation must consider that control elements are not all necessarily in the wheelhouse/chartroom – the engine room, steering flat, etc.
- IMO to identify standards and events for simulations
- Integration of old with new
- Standard and regulations at IMO and SOLAS level
- Interfacing with different technologies and class/age of vessels
- Training standards to be set
- Dedicated frequency or communication protocols
- Customising/adapting existing technologies/equipment
- Technology development needs to be more user driven
- Functional requirements approach is required
- Intuitive controls based on fundamental principles
- Cost impacts must balance the benefits
- Provide/expose incentives to manufacturers
- Greater emphasis on type training/certification
- Retrain/preserve traditional functions to ensure familiarity during transition
- Common vocabulary is required
- There are too many variants
- Ensure standard keeps abreast of emerging technology and application
- Understanding and accepting that e-navigation does not apply to all sectors of industry
- Making it into a holistic system architecture
- Systems should be able to plug and play with each other (rock solid interface standards – open architecture)
- Installation standards and certification
- Trapping of technical standards under “port state”
- Cost/investments
- Training
- Minimum/base level required for e-navigation (i.e. what is the enhanced navigation that we want?)
- E-training – costs involved versus time to absorb
- Lack of international regulation on the standardisation of systems and equipment and specifications
- High range of operational standards (equipment and technology)

- The challenge of the will to change
- Cost to the operators as against benefit
- System redundancy required and plug and play capability/interoperability essential
- Data quality maintenance/verification
- Limitations of simulation technology
- Development/agreement of standards and timeframe for developing
- Cost of systems integration

Focus Question 3

What are the key benefits for the mariner, and the marine industry, that can be gained from developing e-navigation?

- Future proofing – preparing for increased traffic densities (safety and efficiency) – allows higher workload safety
- Standardised procedures and practices (defined by the HMI) – clear information for ship handlers and ship managers – recorded data for feedback on BRM competence
- Creation of standardised knowledge base – handling multiple regulatory regimes and reporting systems for example
- Efficient ship operation – traffic scheduling for ports, pilotage waters etc – management of ship movements for peak efficiency – optimise human actions in the system (avoid both panic and boredom)
- If standardisation of bridge control layout can be achieved it would simplify the training and auditing of personnel.
- The increased use of text is a positive to assist 'non-English' speakers
- The opportunity to lessen the overall costs involved in incorporation of e-navigation
- Potential commonality of bridge systems/standardisation – benefits – reduce training costs and improve safety
- Information redundancy and increased reliability (co-ordinated systems)
- Common training at base level
- Provide real-time, up to date information on any matter that may affect a ship's intended plan.
- Customised information specific to a ship's area [of operation]. The avoidance of information overload – e.g. location specific, restricted areas due to vessel type, active restricted areas, etc
- All navigation information formed into one unit
- Could encourage good ergonomic design [onboard]
- Will only be of benefit if improves safety
- Internal and external means of sharing initial safety information quickly
- Real-time navigation
- Safety improvements
- Access to reliable and relevant information as and when required
- More efficient maritime operations
- A significant focus on navigation that could promote a unified cultural change in marine navigation
- Potential to standardise primary positioning systems and ergonomic layout
- Security
- Improved environmental protection
- Reduction in risks
- Cost benefits that outweigh investment
- More accessible info/data to assist onboard decision making
- More timely decision making on bridge which improves navigation safety

- Greater standardisation within industry
- Reduced publications on bridge, improved communications from ashore
- Savings, efficiency both ship and shore
- Better communications between state and international vessels
- Simplify jobs for mariner
- Provide useful (additional) information to mariner and shore (trends, take advantage of currents etc)
- Save lives, [reduce] injuries
- Environmental benefits
- Fill the need that created the concept for e-navigation
- No mariners on some journeys
- Reduces probability of navigational errors, incidents and accidents
- Enhance efficiency by eliminating on-board pilotage
- Improves efficiency in delivery of cargo
- With sufficiently enhanced onboard and shore-based navigation, ships would no longer need a seaman specialist as master
- Ultimate will be autonomous ship!

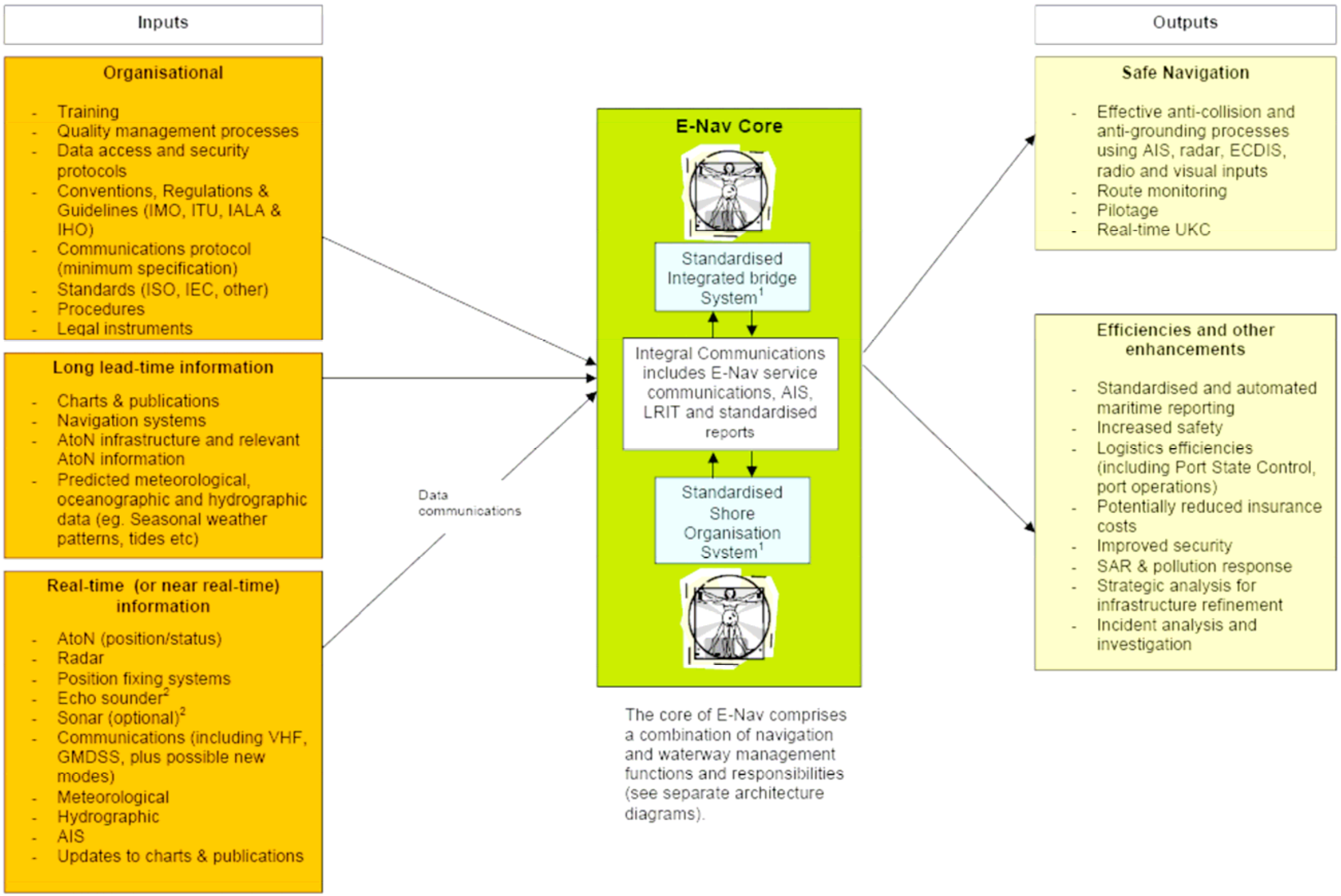
Annex 4

Ranked tabular listing of human factors and technical challenges facing the development of e-navigation

No.	Challenge	Type	Priority		
			High	Medium	Low
1	Retraining and ongoing training to ensure familiarity and competence	HF	9	1	0
2	Training and re-training of mariners	HF	8	2	
3	Agreement on standards (functional, technical)	REG	9	0	0
4	Fully engage mariners in the development of e-navigation concept and solution	HF	8	1	0
5	Requirements for international standards	REG	8	0	0
6	Ensuring new e-navigation systems fit the mariner's needs	HF	7	0	1
7	Ensuring that e-navigation technology development is user driven	HF	6	2	0
8	Cost of development / implementation	TECH	6	2	0
9	Use of simulation in training, and ensuring simulators are of a suitable standard	HF & TECH	5	3	1
10	Cost of re-design/integration of bridge systems	FIN	5	3	1
11	Reducing the many equipment variables that currently exist (there are too many variants)	HF, TECH & REG	5	3	0
12	Use of simulators to assist in developing e-navigation, to help achieve standardisation and overcome human factors problems	HF	4	4	1
13	Developing intuitive controls based on fundamental principles	HF	5	2	1
14	Continuity across the mariner community (variations in needs due to, generation, capability, motivation and attitude)	HF	2	7	0
15	Providing a holistic response to e-navigation, integrating old and new equipment, and taking account of personnel issues	TECH & HF	3	5	0
16	Increased demands on finite resources and mariner fatigue	HF	3	4	1
17	The challenge and the will to change (change management)	REG & HF	3	3	2
18	Defining sectors where e-navigation applies / does not apply (understanding and accepting that e-navigation will apply differently to different classes of vessels)	REG & HF	2	4	1
19	Increased automation can often cause reduced job satisfaction and skill levels - this will need to be avoided	HF	1	6	0
20	Electronic equipment back up - at present the human being at sea is often a sole operator	HF	0	5	1
21	System redundancy, reliability, continuity of service	TECH	2	1	0
22	Cost effect/accountability/funding	FIN	1	0	0
23	Ensuring the necessary levels of technical expertise at sea	REG	1	0	0

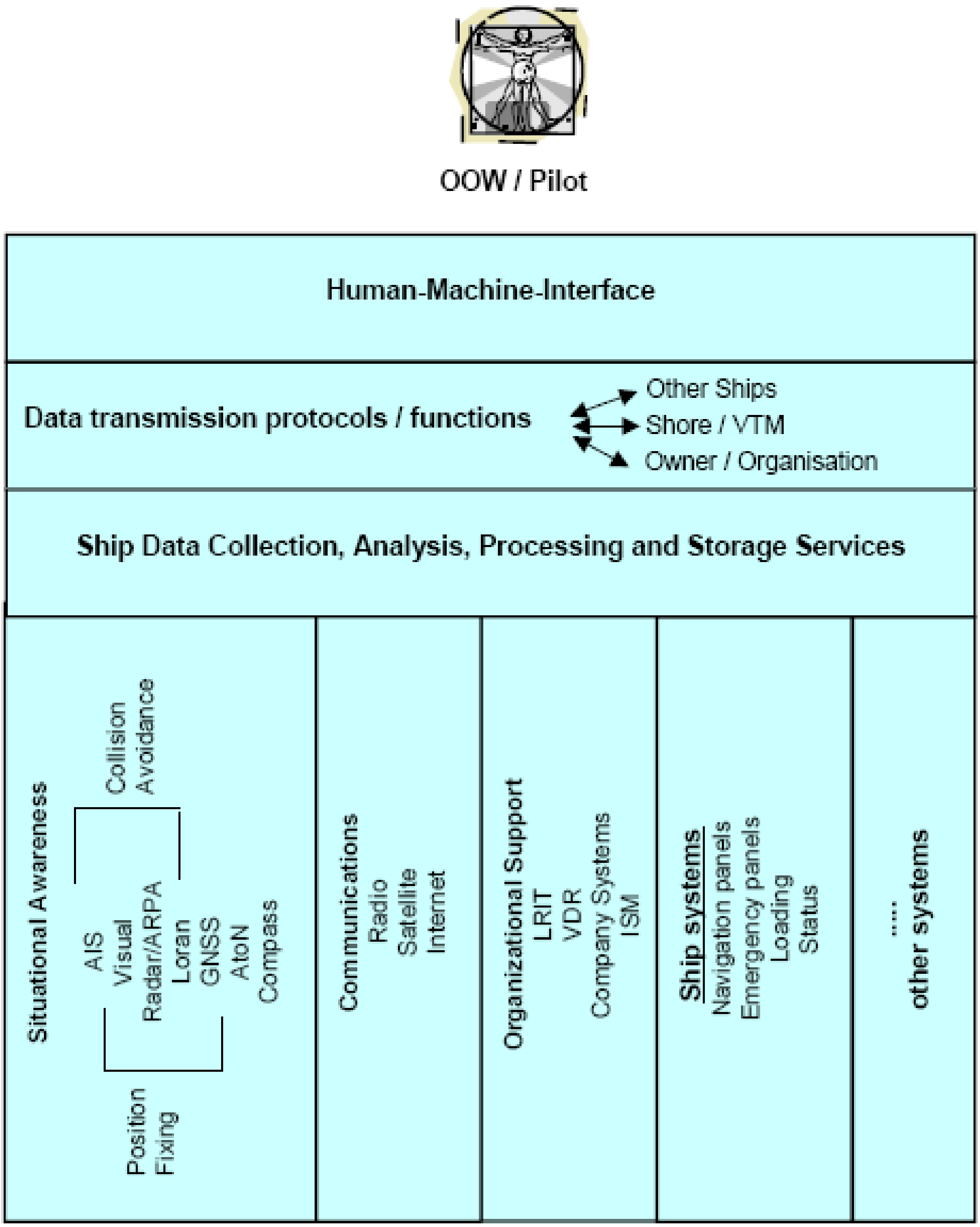
HF – Human Factors   REG – Regulatory   TECH – Technical   FIN – Financial (cost related)
Ranking based on High = 3, Medium = 2 & Low = 1

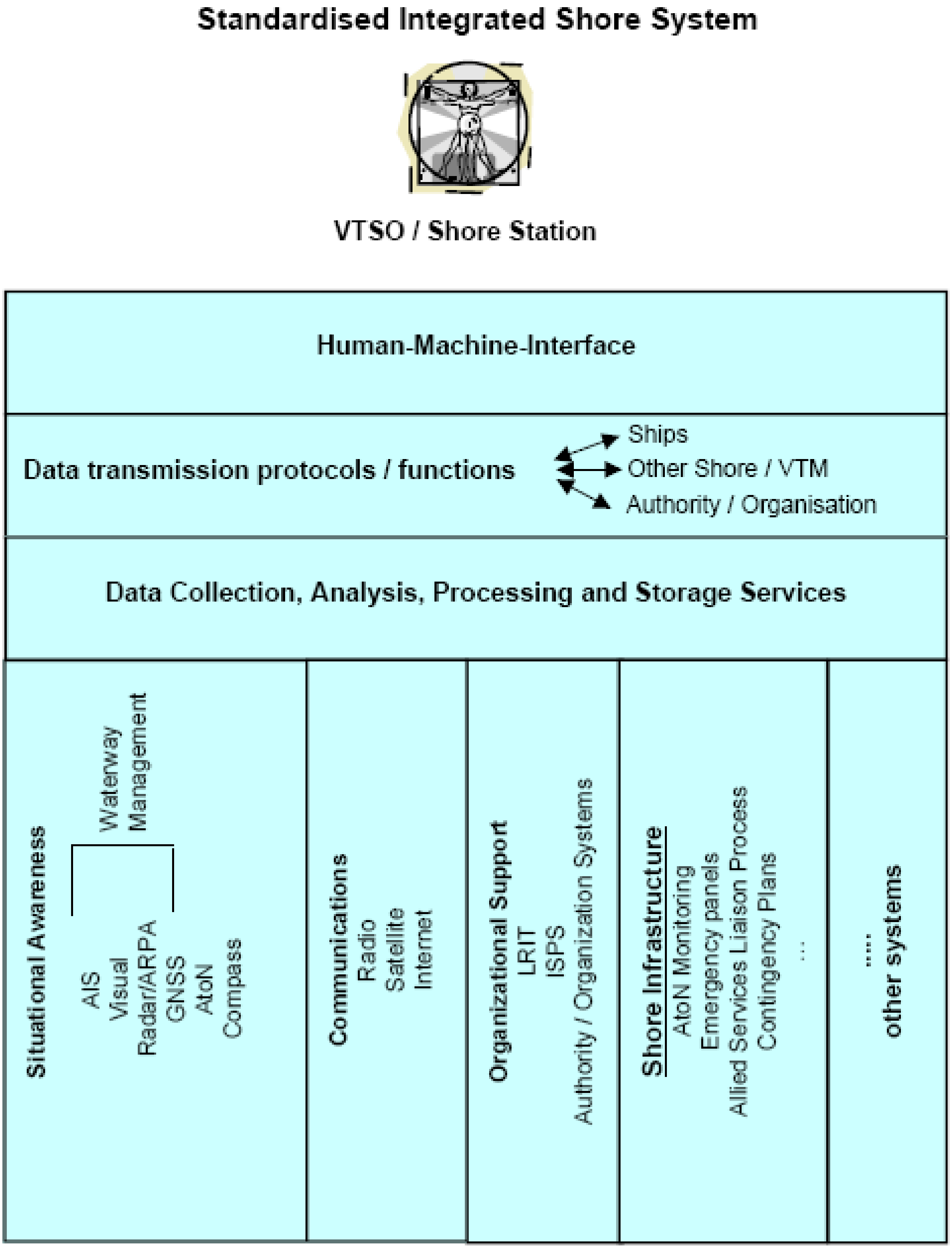
A Descriptive Model for E-Navigation



1. Systems to have appropriate redundancy, backup and individual integrity
2. Ship specific

Standardised Integrated Bridge System




Standardised Integrated Shore System
VTSO / Shore Station
Human-Machine-Interface
Data transmission protocols / functions
Ships
Other Shore / VTM
Authority / Organisation
Data Collection, Analysis, Processing and Storage Services
Situational Awareness
AIS
Visual
Radar/ARPA
GNSS
AtoN
Compass
Waterway Management
Communications
Radio
Satellite
Internet
Organizational Support
LRIT
ISPS
Authority / Organization Systems
Shore Infrastructure
AtoN Monitoring
Emergency panels
Allied Services Liaison Process
Contingency Plans
...
....
other systems