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IAMU 2010 Research Project
(No. 2010-1)

e-Navigation Course : Research and Development

By

California Maritime Academy (CMA)

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Abstract: *The International Maritime Organization has defined e-Navigation as the ". . . integration, exchange, presentation and analysis of marine information . . ."*[1] *While this definition has often been used, it is little understood from either an operational or functional perspective. Moreover, there is little research being done to help understand the complexities of the concept. A better understanding of the overall concept, and a more precisely defined set of operational constructs would help to inform maritime educators and users alike. This lack of understanding stems, in part, from the overly broad definition of e-Navigation, from the lack of training standards that recognize the need to incorporate the new technology into bridge resource management (BRM) techniques, and from the reliance on old, more traditional methods of educating the mariner.*

This project was conducted from September-December 2010 and had four primary research objectives: 1) to examine the level of stakeholders' understanding of the definition of e-Navigation as it is currently proposed by the International Maritime Organization; 2) to develop Maritime Education and Training and simulation pedagogies dealing with marine navigation equipment and methods identified as integral components of e-Navigation; 3) to develop an appropriate course syllabus for future e-Navigation courses; and 4) to continue with simulation pilot studies (this work was begun in 2009) to investigate features and uses for prototype e-Navigation systems involving Head-Up Display (HUD).

Keywords: *e-Navigation, Head-Up Display, Full-Mission Simulator*

1. Introduction

Notification of the acceptance of our grant proposal for an e-Navigation course and Head-Up Display (HUD) development was not received until 3 August 2010. Course development began immediately as the course was due to begin 13 September 2010. A draft syllabus was drawn up and a time for simulator use was secured. Our research partner, Dr. Eric Holder of Anacapa Sciences, Inc. was notified. Jim Hefner, the computer programmer who worked on the HUD program in the first e-Navigation course run during the spring semester, was contracted to begin work on continuing to develop the program for use in the new course. The California Maritime Academy (CMA) simulator director, Captain Michael Noonan, assisted in researching the hardware needed for running the HUD mockup prototype in four of the eight part-task simulators (IBEST) to be used for the lab portions of the course. The CMA simulation department then purchased the required equipment, to be rented out to the grant project for the duration of the course.

2. Developing the e-Navigation Course

2.1 Course Structure and Status

The course design called for a three hour per week, fourteen week course beginning in mid-September and finishing in mid-December 2010. This is the normal duration for the fall semester at Cal Maritime. The course was divided into lecture and lab components. Wherever possible, the topics covered in the lecture were the same examined during the lab simulations. The class was held once a week on Monday evening 1630-2000 with a 30-minute break for dinner. As the course was still classified as experimental (assigned a NAU395 course number as a special topics class), students received 2 Units of course credit on a Credit/No Credit instead of graded basis. After consultation with the academic dean, and due to the importance assigned to the course by academic administration, students who successfully passed the e-Navigation course were exempted from another course in their major, NAU400 Advanced Maritime Topics.

2.2 Literature Search

There are no e-Navigation textbooks as yet in existence. The concept of e-Navigation is less than five years old and is still being developed. Most of the information available on e-Navigation is from official sources like the International Maritime Organization (IMO), the International Association of Lighthouse Authorities (IALA), and in the United States, the U.S. Coast Guard. The IMO is the worldwide organization primarily responsible for the development of e-Navigation. See the appendix at the end of this report for a complete listing of background information sources used for this project.

2.3 Lectures

The lecture component of the course was designed to make up approximately 1/3 of the total course hours. The selection of topics to be covered each week generally followed the course syllabus but there were modifications as the course progressed through the semester. A brief list of topics included:

- The e-Navigation concept
- Bridge Team Management and Bridge Resource Management in the integrated age
- What is a Head-Up Display (HUD)?
- The marine HUD compared to the aviation and automobile HUD
- High Speed Vessels (HSV) and specialty vessels in e-Navigation

- With e-Navigation, should Vessel Traffic Services (VTS) be mandatory?
- Use of HUDs in hopper dredging
- North-Up verses Head-Up Displays
- 3D charting research of Dr. Thomas Porathe
- The importance of GPS to e-Navigation
- The EfficienSea Project
- ECDIS and e-Navigation
- AIS and e-Navigation
- ARVCOP (Augmented Reality Visualization of the Common Operational Picture)

2.4 Exams

For nine of the fourteen weeks, students were given short exams at the beginning of each class. The questions covered topics discussed in lecture or experienced in simulations of the previous week or posted as reading material on the online web portal for the course called Moodle. The results of those exams are presented in Section 6.2 below.

2.5 Laboratory Simulations

Two hours of simulation laboratory were included every week except the one in which students gave presentations on various e-Navigation topics. These were simulations designed specifically for the e-Navigation course. Many of the topics discussed in lecture such as BTM and BRM, use of marine HUDs in different situations, conditions and vessels, North-Up vs. Head-Up Displays, HSV, and different types of VTS systems were explored by students in an interactive manner though simulation. A laboratory instruction sheet was handed out to students before each simulation specifying the purpose of the simulation and any special instructions that were to be followed. Lab topics included:

- Baseline measurement of bridge team navigational performance
- Proper utilization of BTM and BRM as required for e-Navigation
- Comparison of performance with and without HUD in a piloting situation
- VTS procedures in an advisory VTS system
- Examine the use of HUD in a slow speed, high level of accuracy situation (hopper dredger)
- Evaluate new Augmented Reality (AR) HUD features (horizon line, virtual nav aids, areas)
- VTS procedures in a mandatory, vessel controlled VTS system
- Evaluate new AR HUD feature showing AIS targets
- Compare navigation using Head-Up vs. North-Up orientation in radar and ECDIS displays

Needless to say, the simulation component of the course was by far the most popular with all the students. As a result, student enthusiasm was extremely high throughout the duration of the course and absenteeism the lowest I have ever seen in ten years of teaching. This is particularly telling since the course was conducted after normal class hours.

With my former research partner and mentor Dr. James Buckley, I have conducted studies on the use of simulation in Maritime Education and Training (MET). The results or trends of all these studies (see appendix) seem to indicate that, 1) simulation is a very effective way to train younger students today, and 2) simulation should be introduced earlier into the MET curriculum than it has been hitherto. Nothing that I witnessed in the lab simulations throughout the e-Navigation course has dispelled these opinions. Approximately 50% of the student participants in this course were freshmen. Longitudinal studies of these students' educational performance will be undertaken to supply quantitative data to back up this anecdotal evidence on the efficacy of simulation in MET.

The simulator software retains a record of each ownship behavior throughout each scenario run. This data will remain accessible for years to researchers wishing to make a quantitative study of student performance in each scenario. This will become especially important later on as we compare performance over time both with and without the use of HUD as described in Part 3 below.

2.6 Surveys

Many lab sessions required students to fill out pre-simulation and/or post-simulation surveys. These contained questions and answers in standard survey formats, such as Likert, semantic differential, and other appropriate formats for rating, comparison and quantification. Any lab session that utilized the HUD mockup had one or more surveys associated with it. Our research partner Dr. Eric Holder, a human factors specialist, wrote the surveys that concerned student perceptions of the HUD. The principal investigator drew up other surveys on student perceptions of their navigational performance. Preliminary survey results and selected student comments are discussed in Part 6 below.

3. Development of the Head-Up Display Mockup

3.1 Waypoint Line Drawer Programming

The operating program used for the HUD mockup was written in Adobe Air. Screenshots of the Graphical User Interface (GUI) and the Augmented Reality Display screen appear below.

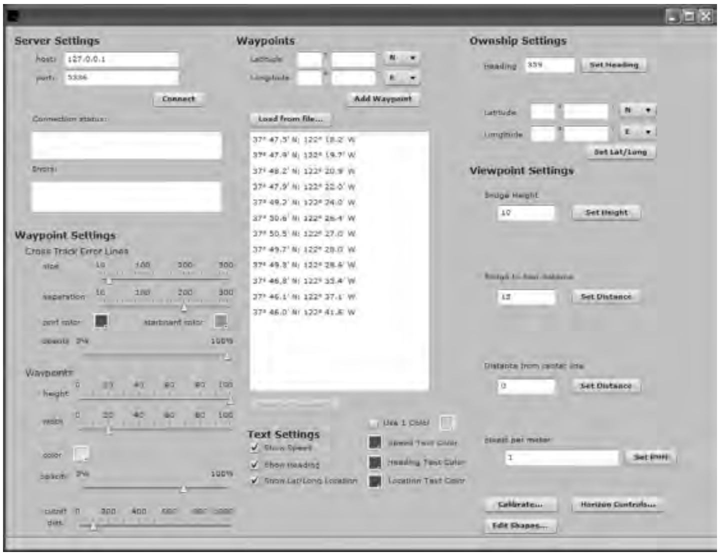

Fig. 1. HUD Administrative Interface

Fig. 2. HUD Augmented Reality Projection

3.2 Equipment Setup

The equipment setup for the HUD mockup used in the simulators is presented in the diagram below.

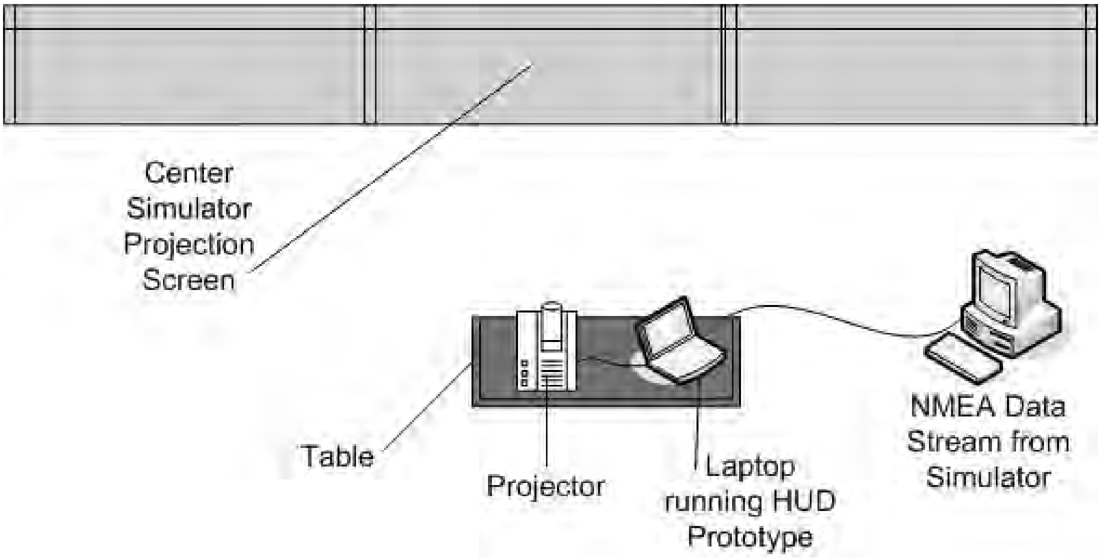

Fig.3. HUD Mockup Setup in Simulator

The (4) projectors used were type Optoma PK301. Each projector was connected to the Dell laptop computer via VGA connection. Also connected to the laptop was a SeaLINK +4 DB9 Serial Interface Adapter that translated the simulated NMEA data output from the Transas simulator running NT Pro 5000 software. A standard null modem cable connected the serial adapter to one of the simulator computers driving the radar display.

3.3 HUD Equipment Performance

The HUD mockup equipment often proved somewhat time-consuming and difficult to setup properly in the very limited time available after prior class commitments. Several labs started late or had to be conducted without the use of one or more of the HUD setups. The projectors were disappointing in their maximum luminosity and most simulations had to be run in dusk or night conditions in order for the AR features to show up well enough on the simulator forward visual channel screen. Nevertheless, most equipment shortcomings were dealt with sufficiently to the point that the HUD mockup performed in a satisfactory enough manner for students to get a feel for what navigating with a real HUD might be like.

The Waypoint Liner Drawer program was improved steadily over the duration of the course. Added features included cross track error lines, screen calibration functions, point shapes, areas, and AIS target images. Problems as yet to be solved were jerky visual imaging due to the once per second updating rate generated by the simulator, positional lagging during high speed turns, and horizontal referencing to the deck of own ship rather than the horizon. These are not insurmountable problems and are scheduled to be corrected before the next e-Navigation course is run in the summer or fall of 2011.

4. Student Participants

4.1 Securing the Required Student Participants

As previously mentioned, the notice of the award of Phase 1 of the e-Navigation grant was not received until early August 2010. The Cal Maritime community was on summer break then and due to start the fall semester a month hence. Half of the Marine Transportation (MT) students were still on summer cruise and the rest on summer vacation. Communicating to the students the adding of the e-Navigation course to the fall curriculum was difficult at best. By early September only six students had enrolled. At least twenty-four were needed to run a viable class with sufficient research participants for the HUD development. Accordingly, the decision was made to allow entering freshmen (many of whom had some nautical background) into the course to fill the required seats. The response from the freshmen when the announcement was made at orientation was overwhelmingly positive. Before enrollment could be closed, thirty-four students had enrolled in the class. It was necessary, therefore, to run the class with teams of four or five students instead of the planned three.

In any event, the extra students did not seem to adversely affect the simulations and increasing the number of research participants will undoubtedly contribute to more powerful statistical results. In addition, the use of freshmen has allowed us again to study the effectiveness of early introduction of simulation in the maritime curriculum – this time at the very beginning.

4.2 Student Demographics

All students were in the MT program. There were one senior, six juniors, nine sophomores, and seventeen freshmen. All eight teams had a senior or junior as team leader except Team 8, which had two sophomores sharing the lead over the team of five students. There were five female students. There were several non-traditional older students and several with former maritime or military experience.

5. Conducting the Class

5.1 Course Schedule and Instructor Availability

The e-Navigation course was scheduled for the entire fourteen weeks of the fall 2010 semester. For two of those weeks the Principal Investigator was unable to attend due to administrative commitments as department chair and a presentation of the HUD research at the Royal Institute of Navigation's NAV10 conference in London in early December. Captain Browne conducted the class with the aid of two other experienced Marine Transportation instructors, Mr. David Coleman and Mr. Scott Powell. Both these instructors were present and participated in all the other e-Navigation classes throughout the semester and were a tremendous asset, especially in helping to set up the cumbersome HUD mockup equipment. Both instructors will be part of Phase 2 of this grant in 2011.

5.2 Lecture Topics

The complete list of lecture topics was given in Section 2.3. Each of the topics had an associated PowerPoint presentation either created by the instructors in this course, or borrowed from others who have written on the e-Navigation subject. Those PowerPoint presentations will accompany this report and are listed in the References section as well. One of the most interesting of these is Thomas Porathe's work entitled 3D Charts and Safe Navigation.

5.3 Lab Simulation Difficulties

As is to be expected in an experimental course such as this, things do not always run smoothly. Such was sometimes the case in the simulations portion of the course. As stated earlier, the HUD equipment setup was difficult and balky at times. In a number of labs, some HUD equipment refused to operate correctly: NMEA interfaces would not work, projectors died or refused to turn on, and the Transas simulator (which had been running all day for other classes since 0900) sometimes became overloaded when simulations became too complex with eight ownships and slowed down or simply froze and had to be rebooted. In the final lab session that involved testing the HUD with AIS target data presentation, the laptops could not keep up with the simulator data output because an AIS data stream debugging feature in the HUD programming had been mistakenly activated, bogging down the whole display almost to the point of uselessness.

All equipment being used in this course was being pushed to the limit and sometimes beyond. That is the nature of research. The information collected in these simulations will be analyzed with the full realization that some of the data may have to be discarded due to equipment difficulties.

5.4 Student Presentations

In week 13, no simulations were run to allow students to present their research on various e-Navigation topics of interest. There were many interesting and well-done efforts on their part, demonstrating a high level of interest in what the future of navigation may be for these neophyte mariners. One particularly noteworthy and original presentation is included in the materials accompanying this final report. It involved an intriguing proposed simplification of maritime communications that very well may come to pass.

6. Preliminary Analysis of Data

6.1 Survey Results

Lab 4

During Lab 4 the students observed the HUD display while ownship transited through San Francisco Bay on course-control autopilot. There was no student interaction with the simulation – they merely observed the HUD display for approximately 30 minutes. The students then completed a survey to capture their initial impressions of a maritime HUD. The survey included the fourteen items (listed below) with space for commentary.

Each item was presented on a 1-5 Likert scale with 1-5 representing Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree respectively. The t-tests performed compared the group mean to the neutral value of 3 with a null hypothesis that participants' opinions were neutral. The significance criterion was set at $p < .0071$ and any finding with a $p \leq .007$ or less was considered significant[1]. A significant finding with a positive t-value would indicate significant agreement with an item and a significant finding with a negative t-value would indicate significant disagreement with an item. The results are presented below along with a summary of relevant comments for each item and conclusions at the end.

Item 1: The HUD would be very useful in piloting situations.

Mean	T-value	df	P	SE	Range
4.48	11.973	32	< .0001*	.124	3-5

This result was significant. Participants felt that the HUD would be very useful in piloting situations. Several students commented that it was useful to have an easy to see route and an indication of where to go, much like having a land reference point like a tower. Additional features were also requested, such as providing better cues in the HUD to indicate distances.

Item 2: The HUD would be very useful in docking situations.

Mean	T-value	df	P	SE	Range
3.85	5.382	32	< .0001*	.158	2-5

This result was significant. Participants felt that the HUD would be very useful in docking situations. Most of the comments identified additional features that would benefit a docking-specific HUD, such as set and drift indication, providing ship movement parameters, visually augmenting dock features, and the need for increased sensitivity and accuracy.

Item 3: The HUD would be very useful in coasting situations.

Mean	T-value	df	P	SE	Range
4.19	9.105	31	< .0001*	.130	3-5

This result was significant. Participants felt that the HUD would be very useful in coasting situations. Comments identified specific situations of high value such as in low visibility and locations with dangers such as shoal areas, wrecks, or for an oil spill situation.

[1] The overall significance criterion was set a $p < .10$, rather than the standard .05, to reduce Type 2 error potential but also represent an acceptable and still Type 1 Error conservative value for an exploratory study. The Bonferroni Correction was then applied based on the number of tests (14), resulting in the value listed above of $p < .0071$ (.10 divided by 14). Significant items are marked with a *

Item 4: The HUD would be very useful in the open ocean.

Mean	T-value	df	P	SE	Range
3.56	2.616	31	= .014	.215	1-5

This result was not significant. Participants were neutral concerning a HUD-related advantage in the open ocean. Most of the comments acknowledged HUD as a nice feature to have but unnecessary given the needs of open ocean transit. These included factors such as the standard use of autopilot and lack of items to avoid. Comments suggested potential HUD usefulness if challenging weather, sea state, or traffic, there were submerged hazards, or if AIS information could be integrated.

Item 5: I feel that using properly formatted HUD information would reduce my navigational workload.

Mean	T-value	df	P	SE	Range
4.30	10.944	32	< .0001*	.119	3-5

This result was significant. Participants felt that using properly formatted HUD would reduce their navigational workload. The value was seen to come from more readily available information. Cautions were put forward that reliability would have to be very high and performance smoother.

Item 6: I feel that HUD target information would reduce my collision avoidance workload.

Mean	T-value	df	P	SE	Range
4.25	8.394	31	< .0001*	.149	1-5

This result was significant. Participants felt that HUD target information would reduce their collision avoidance workload. Comments suggested that seeing an overlay of the information would be powerful as long as the user could still clearly see reality.

Item 7: I feel that using HUD information would reduce my stress level.

Mean	T-value	df	P	SE	Range
4.12	9.911	32	< .0001*	.113	3-5

This result was significant. Participants felt that HUD information would reduce their stress level. Comments suggested benefits to having more information at one's fingertips with increasing benefits as course, distance, speed, and other information become available. Higher confidence in one's manoeuvring and knowledge of the situation was seen to equate to lower stress.

Item 8: I feel that having HUD information would improve my situational awareness.

Mean	T-value	df	P	SE	Range
4.41	10.522	31	< .0001*	.134	3-5

This result was significant. Participants felt that HUD information would improve their situational awareness. Comments suggested that labels placed over geographic features increase confidence, a lookout would still be needed, and at least some of the bridge windows should be kept clear of HUD.

Item 9: The use of HUD would reduce my head down time in comparison with ECDIS navigation.

Mean	T-value	df	P	SE	Range
4.30	10.279	32	< .0001*	.127	3-5

This result was significant. Participants felt that the use of HUD would reduce head down time in comparison with ECDIS navigation. Comments suggested that participants would like ECDIS information to be displayed in the HUD, liked the benefits of an outside view perspective, but would still need to look at ECDIS as well.

Item 10: The use of HUD would reduce my head down time in comparison with radar navigation.

Mean	T-value	df	P	SE	Range
4.12	6.946	32	< .0001*	.161	1-5

This result was significant. Participants felt that the use of HUD would reduce head down time in comparison with radar navigation. Most of the comments were cautionary, such as questioning how much information could be integrated into a HUD, an inability for HUD to do long-range scanning without pre-existing land data, AIS inability to pick up anomalies, and the remaining need to still check radar frequently.

Item 11: The use of HUD would reduce my head down time in comparison with paper chart navigation.

Mean	T-value	df	P	SE	Range
4.69	13.781	31	< .0001*	.122	2-5

This result was significant. Participants felt that the use of HUD would reduce head down time in comparison with paper chart navigation. Comments suggested that participants viewed paper charts as inefficient and more of a historical redundancy. One participant noted that the same amount of time would be needed with paper charts. Another comment requested integration of dangerous depth area markings and display of buoys with data tags.

Item 12: A HUD application would provide a valuable addition to the navigating bridge environment.

Mean	T-value	df	P	SE	Range
4.73	21.939	32	< .0001*	.079	4-5

This result was significant. Participants felt that a HUD application would provide a valuable addition to the navigating bridge environment. Comments suggested that HUD would be most valuable in fog, it would be great to work on a ship with a working HUD, and since people gravitate towards electronic information that the HUD would encourage looking outside. Note in the range column that the lowest rating given on this item was a 4 (agree).

Item 13: A HUD application would be useful for reduced-visibility operational conditions.

Mean	T-value	df	P	SE	Range
4.82	26.667	32	< .0001*	.068	4-5

This result was significant. Participants felt that a HUD application would be useful for reduced-visibility operations. Comments suggested a great advantage in fog, rain, or heavy seas to know your course, where you are, what is around, and get a feel for how you are making way. Note in the range column that the lowest rating given on this item was a 4 (agree).

Item 14: Use of a properly formatted HUD would be useful in heavy traffic situations.

Mean	T-value	df	P	SE	Range
4.38	10.352	31	< .0001*	.133	3-5

This result was significant. Participants felt that the use of a properly formatted HUD would be useful in heavy traffic situations. Comments suggested some cautions concerning potential clutter but that HUD would still be helpful, especially if HUD had the ability to identify other vessels by name.

Lab 4 Conclusions: Overall participants saw potential for HUD to add value to the bridge environment. This can be seen in the fact that a rating of 4 (agree) was the lowest rating given on item 12. This is further bolstered by significantly positive ratings on all of the other items, with the exception of item 4, concerning use in the open ocean. The open ocean was not envisioned as a primary application for HUD information and this result is not surprising. The student comments echo the sentiments of the researchers quite nicely. The primary benefits of HUD are to increase situational awareness and reduce workload, stress, and mariner head down time. These benefits should be most pronounced in reduced visibility conditions, confined waters, and potentially in heavy traffic situations if developed to integrate accurate, reliable, and user-friendly target information.

Lab 8

During Lab 8, session 1, students navigated a hopper dredge through the Boliver Roads Anchorage in Galveston, Texas with half of the participant teams equipped with HUD, and half with No HUD. At the end of the session students completed a 9-item survey providing a rating between 1-100 of scenario performance based on their perceived level of the following variables:

- Mental demand
- How hurried or rushed the pace felt
- Frustration
- Stress
- How hard they felt they had to work (effort)
- Situational Awareness (staying ahead of the vessel and surroundings)
- Confidence (of mission success) throughout the scenario
- Success in accomplishing what had to be done
- How well the crew worked together (team work)

Results: A one-way ANOVA was performed on the data to compare the ratings of students that completed the scenario with HUD to students who completed the scenario without HUD. None of the individual items were significant. Only the rating of perceived successful performance was marginally significant, $F(1,26) = 3.647$, $p = .067$. Students using the HUD felt moderately more successful at accomplishing their tasks than the group without HUD, with mean ratings of 65.55 and 39.12 respectively. This might suggest an actual performance improvement (greater success) or the ability of the HUD to provide more consistent feedback on the vessel's location and progress, allowing increased opportunity to judge success and feel successful.

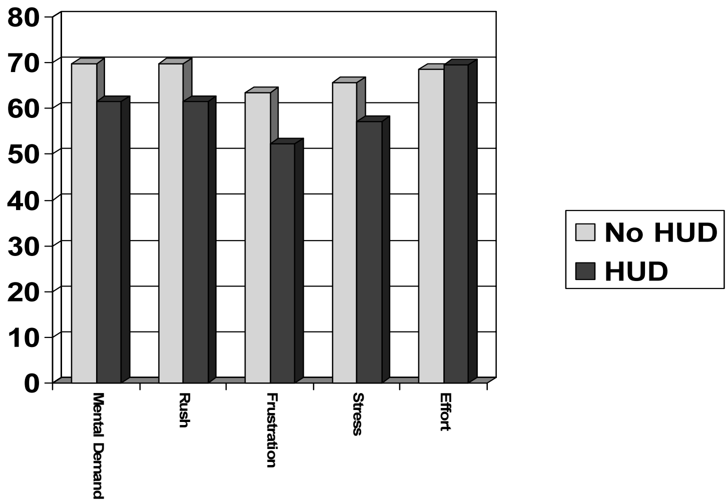

Fig. 4. Lab 8 HUD vs. No HUD (lower rating preferred)

The pattern of means for all other items favored the participants with HUD as well, with the exception of how hard participants felt they had to work where the HUD rating was slightly higher than the No HUD rating. The means were 68.59 and 69.45 respectively, a difference of a mere .86 on a 100 point scale. See the figures below. In Figure 4 a lower rating represents preferred performance for all of the items and in Figure 5 a higher rating represents preferred performance.

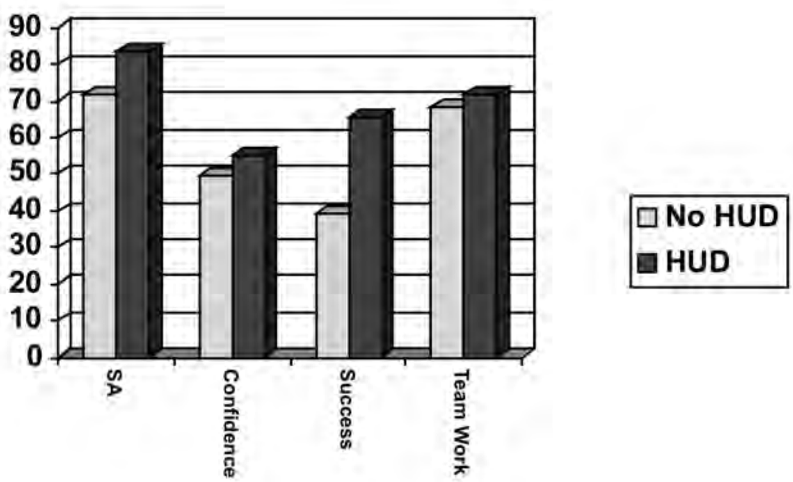

Fig.5. HUD vs. No HUD (higher rating preferred)

Lab 8 Conclusions

Although the results were not significant, the patterns of the means suggest a potential HUD advantage on several variables that can be more fully tested in the future. It is the opinion of the researchers that some of the potential HUD benefits were reduced or nullified by technical difficulties and alignment problems experienced with the HUD prototype.

Also, due to time constraints, the participants were not able to complete the second session and subsequent ratings. For session 2, the students that had completed session 1 with No HUD would use HUD and vice versa to complete a comparable scenario. This would have provided an experience-based comparison by each participant of performance with and without the HUD. It is crucial for a within-subjects comparison across sessions, such as this, that the scenarios are evenly matched on the key variables that define the scenario to control the variance that is not due specifically to HUD vs. No HUD differences. The creation of comparable scenarios to use for testing will be a key component of future e-Navigation evaluations.

6.2 Student Exam Performance

The chart below represents student performance on the nine e-Navigation quizzes administered during the semester. In general the scores were rather disappointing, especially when the study material for the exam was posted online five days beforehand. The exams where the students performed best were those concerning the equipment in the simulator, radar, AIS, ECDIS, conning controls, etc. (numbers 3 and 9). The topics of each quiz were:

1. What do you know about e-Navigation? (Before taking this class)
2. e-Navigation basics
3. IALA's vision of e-Navigation and simulator equipment
4. NAV55 document "Development of an e-Navigation Strategy…"
5. GPS theory and HUD basics
6. GPS theory and Dr. Porathe's 3D charting
7. Vessel Traffic Systems
8. More on 3D charting, hopper dredging basics
9. Simulator equipment knowledge

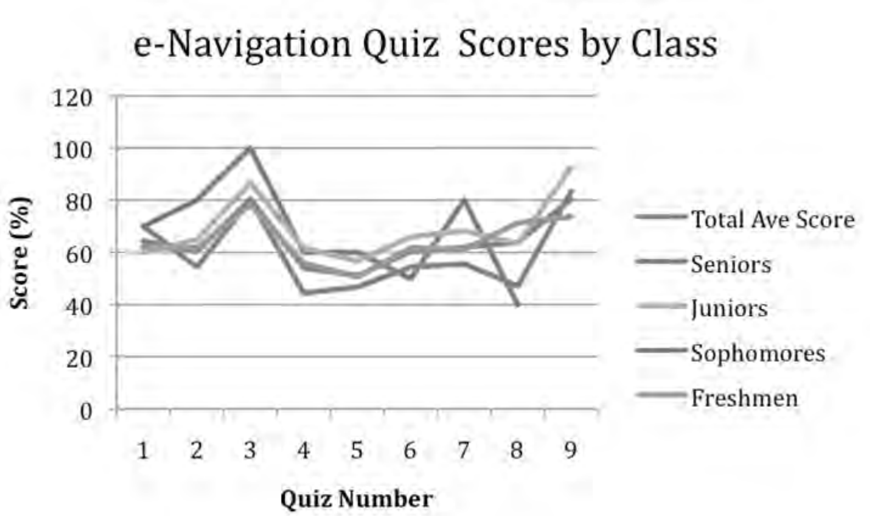

Fig. 6. e-Navigation Exam Scores

Some interesting facts about student performance on these quizzes are:

- Juniors scored better than freshmen or sophomores which was expected
- Freshmen scored better than sophomores which was unexpected (and disappointing)
- Freshmen scored about the same as the average of all students
- Freshmen scores on the quizzes involving the navigation equipment in the simulator were very respectable considering they had no prior knowledge of any of it

The results for the seniors (only one person) cannot be considered significant and were only included for completeness and comparison. The results for the freshmen on quizzes 3 and 9 are very encouraging and may indicate that some implicit learning was taking place during the simulation scenarios.

7. Writing of the Model Course

7.1 Use of the IMO Model Course Format

The Principal Investigator made the decision to use the standard IMO format for producing the model course, one of the primary deliverables of this research project. The reasons for this are as follows:

- The IMO format is already familiar to the world's MET professionals
- The format is well organized and makes for easy conversion into actual courses
- The experience gained in conducting two experimental e-Navigation courses without the well-ordered guidance contained in a document like an IMO model course made the PI wish that he had had such a model course on which to build

Nevertheless, it is important to note that the e-Navigation model course written as part of this research project, no matter how finished it may appear, is still a first draft that has not undergone extensive peer review. It would be very premature to send it off to the IMO for publication as a full-fledged model course without such review. The model course is completely the work of one person, the PI, and as such should be thoroughly vetted before being used for an official IMO model course. The time constraints inherent in the deadlines of Phase 1 of this grant project have not permitted the required vetting process to be accomplished.

7.2 Selection of Topics

The topics selected for inclusion in the model course, while fully the choice of the PI, are nevertheless for the most part common e-Navigation concepts, operations, or concerns expressed by many official bodies like the IMO, IALA, USCG and others in the documents listed in the appendix of this final report. For example, the definition of e-Navigation, how it is to be implemented, how it will affect shipboard navigation, how VTS will be affected by e-Navigation, and what the future of GMDSS will be, are all issues of note to a wide variety of e-Navigation stakeholders.

7.3 Research Component of the Course

e-Navigation Research, the last section of the model course, has not been specifically mentioned by the IMO or any other official body as a major concern for mariners today or in the future. Groundbreaking maritime research has rarely been carried out by the world's maritime universities or training institutions in the past, mainly due to the lack of proper research facilities. Today, many institutions are capable of conducting such important research because of the widespread introduction of advanced full mission and part-task simulators. These units are expensive to purchase and maintain. It would be a shame if they were not utilized in the future for more than the training and assessment of mariners as they have been so limited in the past. They are terrific research tools and the proper development of e-Navigation cries out for such tools.

Accompanying this final report is a preliminary report and presentation on the Maritime Head-Up Display research being jointly conducted by Cal Maritime and Anacapa Sciences, Inc. This research was an integral part of this IAMU research project and should serve as an example of what MET institutions can do to help shape the future of e-Navigation. The instructional component of e-Navigation must remain nimble to keep up with emerging technologies, or their prototypes, and how these items will mature and be integrated into the overall bridge resource management system. That is why the PI felt it desirable to include research as an optional part of any e-Navigation course that is created from the model course.

8. Conclusion and Notes on Further Research in Phase 2

8.1 Some Thoughts on Course Design for Phase 2

One of the goals of Phase 2 of this IAMU research project is to develop a true e-Navigation class from the model course written in Phase 1 and deliver this course aboard the Cal Maritime Training Ship *Golden Bear* during the summer cruises of 2011. This objective was contingent on the completion and full outfitting of equipment in the Navigation Laboratory on the 04 level of the after house of the ship. To date (31 Dec 2010) no equipment has yet been fitted into the shell of the Nav Lab. Although the equipment has been ordered and should be delivered sometime in January 2011, it is doubtful, even if the equipment installation is completed before the vessel departs in April, whether there will be enough time to test the equipment adequately. Furthermore, the new equipment includes a complete modern bridge mockup with equipment no one has yet learned to operate. Therefore it is looking doubtful that delivery of the new e-Navigation course aboard the training ship over cruise will be effective way to introduce the course. There are too many things that could go wrong with the equipment that will have a deleterious effect on the e-Navigation course.

Accordingly, the next e-Navigation course will be pushed back to fall 2011 and offered on the Cal Maritime campus again. This will also allow greater time for instructors to produce as effective a course as possible. There are few if any perceived downsides to this approach.

8.2 HUD Research Planned for Phase 2

The search for a commercial marine navigation equipment manufacturer partner to help produce a working, seagoing marine HUD prototype has not proven successful so far. To date, Jeppesen, Kelvin Hughes, Transas, Northrop Grumman, and Rockwell Collins have been approached but none has shown a real interest in the project. Although this is disappointing, it is not unexpected given the state of the world's economy. Long range projects or ideas with few precedents like the marine HUD have major difficulties attracting the attention of marketers and investors in large companies such as those we have contacted.

A new approach may be to explore interested video gaming companies that have the Augmented Reality and associated hardware experience to make the marine HUD a working device. Whether there is any interest in such a non-entertainment product among such companies is a question to which we hope to have the answer soon.

8.3 International Researchers Interested in this Project

There has been a keen interest shown in our maritime HUD and e-Navigation research by several other researchers around the world.

First, Dr. Thomas Christiansen of the EfficienSea project has spoken with Dr. Holder and the PI over the phone and via email about his work on e-Navigation in the Baltic. His main interest is in the promising new navigation operation improvements that are being explored through more efficient use of existing technologies. He is most concerned about how we will train future mariners to navigate more effectively in an e-Navigation environment.

Second, Dr. Thomas Porathe has shown great interest in our work, as it parallels his own studies experimenting with 3 Dimensional charting. We have spoken at length on a conference call and he allowed us to use his 3D charting demo program in the e-Navigation course this fall. The students were most impressed with the demonstration, particularly with the lifelike representation of a vessel supplied entirely by AIS data. In return, we have sent Dr. Porathe the HUD prototype program to use in his own experiments.

Third, Mr. Simon Gaskin and Dr. Nick Ward of the Research and Radionavigation branch of the General Lighthouse Authorities in the U.K. were most interested in our maritime HUD presentation at the NAV10 conference in London. They see the AR features of a maritime HUD as a potentially effective way to display virtual and synthetic AIS Aids to Navigation (AtoNs).

Finally, Mr. Charles Benton of Technology Systems, Inc. of Brunswick, ME contacted us about our research. His company produces a device known as ARVCOP (Augmented Reality Visualization of the Common Operational Picture), which is an early form of maritime HUD. However, instead of projecting the AR picture directly over the outside view, ARVCOP uses a forward-looking video camera to send an image to a computer screen upon which scaled 3D perspective representations of objects, areas and tracklines are superimposed. The device was introduced over five years ago but was not commercially successful. Mr. Benton has graciously provided us with a copy of ARVCOP, which we intend to test out aboard the Cal Maritime small craft this spring and if successful, possibly use aboard the training vessel on cruise this summer.

9. Appendix

9.1 List of all sources used for the e-Navigation research project

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Buckley, James J. and Samuel R. Pecota, "Integration of ECDIS in bridge simulation courses: Are there performance or perception differences?" *INSLC,* St. Johns, Newfoundland, Canada, July 2008.

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10. References (for this report only)

[1] "Development of an E-Navigation strategy", MSC 81/23/10, 19 December 2005.

MODEL COURSE 1.XX
Prplesinci of SHIPBOARD e-NAVIGATION

2011 Edition

Foreword

Secretary General

Contents

Introduction

■ Purpose of the model courses

The purpose of the IMO model courses is to assist maritime training institutes and their teaching staff in organizing and introducing new training courses or in enhancing, updating or supplementing existing training material where the quality and effectiveness of the training courses may thereby be improved.

It is not the intention of the model course programme to present instructors with a rigid "teaching package" which they are expected to "follow blindly". Nor is it the intention to substitute audio-visual or "programmed" material for the instructor's presence. As in all training endeavours, the knowledge, skills and dedication of the instructors are the key components in the transfer of knowledge and skills to those being trained through IMO model course material.

Because educational systems and the cultural backgrounds of trainees in maritime subjects vary considerably from country to country, the model course material has been designed to identify the basic entry requirements and target trainee group for each course in universally applicable terms, and to specify clearly the technical content and levels of knowledge and skill necessary to meet the technical intent of IMO conventions and related recommendations.

■ Principles of e-Navigation

The IMO has defined e-Navigation to be "*…the harmonized collection, integration, exchange, presentation and analysis of marine information onboard 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.*" This is a concept that was introduced in November 2005 at a conference of the Royal Institute of Navigation and submitted to the IMO at Maritime Safety Committee meeting 81 (MSC 81) that December. The report from MSC 81 went on to state that "*…IMO now has an opportunity to develop and map out a clear strategic vision for integrating and utilizing all the navigational technological tools at our disposal to secure a greater level of safety and incident prevention…*" and "*Implementation of this new strategic vision might require modifications to working methods and navigational tools, such as charts, bridge display equipment, electronic aids to navigation, communications and shore infrastructure.*" Finally, the authors of the report concluded, "*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.*"

The purposes of this IMO model course, *Principles of Shipboard e-Navigation,* are to:

- Introduce students to the basic concepts and compelling need for e-Navigation
- Engage students and instructors in a discussion about the future directions e-Navigation should take

- Allow students to experience through simulator exercises e-Navigation operations which may be quite different from marine navigational methodologies of the past
- Actively investigate some of the latest e-Navigation technologies through use of experimental equipment in a simulated navigational environment

Because e-Navigation is such a broadly based conceptual schema that is still in its developmental infancy, it is not expected that this model course can be used without modification very far into the future. Indeed, the term e-Navigation itself may become obsolescent when the navigational systems, equipment and methods that arise out of the push for e-Navigation become commonplace throughout the maritime world. We may well then refer to e-Navigation as simply "navigation."

Instructors who wish to use this model course to create their own e-Navigation courses are reminded that because the subject is still so fluid and ever-advancing, the standard IMO model course disclaimer to not be too rigid in following the outline presented should apply even more so to this course. In this model course there will be many examples of possible shipboard e-Navigation topics to be explored during the conduct of the course. (The possible future development of the Maritime Head-Up Display is one such example.) The model course designer encourages all instructors or researchers who wish to use this e-Navigation model course first to decide on what available e-Navigation components they wish to have their students study and then to build their individualized course around those particular pieces of equipment, systems, or operational methods. *Principles of Shipboard e-Navigation* will then serve not only as an e-Navigation primer but will ultimately allow the end user – the mariner – to have an impact on the future development of marine navigation.

■ Use of the model course

To use the model course the instructor should review the course plan and detailed syllabus, taking into account the information provided under the entry standards specified in Part A Course Framework. The actual level of knowledge and skills and the prior technical education of the trainees should be kept in mind during this review. Also, any areas within the detailed syllabus, which may cause difficulties because of differences between the actual trainee entry level and that assumed by the course designer, should be identified. To compensate for such differences, the instructor is expected to either delete from the course, or reduce the emphasis on, item with knowledge or skills already attained by the trainees. The instructor should also identify any academic knowledge, skills or technical training which they may not have acquired.

By analyzing the detailed syllabus and the academic knowledge required to allow training in the technical area to proceed, the instructor can design an appropriate pre-entry course or, alternatively, insert the elements of academic knowledge required to support the technical training elements concerned at appropriate points within the technical course.

Adjustment of the course objective, scope and content may also be necessary if the trainees completing the course are to undertake duties which differ from the course objectives specified in the model course.

Within the course plan the course designer has indicated his assessment of the time that should be allotted to each area of learning. However, it must be appreciated that these allocations are only suggestions and assume that the trainees have fully met all entry requirements of the course. The instructor should therefore review these assessments and may need to allocate the time required to achieve each specific learning objective or training outcome.

■ Lesson planning

Having adjusted the course content to suit the trainee intake and any revision of the course objectives, the instructor should draw up lesson plans based on the detailed syllabus. The detailed syllabus contains specific references to the textbooks or teaching material proposed to be used in the course. Where no adjustment has been found to be necessary in the learning objectives of the detailed syllabus, the lesson plans may simply consist of the detailed syllabus with keywords or other reminders added to assist the instructor in preparing the presentation of the material.

■ Course implementation

For the course to run smoothly and to be effective, considerable attention must be paid to the availability and use of:

- Properly qualified instructors
- Support staff
- Rooms and other spaces
- Equipment, especially simulators and any experimental devices
- Suggested references, textbooks, technical papers and other reference material

Thorough preparation is the key to successful implementation of the course. The IMO booklet entitled *Guidance on the implementation of IMO model courses,* which deals with this aspect in greater detail, is included in this course.

Part A: Course Framework

■ Aims

This course provides an introduction to the concepts and goals of the IMO's vision of marine navigation and vessel operational control of the future now known collectively as *e-Navigation.* It is designed for officers in charge of a navigational watch on vessels that are or will be fitted with equipment identified as crucial components of the all-embracing e-Navigation system. Its main aims are to increase navigational safety and efficiency and to protect the marine environment. It does this by giving instruction and guidance on the integrated use of existing navigational systems operated in an e-Navigation environment, including illustrations of dangerous or improper use. Successful completion of the course enables trainees to benefit fully from familiarization training for actual installed bridge equipment.

Additionally, this course provides a vehicle for maritime personnel such as currently practicing seagoing professionals, maritime education and training instructors and maritime academy students to have a voice in the discussion of what should or should not constitute the best practices in the implementation of e-Navigation. It does this by giving examples of research and development projects and simulation experiments that these stakeholders can conduct in order to provide IMO with informed opinions as to how e-Navigation systems and operational methods can be successfully developed.

The course takes into account all relevant IMO resolutions and guidelines on e-Navigation available at the time the model course was prepared. Where appropriate, it takes note of common implementation practice, as influenced by Administrations, classification societies, international standards institutions and manufacturers.

■ Course objectives

Trainees successfully completing this course and meeting the required performance standards [still to be developed for e-Navigation operational tasks], will be able to:

- Understand the objectives of e-Navigation
- Understand the types of systems that comprise the e-Navigation suite
- Understand the benefits and limitations of e-Navigation
- Understand the necessary ergonomics and human interface with shipboard e-Navigation systems
- Understand the decision-making process that needs to be applied when using such systems
- Understand the need for proper bridge resource and bridge team management procedures in the e-Navigation environment
- More easily adapt to the significant changes in marine navigation practices that will be necessary under e-Navigation

■ Entry standards

This course is designated both for candidates for certification as officers in charge of a navigational watch and for experienced nautical officers and other persons with responsible duties in navigation work, such as pilots.

Those wishing to enter this course should have already had training and experience in the use of relevant stand-alone equipment such as radar, ARPA, AIS, ECDIS, and GMDSS. They should also be familiar with standard human-computer interfaces including elements such as windows, menus, trackballs and other control and display technologies. Although not strictly required, familiarity and experience with maritime full-mission and part-task simulators is recommended.

■ Course certificate, diploma or document

On successful completion of this course, a document may be issued certifying that the holder has successfully completed a course of familiarization and training in e-Navigation concepts, systems, and methods in accordance with the recommendations contained in this course.

■ Course intake limitations

The course intake will be limited by the capacity and type of simulator equipment available. Experience shows that the efficacy of practical training is optimized when the intake does not exceed four trainees in a full-mission simulator. Part-task simulators may be adequate for training in this course depending upon the facets of shipboard e-Navigation on which the instructor decides to focus. See the section on *Teaching facilities and equipment,* below.

■ Staff requirements

The qualifications of the instructor should be in accordance with the requirements laid down in Section A-I/6 of the STCW Code. In addition, if there is to be a research component to the course, as is highly recommended by the course designer, the instructor should be familiar with standard research methodology as described in one or more of the research methods textbooks listed in the bibliography of this model course.

■ Teaching facilities and equipment

For the lecture part of the course, a classroom equipped with at least an overhead projector and whiteboard (or equivalent) will be required. A computer driven projector is ideal as this can be used to demonstrate many aspects of e-Navigation practice, utilizing a basic software simulator.

Many useful exercises can be performed by trainees in part-task simulators as long as some electronic navigation integration is possible. This alleviates the necessity of using full-mission simulators for all exercises or research studies and may allow the intake of more trainees per course.

For some practical exercises a full-mission navigation bridge simulator is ideally used, having the following facilities:

- Twin ARPA radar displays, one or both with radar and AIS overlay capability
- ECDIS, ideally with back-up
- An INS conforming to an INS(C) as defined in Reference R6 (below) and interfaced to the radars and ECDIS
- At least one IBS function in addition to INS, for example:
  - Communication
  - Loading, discharging and cargo control

■ Teaching aids (A)

A1 Instructor Manual (Part D of this course)

A2 DVD player

A3 DVDs about e-Navigation where available

A4 Simulator software

A5 Simulator databases for areas appropriate to e-Navigation

■ IMO references (R)

R1 MSC 81/23/10, Development of an E-Navigation strategy, 19 December 2005

R2 NAV 55/WP.5, Development of an e-Navigation Strategy Implementation Plan, 29 July 2009

R3 MSC.232(82) , Adoption of the Revised Performance Standards for ECDIS, 5 Dec 2006

R4 MSC.191(79), Annex 33, Performance Standards for the Presentation of Navigation-Related Information on Shipborne Navigation Displays, 6 Dec 2004

R5 MSC.64(67), Annex 1, Recommendation on Performance Standards for Integrated Bridge Systems (IBS), 1996

R6 MSC.86(70), Annex 3, Recommendation on Performance Standards for an Integrated Navigation System (INS), 1998

R7 MSC.Circ.1061, Guidance for the Operational Use of Integrated Bridge Systems (IBS), 3 Jan 2003

R8 MSC.74(69), Annex 3, Recommendations on Performance Standards for a Universal Shipborne Automatic Identification System (AIS), 1998

R9 Resolution A.917(22), Guidelines for the On-Board Operational Use of Shipborne Automatic Identification Systems (AIS)

R10 MSC 85/26/Add.1, Annex 20, Strategy for the Development and Implementation of e-Navigation, 2008

R11 Resolution A.857 (20), Guidelines for Vessel Traffic Services, 27 November 1997

■ Textbooks and other references (T)

At the time of writing there were no standard textbooks on e-Navigation. There are however many fine background texts on the various component systems that make up the e-Navigation suite. These are listed as part of the bibliography below.

■ Bibliography (B)

B1 Pecota, Samuel R. *Radar Observer Manual.* Houma: Marine Education Textbooks, 2006.

B2 Norris, Andy. *Radar and AIS.* London: The Nautical Institute, 2008.

B3 Norris, Andy. *ECDIS and Positioning.* London: The Nautical Institute, 2010.

B4 Bole, Alan, Bill Dineley and Alan Wall. *Radar and ARPA Manual, 2nd Ed.* Oxford: Elsevier Butterworth-Heinemann, 2005.

B5 IALA e-Navigation Committee *Frequently Asked Questions* (Version 1.5 dated September 2010

B6 Patraiko, David, *Introducing the e-navigation revolution,* The Nautical Institute, 2007

B7 Chakraborty, Devbrat, *IMO's e-Navigation Project: Current Status,* National Maritime Foundation, 26 Aug 2009

B8 Pillich, Bohdan, *Developing e-Navigation, the early stages,* BMT Ports and Logistics, 2007

B9 Ward, Nick, *The IMO e-Navigation Initiative,* Research & Radionavigation, General Lighthouse Authorities, UK and Ireland, 2009.

B10 *The EfficienSea Project,* DaMSA, 2007-2013, information PowerPoint

B11 Swift, A.J. and T.J. Bailey. *Bridge Team Management: A Practical Guide, 2nd Ed.* London: The Nautical Institute, 2004.

B12 IMO Model Course 1.27 *Operational Use of ECDIS*

B13 IMO Model Course 1.32 *Operational Use of Integrated Bridge Systems*

B14 IMO Model Course 1.34 *Automatic Identification Systems*

B15 Weintrit, Adam. *The Electronic Chart Display and Information System (ECDIS): An Operational Handbook.* London: CRC Press, 2009.

B16 Hecht, Berking, et. Al. *The Electronic Chart, 2nd ed.* Lemmer: GITC, 2006.

B17 Fuechel, Jack and Robert Markle, *Conclusions of the 20 May 2010 GMDSS Modernization Workshop*, GMDSS Taskforce Modernization Notes

B18 *SharpEye White Paper.* Promotional pamphlet for new solid-state radar produced by Kelvin Hughes Company, 2009

Part B: Course Outline and Timetable

The course comprises lectures, demonstrations and simulator exercises. The outline below identifies the main areas of the course and the approximate time that should be allocated to each activity of teaching. With modern classroom technology these activities can often be merged into a continuous exposition of a particular area of understanding, rather than having to move from room to room.

In particular the lecture can be digitally projected from presentation material (slides, animation and video) directly from a computer that also runs bridge simulation software, making it easy for the lecturer to alternate between theory and example. Readily available software tools facilitate this. The use of simulators for demonstration and trainee exercises is discussed in the final section of Part D.

Some simulator exercises emphasizing particular skills can be performed beneficially in the classroom on individual personal computers (PCs). If possible, exercises on full-mission bridge simulators are very useful toward the end of a course to demonstrate that a complete understanding has been obtained (particularly in abnormal and emergency conditions) and within a team-working environment.

Learning objective format is used in the Detailed Teaching Syllabus given in Part C; the outline below is a straightforward summary of the course material. The numbering system used below reflects the Detailed Teaching Syllabus.

In the following table all lesson times are given in hours for lectures, demonstrations and simulator exercises. Durations are given in bold type are the totals for each section.

Training area	Lecture	Dem	Sim Ex
1 **Definition of e-Navigation** Definition of terms Why we need e-Navigation Existing problems that led to e-Navigation Fundamental elements of e-Navigation e-Navigation implementation timeline	**1.0**	**0.0**	**0.0**
2 **e-Navigation details** Benefits of e-Navigation Core objectives of e-Navigation The e-Navigation stakeholders User requirements Training requirements	**1.0**	**0.0**	**0.0**
3 **BTM and BRM procedures** Existing procedures before e-Navigation Modifications to BTM and BRM through e-Navigation	**1.0**	**0.0**	**2.0**
4 **ECDIS and GNSS** The importance of ENCs to e-Navigation The need for GNSS redundancy	**1.0**	**1.0**	**5.0**

	Training area	Lecture	Dem	Sim Ex
5	**Radar and AIS** New technology radar and e-Navigation Enhanced AIS for collision avoidance AIS communications in e-Navigation	**1.0**	**1.0**	**4.0**
6	**INS and IBS** Are INS/IBS ships already using e-Navigation?	**0.5**	**0.5**	**2.0**
7	**VTS and LRIT** Benefits of e-Navigation for VTS Existing advisory VTS systems w/out e-Navigation Future mandatory VTS systems with e-Navigation LRIT and satellite AIS	**2.0**	**0.0**	**4.0**
8	**GMDSS and e-Navigation** How e-Navigation enhances GMDSS Changes needed in GMDSS for e-Nav	**1.0**	**0.0**	**2.0**
9	**e-Navigation and traditional navigation** Traditional navigation / e-Navigation compatibility The problem with training for both	**1.0**	**0.0**	**2.0**
10	**e-Navigation research** Current research and development in e-Navigation Optional research project for course	**0.5**	**0.5**	**6.0**
	Total training duration = 40 hours	**10.0**	**3.0**	**27.0**

Part C: Detailed Teaching Syllabus

The detailed teaching syllabus indicates the contents of the course and appropriate references and teaching aids.

■ Learning objectives

The detailed teaching syllabus has been written in learning objective format in which the objective describes what the trainee must do to demonstrate that knowledge has been transferred. This format is an appropriate teaching and assessment tool to express:

- The depth of understanding of a subject and the degree of familiarization with a subject on the part of the trainee
- What capabilities the trainee should really have and to be able to demonstrate

Every instructor is encouraged to teach learning in an 'objective-related' way instead of 'material-related'. In this context, all objectives are understood to be prefixed by the words, 'The expected learning outcome is that the trainee is able to…'

To indicate the degree of learning outcome of this course, the learning objectives for the Detailed Teaching Syllabus can be classified in three 'dimensions':

- C (cognitive)
- A (affective)
- P (psychomotor)

Within a dimension, they are hierarchised by increasing complexity (C1 to C6, A1 to A5, and P1 to P5) where the complexity (depth, familiarization) is expressed (following B. Bloom and others) by a typical verb as follows:

Cognitive dimensional learning objectives

C1	Knowledge	describe, outline
C2	Comprehension	explain
C3	Application	apply, perform, operate
C4	Analysis	analyze
C5	Synthesis	synthesize, construct, plan
C6	Evaluation	assess

Affective dimension of learning objectives

A1	Reception; notice	recognize
A2	Response	respond
A3	Value	value
A4	Organization	organize
A5	Value characterization	accept, appreciate

Psychomotor dimension of learning objectives

P1	Imitation	imitate
P2	Manipulation	manipulate
P3	Precision	move, mark
P4	Coordination	co-ordinate (operations, menus)
P5	Naturalization	automate, internalize

■ References and teaching aids

In order to assist the instructor, references are shown against the learning objective to indicate IMO references and publications, bibliographies, textbooks and other references, as well as additional teaching aids that the instructor may wish to use when preparing course material. The material is listed in the course framework. The following notations and abbreviations are used:

R	IMO reference
T	Textbook and other references
B	Bibliography
A	Teaching aid
Ap.	Appendix
Ch.	Chapter
p.	Page
Para.	Paragraph
Sc.	Section

The following are examples of the use of references:

'R3 Para.3.1', refers to paragraph 3.1 of MSC Circular 1061
'A1 Para.D5.4, refers to paragraph 5.4 in Part D of this manual
'A1 Sc.DSim', refers to the Simulator Exercises section in Part D of this manual

■ Instructor manual

The Instructor Manual (Part D) is included to provide additional information to instructors. It is designed to help further in structuring and organizing a specific course. At the time of compilation of this model course there were no known textbooks covering the subject material. For this reason, Part D includes extra information on the subject. The instructor is recommended to gain additional material from radar, AIS, ECDIS, INS and IBS, and GMDSS suppliers. Suppliers of simulators are also good sources of information.

The instructor should take pains to present the material within a 'use-at-sea' context. It is not just a matter of imparting technical knowledge. In order to do this, the instructor needs to extrapolate his or her seagoing experience (which is unlikely to have covered e-Navigation principles) to incorporate the ideas and disciplines involved in operating in an e-Navigation environment.

■ Detailed Teaching Syllabus

All objectives are understood to be prefixed by the words 'The expected learning outcome is that the trainee is able to…' The Teaching Aid reference to A1 Sc.DSim refers to the section on Simulator Exercises in Part D of this model course.

Learning Objectives	IMO Reference	Biblio-graphy	Teaching Aid
1 Definition of e-Navigation ***Section objective: to understand the basic concepts, elements and need for e-Navigation***			
1.1 ***Explain*** the meaning of the term *e-Navigation*		B5, B6	A1 Para. D1
1.2 Discuss why we need e-Navigation	R1, R10	B6, B7	A1 Para. D1.2
1.3 Describe the most important existing problems in marine navigation that led to the proposal for e-Navigation	R10	B7	A1 Para. D1.3 A2, A3
1.4 Identify the fundamental elements of e-Navigation	R1 p.3	B9	A1 Para. D1.4 A2, A3
1.5 Describe the proposed e-Navigation implementation timeline		B9, B10	A1 Para. D1.5
2 e- Navigation Details ***Section objective: to understand the benefits and objectives of e-Navigation, its primary user requirements and training requirements***			
2.1 Explain the primary benefits of e-Navigation to the mariner, the maritime community and the public	R1	B5	A1 Para. D2.1 A2, A3
2.2 Describe the core objectives of e-Navigation as envisioned by IMO, IALA and other groups	R10	B5	A1 Para. D2.2 A2, A3
2.3 Identify the principal e-Navigation stakeholders	R10	B5	A1 Para. D2.3
2.4 Outline current user requirements	R10	B5	A1 Para. D2.4
2.5 Discuss the need for e-Navigation training and the required elements of that training			A1 Para. D2.5
3 BTM and BRM procedures ***Section objective: to understand basic principles of BTM and BRM and how they may be modified by e-Navigation***			
3.1 Describe the basic tenets of Bridge Team *Management* and Bridge Resource Management procedures as they are taught today		B11	A1 Para. D3.1 A2, A3, A4, A5

Learning Objectives	IMO Reference	Biblio-graphy	Teaching Aid
3.2 Recognize how BTM and BRM procedures will change in an e-Navigation environment			A1 Para. D3.2
4 ECDIS and GNSS			
Section objective: to understand the importance of ECDIS and GNSS positioning systems to e-Navigation			
4.1 Explain the importance of ECDIS to the e-Navigation concept	R1	B12	A1 Para. D4.1 A2, A3
4.2 Describe the need for more worldwide ENC coverage to enhance e-Navigation		B3, B15	A1 Para.D4.2 A2, A3
4.3 Explain the basic operating principles behind GNSS systems like GPS		B4	A2, A3
4.4 Recognize that e-Navigation would be impossible without satellite positioning systems like GPS			A1 Para. D4.4
4.5 Describe the importance of GNSS redundancy to the effectiveness of e-Navigation			A1 Para.D4.5
5 Radar and AIS			
Section objective: to understand how radar and AIS fit into e-Navigation operations			
5.1 Describe the role that radar plays in the e-Navigation operation		B1, B4	A1 Para. D5.1 A4, A5
5.1.1 Explain how New Technology Radar systems work and what they will contribute to e-Navigation		B2	A1 Para. D5.1.1
5.2 Describe the role that AIS plays in e-Navigation		B2, B14	A1 Para. D5.2
5.2.1 Explain the strengths and weaknesses of AIS		B14	A1 Para. D5.2.1
5.2.2 Explain how AIS can be enhanced to better serve e-Navigation			A1 Para. D 5.2.2
5.3 Describe the use of AIS communications		B2	A1 Para. D5.3
5.3.1 Assess the use of AIS text messaging in e-Navigation		B2, B14	A1 Para. D5.3.1, A4, A5
6 INS and IBS			
Section objective: to understand Integrated Navigation Systems and Integrated Bridge Systems with the context of e-Navigation			

Learning Objectives	IMO Reference	Biblio-graphy	Teaching Aid
6.1 Describe briefly what Integrated Navigation Systems an Integrated Bridge Systems are and how they fit in the e-Navigation concept		B13	A1 Para. D6.1
6.2 Assess the necessity of INS and IBS to effective e-Navigation operations		B13	A1 Para. D6.2 A4, A5
7 VTS and LRIT ***Section objective: to understand the ship-to-shore link in e-Navigation through Vessel Traffic Systems and Long-Range Identification and Tracking systems***			
7.1 Explain the benefits to Vessel Traffic Systems that e-Navigation provides	R11		A1 Para. D7.1 A2, A3
7.2 Describe the way in which most VTS systems presently operate (advisory)	R11		A1 Para. D7.2 A2, A3
7.3 Describe the way in which future VTS systems may operate under e-Navigation (mandatory vessel control)			A1 Para. D7.3
7.4 Describe the basic operating principles behind Long-Range Identification and Tracking systems and satellite AIS systems			A1 Para. D7.4.1, 4.2 A2, A3
7.4.1 Explain how LRIT and Satellite AIS enhance e-Navigation operations with regard to shipboard to shoreside communications			A1 Para. D7.4.1, 4.2 A2, A3
8 GMDSS and e-Navigation ***Section objective: to understand how GMDSS will provide the communications needed under e-Navigation***			
8.1 Explain how e-Navigation concepts will enhance the capabilities of the GMDSS system		B17	A1 Para. D8.1 A2, A3
8.2 Describe the changes needed in the existing GMDSS system in order for it to operate in an e-Navigation environment		B17	A1 Para. D8.2
9 e-Navigation and traditional navigation ***Section objective: to understand how e-Navigation could fundamentally alter the way in which marine navigation is practiced In the future***			
9.1 Discuss the compatibility of traditional marine navigation methods with e-Navigation			

Learning Objectives	**IMO Reference**	**Biblio-graphy**	**Teaching Aid**
9.1.1 Evaluate the effectiveness of traditional navigation techniques as a backup to e-Navigation methods 9.1.2 Evaluate the effectiveness of system redundancy as a backup for e-Navigation 9.2 Discuss the potential problems associated with effective training of navigators in e-Navigation as well as traditional navigation			A1 Para. D9.1.1, A4, A5 A1 Para. D9.1.2, A4, A5 A1 Para. D9.2
10 e-Navigation Research (optional) ***Section objective: to allow instructors and students to investigate a developing e-Navigation system or operating method*** 10.1 Select a developing e-Navigation technology or system and examine its usefulness in a simulated e-Navigation operating environment			A2, A3, A4, A5

Part D: Instructor Manual

■ General

This manual reflects the views of the course designer on methodology and organization, including the:

- Selection of principal e-Navigation subjects
- Relative importance of these subjects
- Interrelations between these subjects
- Learning objectives
- Necessary teaching tools
- Time allocated in achieving the learning objectives

The guidance given is intended to give the instructor a baseline on which to work out and develop a course that will meet the particular local requirements and the instructor's own experience and ideas. As the course develops the instructor should refine and develop what is successful and discard those ideas that do not work.

Guidance is provided in the booklet entitled 'Guidance on the implementation of IMO model courses' which includes a checklist for preparation of courses. Preparation and planning constitute an important factor, which makes a major contribution to the effective presentation of the course.

A prime purpose of the course is to prepare future users of e-Navigation technologies and methods of operation to be able to more quickly assimilate and understand these new technologies and their proper use as they are introduced to the maritime world in the years to come.

■ Theory, demonstration and exercises

Theory lectures

The safe use of shipborne navigation and communications equipment in an e-Navigation environment requires knowledge and understanding of the basic principle underlying the e-Navigation concept. These should be taught as classroom lectures.

As far as possible, such lessons should be presented within a familiar context and make use of practical examples. They should be well illustrated with diagrams, photographs and charts where appropriate and be related to subject matter learned or reinforced during simulator exercises. The use of an overhead projector, if possible computer based, will greatly enhance the value of these lectures. Distribution of copies of the presentation screens as trainee handouts contribute to the learning process.

Demonstration

During presentation of the theory many of the concepts can be shown as a computer simulation, ideally projected as part of the overhead presentation, but possibly shown on a computer screen, or screens, easily viewable by participants.

Simulator exercises

It is an essential part of this course that sufficient practical experience is gained on suitable simulators. Many aspects can be learnt on single screen simulators running suitable software, especially when trainees are being introduced to a new type of e-Navigation device in the research component of this course. Some time should be spent on a more complex simulator. As a minimum this should consist of a multi-screen (2+) PC based simulator linked to some actual (physical) controls. For real time navigation exercises, navigation simulators are necessary to cover complex navigation situations.

Ideally, a full-mission simulator should be used in some exercises, as these can provide 'true-to-life' experiences and can enable a bridge team approach, increasing the learning experience. However, these can be expensive to procure and maintain. The section on 'Teaching facilities and equipment' in Part A includes a brief definition of a suitable full-mission simulator. It is not necessary for the equipment to replicate a particular bridge. It is to be used to gain experience on the principles of operating such equipment in the e-Navigation operating environment.

The exercises should provide training in using integrated features of equipment, as this is an essential component of e-Navigation. Initial training in the use of radar, ARPA, AIS, and ECDIS used in a 'stand-alone' manner is not assumed to be part of this course. It is expected that trainees have had experience and dedicated training on all these units prior to taking the e-Navigation course.

■ Evaluation

The outcome of the training course should be evaluated. Because the course includes theoretical knowledge as well as practical skills and guidance in decision-making, the method of evaluation and the criteria for evaluating competency (correctness of method, correctness of outcome, duration, compliance, effectiveness, etc) should take all these aspects into account. The learning objectives used in the detailed syllabus should provide a sound basis for the construction of suitable tests for evaluating trainee progress. The effectiveness of any evaluation depends on the accuracy of the description of what is to be measured.

Further guidance on method of evaluation, validity, reliability, subjective testing, objective testing, distracters and guessing (if using multiple choice tests) and scoring is provided in the booklet entitled 'Guidance on the implementation of IMO model courses' which is included at the end of this course.

■ Lesson plans

The instructor should draw up lesson plans for the individual lessons based on the course objectives and the detailed syllabus taking into account any necessary revision of course content to suit the trainee intake. An example of a lesson plan is shown below. The lesson plans may simply consist of the detailed syllabus with keywords or other reminders added to assist the instructor in making the presentation of the material. The lesson plans may contain specific references to the teaching method, IMO references, bibliography, textbooks and other teaching material proposed for use in the course, instructor guidelines and time (in minutes) allocated to a specific learning objective.

Example of e-Navigation Lesson Plan

5.2	Describe the role that AIS plays in e-Navigation	Teaching Method	IMO Reference	Bibliography Textbooks	Instructor Guidelines	Time (min)
5.2.1	AIS overview AIS strengths AIS weaknesses	Lecture, Dem	R8, R9	B2	A1 Para. D5.2.1	15
5.2.2	Improvements to AIS system needed for e-Navigation	Lecture, Dem			A1 Para. D5.2.2	5
5.2.3	AIS as a collision avoidance tool	Dem, Sim		B1, B2	Sim Ex	30
5.2.4	AIS role in Long Range Identification and Tracking (LRIT)	Lecture			A1 Para. D7.4.1	10
5.2.5	Satellite AIS systems	Lecture			A1 Para. D7.4.2	10
					Total	70

■ Guidance on specific subject areas

This section contains guidance to the instructor on the coverage of the e-Navigation subject areas listed in the course outline and the detailed teaching syllabus. The scope and depth of the subject areas are reflected; essentials are pointed out.

Many of the subjects contain objectives that are relevant to different exercises at different levels. Their inclusion in any exercise can reinforce the learning process. A methodology based on the instructor's own experience should be developed bearing in mind that the IMO references help to indicate the required training under each heading.

The paragraph numbering scheme matches the course outline and syllabus, defined in Part C and D, respectively.

1. Definition of e-Navigation

1.1 Definition of terms

e-Navigation is an International Maritime Organization (IMO) led concept that is currently defined as follows:

> *e-Navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard 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.*

Instructors should include all appropriate IMO definitions like the one quoted above throughout the course as part of the presentation material. These definitions provide the basis for key points that need to be stressed and will help to keep the course focused on the most important aspects of e-Navigation. Since e-Navigation is still a developing concept, it is critical that the instructor provides trainees with the latest IMO resolutions on the topic of e-Navigation and not blindly use those listed in the bibliography of this model course that may soon become out of date.

The scope of the e-Navigation proposal of IMO (as seen in the official definition above) is broad. As such, it will be difficult to delve deeply into all of the separate e-Navigation topics to follow.

1.2 Why we need e-Navigation

Ships are getting more and more complicated, larger and faster. Much of the world's shipping operates under conditions of severe congestion, difficult passages, poor weather, and reduced manning scales. These and other factors have demanded that shipboard and shoreside stakeholders in the commercial maritime industry be provided with the most modern equipment and most efficient operational procedures in order to enhance safety and optimize decision-making.

1.3 Navigational/operation problems that led to e-Navigation

As marine navigation equipment has advanced in sophistication in recent years, it has also become highly complicated and not necessarily complimentary with other shipboard and shoreside systems. It has become common for a vessel's bridge to be overwhelmed with a large number of computers, displays, and alarms that do not necessarily make a safe and efficient navigating environment for the mariner. The e-Navigation concept was introduced in 2005 as an attempt to alleviate this mounting problem. Should technological advances continue in their current disassociated state without an overarching organizing architecture such as the e-Navigation concept, marine navigation is quite likely to become a more dangerous and less efficient endeavor than that practiced even today.

1.4 The fundamental elements of e-Navigation

The IMO laid down the primary components and concepts of e-Navigation in Dec 2005 at the 81st session of the Maritime Safety Committee. They are:

- Accurate, comprehensive and up-to-date Electronic Navigational Charts (ENCs)
- Accurate, reliable, and redundant electronic positioning
- Provision to provide vessel route, course, and other status items in real-time electronic format
- Transmission of positional and navigational information via ship-to-shore, shore-to-ship, and ship-to-ship communications
- Accurate, clear, integrated and user friendly display of information onboard and ashore
- Information prioritization and alert capability in risk situations both onboard and ashore
- Reliable transmission of distress alerts and maritime safety information with reduction of current GMDSS requirements by utilizing newly emerged communication technologies

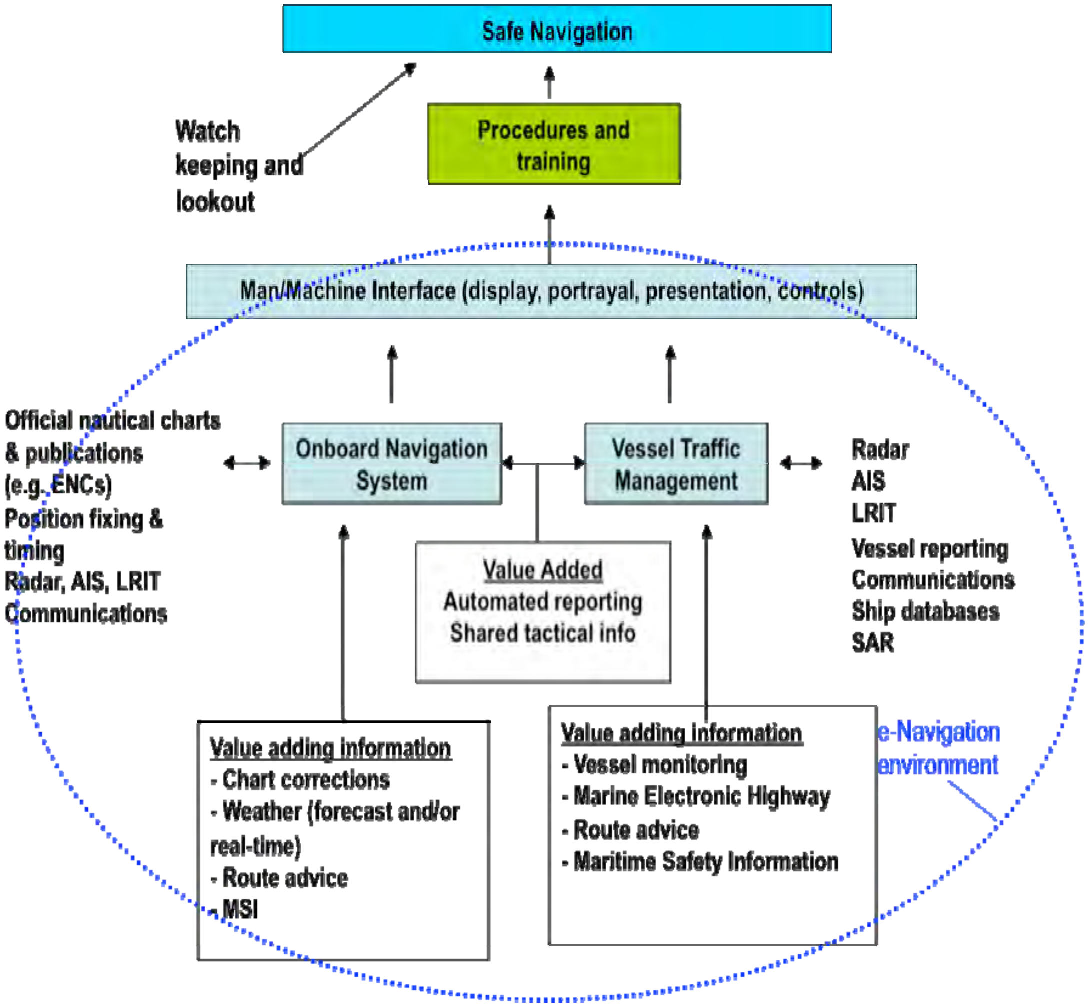

Figure 1 e-Navigation Architecture

1.5 The e-Navigation implementation timeline

- Strategy implementation plan (2008)
- User needs (2009)
- Architecture (2010)
- Gap analysis (2010)
- Cost-benefit and risk analysis (2011)
- Implementation plan (2012)

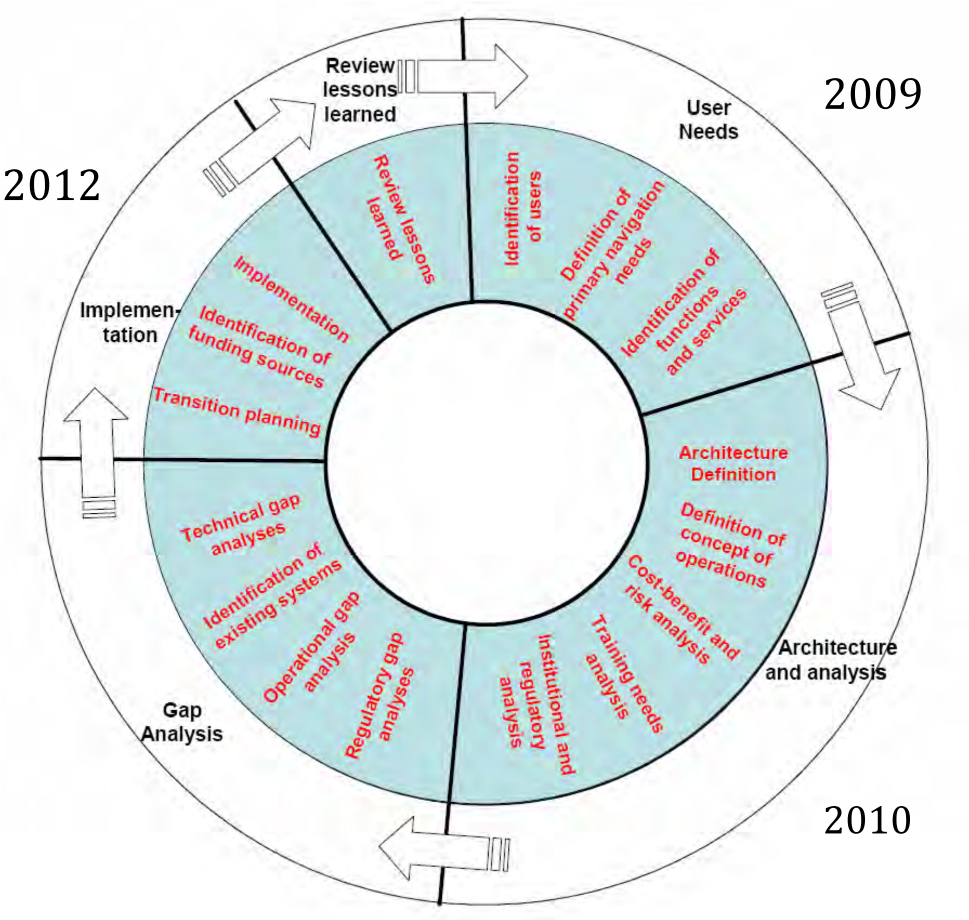

Figure 2 e-Navigation Implementation

(CMA)

2. Benefits of e-Navigation

2.1 Primary benefits to the mariner, the maritime community and the public

In general, e-Navigation should provide benefits to the mariner in the following ways:

- Minimize navigational errors, incidents and accidents
- Improve decision-making support
- Improve bridge watchstanding and lookout practices
- Reduce the workload of ship's crews
- Improve security
- Improve search and rescue operations

To the maritime community:

- Better monitor vessel locations and regulate traffic flows
- Reduce shipping costs
- Provide interfaces to other modes of transportation
- Automate and standardize reporting procedures
- Reduce administrative overhead
- Better integration of ship and shore-based systems
- Better utilization of all human resources
- Allowing global standardization of equipment
- Utilization of systems already in place, maximizing economy

To the public:

- Reducing maritime accidents and associated oil pollution
- Reducing stack emissions through optimum vessel routing
- Increasing port security

2.2 Core objectives of e-Navigation

The IMO has agreed that the core objectives of an e-Navigation concept should:

- Facilitate safe and secure navigation of vessels having regard to hydrographic meteorological and navigational information and risks
- Facilitate vessel traffic observation and management from shore/coastal facilities, where appropriate
- Facilitate communications, including data exchange, among ship to ship, ship to shore, shore to ship, shore to shore and other users
- Provide opportunities for improving the efficiency of transport and logistics
- Support the effective operation of contingency response, and search and rescue services
- Demonstrate defined levels of accuracy, integrity and continuity appropriate to a safety- critical system
- Integrate and present information onboard and ashore through a human interface which maximizes navigational safety benefits and minimizes any risks of confusion or misinterpretation on the part of the user
- Integrate and present information onboard and ashore to manage the workload of the users, while also motivating and engaging the user and supporting decision-

making

- Incorporate training and familiarization requirements for the users throughout the development and implementation process
- Facilitate global coverage, consistent standards and arrangements, and mutual compatibility and interoperability of equipment, systems, symbology and operational procedures, so as to avoid potential conflicts between users
- Be scalable, to facilitate use by all potential maritime users

2.3 Principal e-Navigation stakeholders

The following individuals, groups of individuals and organizations are the most likely to be heavily impacted by the development, introduction, and widespread use of e-Navigation equipment and operations:

- Mariners, especially commercial mariners
- Marine pilots
- Equipment manufacturers
- Vessel Traffic Services (VTS)
- Classification societies
- Marine insurance companies
- Coastal states
- Port States and Flag States
- Hydrographic Offices
- Ship owners
- Ship operators
- Ship charterers
- Training institutions including maritime colleges and universities

2.4 Current user requirements

IMO has identified the following shipboard user needs that can be fulfilled by e-Navigation:

- Improved ergonomics
- Greater standardization of interfaces
- Better familiarization training
- More effective display of Navtex and other MSI
- Alert/alarm management
- Improved reliability and better indication of reliability
- More standardized and automated reporting facilities
- Improved target detection
- More effective guard zones
- Reduction of administrative burden
- More automated updating of essential information

Shore based needs are being developed with the assistance of IALA and are:

- Better data collection for marine domain awareness
- More effective information management
- Better provision of information to vessels

- Greater quality assurance
- More effective sharing of information between authorized shore users to reduce the burden on seafarers and improve logistic management

Improvements in all these areas will not be accomplished solely by introducing better and more capable equipment. An extremely vital component in the successful implementation of e-Navigation is the proper training of all stakeholders, especially mariners, in the use of new equipment and methods as they are introduced.

2.5 e-Navigation training

Training courses in e-Navigation equipment and procedures do not yet exist. This model course is the first attempt to provide at least one group of stakeholders, the mariners, with an initial introduction to the world of e-Navigation as it is being developed. Although much of the equipment, methods, and organization remain to be created as of the date of writing, much preliminary thought has gone into the development of e-Navigation architecture by many competent authority representatives to the IMO from all over the world.

3. BTM and BRM Procedures

3.1 Basic tenets of BTM and BRM

The introduction of e-Navigation will not mean the end of current best practices in Bridge Team Management and Bridge Resource Management. Accordingly, for trainees to get the most out of this course, especially in the simulator exercises, a quick review of BTM and BRM theory is in order.

In recent years, the role of the watch officer has changed. There is less hands-on work and more management of systems, both electronic and human. The modern bridge has become crowded with a kaleidoscope of electronic devices such as:

- ECDIS
- ARPA
- AIS
- Electronic logger
- Gyrocompass
- Fluxgate magnetic compass
- GPS/DGPS
- Wind/weather sensors
- Engine control systems
- Satellite phones
- Doppler speed log
- Fathometer
- Weather routing systems
- Navtex
- Internal phones
- PA system

- Alarm systems

The goal of Bridge Resource Management training is to assist the watch officer in dealing with these many disparate pieces of equipment and systems and use them in a way that best allows him or her to navigate the vessel safely and efficiently. These systems are complex and unless utilized properly, the consequences of error are severe.

Bridge Team Management deals with those other resources on the vessel itself or in active communication with it, humans. These include:

- Watch officer
- Helmsman
- Lookout
- Master
- Pilot
- Engine watch
- VTS personnel
- Other vessel's watch officer, master or pilot

The following are the basic principles of BTM and BRM:

- Resources must match demand
- Error trapping/error chain management
- Clear and open communication
- Master/pilot relationship
- Effective passage planning and execution
- Emergency situation preparedness

Let us examine each of these principles in detail:
Resources must match demand – More demands mean greater danger to the vessel that in turn requires either greater resource allocation or reducing the danger (if possible).

Examples of greater danger:

- Reduced visibility
- Heavy traffic
- Narrow waters
- Inclement weather
- Fire, flooding, man overboard and other emergencies

Since it is not possible in the course of a voyage to add more bridge equipment to assist the watch officer, increased resources to account for the greater danger mean increased human resources. This has been standardized as follows:

- Watch Condition I
  Open ocean, clear weather, light traffic
  One-man bridge
- Watch Condition II
  Limited visibility, limited sea room, heavy traffic

Additional lookout, helmsman and/or another officer

- Watch Condition III & IV

  Serious/severe constraints to navigation due to visibility, traffic, or sea room, leaving or entering port

  Add master and/or pilot

Examples of reducing the danger:

- Reduce speed
- Change the route
- Heave to
- Anchor
- Delay departure

Error trapping/error chain management – Maritime accidents are rarely caused by one event. They are the result of a series of non-serious events know as the *Error Chain*. First it is necessary to recognize a developing error chain. Next, the chain must be broken to prevent an accident.

Signs of an error chain:

- Ambiguity – position fixes not agreeing
- Distraction – loss of focus on primary event (steer the ship!)
- Inadequacy and confusion – you've lost that 'warm and fuzzy' feeling
- Poor communication – language barriers, personal conflict
- Improper lookout
- No plan or not following the plan
- Violation of laws, rule or procedures

Clear and open communication – although ships are hierarchical in organization,

- Each team member must understand his/her role and duty
- Orders must be given clearly
- Orders must be obeyed
- Yet, team members must speak up when something looks wrong

Master/pilot relationship – The pilot is an expert hired for his/her shiphandling skills and local knowledge. The pilot is officially considered an advisor to the master who retains command of the vessel. However, in practice, it is usually the pilot who assumes the conn. Not considered a part of the bridge team, the pilot is nevertheless an extremely important bridge resource. During the master-pilot exchange soon after the pilot first arrives on the bridge, vital navigational information is passed such as:

- Vessel particulars
- Status of bridge equipment
- Navigational intentions
- Local conditions
- Berthing plan
- Use of tugs
- Unusual circumstances

A classic example of a poorly handled master-pilot exchange that led to a marine accident is the case of the *Cosco Busan* in San Francisco Bay on 7 November 2007. Instructors should use such case studies where appropriate to inform trainees not only of how BTM and BRM procedures can be violated today, but also get them thinking about how e-Navigation can help to reduce the occurrence of such incidents in the future.

Effective passage planning and execution – It is well known that proper passage planning involves preparation, appraisal, communication, and execution of the voyage plan from berth-to-berth. This is surely in keeping with the IMO's vision of e-Navigation as a means to "… enhance berth to berth navigation and related services…"

Emergency situation preparedness – Having some idea of how to handle an emergency situation before it happens involves:

- Making plans
- Conducting regular drills
- Improve emergency plans as needed and revealed by drills
- Keep the plans readily at hand
- Create and utilize checklists

3.2 How e-Navigation will affect BTM and BRM

It is certainly not the intention of the developers of e-Navigation to completely overthrow BTM and BRM procedures and practices that have been employed successfully for decades. Rather, e-Navigation is viewed as a vehicle to insure that the operational advantages that BTM and BRM have brought to the maritime industry are not overwhelmed by the inexorable introduction of new technologies. Undoubtedly, new BTM and BRM procedures will have to be developed to allow successful integration of these new technologies into organizational systems already in place. The continued use of existing bridge equipment can be expected to last well into the future, many years after e-Navigation operations become commonplace throughout the world.

For the purposes of this course then, instructors are encouraged to use the simulator exercises corresponding to this portion of the course to explore the possible changes to BTM and BRM that e-Navigation may bring. These may include:

- Greater emphasis on integrating navigation systems
- More frequent involvement of shoreside establishments in the navigation of the vessel
- Simplification of the navigational workload possibly requiring less human resources
- Better methods of cross-checking navigational information in light of greater uses of automated systems

4. ECDIS and GNSS

4.1 The importance of ECDIS to e-Navigation

The importance of ECDIS to the whole concept of e-Navigation cannot be overstated. Probably no single device currently contributes more to the e-Navigation ideal of "…the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services…" This does not mean however that vessels navigating in a paperless fashion through use of ECDIS as their primary navigation system are completely satisfying the IMO's definition of e-Navigation. Still, it is fair to state that e-Navigation would probably be impossible without the contributions that ECDIS provides. For that reason, completion of ECDIS training in a course based on IMO Model Course 1.27 *The Operational Use of ECDIS* should be required of all trainees entering this course.

4.2 The need for worldwide ENC coverage

ECDIS is still a developing system. There are few commercial vessels in the world today operating in a completely paperless fashion the way that the IMO envisions in the future. As mandatory ECDIS is phased into the world's commercial fleet beginning in 2012 and ending in 2018, ECDIS use will become ubiquitous as will the need for ECDIS training for all commercial mariners. A complete discussion of ECDIS, a somewhat complicated subject, is beyond the scope of this work, and instructors are encouraged to refer to IMO Model Course 1.27 as they create an e-Navigation course using this model course. There is a provision for time allotted in this course to allow instructors to refresh trainees on the use of ECDIS.

One factor concerning ECDIS that does need to be covered here is the general lack of worldwide Electronic Navigational Chart (ENC) coverage to date (2011). ENCs are the only IMO approved electronic charts that can be used in fully type approved ECDIS systems to allow a vessel to operate without the need for paper chart backups. As such, the lack of worldwide ENC coverage is not only a hindrance to the general implementation of ECDIS but also to the development of e-Navigation.

4.3 Basic operating principles of GNSS systems

Global Navigation Satellite Systems (GNSS) of which the Global Positioning System (GPS) developed and operated by the Unites States Air Force is the most successful example, are very complex systems quite beyond the scope of this model course to describe in the sort of detail necessary for even a general understanding of their operating principles. Instructors who wish to include a brief review of GPS will find a very good (and short) summary in Chapter 10 of the *Radar and ARPA Manual* (B4).

4.4 GNSS a prerequisite to e-Navigation

Just as e-Navigation would not be possible with ECDIS, so ECDIS would not be possible without GNSS. For one to claim that the whole architecture of e-Navigation is necessarily based upon the foundation of satellite-based navigation systems like GPS would not be an exaggeration in any way. GNSS is also the underlying system of AIS and LRIT, to be discussed in sections 5 and 7 below.

4.5 The need for GNSS redundancy in e-Navigation

Because GNSS is such a fundamentally vital component of e-Navigation, the need for a reliable backup system in the event of satellite positioning errors or outright system failure is obvious. Unfortunately, there exists today only one such electronic backup to GPS that would fit the bill: the Russian GLONASS system. Still, GLONASS receivers are rather expensive ($4000-$5000 US) and not very common even today. Also, the GLONASS system, while completely independent of GPS, is a satellite navigation system very similar in configuration to GPS with the same vulnerabilities and potential error problems. The European Space Agency is very close to launching the first satellites in their Galileo system, another GNSS roughly similar to GPS and GLONASS. The Chinese are developing their own GNSS called Compass, which is also due to begin launching the first satellites soon. Were all these GNSS systems to become operational and readily available in the near future, they could, taken together form adequate redundancy for confident positioning in e-Navigation.

Even with four fully operational and reliable GNSS systems comprising the positioning sources required for e-Navigation, there are some who are not fully comfortable with having to rely solely on satellite-based navigation systems. They argue for a backup system that is completely ground-based and therefore not subject to the debilitating effects of solar flares, multi-path errors, and even intentional jamming and spoofing. The problems associated with ground-based electronic positioning systems to date have been expense, limited coverage and limited accuracy. An attempt to promote an enhanced, more accurate version of the old Loran C system known as e-Loran, has not been successful. The whole e-Loran concept was dealt what is probably a fatal blow when the United States shutdown the entire Loran C system in January 2010 and cutoff any future funding for developing or maintaining the system. For now, e-Navigation will have to remain totally reliant on GNSS.

5. Radar and Automatic Identification Systems (AIS)

5.1 The role of radar in e-Navigation

Radar has served the maritime industry well for over sixty years as a completely independent navigation and collision avoidance system. Stand-alone radar displays were the norm until relatively recently with the introduction of the integrated display.

As many of the various components of shipborne navigation systems become more and more linked together, radar is beginning to lose its unique identity. For example, in modern ECDIS displays, full integration with radar, ARPA and AIS is common. It is understandable for mariners to become rather uncertain where one system begins and the other ends. If the display is showing erroneous information for example, how can one be sure which device is the source of the error? These are major concerns for the further development of e-Navigation, which is founded in part on the successful integration of all these systems in order to simplify the information presented to the mariner without obscuring or deleting important information. Radar information, reduced to its basics is:

- The presence of a target
- The distance to a target

- The approximate bearing of a target

All the other information that a modern radar display can provide is derived from internal computer programming based on relative movement of the target over time compared with known ownship course and speed (in essence, ARPA). It is important to remember that none of this vital information is reliant on information from GNSS. As such, radar, when used properly, can serve as a powerful cross checking device to determine the validity of navigational information from other equipment driven by GNSS inputs (ECDIS, AIS, LRIT, etc.). Accordingly, because of its reliability and independence from GNSS derived data, there should always be a provision to display a pure radar picture alone, no matter how fully integrated our navigation systems become under e-Navigation.

1. New Technology Radar (NTR)
There were exciting developments recently in the field of commercial marine radar. The first fully coherent radar system to come on the commercial market was introduced by the Kelvin Hughes Company in 2008. This radar employs a completely different transceiver unit from the standard magnetron-driven systems in use since World War II. A very good introductory piece on this new type of radar system is found in *Radar and AIS* (B2).

A full discussion of the operating principles of coherent radar is not possible here. Suffice it to say that the best attributes of these new radar systems such increased reliability, longer life, reduced output power and bandwidth, and most importantly, vastly superior target detection in rain and sea clutter, will make New Technology Radar a welcome addition to the suite of shipboard e-Navigation equipment.

Finally, one of the most intriguing potential uses for these new radar systems lies in their ability to extract much more information from the radar signal than standard magnetron radar can. For example, because every object that reflects radar waves has a unique radar signature, it is possible with coherent systems to identify individual target vessels by comparing their received echo signals with a known database. Military radars have been capable of such target identification for decades. There is no reason to believe that such capabilities will not be possible in future commercial systems. This form of target identification can provide a means of verifying the data received from other systems such as AIS.

5.2 The role of AIS in e-Navigation

The Automatic Identification System (AIS) holds tremendous promise as a real asset to e-Navigation. Indeed, it is difficult to envision e-Navigation as a viable concept without the information inputs that AIS provides. AIS is a rather new system that did not begin to come into general use throughout the maritime industry until 2002. It can be stated fairly that AIS is in many ways not yet a fully mature system that still has some developmental hurdles to overcome before it can be fully integrated into the envisioned architecture of e-Navigation.
1. AIS strengths and weaknesses
The vast amount of target information that AIS can provide is staggering. This includes:

- Maritime Mobile Service Identity (MMSI)

- Name
- Cal sign
- IMO number
- Vessel type
- Length and beam
- Position
- Course over Ground (COG)
- Speed over Ground (SOG)
- Heading
- Rate of Turn (ROT)
- Draft
- Vessel status (moored, anchored, underway using engine, et.)
- Destination and ETA
- Cargo on board – especially dangerous cargo
- Number of people on board

In addition, AIS can be used to show the navigator AIS aids to navigation (AtoNs) which provide the following information:

- Type of AtoN
- Name of AtoN
- Position of AtoN
- Position accuracy
- RAIM indicator
- Type of position (GPS, fixed, surveyed, etc.)
- Off-position indicator
- Dimension of AtoN
- Whether a virtual or real AtoN

All of the above AIS information can be displayed in the following ways:

- On the AIS receiver Minimum Keyboard and Display (MKD)
- On a radar display capable of displaying AIS targets
- On an ECDIS display

The latter two display methods are the most useful to the mariner. All recent ECDIS units and all commercial radars produced after 2008 are AIS capable.

With all its tremendous advantages, AIS has some serious weaknesses that have been identified by users soon after its introduction. Some of these are:

- Erroneous or missing target dynamic data
- False or ghost targets
- Missing targets
- Erratic target behavior
- Propensity of overloading the radar or ECDIS screen with unwanted information
- Incorrectly entered static data

Perhaps the greatest handicap that presently exists in the AIS system is its total reliance on GNSS systems for any sort of functionality. AIS when used as a primary collision avoidance device can be dangerous. Vessels have been documented as being quite far from their displayed AIS location, thus leading to confusion in close quarters situations. As a result, mariners have been advised not to rely solely on AIS to make collision avoidance decisions but to use radar and ARPA instead. Many ARPA radars have correlation programming that can warn the user of any discrepancies between target information shown by radar and that shown by AIS. Similarly, AIS AtoNs should be used with caution as well.

2. AIS enhancements for e-Navigation
Before AIS can be used with confidence in an e-Navigation environment, the issues related in the previous section must be resolved. Autonomous correction features are not yet part of the AIS system. Mariners may have to wait some time before solutions are found.

One possible answer may lie in the greater use of New Technology Radar. As previously stated in section 5.1.1 above, coherent radar has the ability, with proper programming, to make target identifications without relying on AIS data. The information supplied by AIS could therefore be subject to cross checking by a completely independent system. Target position, course, heading, speed, and even ship ID could be verified by NTR. This is but one example of the sort of autonomous data verification that must be commonplace throughout the whole of e-Navigation if the concept is reach its fully envisioned potential.

5.3 Use of AIS as a communications device

Notwithstanding the problems of using AIS as a collision avoidance device in the traditional sense, its utility as an aid to bridge-to-bridge communications cannot be gainsaid. Mariners who sailed before the advent of AIS are sure to recall many painful attempts to contact other vessels by VHF in order to confirm passing arrangements. (“Vessel on my port bow, what are your intensions? Etc.) With AIS, the target vessel’s name and call sign are displayed on the MKD, radar or ECDIS screen, making hailing the other vessel so much easier and more likely to be answered. For the first time, Digital Selective Calling via the GMDSS system became a viable option for communication as well. These contributions to marine communications by AIS contribute greatly to collision avoidance and should not be underestimated.

1. AIS text messaging
The AIS system was designed originally to contain its own communications capability via simple text messaging. Safety and security messages can be delivered to all AIS equipped vessels within range (approximately 20-30 miles) by shore stations. Also, AIS equipped vessels can communicate directly via the binary message system. The use of AIS text messages to transmit and receive safety related messages, particularly as a backup to Navtex and other GMDSS communications could be most helpful. It is difficult for the author of this model course to see the utility or desirability of bridge-to-bridge communications via text messaging however.

6. Integrated Navigation Systems and Integrated Bridge Systems

6.1 INS and IBS operating principles

The IMO definitions of INS and IBS are as follows:
'An Integrated Navigation System (INS) supports safety of navigation by evaluating inputs from several independent and different sensors, combining them to provide information giving timely warnings of potential dangers and degradation of integrity of this information.'

'An Integrated Bridge System (IBS) is a combination of systems which are interconnected in order to allow centralized access to sensor information or command/control from workstations, with the aim of increasing safe and efficient ship's management by suitably qualified personnel.'

The terms INS and IBS are used very loosely and interchangeably within the maritime world. Additionally, the term INS means Inertial Navigation System in military parlance, another source of potential confusion. Briefly, an INS used in the context of e-Navigation means any interconnection of navigation equipment but especially involving the use of multi-function displays. An IBS usually refers to bridge equipment that integrates both navigation and vessel operational controls such as engine controls and cargo handling equipment.

Trainees taking the e-Navigation course may or may not have already taken a course on Integrated Bridge or Navigation Systems. If trainees have already taken a course in INS and IBS, the instructor should feel free to omit or severely reduce the amount of time spent on this topic in the e-Navigation course. Many of the core functions of INS and IBS systems have direct transference into the requirements for vessels operating under the auspices of the e-Navigation concept.

If trainees have not had experience with INS and IBS technologies, the instructor is advised to refer to Model Course 1.32 *Operational Use of Integrated Bridge Systems including Integrated Navigation Systems* and take from that document the salient features of the course to include in this section of the e-Navigation course. It is particularly important that trainees have a primer on the use of INS and IBS if at least some of the e-Navigation course simulations are to be carried out in a fully integrated bridge simulator.

6.2 The importance of INS and IBS to e-Navigation

Recalling that the IMO definition of e-Navigation contains the words "…the harmonized collection, integration, exchange, presentation and analysis of maritime information aboard…" it is hard to imagine a vessel operating in an e-Navigation environment that wasn't equipped with at least an Integrated Navigation System. Therefore INS/IBS should be considered as necessary prerequisites to e-Navigation. This does not mean however that INS and IBS equipped vessels today are completely ready for e-Navigation. That requires an electronic tie in to shoreside establishments as discussed in the next section.

7. Vessel Traffic Systems (VTS) and Long Range Identification and Tracking (LRIT)

7.1 Benefits to VTS from e-Navigation

IMO Resolution A.857(20) adopted by the International Maritime Organization on 27 November 1997 defines a Vessel Traffic Service as "…a service implemented by a Competent Authority, designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area." VTS systems are quite common today, primarily to areas in and around large ports, narrow straits, and heavily trafficked regions of the world's navigable waters. New VTS operations are created every year, along with their associated Traffic Separation Schemes, and add significantly to the safety of life at sea by assisting the mariner in collision avoidance.

Section 2.1.3 of Resolution A.857(20) contains the following observation:

> The efficiency of a VTS will depend on the reliability and continuity of communications and on the ability to provide good and unambiguous information. The quality of accident prevention measures will depend on the system's capability of detecting a developing dangerous situation and on the ability to give timely warnings of such dangers.

One of the core objectives of e-Navigation is the improvement of ship-to-shore and shore-to-ship communications. Another is the facilitation of vessel traffic observation and management. Both developments will be required in order to satisfy the original goals for VTS systems as laid down in Resolution A.857(20).

There are at least two long-term studies being conducted presently by European government agencies, universities and maritime industry equipment manufacturers whose purpose is to explore new ways to improve vessel navigation and control through greater participation of shoreside competent authorities such as VTS systems; these are the EfficienSea project and the BLAST project. BLAST stands for "Bringing Land And Sea Together." The periodic reports produced by these studies should be included as appropriate by instructors of this course to keep trainees apprised of the latest developments in this sector of e-Navigation. Additionally, portions of the EfficienSea and BLAST simulations can be replicated and studied in the simulation component of this section of the e-Navigation course or in Section 10 E-Navigation Research.

7.2 Present (advisory) VTS systems

With rare exceptions, VTS systems are advisory in nature. This does not mean that participation is voluntary for most vessels. Most VTS systems have compulsory participation requirements for all vessels over a certain size, cargo type, or those carrying passengers. Vessels entering a VTS controlled area are normally required to maintain a VHF radio watch, check in with VTS operators at specified reporting points, and comply with any special navigating restrictions like speed limits in certain areas for reasons such as poor visibility, security areas, heavy traffic conditions, etc.

However, the command and control of the vessel is left entirely up to the navigating officer. VTS operators cannot generally order vessels around within their areas, assigning courses and speeds or specifying passing arrangements with other vessels. This is the type of control that is common in the aviation industry in areas subject to strict Air Traffic Control (ATC). Until recently, the traffic information provided to VTS by radar, AIS, VHF and surveillance cameras has not been sufficient enough in detail or rapid enough in update rate to allow the type of shoreside control of vessels in the maritime environment that is possible in aviation.

7.3 Future (mandatory vessel control) VTS systems

As information and communication systems continue to advance, is it possible that large vessels could be safely and efficiently controlled remotely from shoreside operations such as VTS? Remotely Operated Vehicles (ROVs) have been operated successfully for years in military aviation, underwater exploration, even on other planets (the Martian Rovers, e.g.). However, such robot vessels are perhaps many decades in the future and will not be discussed further in this course that more properly concerns marine navigational developments in the near term.

Conceding for the moment that human shipboard operators will be required for some time into the future, can e-Navigation developments lead to VTS systems that more closely resemble present Air Traffic Control systems? There are many who say yes. Would such a system be desirable? Again, many would say yes. Consider the case of the *Cosco Busan*. Although the vessel dynamic data from AIS that was being viewed by the VTS operator was inadequate for him to feel comfortable giving the pilot guidance on what course to steer to pass safely under the Bay Bridge, the VTS display was clear enough for the operator to see that something was terribly wrong. Improvements in data transfer rates, AIS accuracy and reliability enhancements, and better crosschecking possible with New Technology Radar may allow future VTS operators (assuming they are adequately trained in vessel handling characteristics) to give maneuvering orders to vessels in their jurisdiction if only in unusual circumstances.

For this section of the course, a trained VTS operator would be a most helpful participant in the VTS simulations. Even if the instructor simulator control station does not have displays similar to those of a typical VTS operation, the realism to the simulation possible by using trained VTS personnel would be invaluable. If it is not possible to obtain such participants, the instructor will have to serve as the VTS operator in the simulations. Practice and study of common VTS terminology on the part of the instructor will surely make for a more realistic and meaningful simulation for trainees.

A mandatory vessel control form of VTS as described in this section is not inevitable. There remains much research to be done on the desirability or even possibility of creating such a system. For that reason, an Air Traffic Control model of a future VTS system is certainly a topic worthy of study in Section 10 of this course. It is also an e-Navigation subject that can be studied without the necessity of obtaining or creating some prototype device or system.

7.4 LRIT and other satellite AIS systems

1. LRIT

The Long Range Identification and Tracking (LRIT) system is a designated International Maritime Organization (IMO) system designed to collect and disseminate vessel position information received from IMO member States ships that are subject to the International Convention for the Safety of Life at Sea (SOLAS). An automated system sends out vessel position, course and speed information to a shoreside flag state authority via GMDSS Inmarsat-C. This information is sent every six hours or more often if required. LRIT will most likely be made redundant by the widespread introduction of satellite AIS systems now coming on line.

2. Satellite AIS

The main drawback of the LRIT system is that it only provides data on participating vessels once every six hours. A satellite-based AIS system can provide nearly the same real-time information that AIS provides locally to approved users worldwide. A small constellation of specially fitted satellites receive standard AIS signals from vessels' transponders and build up a constantly updated database of vessel positions over most of the earth's surface.

Besides the obvious security and Search and Rescue applications that satellite AIS already provides, such systems could assist in supplying vessels weather routing advice, facilitate long-range communications between vessels, and improve logistics and transportation management. The archival information produced by satellite AIS data over time could assist vessel operators, charterers and owners in designing new vessel routes and schedules to enhance the efficiency and profitability of the marine transportation industry.

8. GMDSS and e-Navigation

8.1 Enhanced GMDSS through e-Navigation

The Global Maritime Distress and Safety System (GMDSS) was introduced to the maritime world in the 1990s as a way to simplify and consolidate the disparate, non-complimentary maritime communications systems in use since the introduction of radio in the early years of the 20th century. In the opinion of most of the world's mariners who generally hold the system in contempt, the effort at simplification has not been entirely successful. On many vessels, the suite of GMDSS equipment, required in various degrees by SOLAS on all commercial vessels over 300 GRT, lies unused and unloved. The GMDSS component known as Digital Selective Calling (DSC) is particularly inscrutable to the average watch officer and until the advent of AIS, almost never utilized. Although, overall, the GMDSS system is certainly much better than what existed before, it has not lived up to its promise as an efficient and user-friendly maritime communications system.

The IMO mandate to develop e-Navigation has given new emphasis to the desire of many maritime stakeholders to correct the shortcomings associated with the existing GMDSS system. Since true e-Navigation operations will require better facilitation of communications from ship-to-shore, shore-to-ship and ship-to-ship, and the desire to employ existing systems wherever possible remains strong or purposes of economy, improvements to the GMDSS system will likely be attempted before resorting to the scrapping of the entire system and starting again with something entirely new.

At the May 2010 meeting of the GMDSS Taskforce, the group made the following observations concerning the incorporation of GMDSS into the e-Navigation concept:

> **Accommodation of e-Navigation in GMDSS Modernization.** The emerging concept of e-Navigation is likely to utilize many of the same communication systems used for GMDSS, especially VHF which is already heavily loaded. In addition, the expanding e-Navigation requirements overlap in some cases such as the use of MMSI identifiers. Integration of radar and AIS displays on electronic charts invites further integration of MSI warnings as well. New requirements for cargo security monitoring and special broadcasting services make a strong case for dealing with e-Navigation requirements and GMDSS modernization together. There was a divergence of opinions at the workshop about the relationships between the two initiatives. Some stated COMSAR [radio communications for search and rescue] needs should be fully developed independently and then discussed in the context of e-Navigation initiatives rather than emphasizing a parallel effort.

The Taskforce also identified several other systems that they believed more properly belonged under the GMDSS umbrella:

> **Inclusion of AIS, SSAS, and LRIT in the GMDSS System.** Recognizing the case for AIS as outlined in the preceding paragraphs, it should be declared a GMDSS system in addition to its other applications for safety of navigation. In the same fashion, the IMO created the Ship Security Alerting System (SSAS) and the Long Range Identification and Tracking (LRIT) system; both have clear safety and distress applications. All three should be declared GMDSS systems and thus subject to the IMO requirements for reserve power, annual inspections, and operator training.

How such a consolidation of AIS and LRIT could be accomplished without making the GMDSS system more complicated has not yet been addressed. Clearly, the communications features inherent in AIS make the system something of a hybrid as it does have security and collision avoidance functions as well.

8.2 Changes required in GMDSS to operate in e-Navigation environment

The GMDSS taskforce identified the following concerns that needed to be addressed before GMDSS and e-Navigation policies can be fully reconciled:

- The inadequacies apparent in Digital Selective Calling (DSC) must be rectified
- Which basic communication capabilities are properly part of the GMDSS and which should become a part of the developing e-Navigation concept
- The distress communications should be clearly separated from other types of communications
- The AIS system should be used for distress alerting and messaging

- The need to clarify the difference between power supplies for the GMDSS equipment and other equipment on the bridge
- The Navtex system needs to transition to a much higher data rate to accommodate the volume of coastal warnings being broadcast
- Additional satellite communications systems should be included in GMDSS

Whether GMDSS becomes another integral component of the e-Navigation architecture or remains outside the system, there is little doubt that GMDSS needs an overhaul of some sort. In the simulation associated with this section, instructors are encouraged to select one or more of the issues identified above and have trainees examine them in a carefully crafted simulation.
Some possible examples:

- How effective is DSC for communicating passing agreements with vessels identified through AIS?
- Is AIS adequate for distress alerting and messaging?
- What are the best methods to communicate with shore establishments like VTS? Voice-only VHF, VHF DSC, or AIS binary messaging?

9. e-Navigation and traditional navigation

9.1 Does traditional navigation have a place in the e-Navigation world?

The discussion of how e-Navigation will affect the practice of traditional marine navigation has only just begun. There are basically two schools of thought:

(1) Traditional navigation methods such as visual piloting, celestial navigation, the sailings, and dead reckoning, must not be eliminated or reduced in importance because they provide an effective backup to e-Navigation, and

(2) Traditional navigation methods are unnecessary as long as sufficiently robust and reliable e-Navigation systems are created and widely used

This debate is an important one and will likely engage the maritime community for some time to come. How it is finally resolved is unclear at present, especially as new technologies are being introduced at an accelerating rate, any one of which could decide the issue once and for all. Still, it is worthwhile to examine both sides of the debate in order for trainees to be made aware that their future activities and practices as marine navigators are far from settled with the advent of e-Navigation.

1. Effectiveness of traditional navigation as an e-Navigation backup
The attraction of traditional navigation methods like celestial navigation lies in the fact that they are completely independent of any sort of electricity or electronics and therefore, according to their proponents, bulletproof. Undeniably, the ability for an ocean navigator in a small sailboat to navigate without any sort of electrical power by using a sextant, a chronometer, a nautical almanac, sight reduction tables, and a paper chart is a very useful and prudent thing to do. It is not obvious however that a large, modern containership or high speed ferry with a large number of redundant electronic navigation systems and

sophisticated communications systems has the need to rely on such antiquated navigational methods or whether those methods would provide any sort of adequate backup in the event of catastrophic failure of the vessel's primary navigation systems. Would it be acceptable for instance, to bring a large, loaded tanker through the Golden Gate in dense fog without the use of radar? Hardly.

To a large degree, the effectiveness of any navigation method lies in the proficiency of the navigator who uses it. Electronic navigation systems have been around for over one hundred years beginning with the introduction of Elmer Sperry's gyrocompass and continuing on with RDF, radar, Loran, Decca, Omega, Transit, GPS, and ECDIS. All these devices have proven their worth, and although not infallible, there were probably few mariners, once they became familiar with the equipment, that would cheerfully volunteer to sail without them. Overreliance on one particular navigation system has always been the hallmark of an inferior navigator but virtuosity in many disparate methods has proven very difficult to achieve. The less one uses some particular tool, the more the ability to use that tool deteriorates.

The question remains then, will the practice of traditional marine navigation survive the eventual dominance of e-Navigation?

2. Effectiveness of electronic equipment redundancy as an e-Navigation backup
Truly, a robust and reliable electronic backup to any failed e-Navigation component system would seem to be more desirable than depending on paper chart navigation in an emergency. Is such an absolutely reliable system possible? The answer would have to be, at least for now, no. Nevertheless, as future systems are developed and technology continues to progress, nearly perfectly reliable and accurate navigation and control systems are inevitable. But how perfect must the system be in order to be acceptable? Just one marine casualty on the order of the *Exxon Valdez* or even the *Cosco Busan* caused by a navigation equipment failure would not be tolerated.

9.2 Training mariners for both e-Navigation and traditional navigation

The question of whether or not traditional navigation has a place in the upcoming world of e-Navigation may be answered in part by whether or not it is desirable or even possible to train future mariners in both. Maritime education institutions are coming under increasing pressure to streamline their curriculums to increase student throughput, reduce costs and decrease time to graduation and certification. These trends would appear to be incompatible with training future mariners in all forms of navigation from simple visual piloting to the sextant to radar to ECDIS to 3D charts to Augmented Reality Head-Up Displays. There simply isn't the time or funding sources available to accomplish that. Decisions will have to be made on what to keep and what to drop. The promise that e-Navigation shows for increasing the safety and efficiency of marine navigation leaves little doubt as to what those decisions will be.

10. e-Navigation Research (optional)

There are many e-Navigation research and development projects being conducted in the world today, much of it by the Baltic Sea states of the European Union. These are large studies being undertaken by governmental bodies with large budgets. Clearly, replicating any of these research projects would be completely beyond the scope of many small maritime education and training institutes of the type offering this e-Navigation course. Accordingly, this section of the course can be considered optional if deemed unfeasible by the instructor. More time could be devoted to simulations in any of the other sections of the course in which the instructor deems particular important.

However, if there is any aspect of e-Navigation that is of enough interest to the instructor to investigate by a modest research experiment involving the trainees, the value added to the course thereby is great. If the instructor has access to any of a number of new navigational devices such the Furuno NavNet 3D or similar equipment, small simulations examining the usefulness of these systems to e-Navigation could be very valuable. Not every new marine navigation and communications device will be successful and any shortcomings can probably be better (and more safely) identified in the simulator rather than on board real vessels.

Some possible research topics for this section include:

- Improved ergonomics – bridge equipment layouts
- Standardization of equipment
- S-Mode (as suggested by The Nautical Institute)
- Improved alarm/alert management
- Further examination of text messaging in AIS
- Emergency backup systems for e-Navigation
- Improved navigation displays
- Investigation of Augmented Reality
- Investigation of Marine Head-Up Displays
- Consolidation of GMDSS equipment
- Improved ship-to-shore communications systems
- Mandatory VTS operations and scenarios
- New methods of vessel control interfaces such as voice control

■ Guidance on simulator exercises

It is essential that trainees get practical experience in e-Navigation equipment and techniques by using simulators. Such simulators can range from single screen computers representing individual components of e-Navigation equipment up to and including full-mission simulators with multiple workstations, 'real' controls, and multi window or 360^{o} projected representation of the external scene.

Although full-mission bridge simulation has many advantages as previously stated, it is expensive to procure and maintain. Also, only a few trainees at a time can participate. Full-mission simulation is not absolutely essential to the demonstration of many e-Navigation concepts. Training facilities without such advanced equipment should not be deterred from teaching this course, as part-task simulation is perfectly adequate in most circumstances.

Even colleges with expensive full-mission simulators find that time can be spent more effectively by having the majority of exercises on single screen classroom simulators or part task simulators, leaving the full-mission simulator for final exercises, particularly to bring in team interaction scenarios. Where possible, however, it is desirable that trainees get at least one session on a full-mission simulator as part of this course.

Finally, simulator exercises should be set appropriately to the facilities available at the training facility. Great care should be used in designing these exercises according to the equipment available, so as to maximize trainee exposure to as many facets of e-Navigation as possible in the most effective manner.

Fictitious versus real sea area

Exercises should produce the greatest impression of realism in limited 'real time'. To achieve this, the scenarios can often be best located in fictitious sea areas, for the following reasons:

- Situations, functions and actions for different learning objectives that occur in different sea areas can be integrated into one exercise and experienced in real time
- It eases the exchange of scenarios and exercises between maritime education institutions

On the other hand it can be difficult to get convincing and sufficient data in fictitious sea areas, particularly Electronic Navigational Chart (ENC) data. This is particularly true when creating simulation of various and different situations, as required by this course (as detailed in the next section below). Therefore the best data available for the particular simulation exercise should be chosen, fictitious or real.

It should here be noted that certain types of simulations involving interactions between shoreside VTS operators and shipboard navigators, would best be accomplished in real sea areas. The creation of a wholly fictitious sea area and a corresponding fictitious VTS system to go with it, would involve a tremendous amount of preparation work on the part of the instructor with very little value added over use of a real area and traffic system. In addition, the demonstration of the value of e-Navigation in an existing traffic area familiar to the trainees is important.

Specific types of sea areas

It is advisable to make use of simulation in at least two types of sea areas for which typical characteristics and attributes, navigational situations and requirements, navigational functions and operators' actions can be identified:

- Shallow waters, pilotage waters and fairways
- Harbour areas

Arguably, e-Navigation will also be utilized on the high seas and so scenarios involving sea passages could also be run. However, since e-Navigation's primary benefits will be most apparent in confined waters and heavily trafficked areas, and there is limited time available in a 40-hour course, e-Navigation simulations on the high seas for the purposes of this course can be omitted.

Compilation of typical situations and actions

In order to design exercises, it is advisable to compile characteristic sets of data containing learning objectives, situations and actions that the trainee has to perform.

Monitoring of exercises

The actions of the trainees should be closely monitored and recorded. The exercises should be recorded and a summary for the purpose of debriefing should be made. On a full-mission simulator it can be beneficial to video record (with sound) the exercises, for this debriefing.

Debriefing

Debriefing of the exercises is essential. The time spent in debriefing should typically occupy between 15% and 30% of the total time used for simulation exercises. Times in excess of this can be useful, especially when introducing uniquely new e-Navigation concepts in order to gauge the trainees' thoughts and acceptances of these new navigational procedures and methods. The instructor should refer to the summary made during the exercise to raise important points and to direct discussion among trainees. The following facilities may be used in debriefing:

- Playback of relevant sequences in the video recording
- Playback of possible simulator recording facilities, which can include plots of ownship maneuvers, surrounding vessels, etc.

Recommended exercises

Part B *Course Outline and Timetable* recommends the time allocated to the elements of teaching, including simulator exercises. This section regroups the simulator exercises into an example logical sequence.

Simulator Exercise		Time (hours)	Syllabus Reference
1	BRM	1.0	3.1
2	BRM & BTM	1.0	3.1, 3.2
3	ECDIS Part 1	2.0	4.1, 4.2
4	ECDIS Part 2	3.0	4.4, 4.5
5	Radar & ARPA	2.0	5.1
6	Radar, ARPA & AIS	2.0	5.2.1, 5.2.2, 5.3.1
7	INS & IBS	2.0	6.1, 6.2
8	VTS Part 1	2.0	7.1, 7.2
9	VTS Part 2	2.0	7.3
10	GMDSS	2.0	8.1, 8.2
11	e-Nav vs. Old Nav	2.0	9.1, 9.1.1, 9.1.2
12	e-Nav research Part 1	2.0	10.0
13	e-Nav research Part 2	2.0	10.0
14	e-Nav research Par 3	2.0	10.0
Total Simulator Exercises		27.0	

Annexes

Annex 1 Development of an E-Navigation strategy

Annex 2 Development of an E-Navigation strategy implementation plan

INTERNATIONAL MARITIME ORGANIZATION

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IMO

MARITIME SAFETY COMMITTEE
81st session
Agenda item 23

MSC 81/23/10
19 December 2005
Original: ENGLISH

WORK PROGRAMME

Development of an E-Navigation strategy

Submitted by Japan, Marshall Islands, the Netherlands, Norway, Singapore, the United Kingdom and the United States

SUMMARY	
Executive summary:	It is proposed to add a new item on E-Navigation to the work programme of the Sub-Committee on Safety of Navigation (NAV) and also to that on Radiocommunications 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 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 of 'safe, secure and efficient shipping on clean oceans'.
Action to be taken:	Paragraph 22
Related documents:	None

Introduction

1 The common objective shared by all the Member States of IMO 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 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.

Scope of the proposal

2 The scope of this proposal is broad. The authors of this submission believe it is now appropriate that IMO develops 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, secure and cost-effective system with the potential to provide global coverage for vessels of all sizes.

3 Implementation of this new strategic vision might require modifications to working methods and navigational tools, such as 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. 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.

Need or compelling need

4 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 three years (to February 2005).

5 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 Global Maritime Distress and Safety System (GMDSS) - which can provide the master and those ashore with the necessary information they require.

6 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.

7 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.

8 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.

9 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.

An integrated E-navigation action plan

10 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.

11 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.

Analysis of the issues involved

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

.1 accurate, comprehensive and up-to-date Electronic Navigational Charts ("ENC"s), covering the entire geographical area of a vessel's operation;

.2 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);

.3 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;

.4 transmission of positional and navigational information: ship-to-shore, shore-to-ship (e.g. by VTS, Coastguard centres, hydrographic offices) and ship-to-ship;

.5 accurate, clear, integrated, user friendly display of the above information onboard and ashore (e.g. using IBS or INS);

.6 information prioritization and alert capability in risk situations (collision, grounding etc), both onboard and ashore; and

.7 reliable transmission of distress alerts and maritime safety information with reduction of current GMDSS requirements by utilizing newly emerged communication technologies.

Issues to be considered

13 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.

Priority and target completion date

14 This should be deemed a high priority item, as the co-sponsors firmly believe that paragraphs 2.11.1 and 2.11.2 of the Guidelines on the Organization and Method of Work of the Committees and their subsidiary bodies (MSC/Circ.1099) are relevant to this proposal.

15 It is envisaged that this proposal should be referred to the next sessions of the NAV Sub-Committee (NAV 52) for initial consideration. It is further proposed that the issue should also be considered by the subsequent meeting of the COMSAR Sub-Committee (COMSAR 11), to discuss any communications-related issues. However, the consideration of the issue by this Sub-Committee would be under the co-ordination of the NAV Sub-Committee. The Sub-Committees should be requested to consider the issues with the aim of developing a strategic vision with an associated work programme for taking this issue forward and report back to the Maritime Safety Committee as soon as possible, and at the latest, by its eighty-fifth session at the end of 2008.

Is the subject of the proposal within the scope of IMO's objectives?

16 Yes. The Strategic Plan for the Organization (for the six-year period 2006 to 2011) (resolution A.970(24)) specifically identifies (in paragraph 2.9) as a challenge for IMO the aim of ensuring that:

> *".1 ...the technological developments adopted are conducive to enhancing maritime safety, security and the protection of the environment;"*
>
> and
>
> *".2 ...the proper application of information technology within the Organization and to provide enhanced access to that information for shipping, for the shipping industry and others."*

The Strategic Plan also states at paragraph 3.3.2 that:

IMO will take the lead in enhancing the quality of shipping by:

> *".1 encouraging the utilization of the best available techniques not entailing excessive costs, in all aspects of shipping;"*
>
> and
>
> *".3 promoting and enhancing the availability of, and access to, information – including casualty information – relating to ship safety and security (i.e. transparency);"*

Do adequate industry standards exist?

17 No. Considerable work has been carried out by numerous organizations, including IMO, IHO and IALA that have led to the development of standards for individual electronic navigational technologies, such as AIS, ECDIS etc. However, no single institution has taken the lead in developing a comprehensive vision for E-Navigation, managing buy-in from the various key stakeholders in such a way as to promote its constructive development and standardization.

18 IMO is the appropriate, and indeed the only international body, capable of managing a programme with these objectives and of this scope and magnitude. However, the involvement of other bodies, such as IHO, IALA, IEC and ITU will be needed to help realize some essential components.

Do the benefits justify this proposed action?

19 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. Focussing resources on the co-ordination of improvements to navigational and communication tools will bring substantial overall safety, security, environmental protection and commercial benefits.

20 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.

21 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.

Action requested of the Committee

22 The Committee is invited to note the information provided above and agree to include a new item on the work programmes of the Sub-Committees on Safety of Navigation (NAV) and Radiocommunications and Search and Rescue (COMSAR) on the 'Development of an E-Navigation strategy' as proposed in paragraph 15 above.

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INTERNATIONAL MARITIME ORGANIZATION

IMO

SUB-COMMITTEE ON SAFETY OF NAVIGATION
55th session
Agenda item 11

NAV 55/WP.5
29 July 2009
Original: ENGLISH

DEVELOPMENT OF AN E-NAVIGATION STRATEGY IMPLEMENTATION PLAN

Report of the Working Group

1 GENERAL

1.1 As instructed by the Sub-Committee, the Working Group on development of an e-navigation strategy implementation plan met on 28 and 29 July 2009 under the chairmanship of Mr. John Erik Hagen (Norway).

1.2 The Working Group was attended by delegates from the following Member Governments:

ARGENTINA
AUSTRALIA
BAHAMAS
BRAZIL
CANADA
CHINA
DENMARK
FINLAND
FRANCE
GERMANY
JAPAN
MARSHALL ISLANDS
NETHERLANDS
NIGERIA
NORWAY
PANAMA
POLAND
REPUBLIC OF KOREA
RUSSIAN FEDERATION
SOUTH AFRICA
TURKEY
UNITED KINGDOM
UNITED STATES

1.3 The session was attended by a representative from the following United Nations specialized agency:

WORLD METEOROLOGICAL ORGANIZATION (WMO)

and observers from the following intergovernmental and non-governmental organizations in consultative status:

EUROPEAN COMMISSION (EC)
BIMCO
INTERNATIONAL CHAMBER OF SHIPPING (ICS)
INTERNATIONAL HYDROGRAPHIC ORGANIZATION (IHO)
INTERNATIONAL MARITIME PILOTS' ASSOCIATION (IMPA)
INTERNATIONAL MARITIME RESCUE FEDERATION (IMRF)
INTERNATIONAL MOBILE SATELLITE ORGANIZATION (IMSO)
INTERNATIONAL RADIO-MARITIME COMMITTEE (CIRM)
INTERNATIONAL TRANSPORT WORKERS' FEDERATION (ITF)
INTERNATIONAL ASSOCIATION OF MARINE AIDS TO NAVIGATION AND LIGHTHOUSE AUTHORITIES (IALA)
INTERNATIONAL ASSOCIATION OF INSTITUTES OF NAVIGATION (IAIN)
OIL COMPANIES INTERNATIONAL MARINE FORUM (OCIMF)
THE NAUTICAL INSTITUTE

2 TERMS OF REFERENCE

2.1 The e-navigation Working Group should consider the relevant documents submitted under agenda item 11, namely, NAV 55/11/1 (IALA), NAV 55/11/3 (Germany), NAV 55/11/4 (United Kingdom), NAV 55/INF.8 (IFSMA) and NAV 55/INF.9 (Germany) including documents NAV 53/13, (MSC 85/26, annexes 20 and 21), MSC 86/23/4 plus the outcome of COMSAR 13 and STW 40 including relevant outcome of MSC 86 and, taking into account any decisions of, and comments and proposals made in, Plenary, and undertake the following tasks:

.1 consider documents NAV 55/11/1, NAV 55/11/3, NAV 55/11/4, NAV 55/INF.8 and NAV 55/INF.9 and finalize the more detailed user needs;

.2 consider document COMSAR 13/14 (paragraphs 4.60 to 4.64) and provide comments and recommendations regarding future spectrum requirement with respect to e-navigation;

.3 consider document STW 40/14 (paragraph 7.11.8) and provide advice on the correct generic term to replace the terms "Decca" and "Loran";

.4 consider documents NAV 53/13 (paragraphs 12 to 16) and MSC 85/26 (annex 20, paragraph 9.7.2 and annex 21, paragraph 5) and develop the initial identification/ outline of the system architecture;

.5 consider document MSC 85/26 (annex 20, paragraph 9.7.3 and annex 21, paragraph 6) and undertake an initial gap analysis;

.6 consider document MSC 85/26 (annex 21, paragraph 7) and develop/recommend an appropriate methodology for carrying out cost-benefit and risk analyses;

.7 develop the terms of reference for a correspondence group to progress work intersessionally based on the joint plan of work approved by MSC 86 and report to COMSAR 14 and NAV 56;

.8 take into account the role of the human element guidance as updated at MSC 75 (MSC 75/24, paragraph 15.7) including the Human Element Analysing Process (HEAP) given in MSC/Circ.878-MEPC/Circ.346 in all aspects of the items considered; and

.9 submit a report to Plenary on Thursday, 30 July 2009 for consideration at Plenary.

3 USER NEEDS

3.1 The group considered documents NAV 55/11/1 (IALA), NAV 55/11/3 (Germany), NAV 55/11/4 (United Kingdom), NAV 55/INF.8 (IFSMA) and NAV 55/INF.9 (Germany) in determining the user needs for e-navigation. The group recalled that the working group at NAV 54 (NAV 54/WP.6) had:

.1 identified the user needs for a typical SOLAS ship and a generic shore authority (paragraph 8.2);

.2 identified potential ship and shore-based users of e-navigation (annex 2); and

.3 agreed that the first step should be to identify users and their requirements. The next step should be to identify the groups of functions or services needed to meet these primary navigational needs, based on a structured, systematic and traceable methodology that relates the functions to tangible operational benefits (paragraph 9.7.1),

and that MSC 85 had approved the Strategy for the development and implementation of e-navigation (MSC 85/26, annex 20).

3.2 The group noted that:

.1 there was a need to standardize and harmonize reporting procedures to avoid repetition and to reduce workload;

.2 mariners favour the possibility of presentation of information received through communication equipment directly to navigation display to assist in decision-making and for the safety of navigation;

.3 VHF, HF and satellite broadband communication might be required and the reliability of systems and equipment should be improved;

.4 an ongoing procedure to verify and update user requirements as deemed necessary was essential during the development and implementation of the e-navigation strategy.

3.3 After some discussions, the group agreed that:

.1 there should be harmonization between the shipboard and shore-based systems and procedures;

.2 there should be coordination of inputs into the e-navigation development from shipboard and shore-based users, and other relevant bodies;

.3 while the shipboard user needs had been identified to a more detailed level, the shore-based user needs require to be further developed; and

.4 there was a need for an effective ship-shore inter-operability.

3.4 The group also recognized that to facilitate the development of shore-side user needs, it was important that there should be a national coordination process between all relevant authorities/organizations which could identify all data providers and data users for a single window concept.

3.5 With regards to shore-based user needs, the group recognized that the development of user needs was a complex exercise and that the method to develop user needs based on functions as proposed by the United Kingdom (NAV 55/11/4) could be effectively used. However, the group acknowledged that IALA could follow whichever method was suitable even if it was different from the approach taken in developing the shipboard user needs.

3.6 Furthermore, the group agreed that user needs were of paramount importance and the driving force for the e-navigation concept and that it was necessary to verify and update the user requirements as and when necessary during the implementation process of the Organization's e-navigation strategy.

3.7 After an extensive discussion, the group agreed that:

.1 information contained in documents NAV 55/11/3, NAV 55/INF.8 and NAV 55/INF.9 could form the basis for the preliminary shipboard user needs;

.2 review the preliminary detailed shipboard user needs as developed by NAV 55 and update them as appropriate, and to consider priorities;

.3 develop a detailed shore-based user needs, taking into account input provided by IALA and other relevant organizations and to consider priorities; and

.4 identify functions and services to support the shipboard and shore-based user needs in a harmonized and holistic manner.

3.8 Furthermore, the group agreed that IALA should be invited to provide the input and contributions of the various IALA Committees to the IMO Secretariat and the correspondence group. In this context, the IALA observer confirmed that IALA was ready to provide input to the correspondence group on shore-based user needs and that the work would be further progressed during the next IALA Committee meetings in September and October 2009 to which all interested organizations were invited.

3.9 The group also recognized that the results of relevant maritime projects, e.g., MarNIS and MEH, should be taken into account during the further development of the user needs. In this context, the European Commission observer agreed to provide the correspondence group with the outcome of the EU/MarNIS project relating to Maritime Information Management which could be used as a background document for the development of shore-based user needs and architecture.

3.10 Accordingly, the group developed the preliminary detailed shipboard user needs as set out in annex 1.

3.11 In light of the foregoing, the Sub-Committee is invited to:

.1 note the preliminary detailed shipboard user needs as set out in annex 1;

.2 agree that the correspondence group should further progress the work intersessionally to:

.1 review the preliminary detailed shipboard user needs, as developed by NAV 55, and update them as appropriate, and to consider priorities;

.2 develop detailed shore-based user needs, taking into account input provided by IALA and other relevant organizations and to consider priorities;

.3 identify functions and services to support the shipboard and shore-based user needs in a harmonized and holistic manner;

.3 agree that it would be necessary to verify and update the user needs, as and when necessary during the implementation process of the Organization's e-navigation strategy.

4 FUTURE SPECTRUM REQUIREMENT WITH RESPECT TO E-NAVIGATION

4.1 The group noted that COMSAR 13 had requested NAV 55 to consider future spectrum requirements with respect to e-navigation and to advise COMSAR 14 accordingly. In this context, the group further noted that COMSAR 13 had endorsed the view of IHO (COMSAR 13/4/2/Rev.1) that there might be a requirement for an additional spectrum to be allocated for broadcasting of additional security-related information on port security levels in major ports and coastal waters and agreed that band 495-505 kHz could be of interest to IMO for this purpose.

4.2 In this context, the group also recognized that the Technical working group had also been tasked to provide its advice to the Plenary on this matter under agenda item 8.

4.3 The group recalled that the Strategy for the Development and Implementation of e-navigation approved by MSC 85 provided for specific high-level needs for robust communication and, data and system integrity. Although the details of these requirements had yet to be defined, it was anticipated that these requirements would be applied to VHF, HF and satellite technologies, as well as onboard networks capable of effectively integrating onboard e-navigation systems. Hence, there was a need for resiliency and integrity of such capacities. Furthermore, the work of COMSAR, ITU working party 5B, and the IEC TC80 and its continuous work on onboard digital interface networks to develop such communication capabilities was relevant.

4.4 In light of the foregoing, the group agreed that:

.1 e-navigation would require a stable broadband VHF, HF and satellite data communications system;

.2 maritime frequency spectrum should not be given up;

.3 e-navigation would probably require additional frequency allocation which would be communicated to COMSAR 14 in due course for onward transmission to ITU; and

.4 ITU should be informed accordingly.

Accordingly, the group advised the Technical working group of its deliberations and discussions on this matter with a view to providing consolidated advice to the Plenary.

5 CORRECT GENERIC TERM TO REPLACE THE TERMS "DECCA" AND "LORAN"

5.1 The group noted that STW 40 had agreed to replace the terms "Decca" and "Loran" with a more generic term. However, STW 40 could not agree on the exact text and, bearing in mind the continuing development of e-navigation, it agreed to seek the advice of NAV 55 on the correct terminology. In this context, the group further noted that STW 40 had the following three alternative proposals in square brackets pending advice from NAV 55:

.1 terrestrial radio navigation systems; or

.2 terrestrial navigation systems; or

.3 hyperbolic navigation systems.

5.2 After some discussions, the group agreed that in light of rapid advancement of technology, it would be appropriate to use a more generic term and that the term "terrestrial electronic position fixing systems" should replace the terms "Decca" and "Loran". The Sub-Committee is invited to instruct the Secretariat to inform STW 41 and the STW Intersessional Working Group accordingly.

6 INITIAL IDENTIFICATION/OUTLINE OF THE SYSTEM ARCHITECTURE

6.1 The group gave preliminary consideration to initial identification/outline of the system architecture taking into account information contained in documents NAV 53/13 (paragraphs 12 to 16) and MSC 85/26 (annex 20, paragraph 9.7.2 and annex 21, paragraph 5) and noted that there were no submissions to this session on this issue. Accordingly, the group agreed that this work should be progressed further intersessionally by the correspondence group, taking into account the components identified at NAV 54, namely the hardware, data, information, communications technology and software needed to meet the user needs and should be based on a modular and scalable concept. Furthermore, the system hardware and software should be backward compatible based on open architectures to allow scalability of functions according to the needs of different users and to cater to continued development and enhancement. When new systems are introduced that cannot be made compatible, a suitable transitional period should be provided for, during which existing systems could continue to be in use. The group also noted that development of system architecture had taken place in the interim period within IALA. Accordingly, the group invited IALA to provide the results of these developments to the correspondence group.

7 INITIAL GAP ANALYSIS

7.1 The group noted that MSC 85 (MSC 85/26, annex 20, paragraph 9.7.3 and annex 21, paragraph 6) had approved that the gap analysis should focus on:

.1 regulatory gap analyses particularly identifying gaps in the present frameworks that need to be filled, e.g., in the provision of services in international waters. Based on this analysis, any institutional reform that is needed should be proposed for implementation;

.2 operational gap analyses to define a reduced concept of operations that could be used based on the integration of existing technology and systems;

.3 identification and description of existing systems that could be integrated into the e-navigation concept covering functionality, reliability, operational management responsibilities, regulatory status as to specification/standardization, fitment and use, generational status and integration with e-navigation system requirements; and

.4 technical gap analyses, comparing the capabilities and properties of existing systems with the architectural requirements to identify any technology or system development that might be needed, based solely on the user needs. This should result in a programme of development work that needs to be done to provide technology solutions to user requirements in their entirety.

7.2 In this context, the group reviewed the preliminary gap analysis as set out in annex 3 of document NAV 53/13. Each of the various elements was discussed briefly, and it was noted that it could be a source of information for the correspondence group in preparing its more complete gap analysis, which include areas of business practices and holistic liability issues. To this end, the group further noted that this preliminary gap analysis was undertaken before the e-navigation strategy was completed, and to some extent was based on assumptions. The group also noted that in certain areas further development had taken place during the interim period within IHO and IALA. Accordingly, the group invited IALA and IHO to provide inputs to the correspondence group.

7.3 The IHO observer expressed the view that the group and subsequently the correspondence group should not attempt to identify, analyse and describe all possible users and uses of e-navigation. The work should be confined to identifying the key purposes of e-navigation and the stakeholders involved from an IMO perspective. It would be unrealistic to attempt to identify and cater for all possible stakeholders, many of whom will be outside the jurisdiction of IMO. The guiding reference for the correspondence group should always be the definition of e-navigation agreed by MSC, in other words, *does its work relate directly to the definition*? The e-navigation system architecture should nevertheless be implemented in such a way that new or additional stakeholders can access or input to e-navigation as and when it is appropriate. Accordingly, the principal outcome of the work being undertaken by the correspondence group should be to describe, in functional terms, the key requirements of e-navigation from the perspective of IMO stakeholders and to what extent systems are already in place or need to be further developed. From this, IMO would be able to determine what measures, including performance standards, guidelines, etc., it must put in place to ensure that e-navigation can be successfully implemented.

7.4 After some discussion, the group agreed that the work should be progressed further intersessionally by the correspondence group in a holistic manner taking into account the components agreed at MSC 85 and that the preliminary gap analysis as set out in document NAV 53/13, annex 3 could be used as a background document for the proposed gap analysis.

8 COST-BENEFIT AND RISK ANALYSES

8.1 The group recalled that MSC 85 (MSC 85/26, annex 21, paragraph 7) had agreed that cost-benefit and risk analysis should be an integral part of the development of e-navigation and should be used to identify strategic decisions and, support decision-making on where and when certain functions need to be enabled. However, as there were no submissions to this session on this issue, the group agreed that this work should be progressed intersessionally by the correspondence group.

9 TERMS OF REFERENCE OF A CORRESPONDENCE GROUP

9.1 In light of the discussions set out in sections 3, 6, 7 and 8 above and, to maintain the proposed time schedule approved by MSC 86, the group developed the terms of reference for a correspondence group to progress the work intersessionally under the coordination of Norway* as set out in annex 2. In case the correspondence group needs to continue its work beyond NAV 56, these terms of reference would need to be reviewed by NAV and COMSAR Sub-Committees.

9.2 Furthermore, the group recalled that, in the joint work plan for COMSAR, NAV and STW Sub-Committees approved by MSC 86, it was envisaged that STW 41 would provide answers to questions related to initial gap analysis and initial cost-benefit and risk analyses, and that no submissions had been made to this session relating to these issues. Hence, bearing in mind that the deadline for submission of documents to STW 41 was 6 November, it would not be possible for the correspondence group to submit any meaningful questions to STW 41. Accordingly, it would be more appropriate for the correspondence group to request STW 42 to answer any questions that might have been identified.

10 ACTION REQUESTED OF THE SUB-COMMITTEE

10.1 The Sub-Committee is invited to approve the report in general and, in particular, to:

.1 note the preliminary detailed shipboard user needs (paragraph 3.11.1 and annex 1);

.2 agree that the correspondence group should further progress the work intersessionally to:

  .1 review the preliminary detailed shipboard user needs, as developed by NAV 55, and update them as appropriate, and to consider priorities (paragraph 3.11.2.1);

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.2 develop detailed shore-based user needs, taking into account input provided by IALA and other relevant organizations and to consider priorities (paragraph 3.11.2.2);

.3 identify functions and services to support the shipboard and shore-based user needs in a harmonized and holistic manner (paragraph 3.11.2.3);

.3 agree that it would be necessary to verify and update the user needs, as and when necessary during the implementation process of the Organization's e-navigation strategy (paragraph 3.11.3);

.4 note the deliberation and discussions relating to future spectrum requirement with respect to e-navigation, as conveyed to the Technical working group (section 4);

.5 agree that "terrestrial electronic position fixing systems" would be the appropriate generic term to replace the terms "Decca" and "Loran" and instruct the Secretariat to inform STW 41 and the STW Intersessional Working Group accordingly (paragraph 5.2);

.6 note the discussions of the group relating to system architecture, initial gap analysis and cost-benefit and risk analysis (sections 6, 7 and 8); and

.7 approve the terms of reference for the correspondence group to progress the work intersessionally on the development of an e-navigation strategy implementation (paragraph 9.1 and annex 2).

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ANNEX 1

PRELIMINARY SHIPBOARD USER NEEDS AND PRIORITIES

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
Human Machine Interface Issues				
Improved Ergonomics Mariners have expressed a desire for bridge layouts, equipment and systems to be better designed from an ergonomic and user friendly perspective.	Many bridges have been designed without much thought given to the effective layout of equipment or workstations. Mariners have expressed that in an e-navigation era, work stations, navigation displays, communication devices, and other bridge equipment must be designed to improve effective bridge operation. Such layouts should take into account expanded bridge teams and the pilot.	• Human Machine Interface • Human Centred presentation needs	Harmonize and apply existing documentation Take note of: IMO documents: • MSC.252(83) (INS) • MSC/Circ.982 (Ergonomic Criteria for Bridge Equipment and Layout) • NAV 55/4, annex 1 (Bridge Equipment, System Arrangements and Integration) • MSC.191(79) (Pres. Of Nav-Related Info on NavDisplays) Other industry standards.	It should be noted that much work has been done in this area, however not widely applied. Consideration of more prescriptive bridge layout requirements. Consideration of more prescriptive work station requirements. Better application of centralized and effective dimming of screens. Innovations and new technology solutions, should concentrate on the needs and capabilities of the users. Promotion of access to information at one place where appropriate (multi-functional workplaces).

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
Standard Interface Mariners expressed a desire for greater standardization of functionality for navigation displays (human/machine interface).	Navigation system functions, operations and presentation (including ECDIS, Radar, AIS, GPS, GMDSS, etc.) can vary widely between manufacturers and even between models by a single manufacturer. The differences include where certain information is displayed (i.e. Speed and Course), how it is displayed, menu functions and interface devices such as knobs or joysticks. This makes type specific training difficult, and leads to ineffective use of features particularly by those watchkeepers who are new to a vessel.	• Human Centred Presentation needs • Human Machine Interface • Analysis	Research should be conducted regarding the functionality of standard interfaces. Take note of: IMO documents - MSC.191(79) (Pres. Of Nav-Related Info on NavDisplays) - MSC.252(83) (INS) - NAV 55/4, annex 1 (Bridge Equipment, System Arrangements and Integration) Other industry standards.	Design specification for current equipment. Note should be made of concept of S-Mode as proposed at NAV 54 (NAV 54/13/1). Need to update and establish balance between standardization and innovation.
Familiarization Requirements Mariners need all safety-related equipment to be provided with familiarization material specific to the model and installation.	Mariners often join ships where non-standard equipment and functions exist. It was thought that if these pieces of equipment or systems could be provided with familiarization material or tutorials safety would improve.	• Human Machine Interface • Analysis • Implementation issues	Identify where familiarization material specifications need to be developed for existing and developing proformance standards. Take note of: IMO document (SN.1/Circ.274) Guidelines for application of the modular concept to performance standards.	Consideration should be given to requiring such familiarization material to be provided by the manufacturer. Consider example using INS Performance Standard (MSC.252(83)).
User-Selectable Presentation of Information Received via Communication Equipment	Mariners expressed to have a desire to have the possibility to present user-selectable information received via communication equipment on the navigational displays	• Effective communication: • Human Centred Presentation needs • Human Machine Interface	Research should be conducted regarding the type of information, equipment and systems involved and how to present and/or filter such information.	Availability of information in real-time with possible presentation on the navigational displays. Information overload

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
	(e.g., vessel in distress, wind speed/ direction, AtoN status, restricted areas). They further requested the possibility to filter some transmitted data for presentation according to user-set parameters (e.g., only information from user-selected sea areas).	• Analysis		needs to be prevented – therefore, presentation of information should be user-selectable to filter required information. Task-oriented presentation based on INS-tasks MSC.252(83).
Marine Safety Information (MSI) Mariners expressed a desire to sort and display MSI, such as NAVTEX, SafetyNET more effectively.	On most ships, NAVTEX information is displayed on a separate screen or printed on a scroll of paper. The Latitude and Longitude of the MSI must then be mentally compared to that of the vessel by the watchkeeper to calculate risk. Notification of a new and dangerous wreck carries the same weight as a buoy that has drifted off station, which may be hundreds of miles away from the ship's intended voyage. This is a very time-consuming and distracting task, and susceptible to human error. Mariners considered that presenting such safety information on the ship's navigation display would be far more effective and a clear benefit of e-navigation.	• Effective communication • Human Centred Presentation needs • Human Machine Interface • Analysis	Work with relevant stakeholders to address technical requirements for presenting MSI on navigation displays. Take note of Methodology for developing e-navigation user needs using a task-based approach (NAV 55/11/4).	Possible re-formatting of NAVTEX data and continuing with transmitting data on same frequencies Transition from old to new format. Task-oriented presentation based on INS-tasks MSC.252(83).

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
Alert Management Bridge alerts (emergency alarms, alarms, warnings and cautions) must be co-ordinated, weighted, and support decision making without undue distraction.	It is not uncommon for the bridge of a ship to have in excess of 500 alarms pertaining to navigation, propulsion, cargo, and communication systems. These alarms are usually uncoordinated, physically located all over the bridge, and give little indication of severity without interrogation, which distracts the navigator. As systems become increasingly complex, all bridge alarms must be coordinated to avoid undue distraction.	• Human Centred Presentation Needs • Data and System Integrity • Analysis	Investigate possibility to apply existing IMO regulations on INS alert management and bridge alert management. Take note of: IMO documents • MSC.252(83) (INS) • NAV 55/4, annex 2 (BAM) • DE 52/4/2 (Code on Alerts and Indicators)	
Indication of Reliability	Mariners have expressed a concern that on systems such as ECDIS, the vessel's position is always indicated as an absolute, leaving mariners to rely on their understanding of technically complex systems to assess the accuracy of such indicated positions. Mariners have expressed a desire for systems to automatically assess the accuracy and integrity of hydrographic data, position fixing data, radar, and other ship sensors to return a graphical indication of assessment.	• Human Centred Presentation Needs • Human Machine Interface • Data and System Integrity • Analysis	Investigate effective ways to indicate levels of reliability using graphical representation. Take note of: • IMO MSC.252(83) (INS) • Other industry/naval standards.	Consideration of using, e.g., ellipses of uncertainty to indicate expected accuracy. Consideration of using, e.g., colour or shading changes to indicate integrity of information.

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
Operational Issues				
Improved Reliability Before mariners can feel confident about relying on systems under the e-navigation concept, they must prove far more reliable than many of the present systems.	Mariners today often struggle with electronic equipment that fails or malfunctions in some respect. This may relate to poor performance from radar; electronic chart software faults; incorrect AIS data, GMDSS alerts or loss of position fixing systems. Even a 99% reliability rating, would result in a problem for one voyage in every 100. This has resulted in many mariners distrusting electronic systems, and now having grave doubts about relying on e-navigation. It must be recognized that there is little competence for fixing such systems on board, and obtaining the services of a qualified technician in some ports can be difficult.	• Effective and Robust Communications • Data and System Integrity	It will be necessary to carry out an assessment to quantify reliability parameters. To include specific assessment of reliability of electronic position fixing systems.	Design specification for current equipment. Type approval process. Competence of installation and repair technicians. Better control and visibility of software and hardware updates.
Standardized and Automated Reporting Mariners have expressed a keen desire to reduce the amount of ship/shore reporting and to adopt the principle of single	A major frustration and distraction for mariners is the repeated reporting of static and dynamic information pertaining to the vessel, cargo, crew, and voyage to shore authorities. A major benefit of e-navigation would be for ships crew to enter such information into their system	• Common Maritime Information/Data Structure • Automated and Standardized Reporting Functions • Effective and Robust Communications	Investigate methods for global standardization of reporting procedures and technology. Investigate the legal aspects associated with access and sharing of information.	Possible increased use of AIS. Possible increased demands on communication means, i.e. spectrum and bandwidth.

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
entry for any information into the system. They have further expressed a desire for globally standardized reporting procedures and forms to avoid repetition of reporting and to reduce workload.	only once and for it to be shared by authorized authorities without further intervention by the ship.			
Improved Target Detection Mariners would be grateful if e-navigation could facilitate better detection of targets.	Mariners are constantly concerned with identifying targets, including leisure and fishing craft, pirates, flotsam and jetsam, ice, etc. Anything that can be done to improve detection would be appreciated.	• Effective and Robust Communications • Human Centred Presentation Needs • Data and System Integrity • Analysis	Investigate technologies to assist with better detection of targets and risk of collision.	High resolution X-band NT radar has potential benefit in this area.
Guard Zones Mariners expressed a desire to have more effective Guard Zones to notify watchkeepers of hazards pertaining to collisions and groundings.	As target detection become more effective, MSI becomes integrated, and passage plans are programmed onto ECDIS, mariners feel that guard zones in three dimensions can be an effective way to warn watchkeepers of undetected hazards. This should include hazards of grounding taking into account UKC in a dynamic environment; air draft; and risk of collision. Warnings from this Guard Zone feature should be integrated into the bridge alert system.	• Human Centred Presentation needs • Human Machine Interface • Data and System Integrity • Analysis	Research effective means of implementing the use of Guard Zones or other means in order to avoid collisions and groundings.	It should be noted that the use of such Guard Zone facility will need to be intrinsic in the training syllabus. Use of Guard Zones must be taught as a decision support feature. Many ships have aspects of Guard Zones on present equipment but don't use them due to poor training with reference to their function and their value.

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
Reduction of administrative burden and increase use of electronic documentation	Users expressed the need to reduce the amount of administrative work on board. They also expressed a desire to provide paper information and documentation in electronic form with means for easy location of information.	• Human Centred Presentation Needs • Data and system integrity	Investigate the best way to harmonize and present maritime documentation in an electronic format to improve efficiency and reduce administrative burden.	Electronic documents should support: - easy localization of information (e.g., with the help of a search function) - automatic updates (e.g., of Notices to Mariners) - Possible integration of information from multiple sources. - the integration of information in other systems on the bridge (e.g., ECDIS) electronic documents should be printable or be additionally provided as paper version. The need for raceability and ability to audit.
Automated Updating of Base Line Data and Documents Mariners expressed a desire for documents such as Charts, and Voyage planning publications to be automatically updated,	Mariners are required to use a plethora of publications associated with voyage planning and monitoring. These include, but are not limited to Charts, Light list, list of radio signals, sailing directions, port guides, etc. Currently, most of these are kept on board in a paper	• Common Maritime Information/Data Structure • Effective and Robust Communications • Human Centred Presentation Needs • Analysis	Investigate and harmonize means for automated updating of baseline data and documents, including consideration of legal aspects communication costs.	Consideration should be given to a proper electronic format for the data rather than digital copies of existing paper publications. This would allow the presentation of relevant data in a succinct manner.

User Need	Justification	Relation to IMO Strategy (Section 8.2)	Priority in terms of work required	Issues to Consider
with minimal shipboard intervention.	format and require a considerable amount of time to keep constantly updated. Mariners believe that e-navigation can be of benefit if it ensures that all these sources of information are automatically maintained up-to-date, and all of this information is accessible from a centralized location. Mariners have also expressed a desire for this information to be easy to access, sort and make sense of. This may be achieved by standard formats or "smart" systems. Mariners are very concerned that e-navigation may lead to more information being made available to them, leading to further overburdening. It is essential that the provision of information via e-navigation should be managed and presented effectively.			The need for traceability and ability to audit.

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ANNEX 2

TERMS OF REFERENCE FOR CORRESPONDENCE GROUP

Taking into account document MSC 86/23/4 (Secretariat) relating to the joint work plan for COMSAR, NAV and STW Sub-Committees for the period 2009-2012, the comments and general views expressed at NAV 55 and, decisions taken by NAV 52 including the guidance in MSC/Circ.1091 on Issues to be considered when introducing new technology on board ship and MSC/Circ.878-MEPC/Circ.346 on Human Element Analysing Process (HEAP); the Correspondence Group on e-navigation should:

.1 review the preliminary detailed shipboard user needs as developed by NAV 55 and update them as appropriate, and to consider priorities;

.2 develop detailed shore-based user needs, taking into account input provided by IALA, IHO and other relevant organizations and to consider priorities;

.3 identify functions and services to support the shipboard and shore-based user needs in a harmonized and holistic manner;

.4 consider documents NAV 53/13 (paragraphs 12 to 16) and MSC 85/26 (annex 20, paragraph 9.7.2 and annex 21, paragraph 5) and develop an outline of system architecture, taking into account input provided by IALA, IHO and other relevant organizations;

.5 consider documents NAV 53/13 (annex 3) and MSC 85/26 (annex 20, paragraph 9.7.3 and annex 21, paragraph 6), and undertake an initial gap analysis;

.6 consider document MSC 85/26 (annex 21, paragraph 7) and develop/recommend an appropriate methodology for carrying out cost-benefit and risk analysis; and

.7 submit a document to COMSAR 14 (8 to 12 March 2010) raising specific questions, if required, that should be addressed by COMSAR and prepare a comprehensive report for submission to NAV 56 (26 to 30 July 2010).

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Maritime Head-Up Display: A Preliminary Evaluation

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A major disadvantage of nearly every marine electronic navigation device introduced to date is the necessity for the navigator to turn his or her attention away from the view outside the bridge windows, even momentarily. Indeed, the uncomfortable feeling experienced by seasoned mariners that this 'head down' posture creates has led many to be initially reluctant to adopt some marine electronic devices (radar, ARPA, ECDIS, to name a few) that have proven their worth over time as useful, even vital navigational aids. Unfortunately, the use of such equipment has always required the marine navigator to leave behind the real world perspective view and enter an unnatural, two-dimensional plan view of the area surrounding the vessel. Mariners have accepted this type of view by necessity rather than by choice. That may be about to change. Advances in technology and a proven track record of performance benefits from Head-Up Display (or HUD) information in the aviation field have made it possible to consider if such a device would be useful in a maritime context. Accordingly, the authors of this paper conducted a preliminary evaluation to examine empirically what the effects of providing this same type of head-up information would be on marine navigation performance. A series of tests were conducted in the California Maritime Academy's advanced simulation facilities utilizing a full-mission simulator, a laptop-based HUD prototype, a projector, and student participants from an experimental undergraduate course entitled *e*-Navigation. The goals were to: 1) define the operational requirements and concept(s) of operations for a maritime HUD system; 2) identify essential information, risks, and concerns; and 3) examine performance variations by conditions (environmental, vessel, crew) and tasks. The results indicate great potential for a maritime HUD system, especially for improving situational awareness in low visibility conditions, confined waters, and for vessels where information changes rapidly (i.e., high speed vessels). The results also suggest that there are some standard information requirements across situations that could be augmented with task and vessel specific information.

KEY WORDS

1. Head-Up Display 2. e-Navigation 3. Full-Mission Simulator

1. INTRODUCTION. Head-Up Display systems for aviation and automobile applications have existed for decades. As of the date of this writing, no comparable HUD equipment has been developed for the civilian maritime domain although there have been some preliminary experiments conducted by a few groups as described below. HUDs may in fact hold one of the keys to the effective application of the wide-ranging, ambitious demands that e-Navigation concepts place on command and control of commercial marine vessels of the future.

The purpose of the current research is not to solve all the technical problems associated with the development of a working marine HUD intended for shipboard use, but rather, to begin to establish which functions and features would be most useful and desirable in a marine HUD system. The simulator chosen for this project uses five plasma view screens to generate a simulated 225° outside view from the bridge of ownship. The HUD mockup used in this study generated a properly scaled perspective view of user selected waypoints and tracklines. This augmented reality egocentric presentation was then projected onto the centerline plasma view screen. Because each plasma screen generates a fixed 45^{o} wide view as seen from the center of the pilothouse, there were no problems with the HUD generated information (tracklines and waypoints) becoming displaced from the simulator visual presentation. Parallax issues, a major concern in the development of any actual shipboard marine HUD, were not a problem for the mockup HUD because both the HUD and simulator images are presented directly onto the flat center panel. Accordingly, the mockup HUD served as an effective research tool for requirements definitions and testing. The HUD mockup is described in more detail in Section 5 below.

2. HUD RESEARCH & DEVELOPMENT. Head-Up Display systems are designed to provide a user with a display that allows him or her to view objects and cues in the real world scene (the far domain) concurrently with the presentation of additional information, typically information from on-board instruments and displays (the near domain) (Newman, 1987; Fadden, Ververs, & Wickens, 1998). Although HUD technology has been utilized in other application domains, such as the aviation and automobile industries and military applications, to varying degrees for some time, its use in the maritime world has been limited. The limited work that has been conducted for marine operations has mostly been conducted in simulator studies with a simulated (projected) HUD, such as the current project, or by utilizing video or synthetic vision systems rather than overlaying information on the operator's view of the outside world. For examples of the latter see the seascape coordination work combining AIS, radar, and a video image conducted in Japan by the National Maritime Research Institute and the Tokyo University of Marine Science and Technology (Imazu, 2006; Fukuto, Hayama, Takanori, & Fukui, 2008) and the ARVCOP work by Technology Systems, Inc. (Technology Systems, Inc., 2010). In 2003 the US Coast Guard also sponsored some prototype research on a Mobile Augmented Reality System (MARS) that provided augmented reality virtual aids to navigation utilizing head-worn displays (Kirkley & Walker, 2003).

In the current research the focus is on the concept of fixed display HUDs that require the user to look through a stationary display element rather than head- (or helmet-) mounted displays. The information needs and requirements results of our research could be applied to both fixed and head-mounted (HMD) HUDs but the overall concept of operations is specific to a fixed display HUD. Initial mariner inputs suggest a reluctance to utilize head or helmet-mounted displays. As technology advances and HMD systems become lighter and more reliable this might change. For instance, mariners may be more inclined to use a HMD the size of a typical pair of glasses connected wirelessly to the control unit.

There are three essential components in the standard fixed HUD (Newman, 1987; Rockwell Collins, Inc., 2010). The first is the combiner which is the surface on which the information is projected. In the aviation world the combiner is often stowable and can be brought out for use. In automobile applications it is often embedded within, or is the actual, windshield surface. The projected display is typically collimated to prevent the need for the user to constantly change focus in order to see both the HUD displayed objects and objects in the outside world. This focal point is typically optical infinity for aviation applications and the distance of the bumper for automotive applications (Head-up Display, n.d.). The collimation process can require an additional collimator component using refractive, reflective, diffraction or other techniques (Newman, 1987).

The second component is the projector unit used to project the image onto the combiner. The positioning of this unit can vary but is typically directly above or below the combiner. The combiner is designed only to reflect the light spectrum transmitted by the projector and hence allows the user to view the HUD information through the combiner without distorting the user' view of the information available in the outside world (Rockwell Collins, 2010).

The third component is the computer that generates the information to display (Newman, 1987). To produce information that is in synch with the outside world the computer requires input from on-board systems concerning the required variables of interest (e.g., chart data, location, heading, speed, etc.). The HUD can provide both conformal information, where the HUD information visually overlies the real-world objects it represents, or non-conformal information that does not overlap (e.g., a digital speed gauge).

There are several important concepts to understand when designing or evaluating a real-world HUD system and these can be impacted by the hardware and software options available, as well as the situational constraints. The first is the eyebox, which is the 3-dimensional envelope that the user can be positioned in from which the HUD information can be accurately viewed (Newman, 1987). The eye-box and accurate viewing are especially important for conformal information that requires alignment of the presented information with real-world objects. Mariners typically are walking around the bridge rather than seated in a stationary position like aviators or automobile drivers, which provides an additional design challenge.

The second concept, the field of view (FOV), is the spatial angle (lateral and vertical cone or wedge) in which HUD information is presented (Newman, 1987). For instance HUD information could be provided only within 18, 30, 90, etc. horizontal/vertical degrees in front of the viewer. When designing a HUD it is essential to consider what the available HUD FOV is and how that compares to the overall FOV utilized by the operators.

The third is the contrast ratio, which is the ratio of the display information brightness to the external visual cue brightness and is impacted by the ambient brightness level. Consideration must also be given to various sources of potential discrepancies, disparities, and alignment issues, including distortion and displacement errors caused by the combiner, as well as by differences in the apparent position of images as presented to each eye, different viewing positions, or multiple viewers. Newman (1987) expands on these and other variables in more detail.

So what are the advantages and disadvantages of a HUD? Many of the features and advantages are domain and application specific because tasks, related information needs, and contexts vary. These differences are due to factors such as variations in the training, tasking, environment, and the speed, accuracy, and control dynamics required for each domain. One of the primary goals of this study was to look at the concept of operations for a HUD system specifically for the maritime domain and begin to define the appropriate advantages, risks, and situational requirements.

Overall, increased "eyes out the window" time is seen as a primary advantage of a HUD system. Keeping an operator's eyes on the outside visual scene reduces the probability that a critical real-world event will be missed (Gish & Staplin, 1995). The ability to present conformal imagery is also seen as one of the primary advantages of a HUD (Yeh, Merlo, Wickens, & Brandenburg, 2003). Some of the conformal features hypothesized to be applicable across transportation domains include information concerning the planned route, boundaries of safe travel, upcoming alterations required, obstacles, and other potential dangers in the projected route. Studies have shown consistent HUD-related performance advantages for path following and trajectory control measures (Wilson, Hooey, Foyle, & Williams, 2002). Another primary HUD advantage found in the literature is reducing the amount of scanning, reaccomodation, and head movement required in order to utilize both near and far domain information (Yeh, et al., 2003; Gish & Staplin, 1995). This benefit can be realized with non-conformal HUD information as well (i.e., speed, notification or aids for required actions such as shifting or turning, targeting information, etc.) and becomes a greater advantage in high-speed operations when risk dramatically increases and the operator removes his or her view from the outside world to retrieve this information. A further reduction in the time it takes to integrate this information can be produced by the intelligent design and placement of HUD information in reference to the outside visual cues.

The potential for clutter is one of the primary risks or disadvantages with HUD presentation. This risk, and the related cost, increases as more information is added to the HUD (Yeh, et al., 2003). There are two basic types of clutter. The first type results in increased time to search and find a specific item of information. This same disadvantage also occurs with information presented through normal head down displays. The second type is due to irrelevant information items overlapping (obscuring) or interfering with (masking) the perception or interpretation of target information items (Tsang & Vidulich, 2003). Another risk often presented in the HUD literature is attentional tunneling, where the HUD related information captures the operator's attention and he or she misses important information in the outside world, or from the on-board environment (Gish & Staplin, 1995). The missed information can be within the HUD FOV or outside the FOV. A related disadvantage is the restricted FOV that is available with most HUDs (Tsang & Vidulich, 2003). Misaccomodation and misconvergence effects ("Mandelbaum effect") also can occur when trying to view a distant object through a nearer object or surface. These effects would impact size and distance judgments (Gish & Staplin, 1995).

All of the factors mentioned above illustrate the point that careful thought and analysis need to be put into the design of the HUD system overall, including hardware as well as the specific features and functionalities available within the display. More information is not always better and the design of the system needs to be appropriate to the overall system context it will be implemented in and the tasks that will be completed in that context. Furthermore, the design of a real-world HUD system should take account of recent innovations in technology that can address or circumvent some of the typical problems and constraints experienced in past applications and produce a HUD that is ideally suited for the marine environment. These can include larger combiner surfaces, emerging innovations in holographic technologies, and cutting edge research such as that being conducted at the University of Washington's Virtual Retinal Display Group on digital information presentation directly on the retina (Lin, Seibel, & Furness, 2003). The most effective design path to a functioning and useful real-world HUD would involve a collaborative endeavor between researchers, an organization experienced in the hardware and technological components of HUD design, and additional technical expertise as required.

3. RELATED MARINE APPLICATIONS: 3-D DISPLAY DEVELOPMENT.

3.1 *Conventional 3-D Displays.* Although little progress has been made to date on marine HUD systems, there has been widespread interest in the development of three-dimensional, perspective-view, egocentric chart displays. Navigators of High Speed Craft (HSC) are envisioned to benefit the most from this type of display due to the very limited time available to the conning officer for making navigational and collision avoidance decisions. A very high level of situational awareness (SA) is needed for operators of these fast vessels, not dissimilar to that required of an aircraft pilot.

A prime example of the disastrous consequences of the lack of SA needed for today's HSC is seen in the wreck of the MV *Sleipner*, a Norwegian fast ferry, in 1999. In his doctoral thesis on 3-D Nautical Charts and Safe Navigation, Thomas Porathe opines that had the bridge crew of the *Sleipner* been equipped with a proper 3-D chart system, the grounding might have been avoided (Porathe, 2006). Recently, marine equipment manufacturers have begun to produce such equipment for shipboard use. Furuno with their "NavNet 3D" and the French company MaxSea have introduced electronic charting systems with 3-D display capabilities. Many of the features described by Porathe and present in currently available 3-D chart systems could prove valuable, and possibly more effective, if implemented in future marine HUDs. Unfortunately, none of these systems yet contain the augmented reality display component of advanced aviation HUDs.

3.2 *The Marine HUD.* The project described in this paper essentially combines the work of developing successful aviation-type HUD systems with the 3-D egocentric marine displays such as those described by Porathe (2006). The advantages of enhanced situational awareness conferred upon users of an augmented reality HUD system will make the technical challenges of its development worth the effort. The e-Navigation course offered at Cal Maritime in the spring of 2010 was the first step in developing such a system.

4. *e*-NAVIGATION COURSE.

4.1 *Course Description.* NAU 395 *e*-Navigation was presented as an experimental, one-time only course to explore marine navigation systems of the future. In the lecture component of the course, students were introduced to *e*-Navigation along with basic concepts of research methods including experiment design and statistical analysis. Students and instructors in the laboratory portion of the course employed these research methods. The labs utilized one or more of Cal Maritime's full-mission simulators to explore the various aspects of *e*-Navigation as envisioned by the International Maritime Organization. One of the primary purposes of the course was to run requirements definitions and testing of a mockup Head-Up Display navigation system being created jointly by Anacapa Sciences, Inc. and Cal Maritime and attempt to determine how such a device would fit into the *e*-Navigation operating environment. Other facets of the *e*-Navigation concept were examined such as: 1) Advanced Bridge Resource and Bridge Team Management (BRM/BTM); 2) Proposed light sequencing patterns for Aids to Navigation; and 3) Comparing the use of north-up and head-up orientations of radar and ECDIS displays. For the purposes of this paper, only the parts of the course dealing specifically with HUD research will be described.

4.2 *Lab Structure.* Each laboratory session consisted of a pre-brief by the instructor to explain the purpose of the simulation session to follow. Students were assigned to their various simulators, stations and tasks. All students were active participants in each simulation. Each student, at the conclusion of the simulation session, completed a post-simulation survey. A post-brief discussion between instructor and students completed each lab session.

4.3 *Methodology.* During the Week 6 simulation session, students in Bridge 3 (the simulator employing the HUD mockup) were asked to observe the HUD display while ownship transited through San Francisco Bay on course-control autopilot. There was no student interaction with the simulation – they merely observed the HUD display for approximately 30 minutes. During Week 11, the students were asked to pilot a tug and barge down the Mississippi River using the HUD, ECDIS, and radar, in fully interactive simulation. The instructor set up and adjusted the HUD equipment when necessary; the students were not allowed to adjust the HUD on their own.

4.4 *Participants.* The students used as participants in this study were sophomores, juniors or seniors in the Marine Transportation program at Cal Maritime. There were a total of twenty-four students in the Week 6 simulation and twenty-one in the Week 11 simulation. The sophomores had received instruction in terrestrial navigation, Rules of the Road and radar/ARPA (Automatic Radar Plotting Aids) and had completed one sea-training period on the academy's training ship. The juniors had in addition to the above spent two months aboard commercial vessels of various types as cadets, and completed an advanced navigation course. Seniors had completed an additional cruise on the training ship on which they stood at least several OICNW (Officer in Charge of a Navigational Watch) bridge watches, and had completed a course on ECDIS, as well as two bridge watchstanding simulation courses (BRM and BTM).

Although all participants in the study had limited seagoing experience, this was not seen as a disadvantage for the purpose at hand; namely development of an entirely new navigational device. Their opinions matter because they will be the ones most likely to use marine HUDs, when they are perfected for shipboard use. Furthermore, younger people are adept at using electronic devices and advanced technologies and less likely to become frustrated and negative when the systems don't always work perfectly. Finally, because their overall navigational skills are not of the level of more seasoned mariners, they are likely to rely more on the HUD and therefore pay more attention to what it displays rather than ignore the HUD information and steer by eye or radar alone.

4.5 *Survey Materials.* Two HUD-specific surveys were administered during the course, one during Week 6 and the other in Week 11. The first was an initial impressions survey based on students viewing, but not interacting with, a HUD. Fourteen Likert-scale items were included with space for commentary addressing maritime operations with HUD. There were also 6 open-ended questions asking about the benefits, concerns, appropriate and inappropriate tasks and situations, appropriate and inappropriate vessel types, and features. The participants were provided a static image of a view out the bridge window and asked to sketch their ideal HUD information presentation design (information items, format, and positioning). The goal of the first survey was to gather the participant's expectations and opinions on the potential advantages, concerns, and envisioned concept of operations (CONOPS) of a HUD system before actually interacting with the prototype.

The second survey (Week 11) was administered after students had several opportunities to interact with multiple iterations of the HUD prototype and in varying scenarios. This survey also included fourteen Likert-scale items, with space for commentary. The goal of the second survey was to gather participants' perception after having had some interaction with a prototype HUD system. This provided the opportunity to collect experiential feedback and allowed for comparisons of how participant's perceptions changed with actual use.

5. TRANSAS FULL-MISSION SIMULATORS. Cal Maritime's three full-mission simulators are quite new, having just been completed in early 2009. Bridges 1 and 2 are large 360^{o} simulators contained inside 30-foot diameter cylindrical drums. Bridge 1 is configured to represent the bridges of large vessels and is equipped with state of the art multi-function displays utilizing the Transas Navi-Sailor 4000 ECDIS program. Bridge 2 is configured for tugboat operations and has Dynamic Positioning capability. Bridge 3 has a 225^{o} view five plasma screen setup and like Bridge 1, is configured to represent larger vessels. The three operator stations are driven by the latest Transas simulator operating system NTPro 4000. The three simulators can be run separately or combined with three ownships in a single interactive scenario. Likewise, each operator station can be setup to control one or more of the simulators as required. Although each simulator has its own specialty in the choice of vessel to be represented, any of the three can be used to represent any type of vessel adequately.

Throughout the duration of the *e*-Navigation course, all three simulators were employed each week with between three to four participants working in each simulator. Many experiments were run utilizing different simulation scenarios, each created to examine one or more aspects of the *e*-Navigation operating environment. The mockup HUD was always set up in Bridge 3. Participants were surveyed concerning their navigational experiences in Bridge 3 utilizing the HUD, as well as their experiences completing the same scenarios without HUD in Bridges 1 and 2.

6. HUD MOCKUP[1]. During the conduct of the course a HUD prototype was developed and continually refined and presented to participants within various scenario contexts. The prototype was developed on the Flex 3 Builder platform using the Sandy 3D plug-in for 3-dimensional drawing. Using a third-party serial-port-to-socket program, the Prototype reads an AIS data stream from an external device. The prototype read and decoded GPGLL, GPGGA, and GPRMC sentences for latitudinal and longitudinal coordinates of ownship. HEHDT sentences were decoded for ownship heading. Each sentence was checked for validity before accepting the data and none of the GP sentences took priority over one another (i.e. lat/long data read from any of the ownship sentences will immediately cause an update in ownship location.) Waypoint coordinates are entered manually in a dialog box in the Administrative Interface (See Figure 3) that runs alongside the graphical display window. Within the graphical display window, waypoints are drawn as spheres with lines projected in 3D space between consecutive waypoints.

Initially the lat/long coordinate system was rendered as a 2D, evenly spaced grid. This created alignment problems as the simulator was running on the WGS 84 grid. In order to remedy this, the coordinate system was updated to account for the spherical nature of Earth, though it was still not fully integrated with WGS 84. This resulted in good, but not perfect alignment by the later sessions of the course. Efforts are currently being made to fully integrate the HUD projection with WGS 84 for the conduct of the second *e*-Navigation course. The components available for testing during the reporting period included: waypoints, trackline, heading, speed, and lat/long location. Properties of each of these features, such as size and color, could be manipulated through the Administrative Interface. Additional components will be implemented as feasible during the conduct of the second *e*-Navigation course.

The prototype was run on a laptop within the Bridge Simulator Environment. The Laptop HUD image was presented via an Epson Model H270A LCD projector (see Figures 1-3), and adjusted to fit the size of the forward plasma screen of the Bridge 3 simulator at CMA. The projection was designed so that when aligned with the corners of the simulator screen, objects presented via the HUD prototype projection would align with the objects presented via the simulator projection. The instructor could use the Prototype Administration Interface (see Figure 3) to change the color and size of items, adjust the camera position to match the viewing angle on various vessels, and display or hide supplemental information (i.e., speed, heading, lat/long information). The instructor would program the simulator controls to set-up the environment and scenario planned for each laboratory session.

[1] The HUD prototype was developed by Jim Heffner, Anacapa Sciences, Inc.

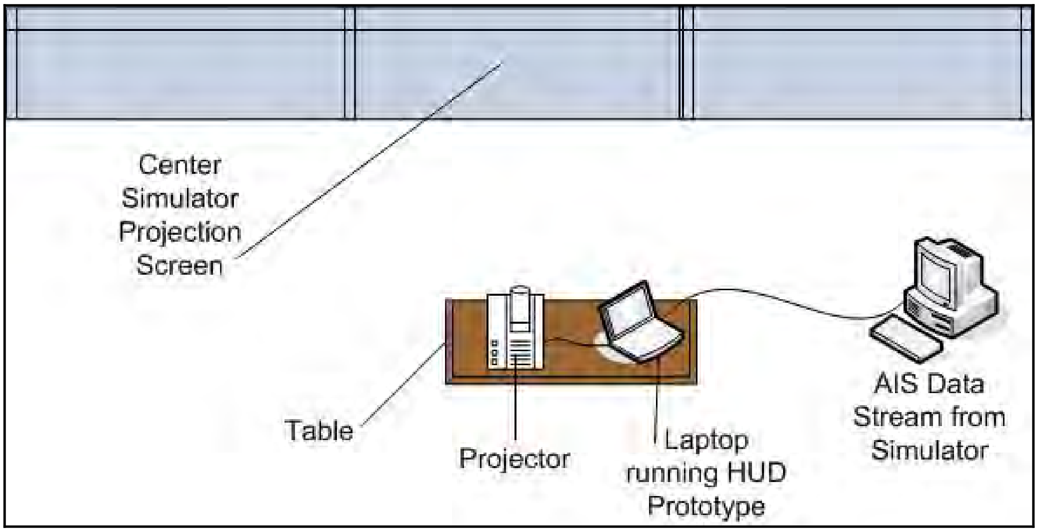

Figure 1. Set-up: AIS to Laptop-based Prototype to Projector to Simulator Presentation

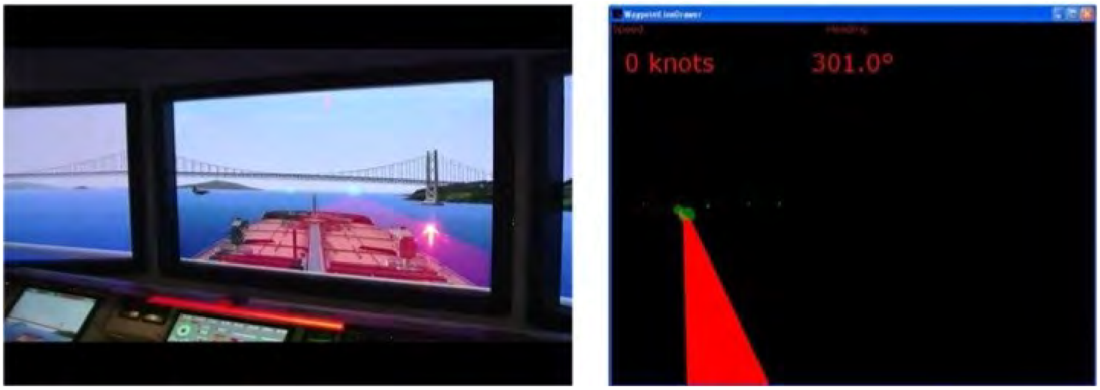

Figure 2: HUD Trackline and Waypoints on Laptop and Projected onto Simulator Screen

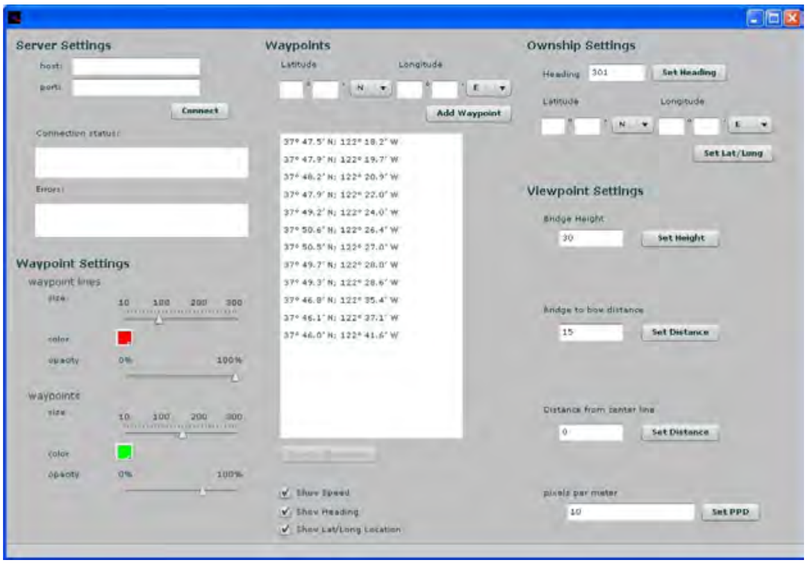

Figure 3: HUD Administrative Interface

7. SURVEY RESULTS AND ANALYSIS.

7.1. *Week 6 HUD Survey Results and Discussion*. There were a total of fourteen survey items in which participants were asked their opinions of various aspects of a marine HUD. Each item was presented on a 1-5 Likert scale with 1-5 representing Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree respectively. The t-tests performed compared the group mean to the neutral value of 3 with a null hypothesis that participants' opinions were neutral. The significance criterion was set at $p < .0071$ and any finding with a $p \leq .007$ or less was considered significant[2]. A significant finding with a positive t-value would indicate significant agreement with an item and a significant finding with a negative t-value would indicate significant disagreement with an item. In the interest of brevity only five of the fourteen items from the Week 6 survey will be discussed here. The additional results and discussion are provided in Appendix A.

Item 1: The HUD would be very useful in piloting situations.

Mean	T-value	df	P	SE	Range
4.25	7.713	23	< .0001*	.162	3-5

This result was significant. Participants felt that the HUD would be very useful in piloting situations. Several participants commented that this would be especially so in restricted visibility situations. Comments also suggested additional usefulness if augmented with stationary long term objects (i.e., buoys, landmasses, bridges, lighthouses) or by highlighting the channel or Traffic Separation Scheme (TSS). Participants liked having their track laid out in front of them in their outside view. Cautionary comments included asking if pilots would be comfortable with the technology and noting that the system would require more refinement to achieve the advantages.

Item 6: The HUD would be useful during restricted visibility in heavy traffic situations.

Mean	T-value	df	P	SE	Range
4.08	6.397	23	< .0001*	.169	3-5

This result was significant. Participants felt that using a HUD would be useful during restricted visibility in heavy traffic situations. Some of the perceived benefits included HUD allowing for a quick understanding of what is going on. See general commentary below on what would be required for HUD to be useful for collision avoidance, along with collision avoidance concerns, as these apply as much or more so to restricted visibility situations.

Item 8: I feel that using properly formatted HUD information would reduce my navigational workload.

[2] The overall significance criterion was set a p <.10, rather than the standard .05, to reduce Type 2 error potential but also represent an acceptable and still Type 1 Error conservative value for an exploratory study. The Bonferroni Correction was then applied based on the number of tests (14), resulting in the value listed above of p < .0071 (.10 divided by 14). Significant results are marked with a *.

Mean	T-value	df	P	SE	Range
3.96	4.699	23	< .0001*	.204	1-5

This result was significant. Participants felt that using a properly formatted HUD would reduce their navigational workload. The primary reduction in workload was seen to come through increased situational awareness (SA). Some participants saw HUD as a one stop shop for bridge information. Some counter comments included that there would be little workload reduction compared to ECDIS if they still had to enter the route data the same way, the need to still do the chart work on paper, and the need to still cross-check data.

Item 9: I feel that HUD target information would reduce my collision avoidance workload.

Mean	T-value	df	P	SE	Range
3.63	2.794	23	ns	.224	1-5

This result was not significant. Participants were neutral concerning a HUD-based reduction in collision avoidance workload. It should be noted that the HUD prototype shown did not contain any target information. The comments clarified that HUD usefulness would depend on the integration of radar, AIS, or other means to plot target symbols relative to ownship position. Some participants also suggested incorporating Closest Point of Approach (CPA) and Time of Closest Point of Approach (TCPA) information. Potential value was seen for easy identification of targets of concern based on the projected trackline and projecting dangerous targets well in advance. Concerns included obscured targets or bad data increasing collisions and what happens when your vessel changes from planned course (i.e., for passing arrangements). Another participant questioned what would happen when targets were abeam or out of HUD view. This non-significant result and the comments taken together may suggest a tendency for some students not to respond based on the question (a HUD with target information) rather than the state of the prototype (no target information).

Item 11: Use of HUD would reduce my head down time in comparison with ECDIS.

Mean	T-value	df	P	SE	Range
4.29	9.167	23	< .0001*	.141	3-5

This result was significant. Participants felt that using a HUD would reduce their head down time (HDT) compared to ECDIS navigation. Participants saw reduced HDT as a primary HUD benefit.

7.1.1. *General Comments and Discussion of Initial HUD Survey.* Responses from the open-ended questions provided further clarity concerning the perceived utility of HUD for various tasks and situations. Participants commented that HUD would be especially good for tasks such as staying on track, determining the course to steer, determining speed to make, and range and bearing assessments (to waypoints). There were some comments that HUD would not be good for primary collision avoidance, with one participant explaining that the outside view might be too cluttered by the trackline in heavy traffic.

Consistent with the findings above, participants commented that HUD would be an asset for low visibility situations when displaying vessels and obstructions and for keeping on track.

Specific low visibility comments included HUD's ability to make the invisible visible and to allow for confident maneuvering in heavy traffic. HUD was also seen to apply best to confined waters contexts (i.e., inland waters and narrow channels and Traffic Separation Schemes or TSS). Some participants commented that HUD was not appropriate for Coastal, Offshore, and Docking operations, which are consistent with the negative and mixed findings reported above and in Appendix A.

High speed vessels and ferries were seen as high priority candidates for a HUD. Comments suggested this was due to rapidly changing information and no need to look down with a HUD. Several participants commented that HUD would be good for large ships due to navigational needs but others found HUD to be excessive for larger vessels (i.e., tankers, RO-ROs, containerships). Two participants commented that HUD would be good for all ships. Additional comments suggested HUD would be good for any ships with set waypoints and routes, or that follow a trackline. There were mixed feelings about the utility of HUD for dredge or surveyor operations, which would depend on the HUD providing task-specific information for these operations. Comments against HUD for dredges argued that the needs and speeds do not justify HUD. One participant commented that HUD would not be good for a vessel without ECDIS.

Overall, participants saw potential for HUD to add value to the bridge environment. The primary benefits included increased situational awareness, reduced head down time, and the potential for reduced stress. The increase in SA would be realized from keeping the eyes out the window yet still seeing targets, tracklines, navigation aids, and danger areas, as well as knowing the course to steer to regain track and your relative position to these items. These benefits would allow mariners to stay ahead of the ship and make it easier to stay within the channel limits. The reduction in HDT was seen to come from HUD's ability to connect the trackline with the reality outside the window and turn electronic navigation back into visual navigation, especially in low visibility. The reduction in stress was seen to come from increased navigation confidence, especially with an easy to see trackline. Overall HUD was seen consistently as most valuable for operations in confined waters and operations in low visibility.

Participants also identified several concerns about HUD implementation. These included HUD information obscuring outside information (i.e., targets, buoys) or distracting the operator. Participants noted that the color and transparency would have to be perfect. Another related concern was the potential for clutter and information overload. Another concern noted was the potential for a sense of complacency or over reliance, especially in the cases of bad data (i.e., a mis-entered waypoint or buoy out of place) or overuse for other tasks such as collision avoidance. Several comments voiced concern about mariners becoming conditioned into poor techniques such as failing to maintain good scan patterns and look out other windows, or ignoring other inputs such as radar. Additional concerns included HUD being another system to cross-check, training issues, and the cost of integration.

Overall, these findings suggest hypotheses and scenarios for further testing along with priority areas of focus. The findings suggest that the primary focus of future HUD research should be on testing the benefits in confined waters and for low visibility operations. Benefits should be compared between high-speed vessels and other larger vessels. The validation of benefits for a HUD providing task-specific information for operations such as dredging should also be tested. Empirical tests should be performed to compare performance (stress, workload, SA, utility) between mariners using various bridge configurations (e.g., combinations of HUD, ECDIS, radar, paper). Track following scenarios and measures are appropriate for inclusion. Scenarios should be developed to test the concerns listed above. Examples would be including hard-to-see targets (e.g., kayaks, small boats, debris) and variations in the locations of these objects in reference to the HUD presentation. Bad, or missing, data and related performance measures should also be integrated into test scenarios.

7.2. *Week 11 HUD Survey*. A second survey using the identical items was administered in Week 11 of the course after students had the opportunity to interact with the HUD prototype. The same analysis methodology was used. In the interest of brevity only five of the fourteen items from the Week 11 survey will be discussed here. The additional results and discussion are provided in Appendix A.

Item 1: The HUD would be very useful in piloting situations.

Mean	T-value	df	P	SE	Range
3.857	4.076	20	< .007*	.210	1-5

This result was significant. Participants felt that the HUD would be very useful in piloting situations. The responses were more mixed this time and there was some indication that after interacting with the HUD the participants were more biased to respond to the appearance and performance of the HUD prototype rather than the potential of a fully functioning and ideal HUD. Most of the comments were about specific features of the HUD presentation, such as the size of the trackline and the potential for distraction when larger tracklines were presented or some of the delays experienced in the performance of the prototype, or variations in the color of items. One participant noted that HUD would be very useful when the mate or master does his/her own piloting (e.g., ferries, dredges, etc.), especially on ships where the person at the con is also steering. Another participant noted that cross-track error input would provide better situational awareness and that presenting distance to the next waypoint would help with turns or wheel-over points.

Item 6: The HUD would be useful during restricted visibility in heavy traffic situations.

Mean	T-value	df	P	SE	Range
3.76	3.074	20	< .007*	.248	1-5

This result was significant. Participants felt that using a HUD would be useful during restricted visibility in heavy traffic situations. The comments provided a mixed review and cautions. This is likely representative of a trend for the participants that gave lower ratings to be more likely to explain their answers. One participant noted that target information would have to be provided. Several participants mentioned potential distraction, especially when there was a lot going on. One participant qualified their answer noting that the user would have to be able to select/deselect targets in close proximity. One participant noted that in heavy traffic, the HUD would make you feel like you had to follow your trackline.

Item 8: I feel that using properly formatted HUD information would reduce my navigational workload.

Mean	T-value	df	P	SE	Range
3.90	6.635	20	< .0001*	.136	2-5

This result was significant. Participants felt that using a properly formatted HUD would reduce their navigational workload. One participant noted that HUD would reduce the amount of walking around required for the officer of the watch. Another noted the benefit of having all of the information on one screen. Some counter comments included that he/she would still rely heavily on ECDIS. Another noted that HUD would be additional information to cross-check but beneficial.

Item 9: I feel that HUD target information would reduce my collision avoidance workload.

Mean	T-value	df	P	SE	Range
3.05	.188	20	ns	.253	1-5

This result was not significant. Participants were neutral concerning a HUD-based reduction in collision avoidance workload. It should be noted that the HUD prototype used did not contain any target information. Comments suggested that HUD would provide a benefit if it provided a light overlay, especially at night. Some participants commented that HUD might create a distraction. One participant commented that they would still want to use as many navigation pieces as possible. One participant noted that they would not rely on HUD target information. These results suggest that future tests with a HUD that intelligently incorporates target information would be required to clarify the varied opinions.

Item 11: Use of HUD would reduce my head down time in comparison with ECDIS.

Mean	T-value	df	P	SE	Range
4.43	12.910	20	< .0001*	.110	4-5

This result was significant. Participants felt that using a HUD would reduce their head down time (HDT) compared to ECDIS navigation. One participant noted much reduced downtime and another cautioned that the benefit would only be realized if it was smooth enough. Note the range of responses with 4 (Agree) being the lowest response provided.

7.3 *Overall Discussion of Both Surveys.* The results indicate great potential for a maritime HUD system, especially for improving situational awareness in low visibility and confined waters conditions and for vessels where information changes rapidly (i.e., high speed vessels). The results also suggest that there are some standard information requirements across situations that could be augmented with task and vessel specific information.

The findings and conclusions from the initial survey before interacting with the HUD prototype were validated by the second survey, administered following participant interaction with the HUD prototype. The results were consistent across the two surveys, as were the trends in two of the three instances where significance testing for an item showed different results across the surveys.

8. CONCLUSION. The requirements testing plan and suggested modifications to the HUD prototype based on the preliminary evaluation are being implemented (starting in September 2010) in a second offering of the *e*-Navigation course being underwritten by a grant from the International Association of Maritime Universities (IAMU). The researchers will prioritize new HUD features to include and evaluate based on perceived overall navigational value and the status of development of the HUD prototype. As the HUD mockup becomes a more refined, capable research tool, continued testing will produce and validate conclusions that: 1) define the operational requirements and concept of operations for a HUD system; 2) identify essential information, risks, and concerns; and 3) examine performance variations by conditions (environmental, vessel, crew) and tasks. The bulk of this groundwork will be completed by the end of 2010. The next step in marine HUD development is to identify a forward-thinking marine equipment manufacturer partner to help produce a working HUD prototype, capable of being tested aboard one or more of Cal Maritime's small craft and eventually the training ship. An application for a continuation of the IAMU grant through 2011-2012 has already been submitted with this type of HUD development being one of its stated goals.

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Appendix A: Additional Results and Discussion

Additional Week 6 Results and Discussion:

Item 2: The HUD would be very useful in docking situations.

Mean	T-value	df	P	SE	Range
2.79	-.926	23	ns	.225	1-5

This result was not significant. Participants were neutral concerning a HUD advantage in docking situations with a trend towards not useful. A few students commented that a HUD could be useful if the information display changed to docking/conning information or possibly for approach but not actual docking. Other comments suggested poor utility because docking should be done visually, the bridge wing view being preferred, and the criticality of seeing the line handlers and others involved. Others suggested that for docking a sky view is better. Concerns included difficulties seeing distress signals and small hazards, and that with winds or major currents the system might just be annoying due to an inability to use a set course.

Item 3: The HUD would be very useful in coasting situations.

Mean	T-value	df	P	SE	Range
3.71	4.303	23	< .0001*	.165	2-5

This result was significant. Participants felt that the HUD would be very useful in coasting situations. One participant cautioned that the usefulness would depend on the proximity to land and difficulty of the route. Another participant clarified that HUD would not be needed in coastal and offshore waters but it would still be nice to have speed and heading information when looking out the window. There was also clearly some confusion on the participants' part as to what was meant by coasting. This should be considered a mixed result that requires further clarification.

Item 4: The HUD would be very useful in the open ocean.

Mean	T-value	df	P	SE	Range
2.29	-3.205	23	< .007*	.221	1-5

This result was significant. Participants felt that the HUD would NOT be very useful in the open ocean. Several participants qualified their answers by saying that the information would be nice but not necessary due to fewer hazards, less precision required, their ability to rely on GPS and radar, and that HUD information could just be a distraction. One comment suggested that route data might be useful but the trackline was not. Another participant saw a potential detriment to night vision as a problem.

Item 5: Use of HUD would be useful during restricted visibility in open waters.

Mean	T-value	df	P	SE	Range
3.71	2.991	23	< .007*	.237	2-5

This result was significant. Participants felt that using a HUD would be useful during restricted visibility in open waters. The participants that disagreed often noted that they did not believe HUD was very useful for open waters (see reasons noted above in Item 4). The researchers suggest that those that agreed were largely responding to HUD's usefulness in restricted visibility situations rather than the open water component.

Item 7: Use of HUD would be useful during restricted visibility in pilotage waters.

Mean	T-value	df	P	SE	Range
4.50	12.460	23	< .0001*	.120	3-5

This result was significant. Participants felt that using a HUD would be useful during restricted visibility in pilotage waters. Some participants commented that the advantage would be there only if the HUD displayed buoys, lights, bridges, and landmasses. This is a clear indication of the combination of the value seen for HUD in confined waters, such as pilotage situations, with the value seen for low visibility operations in general.

Item 10: I feel that using HUD information would reduce my stress level.

Mean	T-value	df	P	SE	Range
4.0	8.307	23	< .0001*	.120	3-5

This result was significant. Participants felt that using HUD information would reduce their stress level. One participant qualified their answer by noting that the HUD system would relieve stress only once the system was trusted.

Item 12: Use of HUD would reduce my head down time in comparison with radar navigation.

Mean	T-value	df	P	SE	Range
3.63	2.698	23	ns	.232	1-5

This result was not significant. Participants were neutral concerning a head down time (HDT) benefit from HUD compared to radar navigation. The trend was in the positive direction. It should again be noted that the HUD prototype did not contain any target information or collision avoidance information. Several comments noted that there was a need to integrate radar and other target data to realize this benefit. Those that did not see a HDT reduction often commented that there is still a need to cross-check information and enter data unless the whole process changed.

Item 13 : Use of HUD would reduce my head down time in comparison with paper chart navigation.

Mean	T-value	df	P	SE	Range
4.33	7.524	23	< .0001*	.177	2-5

This result was significant. Participants felt that using a HUD would reduce their HDT compared to paper chart navigation. Participants saw reduced HDT as a primary HUD benefit. The only participant that responded with a 2 noted that one still has to do the chart work.

Item 14: A HUD application would provide a valuable addition to the navigating bridge environment.

Mean	T-value	df	P	SE	Range
4.54	12.840	23	< .0001*	.120	3-5

This result was significant. Participants felt that a HUD application would provide a valuable addition to the navigating bridge environment. There were few comments on this item as most comments had already been addressed through the other items. Some of the limited comments included that the concept was futuristic but seemed to be the way the world was going. Others compared the concept to technologies from other domains (e.g., automobiles, aviation). One noted that it could put critical information all in one place.

Additional Week 11 Results and Discussion:

Item 2: The HUD would be very useful in docking situations.

Mean	T-value	df	P	SE	Range
2.28	-3.423	20	< .007*	.209	1-4

This result was significant. Participants felt that the HUD would NOT be very useful in docking situations. This is consistent with the non-significant negative trend observed in the initial survey. A few students commented that a HUD could be useful if the information display changed to docking/conning information (e.g., heading, traverse speed, distance to dock) or possibly for approach but not actual docking. One participant suggested that when docking in restricted visibility, HUD would be useful. Other comments suggested that the poor utility during docking was because there are too many variables, docking is more interactive, and that the bridge wing view is preferred.

Item 3: The HUD would be very useful in coasting situations.

Mean	T-value	df	P	SE	Range
3.90	4.663	20	< .007*	.194	2-5

This result was significant. Participants felt that HUD would be very useful in coasting situations. Comments explaining the utility suggested that HUD would help to keep the cross-track error small and cross-check the autopilot. Participants who saw less utility made comments that HUD is unnecessary in open water situations.

Item 4: The HUD would be very useful in the open ocean.

Mean	T-value	df	P	SE	Range
3.09	.384	20	ns	.248	1-5

This result was not significant. Participants were neutral concerning the utility of HUD in the open ocean. One participant noted a benefit to having the route laid out. Another participant stated that they would not need it. In the initial survey most participants thought that HUD would NOT provide a benefit in the open ocean. In this case the trend was slightly positive. Overall though, open ocean operations are not seen as the primary application for the basic HUD information provided by the prototype.

Item 5: Use of HUD would be useful during restricted visibility in open waters.

Mean	T-value	df	P	SE	Range
4.24	9.080	20	< .0001*	.136	3-5

This result was significant. Participants felt that using a HUD would be useful during restricted visibility in open waters. The one comment suggested that a benefit would come from being able to see contacts. Those that agreed were possibly responding more to HUD's usefulness in restricted visibility situations rather than the open water component.

Item 7: Use of HUD would be useful during restricted visibility in pilotage waters.

Mean	T-value	df	P	SE	Range
4.24	9.080	20	< .0001*	.136	3-5

This result was significant. Participants felt that using a HUD would be useful during restricted visibility in pilotage waters. No comments were provided. This is a clear indication of the combination of the value seen for HUD in confined waters, such as pilotage situations, with the value seen for low visibility operations in general.

Item 10: I feel that using HUD information would reduce my stress level.

Mean	T-value	df	P	SE	Range
3.81	4.250	20	< .0001*	.190	1-5

This result was significant. Participants felt that using HUD information would reduce their stress level. The comments again primarily came from those participants that provided lower ratings. One noted that it could also create more stress. Several participants commented on their lack of familiarity with HUD impacting their judgment. These comments again suggest a tendency for some participants to respond to the prototype experience rather than the overall HUD concept.

Item 12: Use of HUD would reduce my head down time in comparison with radar navigation.

Mean	T-value	df	P	SE	Range
3.57	3.009	20	= .007*	.189	2-5

This result was significant. Participants felt that using a HUD would reduce their HDT compared to radar navigation. This is consistent with the positive trend found in the initial survey. It should again be noted that the HUD prototype did not contain any target information or collision avoidance information. Participants noted that radar would still be important to use and necessary for ARPA information. This result brings into question whether the participants were responding to the concept of a HUD that included target information that would typically be provided by radar or just to the benefit of having HUD trackline, waypoint, speed and heading information available. In this instance participants' responses probably represent the former. Further research will be required to better define the potential benefit of HUD-provided target information.

Item 13: Use of HUD would reduce my head down time in comparison with paper chart navigation.

Mean	T-value	df	P	SE	Range
4.52	9.316	20	< .0001*	.164	2-5

This result was significant. Participants felt that using a HUD would reduce their HDT compared to paper chart navigation. The only participant who responded with a 2 stated that even with HUD, paper charts would still be needed.

Item 14: A HUD application would provide a valuable addition to the navigating bridge environment.

Mean	T-value	df	P	SE	Range
4.19	8.027	20	< .0001*	.148	3-5

This result was significant. Participants felt that a HUD application would provide a valuable addition to the navigating bridge environment. One participant noted that HUD could re-orient the bridge team dynamic so that the person at the con could let the helmsman steer the track, rather than constantly giving helm orders and courses to steer. Two participants cautioned that it would have to be implemented correctly and proven in practice.

Appendix B: Analysis Notes

When interpreting results from preliminary studies such as this it is important to understand one's purpose and perform the appropriate analyses and interpretations based on this purpose and all the information available. Therefore, the following explanatory notes are warranted.

The first note is that these surveys are seen as a preliminary step in an overall evaluation of the HUD concept for maritime operations. When conducting research involving statistical analyses, the first challenge is to select a significance criterion that keeps the appropriate balance between the chances of committing a Type 1 Error (a false positive or untrue finding of significance) and a Type II error (a false negative or failing to identify a truly significant finding). The academic world and the standard p value of .05 are heavily biased towards preventing Type 1 errors. The goal of the initial surveys was to identify preliminary conclusions, concepts, and questions (e.g., best and worst scenarios, features, etc.) that required further testing within the scope of the course and through additional evaluations (simulated and real-world). In these situations, where both preliminary evaluation and further testing are planned, greater priority should be given to preventing the elimination of significant items (committing a Type 2 errors) than is normal for the research field.

Although the researchers had firm hypotheses for what the results would indicate, this research was also exploratory and utilized multiple t-tests to evaluate the survey items. Therefore caution against the increased probability of committing a Type 1 error that comes with conducting multiple tests was needed. The approach that was adopted was to raise the overall significance criterion to $p < .10$, an acceptable and still conservative p level for an exploratory study, and then perform a correction based on the number of tests conducted (the Bonferroni Correction). With 14 items in each survey this resulted in a significance criterion of .0071. Therefore any item with a p value of .007 or less was considered significant.

The second note is that to truly understand the survey results it is often important to go beyond just the raw numbers and statistics and look at all the information available. This includes the comments made for each item, as well as the relevant overall comments provided, and observations made by the instructors. These comments often provided indicators of how participants understood the question and framed their response. An example would be response differences based on whether the participant answered in reference to the overall concept of an ideal HUD or to the current state of the prototype and available features. These explanations were provided as warranted in the discussion sections.

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