International Association of Maritime Universities

IAMU 2011 Research Project
(No. 2011-1)

e-Navigation Course Research and Development (Phase Ⅱ)

By

California Maritime Academy (CMA)

March 2012

IAMU
International Association of Maritime Universities

This report is published as part of the 2011 Research Project in the 2011 Capacity Building Project (supported by The Nippon Foundation) of International Association of Maritime Universities (IAMU).

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Published by the International Association of Maritime Universities (IAMU) Secretary's Office
Toranomon 35 Mori Building 7F, 3-4-10, Toranomon, Minato-ku,
Tokyo 105-0001, JAPAN
TEL : 81-3-5408-9012 E-mail : info@iamu-edu.org URL : http://www.iamu-edu.org

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By
California Maritime Academy (CMA)

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e-Navigation Course Research and Development

(Phase II)

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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 2011 and had five primary research objectives: 1) To use the e-Navigation model course developed in Phase I to create an actual e-Navigation course that will become part of the Marine Transportation curriculum at Cal Maritime; 2) to deliver this course to students on the summer training cruise of the Golden Bear *in 2011; 3) to determine the effectiveness of this course by measuring student performance and understanding of e-Navigation concepts and techniques; 4) to continue to develop the HUD mock-up; and 5) to determine the importance of marine HUDs and other prototype applications to the overall concept of e-Navigation.*

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

1. Introduction

This Final Report of Phase II of the e-Navigation Research and Development is a collaborative effort of researchers Sam Pecota, Scott Powell and Eric Holder. One of the original members of Phase I of the project, Steve Browne, was unable to participate in Phase II. David Coleman, another Cal Maritime faculty member, assisted greatly in the administration of the course throughout the fall of 2011. Finally, Michael Noonan, Cal Maritime's Director of Simulations, provided much-needed technical expertise in the use of the advanced simulators and associated equipment used in the project.

1.1 Research Project Changes and Challenges

Phase II of the e-Navigation Research and Development Project, was faced with some unforeseen challenges that occurred after the submission of the grant proposal. Originally, the e-Navigation course component of the project was to be administered aboard the T.S. *Golden Bear,* Cal Maritime's 152 meter training ship, during the summer cruise period from May to August 2011. A state-of-the-art Navigation Laboratory, featuring among other things a Transas full mission simulator, was to be utilized for the lab and research experiment portions of the e-Navigation course. Unfortunately, the Transas simulation equipment, newly installed in April 2011, did not have sufficient time to go through testing and de-bugging before the *Golden Bear* departed CMA on 1 May 2011. As a consequence, the Navigation Laboratory equipment was not reliable enough to be used without severe impact to the integrity of the e-Navigation course. Accordingly, the decision had to be made to postpone the course offering until the Fall 2011 semester at which time either the Nav Lab equipment might be satisfactorily operable or the course could be run in the Simulation Center on campus. The latter choice was taken, as Transas could not immediately attend to their equipment aboard the *Golden Bear* upon her return to Cal Maritime in late August. This change of venue for lab simulations in the e-Navigation class did not have any significantly negative impact on the running of the course. It did however reduce the time available for thorough data analysis from the end of the course to the submission of this final report – only two weeks.

The second project modification involved the number of e-Navigation classes offered and student population utilized. Originally, there were intended to be three simultaneously running e-Navigation classes each being taught by a different instructor. However, there was great difficulty associated with attracting enough students to fill the three classes, designed ideally for twenty-four students each. The primary reason for this problem involved a controversy within the Cal Maritime Marine Transportation Department over the granting of academic credit for the two previous offerings of NAU395 e-Navigation in the Spring and Fall of 2010. Although the Academic Dean at the time, Steve Kreta, suggested and supported the granting of academic credit for the course, several members of the MT Department expressed strong objections to this policy. As a result, the new Academic Dean, Steve Pronchick, reluctantly withdrew support for the granting of academic credit for the Fall 2011 e-Navigation course. The direct consequence of this decision was extreme reluctance on the part of students, particularly seniors and juniors, to add the course as a non-credit addition to their already intensive course schedule. There simply were not enough students enrolled at the start of the semester to run three classes. The twenty-one students who had signed up anyway were consolidated into one class to be taught by Scott Powell on Wednesday evening. The other two classes were cancelled.

The third change to the project as originally proposed was of a decidedly more positive nature. The researchers were offered use of an experimental 3-D navigational device known as ARVCOP (Augmented Reality Visualization of the Common Operational Picture) for testing as part of the e-Navigation course research component. Charles Benton, President of Technology Systems, Inc. of Brunswick, ME, maker of ARVCOP, became acquainted with our research though a presentation made by Eric Holder and Sam Pecota at the Royal Institute of Navigation's NAV10 conference in London, England on 2 December 2010. Mr. Benton suggested that we test one of his units (free of charge) in the course and obtain student impressions of ARVCOP. We accepted his offer. Scott

Powell designed several lab sessions around the testing of ARVCOP both in the simulator and aboard one of Cal Maritime's small craft. We also compared the ARVCOP to our HUD mockup in simulation experiments. The results were quite interesting and will be related later in this report. At his request, Mr. Benton was provided access to the student survey data from the ARVCOP tests.

Lastly, the expected continued development of our Head-Up Display (HUD) program, Way Point Line Drawer, did not occur as planned. The original programmer, Jim Hefner, changed jobs early in 2011 and was not able to devote time to write new code for the HUD. A prolonged search for a new programmer did find one candidate, Evan McPeters, who began work on converting the program from Adobe Air to the more widely used and more powerful C# language. Unfortunately, the complete conversion did not occur in time to be tested as part of Phase II of this grant. Some of the research time devoted to HUD development was therefore diverted into time required for the researchers to obtain the ARVCOP program from TSI (which involved many phone calls, correspondence and lengthy Go-to-Meeting sessions), learn how to use it, determine how to set it up both on the academy crewboat and in the simulator, and run testing and troubleshooting on the device before using it in the e-Navigation course. Nevertheless, Mr. McPeters has submitted a plan for the HUD program conversion to C# and hoped to have a running version before the submission of this final report. Details of this can be found in Section 3 below.

2. Developing the e-Navigation Course from the Model Course

2.1 Course Structure and Class Schedule

The course design, in keeping with the Model Course structure, called for a three-hour per week, eleven-week course beginning in mid-September and finishing in mid-December 2011. This is approximately 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 topics examined during the lab simulations. The class was held once a week on Wednesday evening 1630-2000 with a 30-minute break for dinner. Because 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. However, as stated earlier, 2 units were simply added to the students' transcript as an elective, not credited as units counting toward the Marine Transportation major.

Date	Lecture	Lab
Week 1 9/14/11	Definition of e-Navigation	Familiarization/introduction to IBEST simulators
Week 2 9/21/11	e-Navigation details	*Exxon Valdez* recreation
Week 3 9/28/11	BTM and BRM procedures	Advanced Radar: Controlled Turns in Pilotage
Week 4 10/5/11	ECDIS and GNSS	Advanced ECDIS: AIS text messaging HUD Introduction
Week 5 10/12/11	Radar and AIS	Radar and AIS
Week 6 10/19/11	INS and IBS	INS and IBS
Week 7 11/2/11	ARVCOP: *Ursa*	ARVCOP: *Ursa*
Week 8 11/9/11	VTS and LRIT	Mandatory/Advisory VTS

Week 9 11/16/11	GMDSS and e-Navigation	ARVCOP exercise in FMB 3
Week 10 12/7/11	No lecture	HUD exercise in FMB 3
Week 11 12/14/11	Class Survey	No Lab

2.2 Lesson Planning

The NAU395 e-Navigation course is unique to Cal Maritime in that it allows for both cooperative and collaborative learning between upper and lower class level students in a simulated navigation environment. Cal Maritime's Institutional Review Board (IRB) approval was sought and approved for the application prior to the start of the course with the students completing Informed Consent Forms and being provided a Participant's Bill of Rights.

The first classes were primarily a familiarization with e-Navigation concepts and with the equipment in the IBEST lab (part-task simulators) and full-mission simulator. Scenarios were created to match the training background of the student population. Students with senior and junior class standing were given the leadership role as the mate of each bridge team. Remaining students were predominately freshman and so were given the followership role as helmsman and lookout. The final population of the class was as follows:

Class standing	Number
Senior	3
Junior	5
Sophomore	1
Freshman	8
Total enrolment	17

Table 1: Class enrolment

The original intent was for the class to be offered only to students with either senior or junior class standing. But, there was insufficient enrolment leading up to the first class period due to the lack of academic credit offered within the Marine Transportation curriculum (see Section 1.1 above). Prior to the start of the semester the PI decided to offer the class to sophomore and freshman students who had some maritime background. Initially, there was a total enrolment of twenty-one in the course. Four students dropped by week three due to the academic responsibilities of their other classes.

The bridge teams for each exercise varied due to the number of participants and attendance. Since the subject matter is so new and there are no available textbooks, many resources were provided via the CMA online learning management system Moodle. References listed in each section were used to help develop the particular topic area.

2.3 Week 1

Topic: Introduction to e-Navigation

This class involved the introduction of e-Navigation. Lecture material consisted of a PowerPoint presentation, which followed the Model Course 1.XX *Principles of Shipboard e-Navigation* requirements and introduced the topics and concepts that would be discussed throughout the semester.

In the lab section, students were provided a scenario on the Mississippi River at night using the e-Navigation components of Radar/ARPA, ECDIS, and AIS. Each bridge team was given the task of creating a safe route using the ECDIS from their initial position to a predetermined destination. This scenario also allowed for some of the newer students to become familiar with the simulation equipment in the IBEST lab.

Bridge teams: Watch Officer, Helmsman, and Lookout

Reading material provided: Lecture PowerPoint handouts (in handout form)

Reference(s):

[1] IALA e-Navigation Committee *Frequently Asked Questions* (Version 1.5 dated September 2010
[2] Patraiko, David, *e-Navigation,* Digital Ship, Presentation, The Nautical Institute, 2008
[3] Patraiko, David, *Introducing the e-navigation revolution,* The Nautical Institute, 2007

2.4 Week 2

Topic: The benefits of e-Navigation

The lecture followed the content requirements of the Model Course. The main theme of this class involved the recreation and discussion of the *Exxon Valdez* (1989) grounding incident using the simulator in the IBEST lab projected on the SmartBoards [2]. This allowed for comparisons between the visual channel and radar while the timeline and applicable Bridge Resource Management perspectives were discussed (see figure 1). Prior to transitioning to the lab component of the class, a briefing session was conducted with demonstrations of AIS messaging and Add Info Chart overlays (to simulate AIS Application 1 Meteorological and Hydrological data in the form of Add Info) [1]. The incident was recreated and experienced both with and without the inclusion of current and future electronic navigation technology. The students were allowed to take advantage of new concepts such as AIS binary messages, which were then used to create Add Info chart overlays to represent no-go areas of dense ice fields. A key difference between the actual event and this simulation is highlighted in the dissemination of ice information. Instead of the view as shown in *Fig. 1* below, where a ship would see the ice only when it showed up on radar or provided by vessels that have previously transited the area, this information could be provided by Vessel Traffic Service (VTS) with proper surveillance sensors. Advanced ice reports with positional information could assist in the creation of no-go areas that allow for route deviation within VTS and COLREGS Rule 10 requirements. These routes could then be tested and checked to ensure that they are safe taking into consideration elements such as under keel clearance and other hazards along the route that would yield alarms during the route checking/passage planning phase. Since the IBEST lab has eight stations, the scenario was intentionally designed to use only six of them, allowing one of the extra stations to be used for the two-way transmission of AIS safety messages. This was accomplished through the inclusion of an extra ownship, which was used in addition to the instructor station. This extra ownship was then used essentially as VTS with AIS text messaging capabilities. It was within these capabilities that provision was made for position information such as latitudes and longitudes that could then be sent and used by the bridge teams to create the chart overlay/no-go areas. The *Exxon Valdez* grounding was used as a case study to show students the benefits of modern marine navigation electronics utilizing e-Navigation concepts compared with what was available in 1989.

Bridge team: 2 Watch Officers, Helmsman, and Lookout

Reading material provided: Lecture PowerPoint handouts (in electronic form)

Reference(s):
[1] IMO Model Course 1.34 *Automatic Identification Systems*
[2] National Transportation Safety Board. Marine Accident Report. *Grounding of the U.S. Tankship Exxon Valdez on Bligh Reef Prince William Sound near Valdez Alaska*. March 24, 1989
[3] Patraiko, David, *Accidents, Causes and the Human Element,* Presentation, The Nautical Institute, 2010

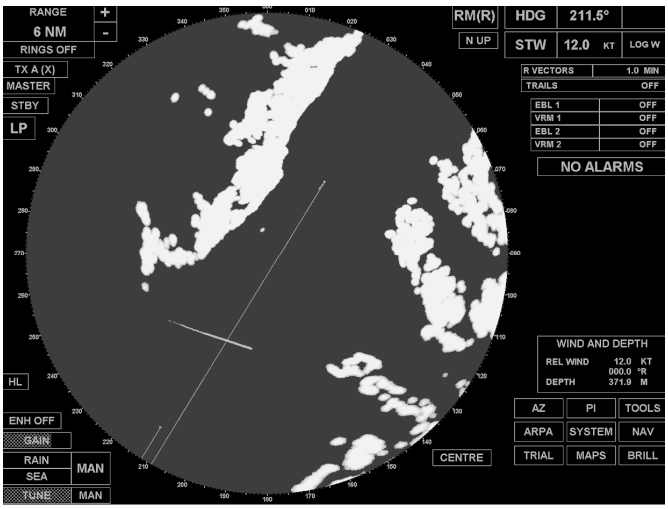


Fig. 1 Exxon Valdez Grounding Recreation

2.5 Week 3

Topic: Bridge Team Management (BTM) and Bridge Resource Management (BRM) procedures

This class involved a discussion of current Bridge Resource Management (BRM) theory. Because the previous week's class consisted primarily of a case study of the *Exxon Valdez* incident, a similar case study would not be used in this class. However, in the debriefing session following the Week 2 lab section, BRM principles were discussed in detail as to how e-Navigation could potentially reduce similar incidents in the future. The lecture section for this class discussed the basic tenets of BRM and the potential shift in the role of the watch officer from 'navigating navigator' to 'monitoring navigator.' Here there was a deviation from Part C: Detailed Teaching Syllabus of the Model Course which discusses BRM from the macro level; instead, BRM was discussed from the micro level in terms of alternative navigational tools that can be used should there be a failure in electronic positioning or Global Navigation Satellite System (GNSS). This deviation was the result of the instructor's belief that BRM is such a broad subject that the one-hour lecture requirement could easily be expanded to two or three lecture periods with accompanying simulation exercises. This in fact is the format followed in one of Cal Maritime's existing courses, *Introduction to Bridge Simulation*.

Recent literature such as *Navigational Advances?* by Captain A. Ian Hale [4] argue that new technologies are degrading "traditional" navigation skills. In order to put this theory to the test, the instructor focused the class period on a simple but fundamental radar skill that can be used to crosscheck both visual and electronic navigation. Would the students be able to use such a basic, old-fashioned radar navigation skill effectively? Could a basic skill such as this prove critical at some point in the case of a rare, but possible GNSS loss?

Captain Paul Chapman advocated the concept of controlled turns in pilotage in his book *Monitoring Turns with Radar*. He promotes the use of radar as a guide to determine if the rate-of-turn is sufficient to maintain or minimize cross-track error while following a charted route [2]. The reason this method was chosen was because it uses radar in the Head-Up display orientation, which does not require a gyrocompass input (see *Fig. 3*). Turns can be made with reasonable accuracy using a Variable Range Marker (VRM) and a suitable reference point. Also, the introduction of this method created the foundation for the class of integrating the use of visual lookout with the Radar/ARPA and ECDIS. Data was collected comparing each method to be used for later research.

Although the approach used in this topic on BRM was to examine possible alternatives the bridge team might use in the face of electronic navigation equipment failure, BRM and e-Navigation could also be explored by studying the effects of introducing a piece of new technology into the mix. The purpose would be not merely to study the efficacy of the new device, but more importantly how the bridge team puts it to use without violating well-understood concepts and practices of proper bridge team management.

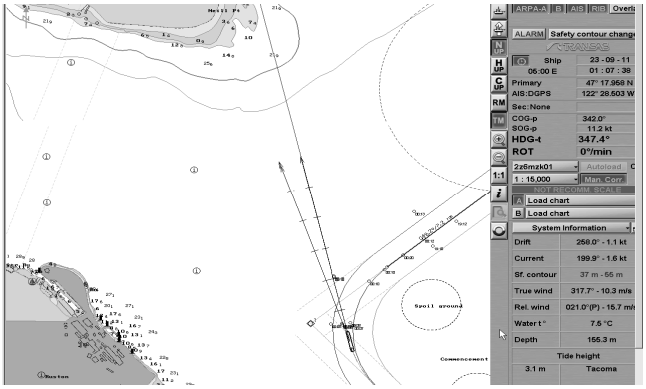


Fig. 2 ECDIS Route

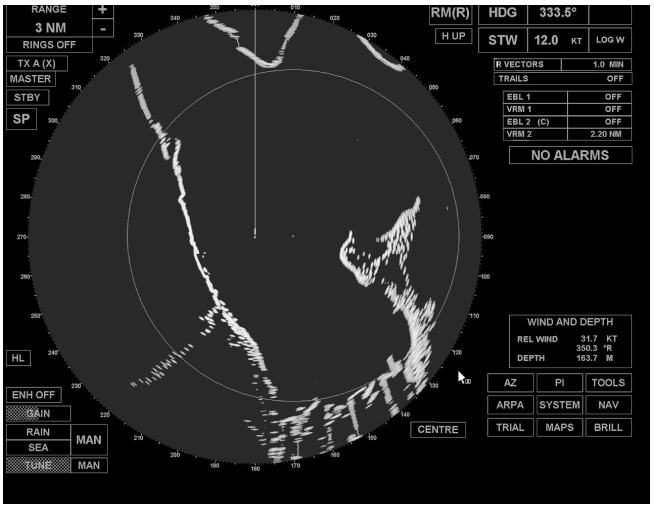


Fig. 3 Controlled Turns using Radar

Bridge team: Watch officer, Helmsman, and Lookout

Reading material provided: Lecture PowerPoint handouts (in electronic form)

Reference(s):
[1] Bole, Alan, Bill Dineley and Alan Wall. *Radar and ARPA Manual, 2nd Ed.* Oxford: Elsevier Butterworth-Heinemann, 2005.
[2] Chapman, Paul. *Monitoring Turns with Radar*. London: Nautical Institute, 2009
[3] *Development of an eNavigation Strategy Implementation Plan*, July 29, 2009, IMO
[4] Hale, A. Ian. *Navigational advances?* September 2011 Seaways, Nautical Institute. Pg. 21
[5] IMO Model Course 1.27 *Operational Use of ECDIS*
[6] Norris, Andy. *Radar and AIS.* London: The Nautical Institute, 2008.
[7] Swift, A.J. and T.J. Bailey. *Bridge Team Management: A Practical Guide, 2nd Ed.* London: The Nautical Institute, 2004.

2.6 Week 4

Topic: ECDIS and GNSS

The primary topic in this class involved the discussion of ECDIS, Electronic Navigational Charts (ENC) and Global Navigation Satellite Systems (GNSS). In addition, the lab section included a short introduction to the Maritime Head-Up Display (HUD) in the Full-Mission Bridge (FMB) 3 in a separate, unrelated scenario. The scenario location for this brief introduction to HUD was in the restricted waters of San Francisco Bay. The scenario included varying levels of visibility with the inclusion of both small and large vessel traffic. An initial impressions survey was given to the students after the completion of the small scenario. Students in the primary lab session involving ECDIS and GNSS used the IBEST lab and were given random vessels with orders either to proceed inbound to San Francisco or outbound for sea. Then each group was required to utilize the route checking capabilities of ECDIS to ensure that their voyage was within the constraints of their vessel. Integrated navigation techniques were also reinforced such as crosschecking their visual lookout with the Radar and other navigational instruments such as AIS and ECDIS. As the simulator operator/instructor, the instructor used voice communication via VHF and AIS Text messaging for the simulated vessels in the scenario. This was the second lab that included the concept of AIS text messages but this lab utilized it for both Safety to Navigation broadcasts and collision avoidance.

Bridge team: Watch Officer, Helmsman, and Lookout

Reading material provided: Lecture PowerPoint handouts (in electronic form)

Reference(s):

[1] IMO Model Course 1.27 *Operational Use of ECDIS*
[2] Norris, Andy. *ECDIS and Positioning.* London: The Nautical Institute, 2010.
[3] *The American Practical Navigator*, Chapter 11, Satellite Navigation, 2002 Edition
[4] *The ECDIS Handbook*, Transas, Retrieved on September 15, 2011 from http://www.ecdisfit.com/ecdis/

2.7 Week 5

Topic: Radar and AIS

This class involved an introduction to New Technology (NT) Radar and AIS. The lecture section consisted of a PowerPoint lecture and a YouTube video [2] on the Kelvin Hughes NT Radar. Also, a presentation given by Captain Wayne Bailey [1] at the 2010 e-Navigation conference in Seattle was reviewed and discussed. This particular presentation highlighted the limitations of AIS and some of the errors in interpretation. The lab section involved a scenario where the bridge teams created routes from the San Francisco sea buoy to Oakland. The scenario was created to run in restricted visibility with greater reliance on AIS information. Each team was instructed to use the Radar/ARPA and ECDIS integrated with AIS information to assist in their voyages. Distracter vessels were included to determine if there was recognition of erroneous AIS data being transmitted. A questionnaire was provided after the completion of the exercise to collect data on the different uses of AIS messages. The intent of this collection was for further development of research topics in this area.

Bridge teams: Watch Officer, Helmsman, and Lookout

Reading material provided: Lecture PowerPoint handouts (in electronic form)

Reference(s):
[1] Bailey, Wayne. *AIS: More than caller ID for vessels.* Presentation. 2010 eNavigation Conference. Seattle, WA
[2] IMO Model Course 1.34 *Automatic Identification Systems*
[3] SharpEye Solid-State Radar from Kelvin Hughes, YouTube video found at http://www.youtube.com/watch?v=wgUaGNOseNQ
[4] USCG AIS website, 2011, http://www.navcen.uscg.gov/?pageName=AIS

2.8 Week 6

Topic: Integrated Navigation Systems (INS) and Integrated Navigation Bridges (INB)

This class involved a discussion about the development of the Integrated Navigation Bridges and their place in e-Navigation. Key areas of the lecture discussion were the integration of sensors and the challenges faced by watchstanders concerning overreliance on electronic navigation. The case study of the *Royal Majesty* grounding was discussed with particular emphasis on sensor integration and the need to cross-check the electronic navigation equipment on the bridge such as GNSS, Radar/ARPA and ECDIS [2]. In addition to the PowerPoint lecture given, an interactive presentation provided by Raytheon Anschutz allowed for the class to have a virtual tour of a modern INB [3]. The lab section involved the introduction of the Augmented Reality Visualization of the Common Operation Picture (ARVCOP) in the Full Mission Bridge. Students were allowed to use the ARVCOP in a small route with varying levels of course changes in a vessel with similar characteristics as the crew-boat *Ursa,* a small training vessel at CMA. The students' initial impressions of ARVCOP were uncertain, most likely because they were making mental comparisons with the HUD, which was introduced to the class two weeks before (see Section 5 for detailed results). In the IBEST lab, there was a comparison between the HUD and ECDIS-equipped groups in a scenario located in the restricted waters of Puget Sound. Performance was measured between each of the groups and surveys were used to collect data on perceptual observations.

Bridge teams: Watch Officer, Helmsman, and Lookout

Reading material provided: Lecture PowerPoint handouts (in electronic form)

Reference(s):

[1] IMO Model Course 1.32 *Operational Use of Integrated Bridge Systems*
[2] National Transportation Safety Board. Marine Accident Report. Grounding of the Panamanian Passenger Vessel Royal Majesty on Rose and Crown Shoal near Nantucket, Massachusetts. June 10, 1995
[3] Next Generation of Integrated Navigation System. Raytheon-Anschutz. Presentation. Retrieved on August 18, 2011 from http://www.raytheon-anchuetz.com/?id=266

2.9 Week 7

Topic: e-Navigation Research: ARVCOP

This class involved the use of the ARVCOP onboard the crew boat *Ursa*. A five-leg course route was created with various course angles/changes to introduce the use of the ARVCOP in small boat operations. The laptop with the ARVCOP software was mounted directly in line with the wheel and centerline of the vessel (see *Fig. 4*). Therefore, each participant was able to maintain a visual lookout and still be able to look down at the ARVCOP. Each student was afforded the opportunity to navigate the vessel and then completed a survey to measure his or her perceptions of its use. There was great student interest in this exercise, where for the first time students were able to use an augmented reality 3D perspective view navigation device in a real, not simulated, environment. Unfortunately, a second edition of the class scheduled for the next week had to be cancelled due to safety considerations involved in running the exercise without adequate daylight. Nevertheless, even after only one run using ARVCOP on the crewboat, many participants commented that they felt that they had more control over the real vessel than they ever had in the simulator.

Bridge teams: Watch Officer (Helmsman)



Fig. 4 ARVCOP aboard the Ursa

2.10 Week 8

Topic: Vessel Traffic Service (VTS) and Long Range Identification and Tracking (LRIT)

This class involved the discussion of Mandatory VTS, Advisory VTS, LRIT and Satellite AIS. The first part of lecture consisted of discussing the history and development of VTS. A YouTube video was shown about the USCG Sector Seattle Vessel Traffic Service to give some further background into an operational VTS [1]. LRIT and Satellite AIS developments were also examined and discussed and were reinforced with a YouTube video about the ORBCOMM Satellite AIS data service [2]. The lab exercise consisted of a scenario that introduced the concept of Mandatory VTS, which could provide route guidance and possible collision avoidance orders to vessels within the particular coverage area. The ports of Los Angeles and Long Beach were chosen for this exercise due to the presence of buoyed channels, restricted waterways within the port, and ferry traffic. Bridge teams were each provided an ECDIS route for their vessel. The Transas ECDIS was then configured to show the routes of other vessels (see *Fig. 5*). This scenario was created using a function of the Transas Navi-Trainer 5000 simulator that is normally used to transfer routes created at an instructor station to the individual ECDIS stations. Under normal circumstances, these routes are named "TRAINER" and are discarded when the next scenario is uploaded to each station. To accomplish the placement of each individual ship's route into all the stations, a common scenario was loaded into all stations and then renamed the "TRAINER" route as was each of the individual ship's name within the scenario. With all of the ship's routes saved in the ECDIS, the individual bridge teams loaded up the routes as directed. To differentiate the ownship routes for other target vessels, each bridge team enabled Route Monitor for their ship, which would create a bold solid track-line as compared to the dashed line of the other routes prior the start of the exercise. All communication with VTS was required to be through the use of AIS text messaging. An additional own-ship was placed in the scenario to handle the two-way AIS text messaging. Supplementary simulated vessels were included within the scenario to highlight the differences between having target routes provided by VTS as in the simulation and actual VTS operations today where such information is not provided. A questionnaire was provided at the completion of the exercise to measure the perceptions of the use of Mandatory VTS with the possible accompaniment of target vessel and ownship routing services.

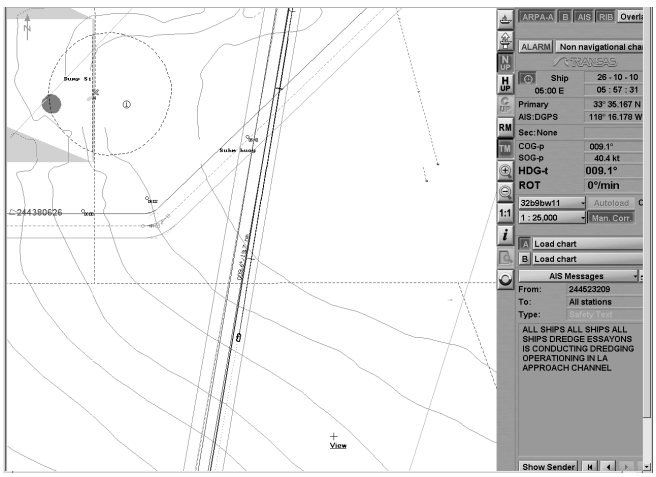


Fig. 5 Vessel Routes provided via Mandatory VTS

Bridge teams: Watch Officer, Helmsman, and Lookout

Reading material provided: Lecture PowerPoint handouts (in electronic form)

Reference(s):

[1] 2004 USCG Sector Seattle Vessel Traffic Service. USCG. Video. Retrieved on September 7, 2011 from http://www.youtube.com/watch?v=Fs2fUCzi6h4.
[2] ORBCOMM Satellite AIS Data Service Video. ORBCOMMAIS. Retrieved on September 7, 2011 from http://www.youtube.com/watch?v=MQDd5xr-jdk

2.11 Week 9

Topic: GMDSS and e-Navigation and ARVCOP study

A short exercise was developed to measure the performance of the ARVCOP in FMB 3. The route consisted of varying levels of course changes and distracters embedded within the exercise. Students were given the instruction to maintain a visual lookout and to navigate their vessel safely using the ARVCOP to follow the route provided. The ARVCOP laptop was mounted near the ECDIS display and was facing forward. This allowed for the mate to look down and compare the ARVCOP information with the visual orientation out the bridge windows. Some of key differences between this exercise and using it on the *Ursa* were the levels of intensity. While using the ARVCOP on the *Ursa*, the students followed an undemanding route; the exercise in the FMB was more challenging with stressors/distracters embedded to measure any deviation from the route. Additionally, there may have been a bias introduced since the ARVCOP was used both in real and virtual exercises. A questionnaire was given to collect students' perceptions of workload, stress and performance using the ARVCOP.



Fig. 6 ARVCOP in Bridge Simulator Exercise

Bridge teams: Watch Officer and Helmsman

Reading material provided: Lecture PowerPoint handouts (in electronic form)

2.12 Week 10

Topic: e-Navigation Research: HUD and traditional navigation

This class consisted of a HUD exercise. The intent was to measure scenario performance both quantitatively and qualitatively when using the HUD in scenario of similar complexity as to the previous Week 9 ARVCOP exercise. The route consisted of varying levels of course changes and distracters embedded within the exercise. Students were given the instruction to maintain a visual lookout and safely navigate their vessel using the HUD to follow the route provided. Distracters were embedded within the route to determine/measure and deviation from the route. A questionnaire was given to collect students' perceptions of workload, stress and performance when using the HUD (the same survey questions from Lab 9 were used to allow comparison). Participants generally agreed that the HUD provided them with greater situational awareness than the ARVCOP since they would tend to look out the window more (see *Fig. 7* photo below and Section 5 for detailed results of the ARVCOP vs. HUD comparison).



Fig. 7 HUD Exercise

Bridge teams: Watch Officer and Helmsman

Reading material provided: Lecture PowerPoint handouts (in electronic form)

2.13 Week 11

Class surveys were distributed in this class period that asked students to evaluate the e-Navigation course in its entirety. (See Section 8.1 below)

2.14 Course review and discussion

The class in general was well received by the students. For many of them, this was their first experience with simulation as an educational resource. While the Model Course does offer some flexibility with regards to content, a suggestion to other instructors that intend to use this Model Course is to balance the lab hours with the lecture hours efficiently. The NAU395 e-Navigation course at CMA allowed for one hour of lecture and two hours of lab weekly. The first two topic areas, *Definition of e-Navigation* and *e-Navigation Details* each require one hour of lecture respectively and

no simulation exercise. The fourth topic, *ECDIS and GNSS,* suggests one hour of lecture and five hours of simulation exercises. With this academic schedule and following the Model Course, the lectures would soon creep out of step with the simulation exercise(s). A challenge with the course was not being able to use more advanced navigational methods due to the student population. While the overall content was covered and allowed for both collaborative and cooperative learning, if the student population was more homogenous in regards to class standing such as a balance between seniors and juniors, more advance topics could be covered and at a more rapid pace. The challenge was evident with the varying levels of attendance, which had some impact on how many bridges could be run at any given time in the simulation exercises. Perhaps if this class were given as credit within an academic program, attendance would be less of a problem. Additionally, if this class had been offered for credit, it could have allowed for greater participation by both senior and junior cadets. Notwithstanding the lack of credit given for the course, attendance was normally higher for the freshman cadets who welcomed the opportunity to use the simulation equipment

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.*" The Fall 2011 e-Navigation course was designed and developed with this definition in mind. The simulation exercises were structured to take advantage of the bridge resources available to each team at the time. Truly, looking out the window or at an ECDIS or radar screen is only effective if you have an appreciation for what you are seeing. Accordingly, each exercise pre-brief included a demonstration of key learning objectives and a refresher of bridge equipment operation. New navigational technologies and procedures, especially those pertinent to e-Navigation, were discussed in the exercise debrief.

A properly constructed course in e-Navigation, as with any modern course in marine navigation, should both teach and promote navigation practice in an integrated manner. The Simulation Center at Cal Maritime promotes this type of integrated navigation approach. This class offered the opportunity to use the Transas Navi-Trainer 4000/5000 simulator in an integrated fashion as opposed to other courses such as Radar/ARPA and ECDIS, which are taught presently as stand-alone courses. This class also allowed for greater creativity in scenario construction than is possible in the existing Cal Maritime bridge simulation courses, demonstrating such novelties as VTS communications with AIS text messaging and the display of target vessel routes on ECDIS. Advanced topics such as Controlled Turns in Pilotage and AIS text messaging can be used within realistic scenarios that impress upon the student the need to utilize all navigation and communications equipment in a harmonious and effective manner.

3. Continued Development of the Head-Up Display Mockup

3.1 Equipment Setup (as reported in Phase I)

The operating program used originally for the HUD mockup was written in Adobe Air, using the Flex 3 Builder Platform. Screenshots of the Graphical User Interface (GUI) and the Augmented Reality Display screen appear below.

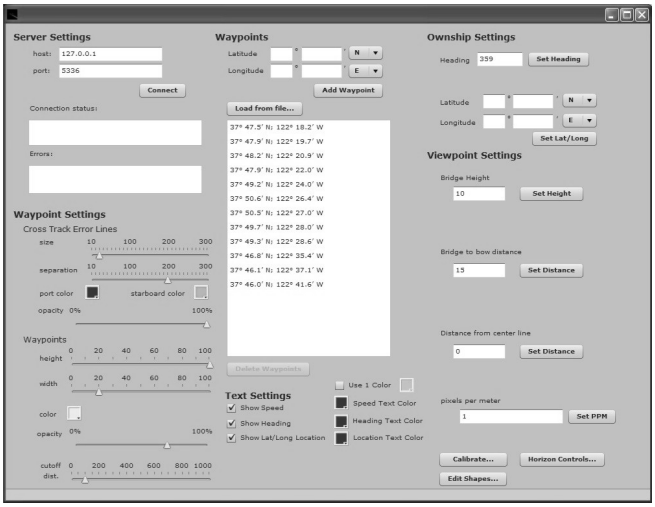


Fig. 8 HUD Administrative Interface



Fig. 9 HUD Augmented Reality Projection

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

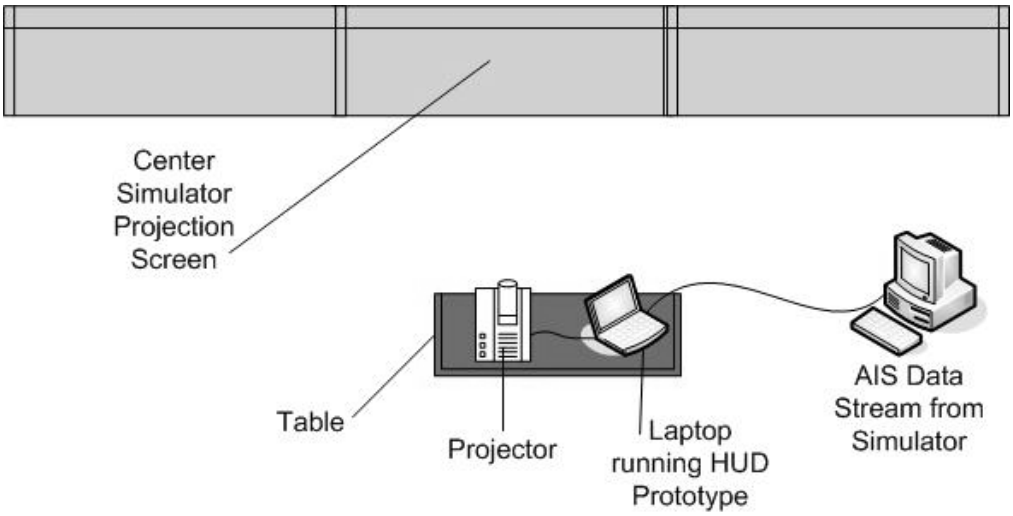


Fig. 10 HUD Mockup Setup in Simulator

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 AIS 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.

This setup was unchanged from that used in the last e-Navigation course in the Fall of 2010.

3.2 Conversion of the program from Adobe Air to C#

Notes from new HUD programmer Evan McPeters:

The Flex 3 Builder platform using the Sandy 3D plug-in for 3-dimensional drawing was used for initial HUD prototype development. Recently, it became clear that Flex Builder platform was not adequate for developing an accurate simulation of fast moving vessels mostly due to its limited screen refresh rate capabilities. As well, Adobe Flash files, those outputted by Flex Builder, are not industry standard for simulation programming and could as such hinder further progress in developing a working system.

Redeveloping the system with Microsoft's C# platform would support using Microsoft XNA for graphics rendering. C# is an industry and military standard programming environment, which, along with XNA will provide ample processing power for simulations of even the fastest moving and most data intensive vessel systems.

Work has already begun on the conversion of the original prototype into the more robust C# language.

The following items will be completed by December 30, 2011:

- An overall project structure will be built
- Initial 3-dimensional data structures will be created
- Initial data translation algorithms will be completed

- Initial data conversion algorithms will be configured to place some 3d objects at grid coordinates

Monthly progress reports will be made as work continues into 2012.

4. ARVCOP

4.1 Introduction to ARVCOP

ARVCOP (Augmented Reality Visualization of the Common Operational Picture) is a 3-Dimensional navigation device produced by Technology Systems, Inc. of Brunswick, ME. It was originally designed for the U.S. Navy LCAC (Landing Craft Air Cushion) community as a real-time navigational tool for enhanced situational awareness in difficult navigational environments such as battle conditions. ARVCOP was meant to be easy to use with an intuitive egocentric perspective forward view that would allow even enlisted ratings (the LCAC operators) with little formal marine navigation training to navigate their craft safely in combat situations. The U.S. Navy has been using ARVCOP successfully since 2005.

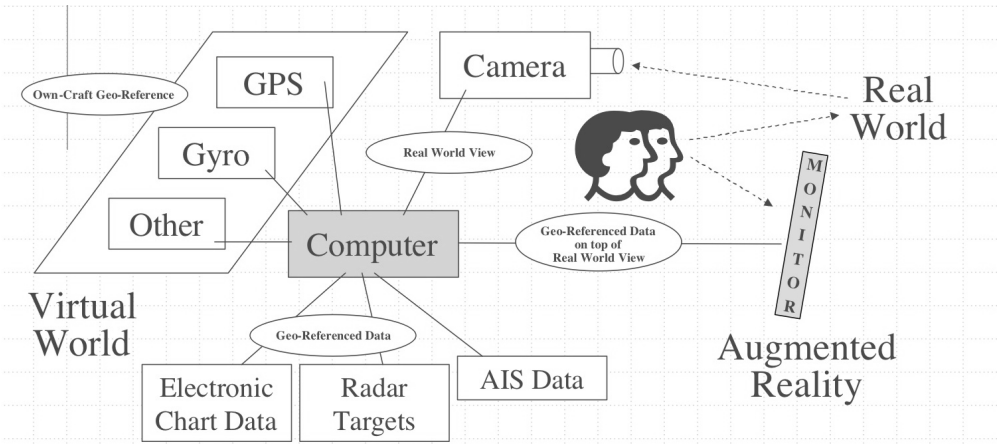


Fig. 11 ARVCOP working diagram

4.2 Obtaining ARVCOP from TSI

Although ARVCOP worked well in its military application and was very well received by the LCAC operators, a civilian version of the device introduced by TSI in 2009 known as *LookSea* was not as successful. Intended for the pleasure boating and yachting market, the expected sales did not reach expectations and the President of TSI, Mr. Charles Benton wanted to know why. After hearing about our Head-Up Display research in November 2010, Mr. Benton contacted the PI and proposed allowing us to use an earlier version of ARVCOP in the next e-Navigation course and obtain student impressions of the device. He hoped that their experiences and comments might highlight performance benefits and provide insight as to how to improve the device and increase sales.

Mr. Benton directed his in-house programmer, Ray Deguio, to provide us with a copy of the ARVCOP program. In late November 2010, Mr. Deguio tried to send us the program via file transfer over the Internet. After many frustrating hours of downloading, uploading and troubleshooting, it was determined that the best approach would be to load the program directly onto a clean personal

computer in Maine. Accordingly, the PI mailed a new PC to TSI in September 2011. This computer was purchased and the shipping paid for by the PI at personal expense since there is no provision in the IAMU grant for the purchase of equipment. The PI also purchased a special dongle from the Jeppesen Company in Norway in order to access the C-MAP charts that are part of the ARVCOP database. These purchases had to be made if ARVCOP were to be included as part of the e-Navigation class. The PI does not expect to be reimbursed for them.

4.3 Testing ARVCOP on crewboat Ursa

ARVCOP was initially used in real mode aboard Cal Maritime's small crewboat *Ursa.* The researchers first tested the device aboard the boat one week before introducing it to the students. The ARVCOP laptop was placed on a shelf directly above the boat's control panel. The sensor pod containing the camera, GPS receiver and fluxgate magnetic compass was attached with a suction cup to the vessel's forward window. A simple route was created in the *Routes* menu of the ARVCOP program that took the vessel from the CMA boat basin under the Carquinez Bridge and back to CMA. Display settings were selected as appropriate for the testing to be conducted the next week. The ARVCOP performed flawlessly.



Fig. 11 Crewboat Ursa



Fig. 12 ARVCOP display

The actual testing of ARVCOP with student participants is described in Section 2.9 above and the results of the corresponding survey in Section 5.2 below.

4.4 Testing ARVCOP in the simulator

Two weeks after testing aboard the crewboat, ARVCOP was brought into the full mission simulator. The equipment setup was similar to that used for the HUD with this notable exception: instead of the Augmented Reality (AR) image being projected onto the forward plasma screen (visual channel) in the simulator as with the HUD, the ARVCOP camera was directed at the plasma screen and its image displayed on the ARVCOP laptop computer screen which was superimposed with AR images. Herein lies the fundamental difference between HUD and ARVCOP, two otherwise seemingly similar devices. The photos of the students conning the vessels in Fig. 6 and 7 in Section 2 say it all; one has his head up, the other down.

4.5 ARVCOP and HUD compared

A full discussion of the qualitative differences, perceptions and preferences of the students for HUD vs. ARVCOP are related below in Section 5. Briefly stated though, the predominant difference between the two devices involved the perceived effect each had on the navigator's level of Situational Awareness (SA). Unfortunately due to the lack of time between the end of the e-Navigation course and the grant report deadline, objective, quantitative data analysis of student performance using ARVCOP and HUD could not be completed. It is hoped that this information can be presented to the IAMU community next year at AGA13 in St. John's, Newfoundland. Whether or not the quantitative data of student performance during the labs confirm the perceived superiority of HUD, the general consensus of the students was that HUD should be preferred over ARVCOP mainly for the greater level of SA it promoted through increased head up and eyes out the window time. One other interesting, though anecdotal, observation by the PI was that the students seemed to have an easier time staying on track using ARVCOP in the real environment on the crewboat than in the simulator. The tasks were very similar in degree of difficulty and yet they seemed to wander off the trackline much more in the simulator. The reasons for this may have something to do with better SA due to the greater variety of sensory inputs (sound, vibration, motion) that the real boat provides that are unavailable in the simulator. In any event, more research on this point needs to be done especially after a real-world maritime HUD prototype is ready for testing.

5. Preliminary Analysis of Data

5.1 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 or ARVCOP 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 or ARVCOP. The principal investigator and course instructor drew up other surveys on student perceptions of their navigational performance. Preliminary survey results and selected student comments are discussed below.

5.2 Survey Results

5.2.1 Lab 4 This lab section included the introduction of the Maritime Head-Up Display (HUD) in the Full-Mission Bridge (FMB) 3. The scenario location for this brief introduction was in the restricted waters of San Francisco Bay. The scenario included varying levels of visibility with the inclusion of both small and large vessel traffic. After completing a small introduction scenario students completed an initial impression survey. 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 $p \leq .0071$ 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
4.27	5.369	10	< .001*	.237	3-5

This result was significant. Participants felt that the HUD would be very useful in piloting situations. One participant noted that the projected lines on the screen help but another cautioned that the quality of the lines and perspective impacted their trust of the system. Advancements, such as contact information, chart NavAids, and other pertinent information, would be seen to increase the utility for one participant. Piloting was listed several times in the general comments as an applicable situation and benefit for HUD. One participant summarized the benefit saying that HUD combines our radar and ECIDS information with the necessary visual confirmation. The more certainty, the less stress. One participant noted that pilotage was not a good situation for HUD as HUD does not change mode for water depth and in port complications.

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

[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 *

Mean	T-value	df	P	SE	Range
2.79	-.699	11	ns	.298	1-5

This result was not significant. Participants were neutral concerning the utility of HUD for docking situations. Several students noted that HUD would not be appropriate for docking as it could be a distraction and a clear view out the window of the dock and approach was essential.

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

Mean	T-value	df	P	SE	Range
4.08	4.733	11	< .007*	.229	3-5

This result was significant. Participants felt that the HUD would be very useful in coasting situations. Several students noted the applicability of HUD to coastal navigation in the general comments and one student clarified the benefit as being able to match up what you see on radar and the chart information with reality.

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

Mean	T-value	df	P	SE	Range
3.42	1.101	11	ns	.379	1-5

This result was not significant. Participants were neutral concerning a HUD-related advantage in the open ocean. Most comments indicated that HUD was unnecessary in open ocean situations with less traffic and obstacles. One comment suggested that HUD might even get in the way in the open ocean.

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

Mean	T-value	df	P	SE	Range
3.75	3.447	11	< .007*	.218	2-5

This result was significant. Participants felt that a properly formatted HUD would reduce their navigational workload. The comments did not clarify the source of the reduction but general comments suggested HUD for use in several high workload situations and vessels (e.g., heavy traffic, congested waters, high speed vessels, large vessels). Cautions were put forward that HUD should be a compliment not a supplement and indicated a concern for operator bias.

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

Mean	T-value	df	P	SE	Range
4.25	9.574	11	< .001*	.131	4-5

This result was significant. Participants felt that HUD target information would reduce their collision avoidance workload. Several comments noted a desire to include AIS target information in the HUD and that this would support effective collision avoidance communications. One participant saw HUD as supporting the application of the COLREGS. A few students commented that HUD would not be helpful, and potentially distracting, in high traffic situations.

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

Mean	T-value	df	P	SE	Range
4.00	4.690	11	< .007*	.213	3-5

This result was significant. Participants felt that HUD information would reduce their stress level. One participant noted this benefit primarily for congested waters conditions and another noted the benefit in low to very low visibility conditions. 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
4.00	3.633	11	< .007*	.275	2-5

This result was significant. Participants felt that having HUD information would improve their situational awareness. Several participants listed increased SA as a primary benefit of HUD, especially in regard to current position in comparison to desired trackline, and via reduced heads down time. Comments also cautioned that there might be a "zone out" or overreliance on 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
4.33	7.091	11	< .001*	.188	3-5

This result was significant. Participants felt that the use of HUD would reduce head down time in comparison with ECDIS navigation. Several participants listed reduced head down time as a primary benefit of HUD.

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

Mean	T-value	df	P	SE	Range
4.08	5.613	11	< .001*	.193	3-5

This result was significant. Participants felt that the use of HUD would reduce head down time in comparison with radar navigation. Several participants listed reduced head down time as a primary benefit of HUD.

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
4.83	16.316	11	< .001*	.112	4-5

This result was significant. Participants felt that the use of HUD would reduce head down time in comparison with paper chart navigation. Several participants listed reduced head down time as a primary benefit of HUD. Note that the lowest rating was a 4.

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

Mean	T-value	df	P	SE	Range
4.50	7.707	11	< .001*	.195	3-5

This result was significant. Participants felt that a HUD application would provide a valuable addition to the navigating bridge environment. The perceived benefits will be discussed below.

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

Mean	T-value	df	P	SE	Range
4.50	5.745	11	< .001*	.261	2-5

This result was significant. Participants felt that a HUD application would be useful for reduced-visibility operations. Several participants listed support for low visibility conditions as a primary benefit of HUD.

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

Mean	T-value	df	P	SE	Range
3.67	2.602	11	< .007*	.256	2-5

This result was significant. Participants felt that a properly formatted HUD would be useful in heavy traffic situations. There were mixed comments with some students seeing a primary benefit for HUD in heavy traffic situations, especially if integrated with AIS information to identify vessels. Other students' comments suggested some cautions concerning HUD being a potential distraction and not appropriate for high traffic situations. Further research is required as HUD development advances.

Lab 4 Open-ended survey items: The Lab 4 survey included several open-ended items to allow students to elaborate on their perceptions of HUD. The first item asked what the students saw as the primary benefits of HUD. Overall, increased situational awareness, reduced head down time, and increased ability to follow the trackline were the most frequent answers. Other responses indicated reduced stress and the ability to relate radar and chart information directly to the outside visual.

The second item asked what students saw as the potential concerns of using a HUD application. The most common responses were overreliance, the potential for distraction (tunnel vision), and information overload. Other responses indicated difficulties judging distance, over or under steering, and the need for HUD-specific hand-off procedures with the change of watch.

The third item asked what operational situations, or tasks, would a HUD application best support and how. The answers varied but commonly included highly congested areas (e.g., pilotage, inland, inbound and outbound, high traffic, crossing traffic) and poor visibility. The advantage was seen to be a better ability to stay on course and make turns while maintaining a lookout.

The fourth item asked what operational situations, or tasks, would a HUD application be inappropriate for and why. The most common answer was docking situations, as HUD was seen as unnecessary or a distraction. A few participants listed heavy traffic and one participant listed clear sunny days so to keep the field of view clear from any distractions.

The fifth item asked if there were any vessel types that a HUD would be especially beneficial for, or inappropriate for, and why. The responses varied quite a bit with several participants suggesting HUD would be good for all vessels. One participant noted that fast moving, hazardous cargo, limited visibility, and small crews were all great reasons to provide easy to understand navigation information. Other participants listed both large (cargo, tankers, cruiseships, liners) and small vessels (fast moving, harbour craft, etc.). One participant suggested HUD as a convoy coordination tool.

The sixth, and last, item asked what additional features, or information, they would like to see integrated into a HUD application. The most common answers were additional waypoint information (ETA, course to steer), and AIS contact information (Identity). Other items listed included environmental factors (current and wind), ROT, heading and distance, and two participants listed a fathometer.

Lab 4 Conclusions: Overall participants saw potential for HUD to add value to the bridge environment. This is further bolstered by significantly positive ratings on all of the other items, with the exception of items 2 and 4, concerning use in docking situations and the open ocean. The open ocean was not envisioned as a primary application for HUD information and this result is not surprising. The current HUD was also not envisioned to support docking operations and is not equipped with docking information. Results from prior surveys (last e-nav class) suggest that the HUD may provide a benefit if it included this information. Regardless, docking functionality is not on the HUD development

priority list. 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.

5.2.2 Lab 7

This lab involved the use of the ARVCOP onboard the crew boat Ursa. A five-course leg route was created with various course angles/changes to introduce the use of the ARVCOP in small boat operations. Each student was afforded the opportunity to navigate the vessel. The students then completed a survey to capture their initial impressions of the ARVCOP system. The survey included the ten 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 $p < .01$ and any finding with a $p \leq .01$ 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. The results are presented below along with a summary of relevant comments for each item and conclusions at the end.

Item 1: I felt having ARVCOP information improved my ability to stay on the planned track.

Mean	T-value	df	P	SE	Range
4.48	9.077	16	< .001*	.143	3-5

This result was significant. Participants felt that the ARVCOP improved their ability to stay on the planned track. One student commented that the system helped significantly with knowing where they needed to be and when to turn. One student found judging distance for turns difficult at first. One student commented that looking at the screen pulled their eyes off the water.

Item 2: I felt having ARVCOP information improved my situational awareness concerning my geographic location.

Mean	T-value	df	P	SE	Range
3.18	.614	16	ns	.287	1-5

This result was not significant. Participants were neutral concerning ARVCOP information improving situational awareness of geographic location. Most of the comments suggested that having to look heads down at a screen was a detriment, especially in high traffic, congested, areas. One noted that the benefit would be realized when presented on the window, allowing eyes to remain looking out. One participant noted a desire to include a mini-map on the display in the upper right-hand corner.

[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 (10), resulting in the value listed above of p < .01 (.10 divided by 10). Significant items are marked with a *

Item 3: I felt having ARVCOP information improved my ability to maintain situational awareness concerning the traffic situation.

Mean	T-value	df	P	SE	Range
3.12	.696	16	ns	.169	2-5

This result was not significant. Participants were neutral concerning ARVCOP information improving situational awareness of the traffic situation. Several comments noted that with the minimal traffic experienced during the scenario it was hard to make a judgment. One noted that AIS would need to be integrated. One participant noted that ARVCOP would be very helpful when piloting a specific course. One participant noted that there is a need to look all around not just in front of the vessel. Several participants noted a disadvantage of the head down time, one noting never looking out the window for traffic or geography, one finding it easier to adapt to the visual information outside the window, and one seeing an advantage when the display is implemented on the window.

Item 4: I felt that ARVCOP could increase my ability to maintain a good visual lookout.

Mean	T-value	df	P	SE	Range
3.29	1.045	16	ns	.281	1-5

This result was not significant. Participants were neutral concerning ARVCOP increasing their ability to maintain a good visual lookout. Three participants reported having tunnel vision on the computer screen. Four participants noted that presentation on the window (HUD) was required.

Item 5: I felt less distracted using the ARVCOP as compared to standard ECDIS.

Mean	T-value	df	P	SE	Range
3.63	4.038	15	= .001*	.155	3-5

This result was significant. Participants felt less distracted using the ARVCOP as compared to standard ECDIS. One participant noted that the benefit was due to the wide lane markers allowing for slight course corrections. Several participants noted a lack of experience with ECDIS overall, or specifically on boats of this size and speed.

Item 6: I feel the trackline course information in the ARVCOP display would be helpful.

Mean	T-value	df	P	SE	Range
4.38	7.652	15	< .001*	.180	3-5

This result was significant. Participants felt that the trackline course information in the ARVCOP display would be helpful. The only comment qualified that it was still hard to judge time to turn.

Item 7: I felt having the ARVCOP allowed me to focus more attention looking out the window.

Mean	T-value	df	P	SE	Range
2.44	-1.952	15	= .070	.288	1-5

This result was not significant. Participants were neutral concerning ARVCOP allowing more attention looking out the window, but the trend was to disagree. Three comments noted tunnel vision on the ARVCOP display. Two noted there was not a benefit on the course used for the evaluation. One noted that once the information was presented on the window it would provide more depth perception.

Item 8: I feel that wheel-over information would be helpful while following the ARVCOP trackline.

Mean	T-value	df	P	SE	Range
4.44	9.139	15	< .001*	.157	3-5

This result was significant. Participants felt that wheel-over information would be helpful while following the ARVCOP trackline. Comments suggested this information, or at least distances to waypoints, would be an advantage. One participant qualified this by noting the difficulty in judging turns.

Item 9: I feel that properly formatted ARVCOP information would reduce my navigational workload.

Mean	T-value	df	P	SE	Range
4.19	5.216	15	< .001*	.228	2-5

This result was significant. Participants felt that the use of ARVCOP would reduce navigational workload. One participant noted it is another tool.

Item 10: The ARVCOP would be very useful in piloting situations.

Mean	T-value	df	P	SE	Range
4.71	11.964	16	< .001*	.143	3-5

This result was significant. Participants felt that ARVCOP would be useful in piloting situations. One comment noted that this might be when ARVCOP would be most useful. One comment cautioned concerning the need to get used to looking out the windows and at the screen.

Lab 7 General Comments and Conclusions: Participants saw several benefits to the ARVCOP system. The primary benefits were seen for track following support. This benefit was seen to have the potential to reduce workload significantly. The comments also suggested an increased benefit if ARVCOP included more information to support upcoming turns (planning and execution). These benefits were consistently qualified by concerns and complaints concerning head down time, tunnel vision, and the need to have this track and turn information but maintain the scan out the window. These are the benefits that would be presented by a HUD application. The labs described below were developed to compare the advantages provided by ARVCOP to those provided by a HUD system.

5.2.3 Labs 9 & 10

The intent of Labs 9 and 10 was to measure the performance of using the ARVCOP system to performance using HUD while completing scenarios of similar complexity. The routes consisted of varying levels of course changes and distracters embedded within the exercise. Students were given the instruction to maintain a visual lookout and safely navigate their vessel using the ARVCOP (Lab 9) or HUD (Lab 10) to follow the route provided. Distracters were embedded within the route to determine/measure deviation from the route. At the end of each lab session students completed the same 9-item survey providing a rating between 1-100 of scenario performance based on their perceived level of the following variables (Indirect ARVCOP vs. HUD comparison 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)

The survey for Lab 10 contained five additional items asking the students to make direct comparisons between ARVCOP and HUD after having experienced both systems in similar scenarios. One item

asked the students to select which display ARVCOP or HUD they feel would better support similar scenarios. A second item asked the students to rate how much better that support would be on a scale of 1 to 10, with 10 representing extremely better support. Space was provided for additional comments. The students then provided a rating between -50 (extreme negative impact) and +50 (extreme positive impact) for both ARVCOP and HUD concerning their ability to support the tasks of:

- Staying on the planned track
- Maintaining situational awareness concerning geographical location
- Maintaining situational awareness concerning the traffic situation

Results: A repeated measures ANOVA was performed on the data to compare the ratings each student provided after completing the Lab 9 scenario with ARVCOP to the ratings he, or she, provided after completing the Lab 10 scenario with HUD, along with the three direct ARVCOP vs. HUD comparison ratings. The significance criterion was set at $p < .0083$ and any finding with a $p \leq .0083$ or less was considered significant[3]. The results are presented below, first for the indirect comparisons and then the direct comparisons.
Indirect comparisons: The means of these indirect comparison ratings can be seen in *Table 1* below and in figures 13-14. In Figure 13 a lower rating represents preferred performance for all of the items and in Figure 14 a higher rating represents preferred performance.

None of the individual items were significant. Three items were marginally significant. For the rating of feeling rushed the difference was marginally significant, F (1, 9) = 4.684, p = .059. Students using the ARVCOP felt moderately more rushed during the scenario than students using the HUD, with mean ratings of 66.50 and 40.50 respectively. The results may be due to a reduced requirement to switch back and forth between head out and head down information with the HUD. Further research is required. Comments suggested that the Lab 9 scenario had a high tempo pace.

For the rating of situational awareness and staying ahead of the vessel the difference was marginally significant, F (1,9) = 4.336, p = .067. Students using the ARVCOP felt moderately less situational awareness during the scenario than students using the HUD, with mean ratings of 59 and 79.5 respectively. This result could also be related to HUD allowing increased time looking out the window. The comments in the general direct comparison section corroborate this explanation.

For the rating of confidence of mission success throughout the scenario the difference was marginally significant, F (1,9) = 6.273, p = .034. Students using the ARVCOP felt moderately less confident during the scenario than students using the HUD, with mean ratings of 62.20 and 87 respectively. This result could be related to HUD's intuitive presentation of information overlaid on the real world scene making it easy to determine if the vessel was in the right location at the same time as monitoring for outside dangers. Consideration needs to be given to the calibration of perceived confidence with real world performance and dangers. This topic should be addressed in future research.

[3] 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 overall tests (12), resulting in the value listed above of $p < .0083$ (.10 divided by 12).

Variable	ARVCOP Mean	HUD Mean
Mental Demand	46.67	45.00
Rushed Pace	66.50	40.50
Frustration	40.00	24.59
Stressful	48.90	36.20
Hard work	61.90	50.60
Situational Awareness	59.00	79.50
Confidence	62.20	87.00
Success	61.20	75.00
Crew Teamwork	94.50	90.50

Table 1 Means for indirect ARVCOP vs. HUD comparison measures (For shaded items higher ratings relate to better performance)

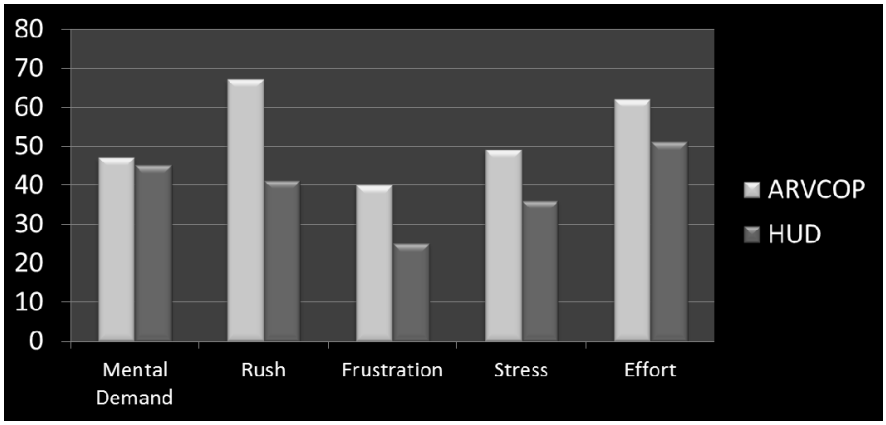


Fig. 13 Labs 9 & 10 ARVCOP vs. HUD (lower rating preferred)



Fig.14. Labs 9 & 10 ARVCOP vs. HUD (higher rating preferred)

The pattern of means for all other items favoured the participants with HUD as well, with the exception of how well the crew worked together where the ARVCOP rating was slightly higher than the HUD rating. The means were 94.5 for ARVCOP and 90.50 for HUD. The difference is small but could represent a positive component of ARVCOP as a collaborative tool or the requirement for additional teamwork with the ARVCOP display. Comments suggested a need to micromanage the helmsman when using ARVCOP that was not seen in the HUD condition.

Direct Comparisons

The first item of direct ARVCOP vs. HUD comparison asked which display would provide better support for similar situations. HUD was selected by 8 of the 9 students that responded. The 9th student selected both HUD and ARVCOP. The average rating on a 1 to 10 scale for how much better that support would be was 7.43. The range was from 5 to 10. The students almost unanimously preferred HUD over ARVCOP in direct comparison.

The results of the Repeated Measures ANOVA on the remaining items are presented next. All items were rated on a scale of -50 (extreme negative impact) to +50 (extreme positive impact). For the rating of task specific support for staying on track the difference between ARVCOP and HUD ratings was significant, F (1,8) = 16.313, $p < .0083$. Students rated the ARVCOP lower than the HUD for supporting staying on the planned track, with mean ratings of 5 and 32.78 respectively. Comments clarified that the track and waypoints on the HUD are easier to keep track of and to hold a course by and that HUD provided visual confirmation to the helmsman that reinforced rate of turn and heading info.

For the rating of task specific support for maintaining situational awareness of one's geographical location there were significant differences between the ARVCOP and HUD ratings, F (1,8) = 20.024, $p < .0083$. Students rated the ARVCOP lower than the HUD for supporting situational awareness of one's geographical location, with mean ratings of -2.22 and 33.89 respectively. Three comments referenced improved situational awareness with HUD and the benefit of bringing the eyes up and out the window, forcing the navigator to be aware of his or her surroundings and leading to better performance. These results are consistent with those found in the Lab 7 data.

For the rating of task specific support for maintaining situational awareness of the traffic situation there were marginally significant differences between the ARVCOP and HUD ratings, F (1,8) = 20.024, $p = .064$. Students rated the ARVCOP moderately lower than the HUD for supporting situational awareness of the traffic situation, with mean ratings of 3.89 and 27.78 respectively. The benefit was not clarified in the comments and neither display provided AIS, radar or other traffic information. The HUD benefit therefore has to be hypothesized to occur from the increased situational awareness of the outside situation.

Lab 9 & 10 Conclusions

The results suggest that the benefits of HUD go beyond the information itself and involve how it is presented as well. Across the survey results of Labs 4,7, 9 and 10 students indicated a need, or at least a preference, for 3-D perspective track and waypoint information for more intuitive assimilation and assessment of the navigational situation. After interacting with this information as presented head down (ARVCOP) and head up (HUD), students showed a near unanimous preference for HUD over ARVCOP. This benefit is realized primarily through the increased head up time that can be spent looking out the window and maintaining awareness of the outside situation. ARVCOP is a system that is mature and ready for use aboard real craft, which is not the case for HUD, and this is a strong benefit for current operations. The research and development necessary to bring HUD to that level is not minor but appears to be achievable with proper funding and technical support. The results of these surveys suggest that the added benefit of developing the means to present this augmented reality

navigation information in a HUD would be worth the time and effort, as has been realized in other domains such as aviation.

6. Presentation at 2011 e-Navigation Conference

In late October 2011, Captain Robert Moore, a well-respected expert in the field of maritime affairs and co-chair of the annual e-Navigation Conference in Seattle, WA, wrote to the PI, Sam Pecota:

> Dear Captain Pecota,
>
> Two synergistic (I hope) things occurred today. First, I read through the paper you and Eric Holder published in the October 2011 issue of the *Journal of Navigation*, and then arrangements for one of the speakers lined up for **eNavigation 2011** fell through, leaving a slot open. I immediately thought that if you were available and willing, a presentation based upon the paper would be an admirable addition to the conference. I must apologize for the tardiness of this request and frankly feel some embarrassment at not having considered you from the beginning. Fred Pot and I are serving as conference co-chairs this year and things have been organized somewhat differently than heretofore. Day 1 deals largely with the evolution of e-Navigation and its impact upon particularly the waterway management infrastructure. Day 2 focus is largely upon ECDIS, but more the underlying complexity rather than mechanics of the display. I expect John Eric Hagen, of the IMO e-Navigation Correspondence Group will, in his presentation on Day 1, describe the revised conceptual architecture reported by the group to NAV 57 during early summer. My thought would be to build on the statement implicit in that architecture that while mariners now deal with AIS, radar and ECDIS the technical tools providing e-Navigation information to the mariner will change with experience and technological developments. One potential route of the several now foreseen may well be HUD, either by itself or in combination with other things. The presentation could also be used to reinforce awareness of e-Navigation as a general maritime information environment wherein technical devices move data and translate it into information immediately useful for decision-making for all of the maritime community, not just positioning and collision avoidance.

The PI could not refuse such a gracious invitation to speak at this prestigious conference and so accepted. The title selected for the presentation (as suggested by Captain Moore) was simply "Alternative Displays."

The presentation was made on 30 November 2011 and was received quite enthusiastically by many (not all!) conference attendees. This was especially gratifying since "Alternative Displays" was the very last presentation to be delivered of some twenty plus over a two-day period. (The PowerPoint slides used for the presentation are included in the documents accompanying this final report.) The HUD demo video produced last year and included as part of the deliverables in Phase I as well as video of the e-Navigation students steering the crewboat using ARVCOP were shown to a very attentive and appreciative audience that was by that stage of the conference fairly well satiated with PowerPoint presentations. Afterward, one of several professional mariner educators from the STAR Center and Pacific Maritime Institute stated, "I wondered when someone was finally going to make one of those things." Somewhat surprisingly, three experienced ship pilots expressed great interest in

the HUD as well, particularly as an aid to docking vessels, something that was not even considered by the researchers as a potential benefit of HUD. Clearly, we have not yet exhausted all research possibilities for this device.

7. Conclusion and Notes on Further Research after Phase II

7.1 Final assessment of the Fall 2011 e-Navigation course

In general, the students who participated in the e-Navigation course were very positive about the experience. Many asked if the course was going to be offered again, and if so, expressed an interest in retaking it. At the last session, an exit survey was administered that asked student opinions about the course overall. Below are the responses, as measured in Likert format, i.e., 1=strongly disagree, 5=strongly agree.

1. This course increased my watchstanding confidence.	4.25
2. This course improved my general watchstanding skills.	4.75
3. This course improved my radar skills.	4.75
4. This course improved my ECDIS skills.	4.75
5. This course improved my Bridge Team Management skills.	4.50
6. The pre-brief helped me perform better during exercises.	4.75
7. The de-briefs were a helpful learning opportunity.	4.75
8. This course is a valuable course in my curriculum.	4.50
9. The course appears to have been carefully planned.	4.82
10. The class followed the syllabus.	4.18
11. I felt that the lab sections reinforced the topic discussed.	5.00
12. I felt that the simulation exercises were realistic.	4.82
13. This course is practical and useful to those students for whom it was specifically planned.	4.91
14. I feel the opportunities to be involved in maritime research were valuable.	4.82

7.2 Future e-Navigation courses

With the completion of the Fall 2011 e-Navigation course on 14 December, research and development to produce a college-level course in e-Navigation for the world's maritime universities drew to a close. The Model Course produced during Phase I of this research project coupled with the actual course syllabus, lecture PowerPoints and Lab instructions produced by Cal Maritime Assistant Professor Scott Powell using that Model Course, should provide any maritime instructor with the necessary tools to create his or her own course in e-Navigation.

As for Cal Maritime, the decision whether to offer e-Navigation instruction to Marine Transportation students as a stand alone course based on the IAMU Model Course or to incorporate components of e-Navigation topics within already existing navigation courses has yet to be determined. What is not in question however, is the need to introduce all future deck students to e-Navigation concepts and systems, even as they are still being developed. Maritime universities can no longer afford to ignore the inexorable movement toward the full implementation of e-Navigation by the world's maritime community. Our students must be prepared to enter into marine navigation environments unlike any that have gone before.

7.3 HUD Research Planned for 2012

The search for a commercial marine navigation equipment manufacturer partner to help produce a working, seagoing marine HUD prototype has still proven unsuccessful. Of the major equipment manufacturers such as Jeppesen, Kelvin Hughes, Transas, Northrop Grumman, and Rockwell Collins, none have shown a real interest in the project. A representative from Jeppesen was present at the 2011 e-Navigation conference in Seattle and observed the presentation "Alternative Displays." While expressing interest in the concept, he was in no way encouraging as to the possibility of us obtaining funding for further research from his company. Although this is disappointing, it is not unexpected given the state of the world's economy, which continues to suffer major challenges. We continue to believe that we are the only group actively engaged in the attempt to develop an augmented reality maritime head-up display and that the whole concept continues to seem too futuristic to most. Nevertheless, as our research to date has shown, HUD shows great promise as an effective way to display crucial, timely navigational information to the mariner in a variety of situations and on a variety of vessel types. For this reason alone, the researchers will continue to develop the HUD at whatever pace the amount of future funding will allow.

As related in Section 3.2 above, the first hurdle in further HUD development to be overcome is the conversion of the program from Adobe Air to the more robust and flexible C# language. It is hoped that this will be accomplished early in 2012. Once the program has been rewritten in C#, extensive testing in the simulator will have to be conducted to assess its operational and display qualities and prove its reliability. After it is determined that the new C# program meets the required standards in a simulated environment, the next challenge will be to procure the necessary hardware to bring the device out into a real operating environment, i.e., on board one of the Cal Maritime small craft. To accomplish that, the first step will be to identify a suitable type of display.

There are several possible existing display methods such as window projection similar to that used in automobile HUDs and flip down combiners as used in aviation HUDs. These types of displays are generally quite small and therefore probably inadequate for a maritime HUD application. In lieu of a larger bridge window application, a more promising display type could be something similar to the Samsung AMOLED display as seen in Fig. 15 below. While presently quite expensive, the price should come down to a reasonable level once an adequate number of applications are identified and production increases. If our HUD could be successfully coupled to such a display, we would be at about the same level of development as ARVCOP is presently.

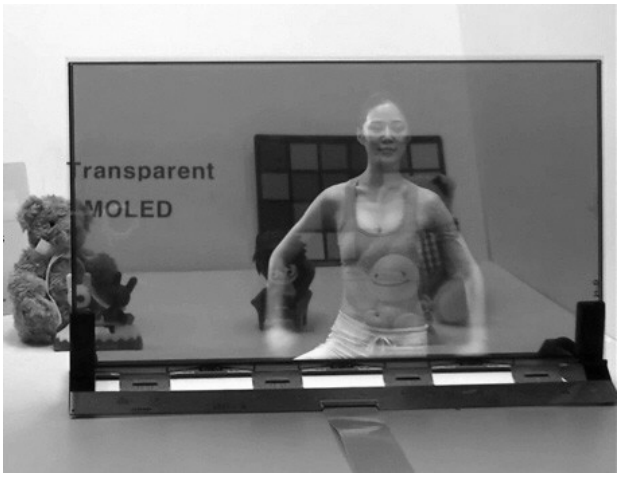


Fig. 15 Samsung 19" Transparent AMOLED Display

Once a suitable display is found, a method to stabilize it with the outside world will be needed. Existing inertial navigation equipment coupled to a GNSS receiver should perform this function quite admirably. The motions of the vessel, pitch, roll and yaw, must be properly dampened out for the HUD image to remain conformal with the outside view, contributing to confidence in the Augmented Reality information presented to the navigator.

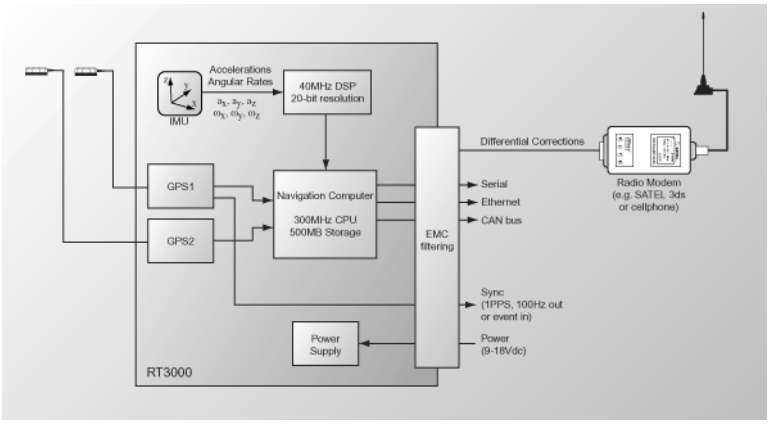
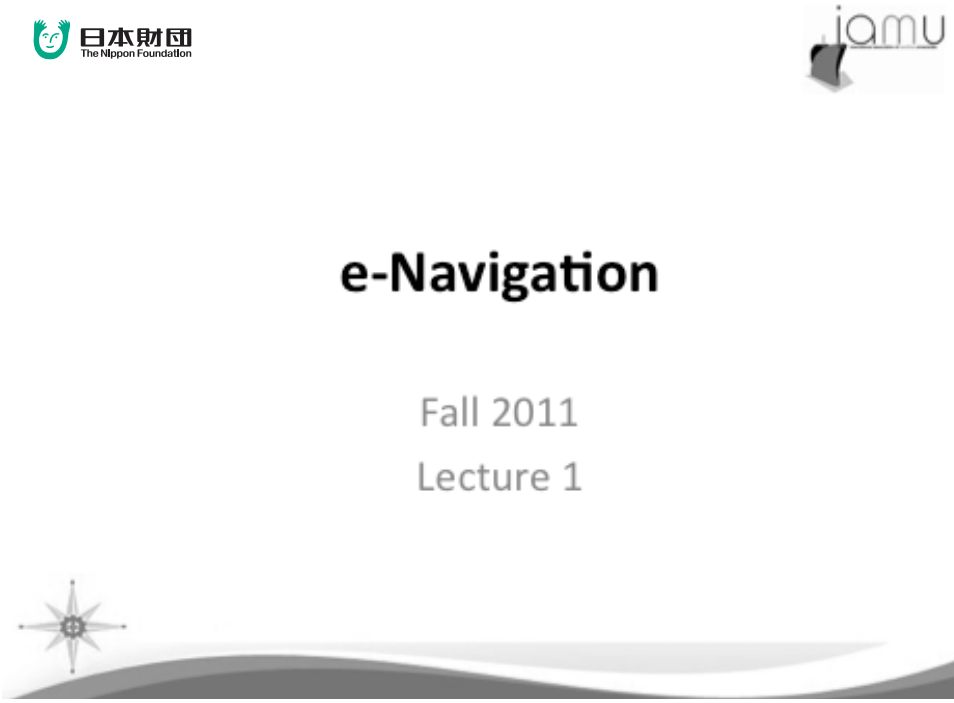


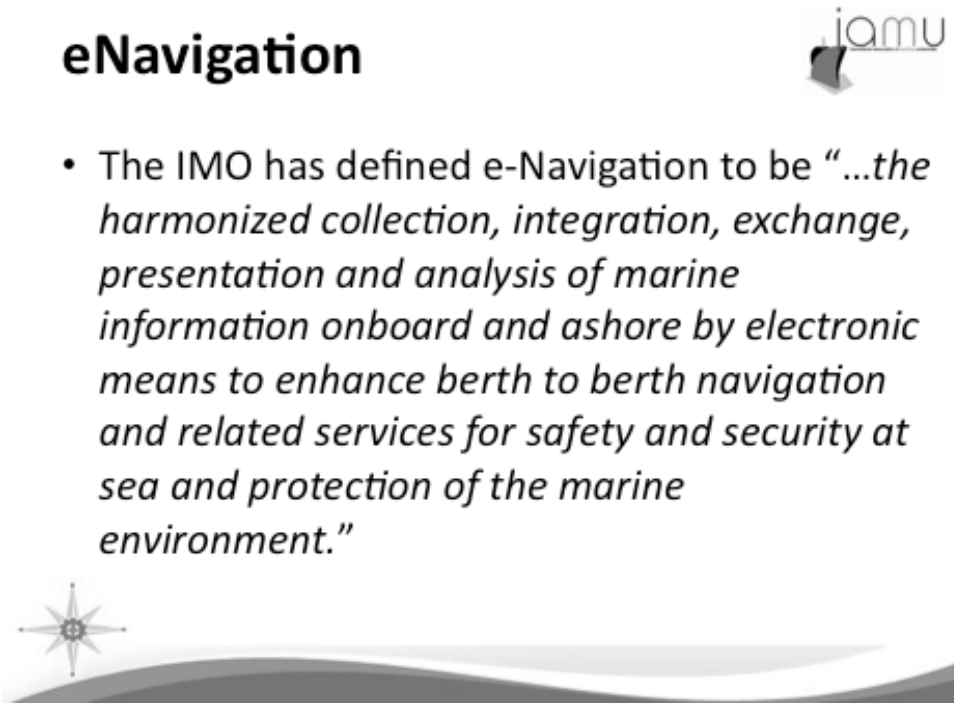
Fig. 16 Inertial Navigation System Diagram

Finally, for a large fixed display maritime HUD (not a small Portable Pilot Unit) a solution to the image parallax problem must be found. Navigators on large vessels in particular tend to move around the bridge, thus causing the image produced on a fixed HUD screen to diverge from conformality with the outside view because of this gross observer movement. Possible corrective measures may consist of any of the following: 1) use of a transmitter, or tracking system, to locate the observer on the bridge and adjust the HUD image accordingly; 2) fitting the observer with special glasses that put the HUD image right on the glasses and focused on infinity (a type of Head Mounted Display or HMD); 3) multiple viewing positions located throughout the bridge; and 4) some sort of holographic application. The final answer to the parallax problem in a large fixed maritime HUD may not be identified for many years. Despite the desirability of such a display, due to the difficulties inherent in producing large, consistently conformal augmented reality displays for large vessels, the likelihood is that, at least for the near future, any effective maritime head-up display will remain limited in size, even portable and more applicable to small high speed vessels where the navigator is relative fixed (seated) at a conning station.

8. Appendix

8.1 e-Navigation course lecture presentations





eNavigation

- 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.*"

e-Navigation

Shipborne users
Generic SOLAS vessels
Commercial tourism craft
High speed craft
Mobile VTS assets
Pilot vessels
Coastguard vessels
SAR vessels
Law enforcement vessels (police, customs, border control, immigration, fisheries inspection)
Nautical assistance vessels (tugs, salvage vessels, tenders, fire fighting, etc)
Counter pollution vessels
Military vessels
Fishing vessels
Leisure craft
Ferries
Dredgers
AtoN service vessels
Ice patrol/breakers
Offshore energy vessels (rigs, supply vessels, lay barges, survey vessels, construction vessels, cable layers, guard ships, production storage vessels)
Hydrographic survey vessels
Oceanographic research vessels

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.*"

e-Navigation

Shore-based users
Ship owners & operators, safety managers
VTM organisations
VTS centres
Pilot organisations
Coastguard organisations
Law enforcement organisations
National administrations
Coastal administrations
Port authorities
Security organisations
Port state control authorities
Incident managers
Counter pollution organisations
Military organisations
Fairway maintenance organisations

We were connected to the office's database for personnel paperwork. I-9s to payroll, to evaluations were submitted and could be obtained through the network with the office. Also, a cargo log was submitted so the office could oversee the loading, unloading, tonnages and times. This information would be evaluated and compared with over vessels in the fleet. Even reached a point where times where compared between vessels as to how fast captains could make docks from breakwall to arrive dock. If they look at this information, eNav is the next step.

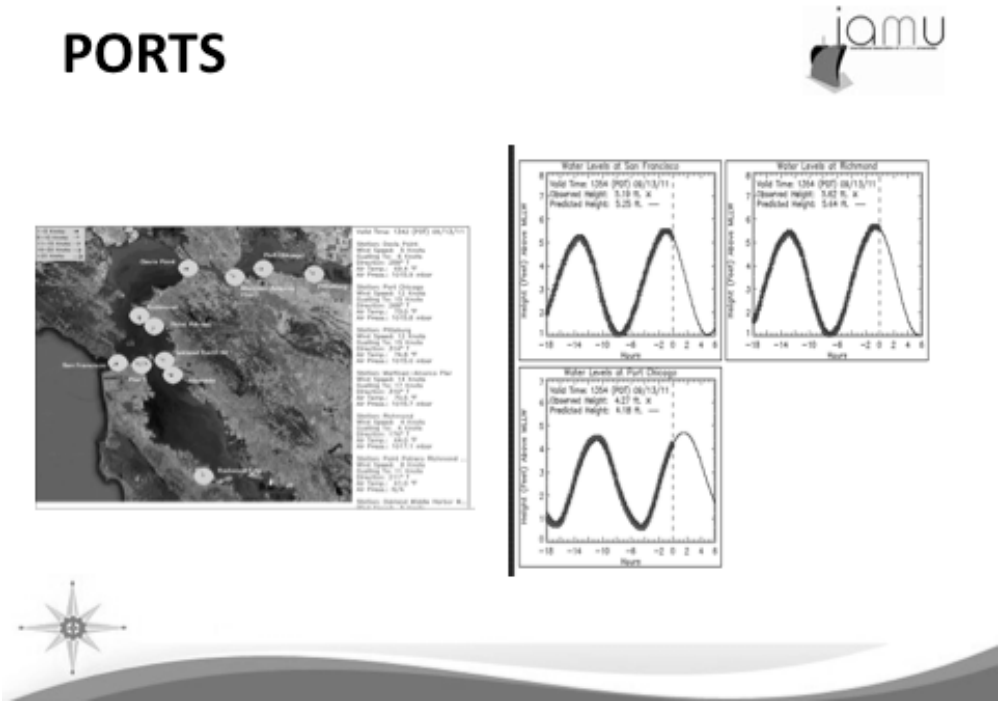




The objective of this page is to demonstrate techniques for the delivery of value-added information to the real-time oceanographic observations collected by NOS/NOAA (InfoHub). The real-time data are displayed in graphical form to show historical changes in these data for the past 24 hours, and to forecast the tidal process for the next 24 hours. The real-time data are assimilated in a marine nowcast numerical model whose results, along with recent field observations, are delivered to the maritime community. This interactive near real-time information is made available to improve navigation safety, provide hydro-meteorological information for spill prevention and cleanup, navigation schedule and planning, search and rescue missions, and for recreation.

The available near real-time data include:

Tides (Water Level)
Currents
Winds (see also San Francisco Bay Wind Patterns page)
Water Temperature
Air Temperature
Air Pressure
Short term forecasts of water level and currents



The Physical Oceanographic Real Time System (PORTS) is designed to provide crucial information in real time to mariners, oil spill response teams, managers of coastal resources, and others about San Francisco Bay's water levels, currents, salinity, and winds. In partnership with the NOAA's National Ocean Service (NOS); the California Office of Oil Spill Preparedness and Response (OSPR), the U.S. Geological Survey, and the local community, the Marine Exchange of the San Francisco Bay operates PORTS as a service to those who must make operational decisions based on oceanographic and meteorological conditions in the Bay.

The number, type, and mix of instruments that collect this information are deployed at strategic locations (figure 1) in the Bay both to provide data at critical locations and to allow nowcasting and forecasting using a mathematical model of the Bay's oceanographic processes. Data from these sensors is fed to a central data collection point; raw data from the sensors are integrated and synthesized into information and analysis products, including graphical displays of PORTS data. These displays will be available in the next few weeks over the Internet. PORTS data are also available through a voice response system.

NAU 395 e-Navigation

- The purposes of this IAMU 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

e-Nav Architecture



e-Navigation

- Primary components and concepts of e-Navigation as defined by IMO in the Dec 2005 Maritime Safety Committee
  - 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 emerging communication technologies

Conventional Bridge



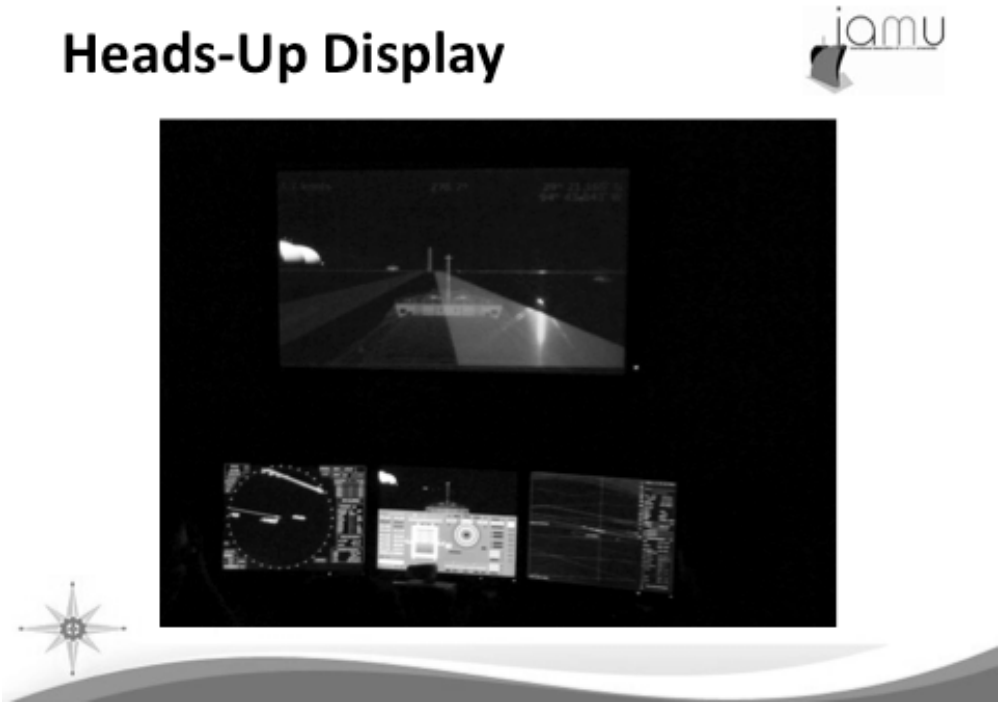


Integrated Navigation Bridge

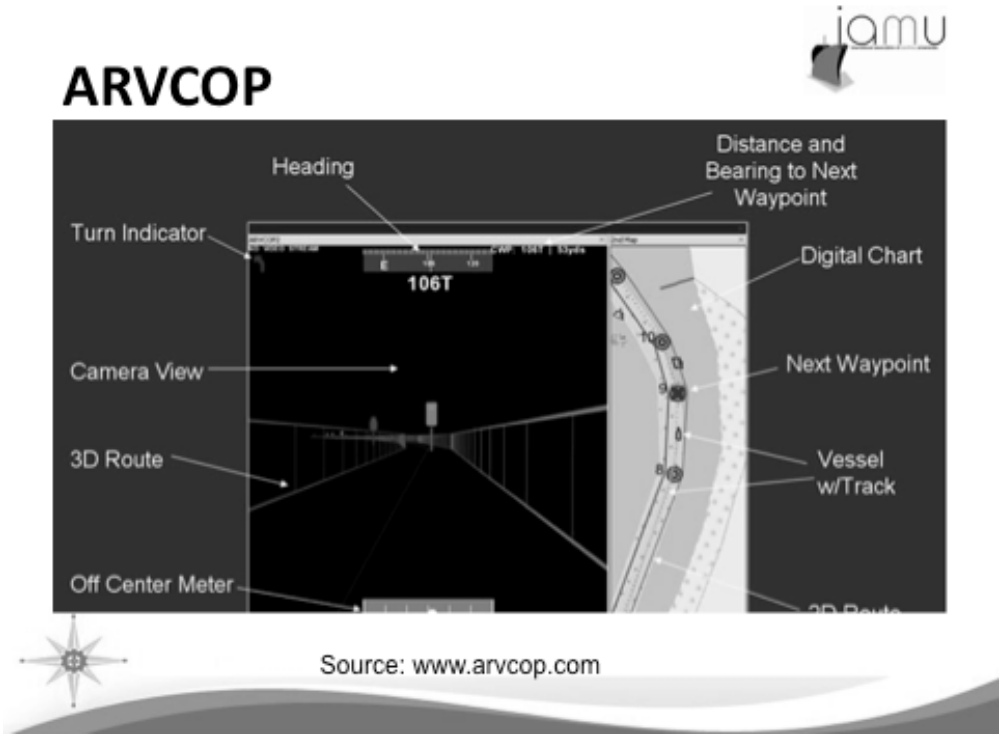


Source: http://www.raytheon-anschuetz.com/commercial-systems





Relevant Features
Conformal: Planned route, safe boundaries, upcoming alterations, obstacles and other dangers (Augmented Reality)
Non-Conformal: Speed, heading, performance parameters, etc.
Potential Advantages:
Less time to integrate information
Less scanning, accommodation, head movement



ARVCOP utilizes augmented reality to increase situational awareness in all conditions by taking a wide variety of information and rendering it into a real-world view, in 3D and in real time. In effect, augmented reality effectively enhances your native senses, maximizing your awareness by limiting unnecessary mental processing time.
In ARVCOP, your view is enhanced by mission related information, such as guide rails and object markers, which allow you to navigate around otherwise invisible objects in any conditions. ARVCOP also includes a Mission Support system, which allows you to edit every aspect of your mission and have it directly affect your augmented view in real time.

ARVCOP





Source: www.arvcop.com

e-Navigation Timeline

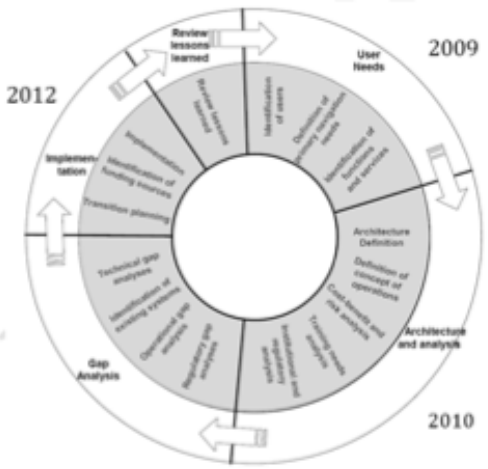


Figure 2 e-Navigation implementation

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.*"

日本財団 The Nippon Foundation

e-Navigation

Fall 2011

Lecture 2

e-Navigation

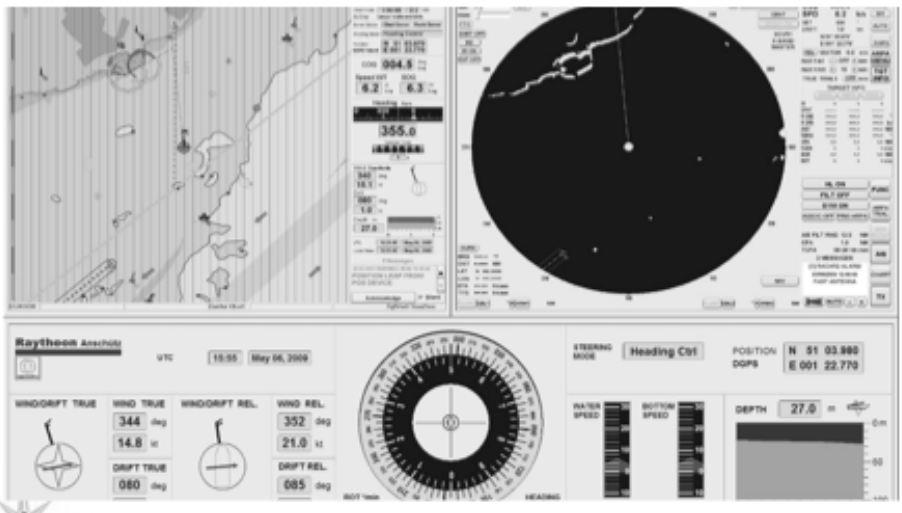
- e-Navigation benefits to the mariner
  - Minimize navigational errors, incidents and accidents
  - Improve decision-making support
  - Improve bridge watchstanding and lookout practice
  - Reduce the workload of ship's crew
  - Improve security
  - Improve search and rescue operations

e-Navigation



Source: http://www.raytheon-anschuetz.com

e-Navigation



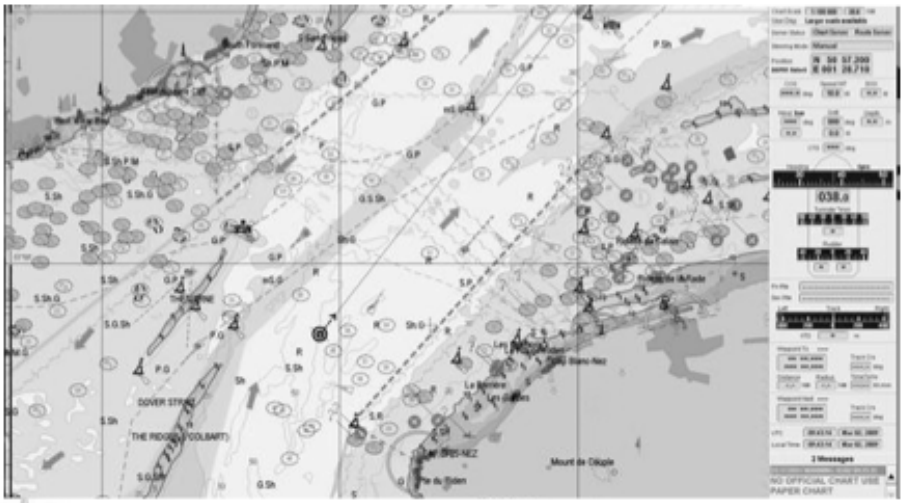
Source: http://www.raytheon-anschuetz.com

e-Navigation

e-Navigation benefits to the maritime community:

- Better monitor vessel locations and regulate traffic flows
- Reduce shipping costs
- Provide interface to other modes of transportation
- Automate and standardize reporting procedures
- Reduce administrative overhead

e-Navigation

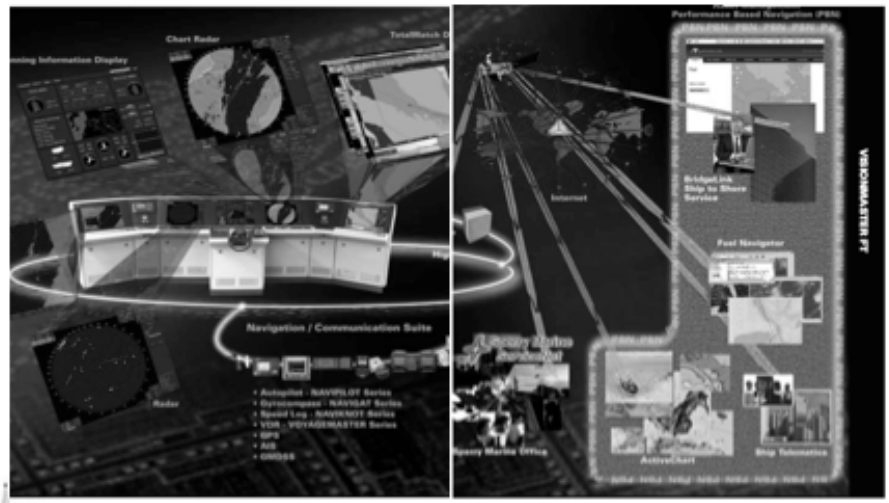


Source: http://www.raytheon-anschuetz.com/

e-Navigation

- e-Navigation benefits to the maritime community:
  - 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

e-Navigation



Source: Sperry VisionMaster INB Brochure

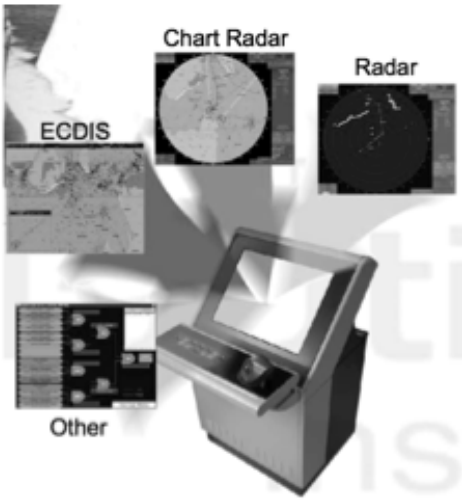
e-Navigation

- e-Navigation benefits to the public:
  - Reducing maritime accidents and associated oil pollution
  - Reducing stack emissions through optimum vessel routing
  - Increasing port security





e-Navigation



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

Core objectives of e-Navigation

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

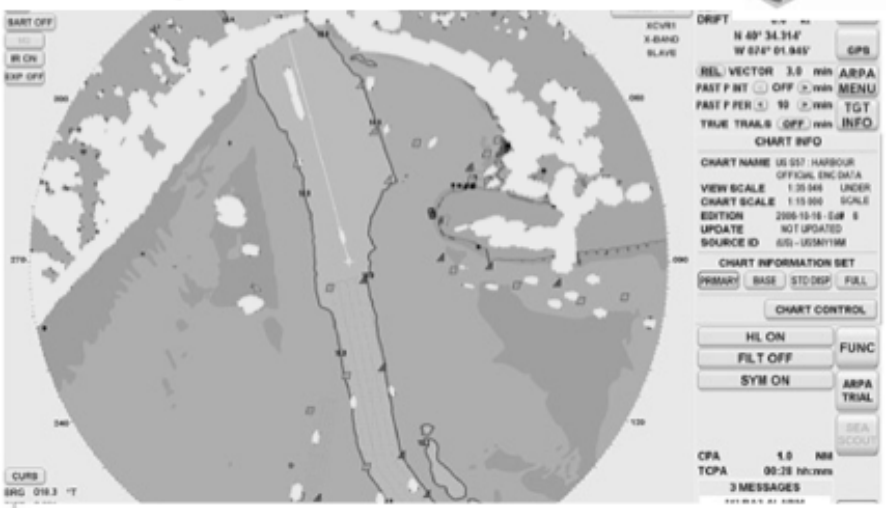
Principle Stakeholders

- 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

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

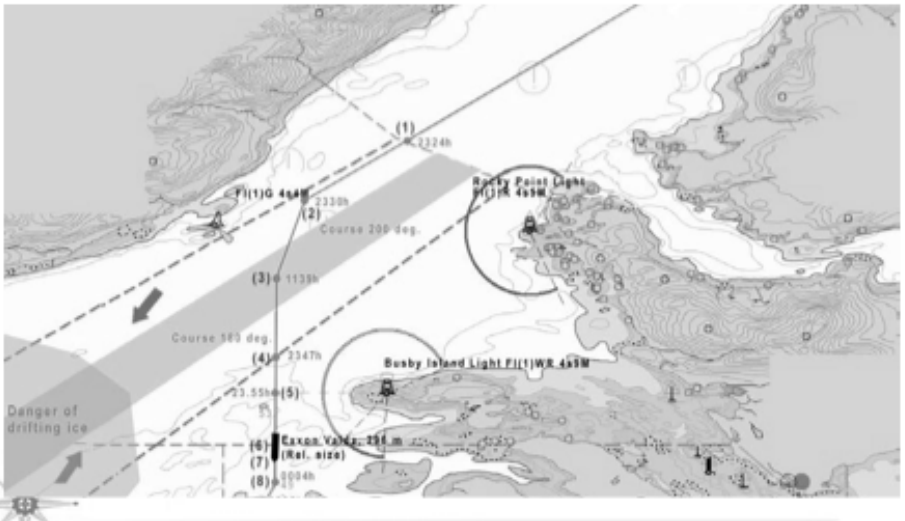
e-Navigation



Source: http://www.raytheon-anschuetz.com

e-Navigation

- 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



Grounding of *Exxon Valdez* (1989)

日本財団 The Nippon Foundation

e-Navigation

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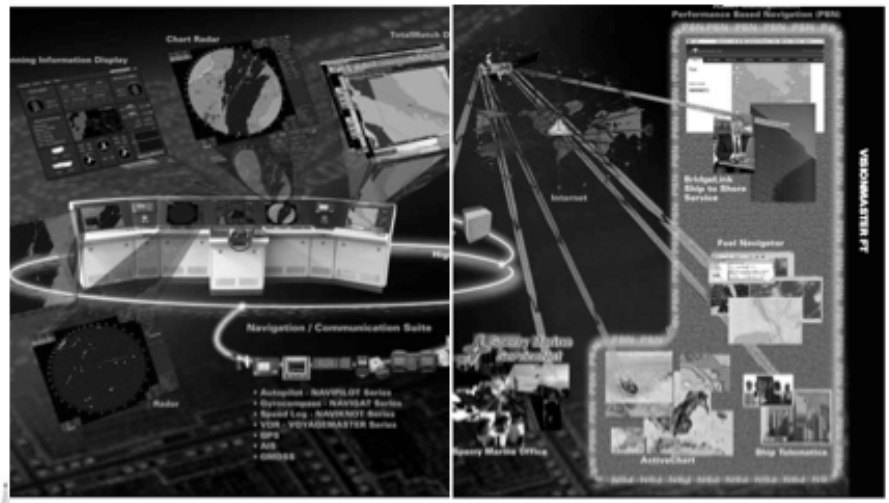
Lecture 3

e-Navigation

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

e-Navigation



Source: Sperry VisionMaster INB Brochure

e-Navigation: BRM

- 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

e-Navigation: BRM

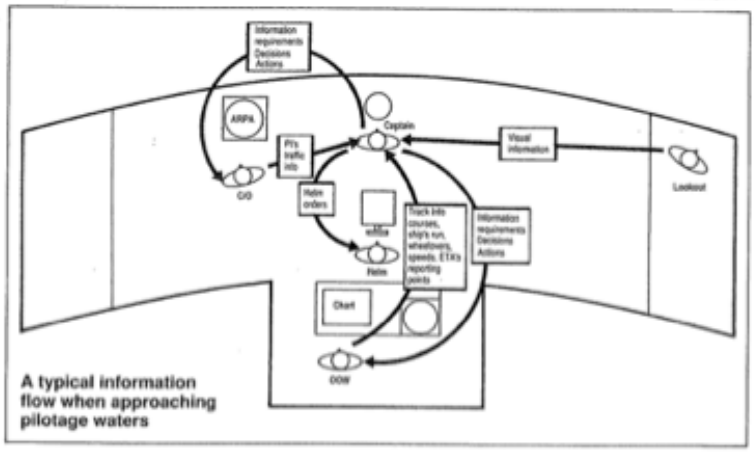


Figure 10

Information flow between the Conning Officer, OOW, Additional Officer, Lookout and Helmsman

Source: Bridge Resource Management, Swift, Bailey

e-Navigation: BRM

- 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

e-Navigation: BRM

- 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

e-Navigation: BRM

- 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

e-Navigation: BRM

- Examples of reducing the danger:
  - Reduce speed
  - Change the route
  - Heave to
  - Anchor
  - Delay departure

e-Navigation: BRM

- 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

e-Navigation: BRM

- 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

e-Navigation: BRM

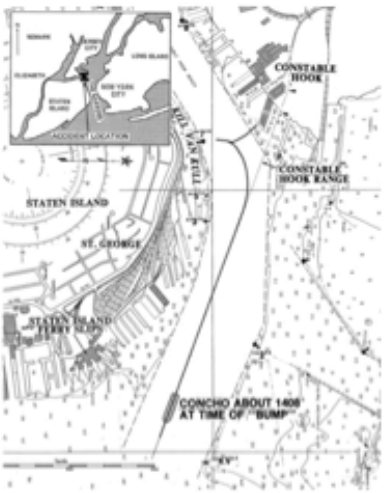
- Effective passage planning and execution – It is well known that proper passage planning involves preparation, appraisal, communication, and execution of the voyage plan from berth-to-berth. This is surely in keeping with the IMO's vision of e-Navigation as a means to "… enhance berth to berth navigation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

e-Navigation: BRM

- Case Studies:
  - SS Concho
  - Exxon Valdez
  - Cosco Busan

SS Concho



(CMA)

MV Exxon Valdez

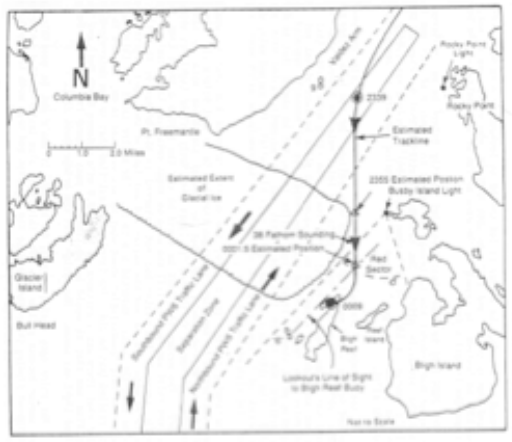


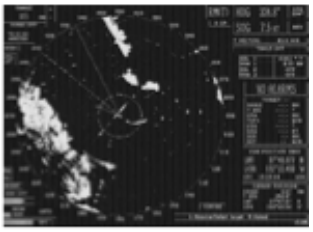
Figure 3.--Trackline of EXXON VALDEZ.





MV Cosco Busan







e-Navigation: BRM

- How e-Navigation will affect BTM and BRM
  - 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

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e-Navigation

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Lecture 4

e-Navigation: ECDIS

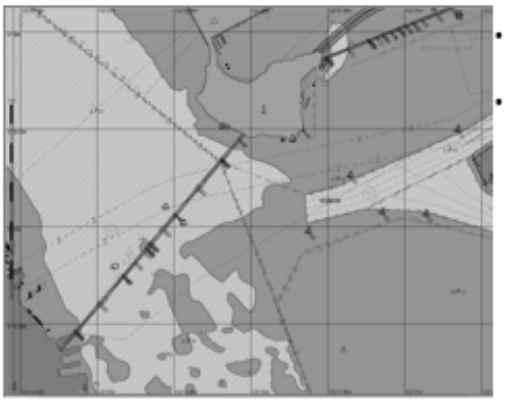
- The importance of ECDIS to the whole concept of e-Navigation cannot be overstated. Probably no single device currently contributes more to the e-Navigation ideal of "…the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic 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.

e-Navigation: ECDIS

- Electronic Chart Display and Information System (ECDIS) means a navigation information system which, with adequate back up arrangements, can be accepted as complying with the up-to-date chart required by regulation V/19 & V/27 of the 1974 SOLAS Convention, by displaying selected information from a system electronic navigational chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and by displaying additional navigation- related information if required.



e-Navigation: ECDIS



- **IMO's definition for the Electronic Navigational Chart – ENC:**
- ENC means the database, standardized as to content, structure and format, issued for use with ECDIS on the authority of government-authorized Hydrographic Offices. The ENC contains all the chart information useful for safe navigation, and may contain supplementary information in addition to that contained in the paper, which may be considered necessary for safe navigation

e-Navigation: ECDIS

- **To legally comply with IMO regulations,** an ECDIS must receive type approval, which is typically conducted by recognized organizations or marine classification societies nominated by flag states.
- The test procedures were developed by the International Electrotechnical Commission (IEC) and are based on IMO ECDIS Performance Standards, applying the IHO requirements S-52 and S-57. The performance standards specify many details, such as:
- ECDIS should present the Standard Display at any time by a single operator action.
  - It should be possible for the mariner to select a safety depth. ECDIS should emphasize soundings equal to or less than the safety depth whenever spot soundings are selected for display.
  - The ENC and all updates to it should be displayed without any degradation of their information content.
  - It should not be possible to alter the contents of the ENC.
  - ECDIS should also be capable of accepting updates to the ENC data entered manually with simple means for verification prior to the final acceptance of the data. They would be distinguishable on the display from ENC information and its official updates and not affect display legibility.
  - It should always be possible to display the SENC in a "north-up" orientation. Other orientations are permitted.
  - The effective size of the chart presentation for route monitoring should be at least 270 mm by 270 mm.
  - It should be possible to plan an alternate route in addition to the selected route. The selected route should be clearly distinguishable from the alternate route.

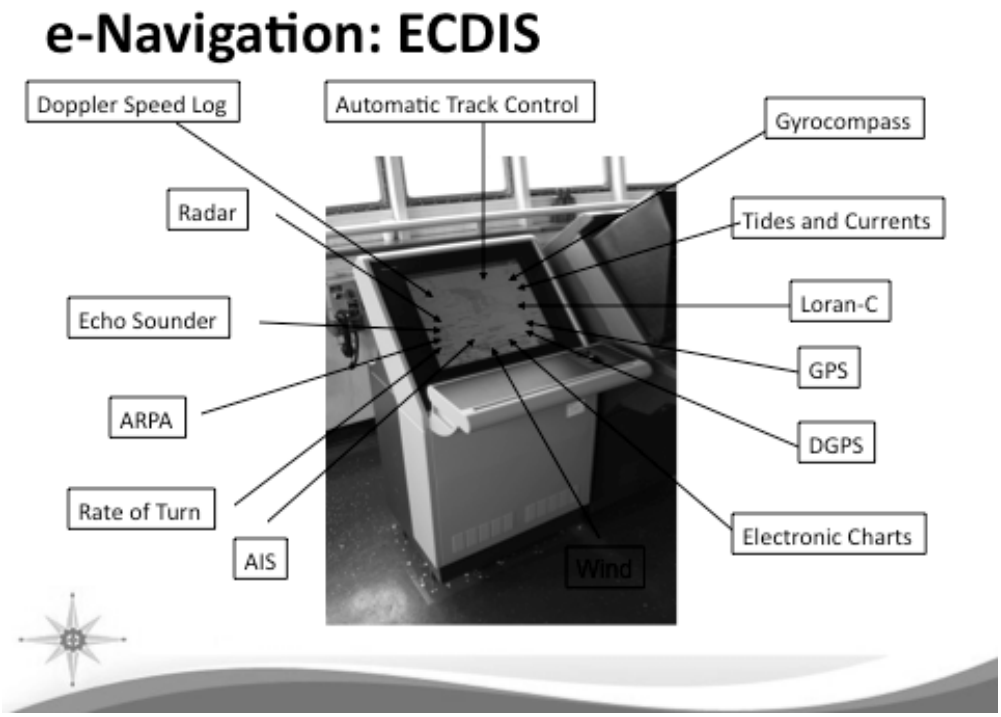




Figure 15.3: A time-sequence display of a 'tide-adjusted' ENC showing changing water levels (depths) based on predicted or real-time tides. This type of ENC contains depth areas (contours) at 1 m intervals that were derived from high-density bathymetric data. The selected 'ship's safety contour' interval is 5 m. (Source: SevenCs)

Source: The Electronic Chart, Hecht, Berking, Büttgenbach, Jonas, Alexander

e-Navigation: GNSS

- Navigation System Using Timing and Ranging (NAVSTAR) Global Positioning System (GPS)
- The GPS system consists of 3 parts (segments)
  - Operational Control
  - Space
  - User
- Full constellation consists of 24 satellites

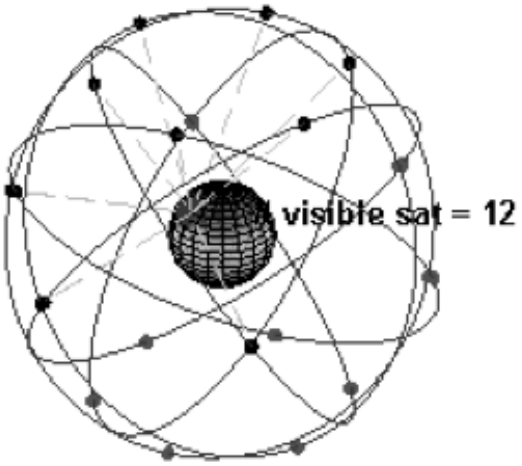


e-Navigation: GNSS



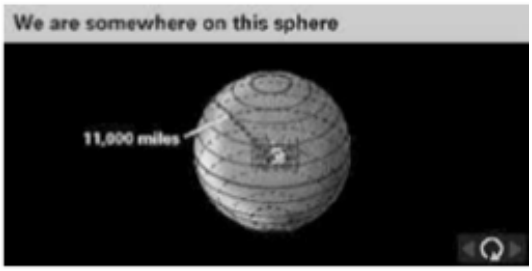
Global Positioning System (GPS) Master Control and Monitor Station Network

e-Navigation: GNSS



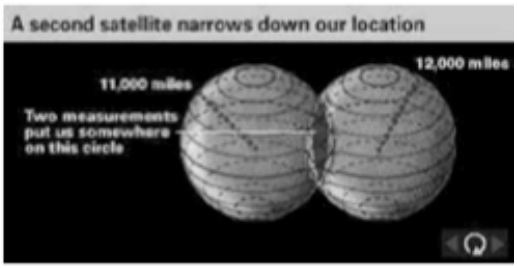
e-Navigation: GNSS

- The timing signal from each satellite can be thought of as a continuous train of pulses in a unique format
- This format is known as Pseudo Random Noise or PRN
- The signal is so very complex that it appears as if it was just random background noise
- However, each GPS receiver has an exact duplicate of each satellite's PRN signal programmed into it's memory
- This is how it can identify the very weak signal (just 50 watts) from other satellites, all other interfering signals, and true background noise



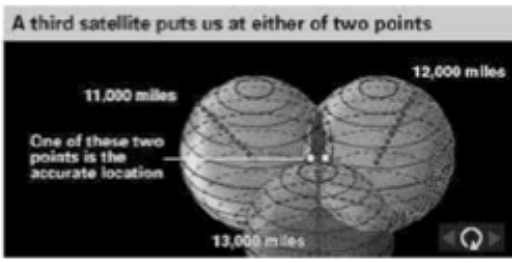
e-Navigation: GNSS

- Also contained in the receiver's memory is a complete ephemeris of all GPS satellites from a particular epoch (time past)
- The navigation message contained in each satellite's PRN signal periodically updates the receiver ephemeris
- In between updates from the satellite, the receiver applies preprogrammed correction factors to modify the satellite predicted position at the time of each range measurement



e-Navigation: GNSS

- The duplicate satellite PRN signal generated within the receiver is phase matched with the incoming satellite signal
- The amount of time that the receiver must offset its own signal to that of the satellite determines the range to the satellite

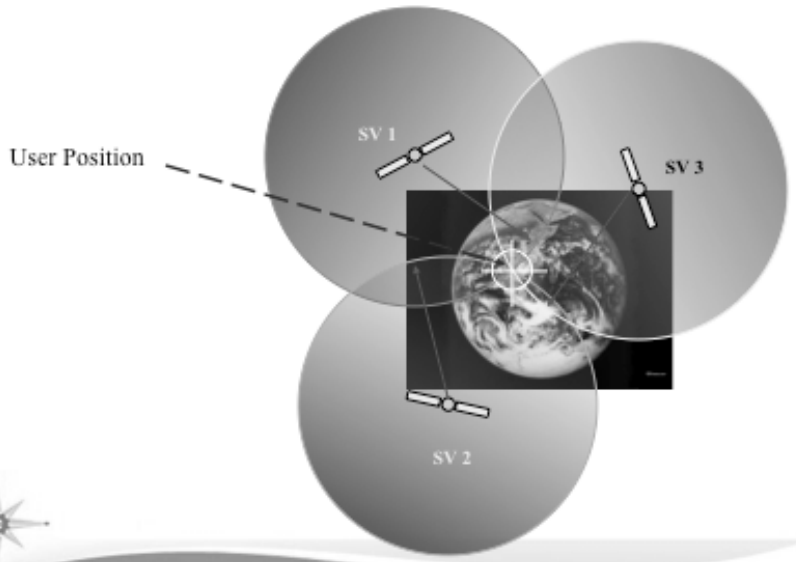


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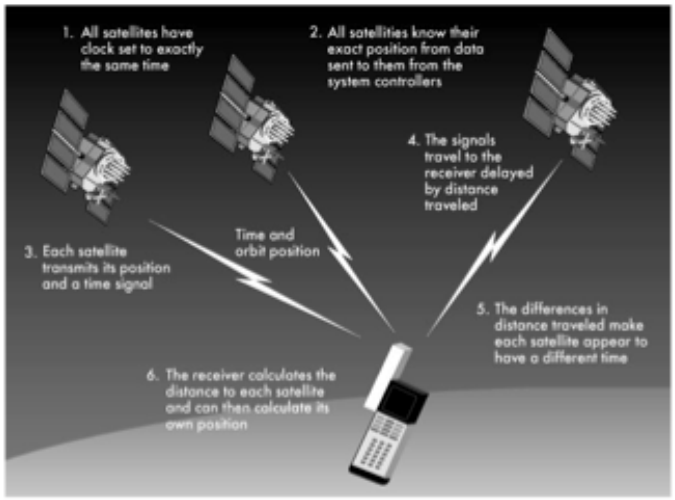
e-Navigation: GNSS

- The measured range from a satellite defines a position sphere around that satellite
- A similar measurement taken on a second satellite produces a second sphere that intersects with the first and places the user somewhere on a position circle
- A third satellite range provides another position sphere that intersects with the first two and reduces the user's possible position to one of two points
- One of these points will be located in space and can be rejected thus fixing the user's position

e-Navigation: GNSS

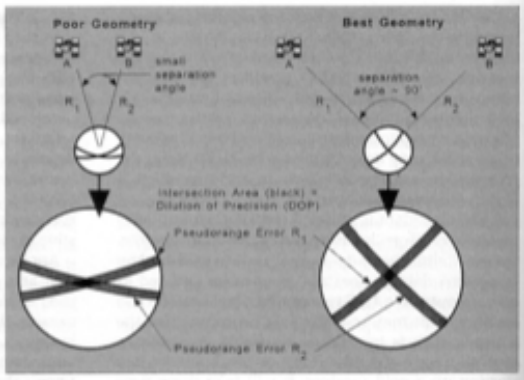


e-Navigation: GNSS

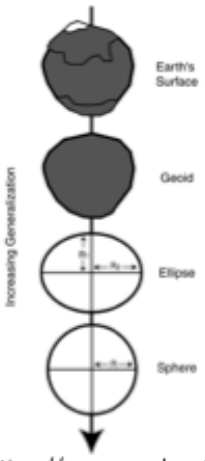


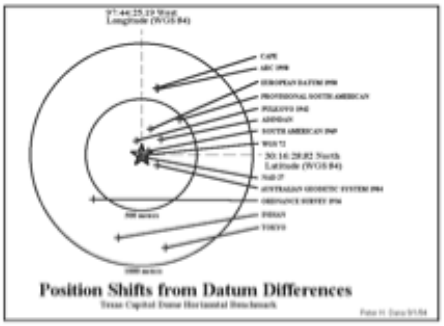
e-Navigation: GNSS

- Geometric Dilution of Precision (GDOP)
  - Position & time ambiguity due to poor geometric spread between satellites
  - The best case: one directly overhead and the other 3 spaced 120° around the receiver on the horizon.



e-Navigation: GNSS

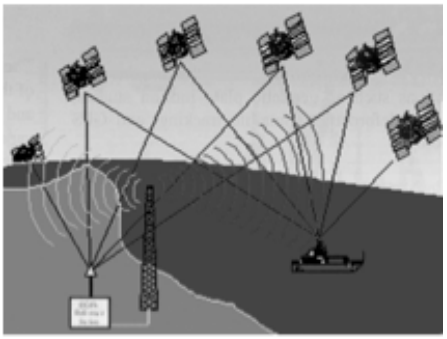




https://www.e-education.psu.edu/geog486/book/export/html/1774

e-Navigation: GNSS

- DGPS is an enhancement of the U.S. Department of Defense's Global Positioning System (GPS).
  - A network of ground based reference stations provides corrections to the GPS satellite ranging measurements.
  - Each reference station monitors all satellites in view, comparing the measured ranges with expected measurements based on the reference stations surveyed location.



The accuracy of WAAS and DGPS is comparable, on the order of a few meters. WAAS was designed to provide 7 meter accuracy 95% of the time. DGPS was designed to provide 10 meter accuracy 95% of the time, but in actual use one can expect about 1-3 meter accuracy when the user is within 100 miles of he DGPS transmitter. Over 100 miles, DGPS accuracy will commonly degrade by an additional 1 meter per 100 miles from the transmitter site. Both systems have been found in actual use to provide accuracies somewhat better than designed.

There are two formal position accuracy requirements for GPS:
1) The PPS spherical position accuracy shall be 16 meters SEP (spherical error probable) or better.
2) The SPS user two-dimensional position accuracy shall be 100 meters 2 drms or better.

e-Navigation: GNSS

- DGPS is an enhancement of the U.S. Department of Defense's Global Positioning System (GPS).
  - Separate corrections are calculated for each satellite, allowing the user maximum flexibility in the choice of satellites for navigation.
  - These differential corrections are then transmitted from the reference station to GPS users who apply the corrections to their received GPS signals.

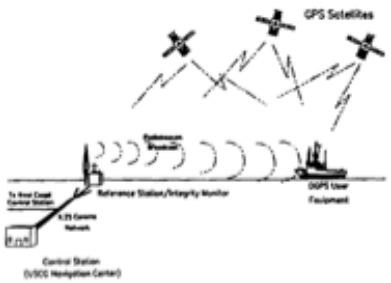


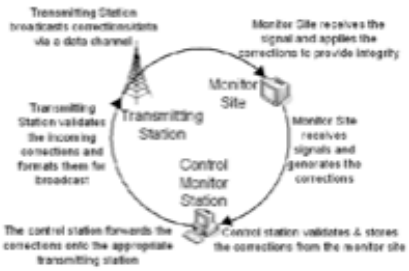
Figure 1. SERVICE ARCHITECTURE

e-Navigation: GNSS

- 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.

GNSS Redundancy

- GLONASS
- Galileo
- eLoran



GALILEO

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jamu

e-Navigation

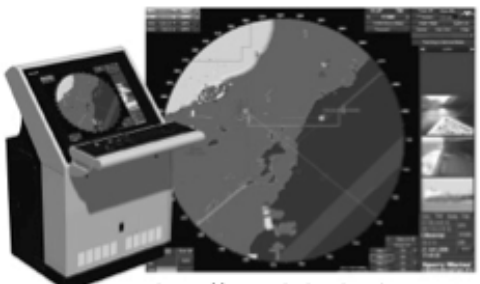
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Lecture 5

e-Navigation: Radar and AIS

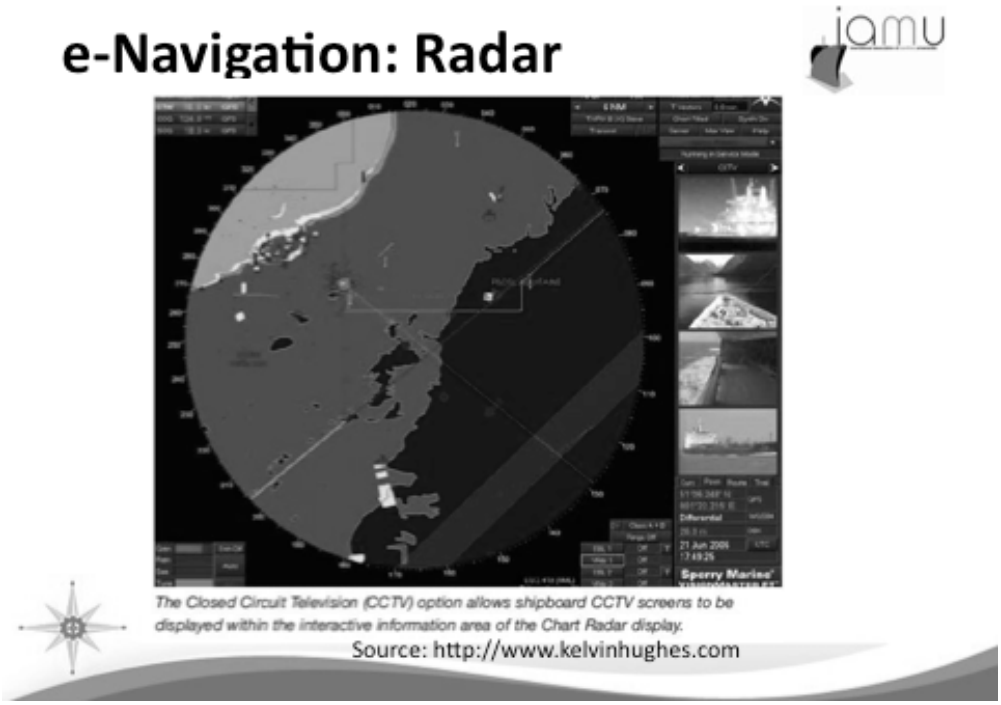
jamu

- **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.

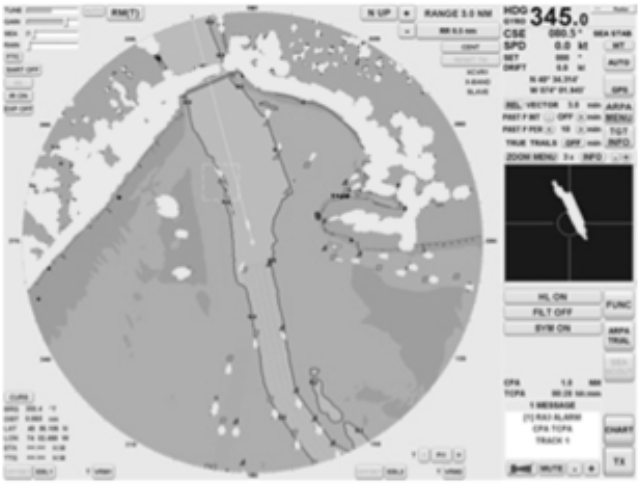


Source: http://www.kelvinhughes.com

Picture a shipboard radar or an electronic chart display that includes a symbol for every significant ship within radio range, each as desired with a velocity vector (indicating speed and heading). Each ship "symbol" can reflect the actual size of the ship, with position to GPS or differential GPS accuracy. By "clicking" on a ship symbol, you can learn the ship name, course and speed, classification, call sign, registration number, MMSI, and other information. Maneuvering information, closest point of approach (CPA), time to closest point of approach (TCPA) and other navigation information, more accurate and more timely than information available from an automatic radar plotting aid, can also be available. Display information previously available only to modern Vessel Traffic Service operations centers can now be available to every AIS user as seen below.

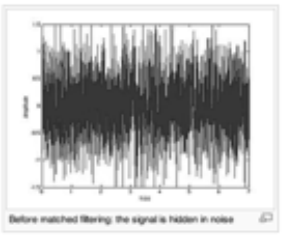


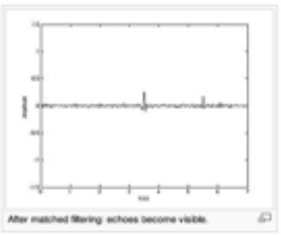
e-Navigation: Radar



e-Navigation: Radar

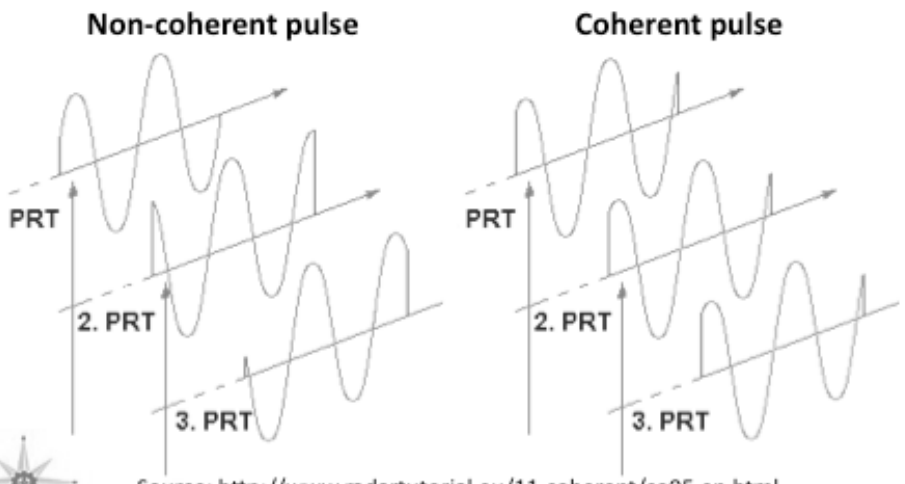
- Transmitter
  - Magnetron
  - NT: Amplifier
- Pulse
  - Modulation
  - Continuous
  - Doppler
- Receiver


Before matched filtering: the signal is hidden in noise


After matched filtering: echoes become visible.

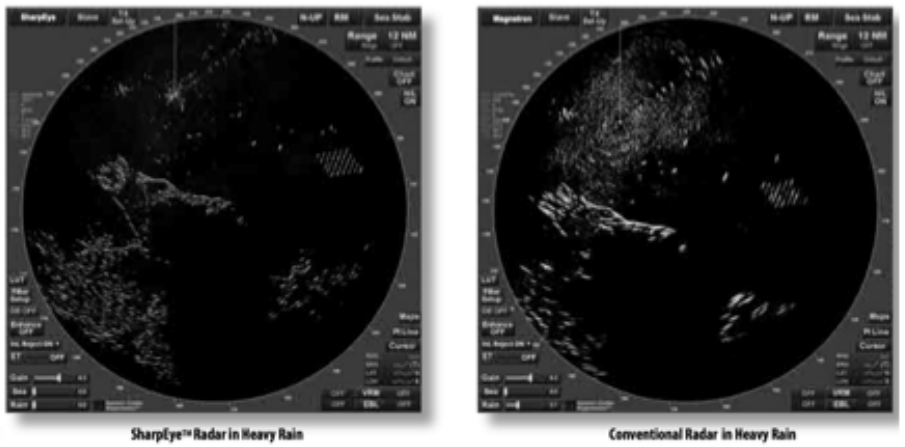


e-Navigation: Radar



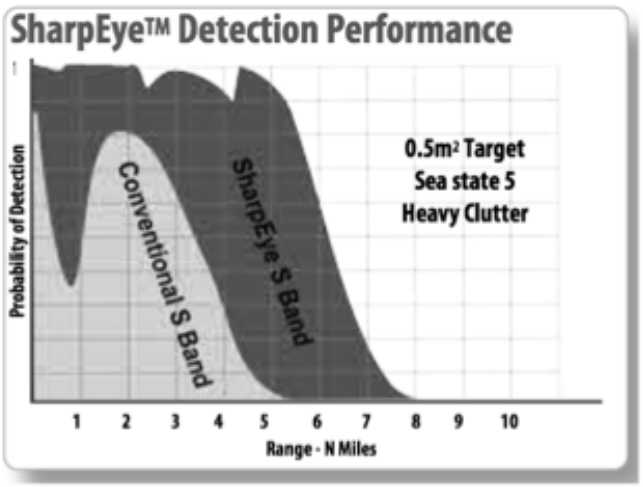
Source: http://www.radartutorial.eu/11.coherent/co05.en.html

e-Navigation: Radar



Source: http://www.kelvinhughes.com

e-Navigation: Radar

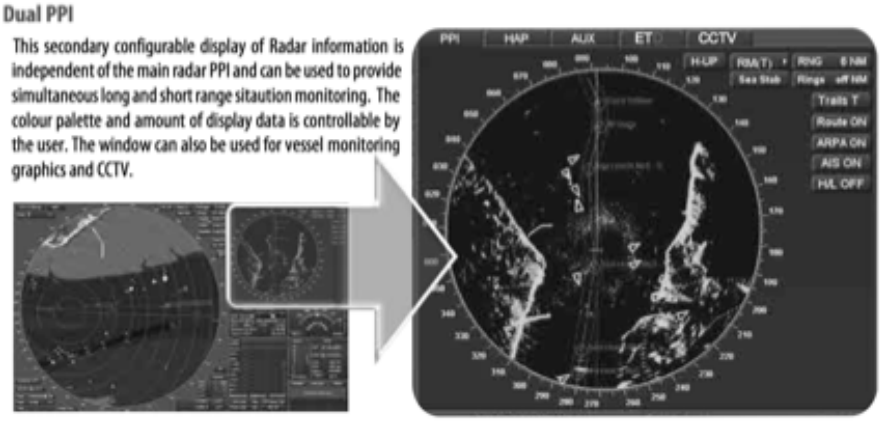


Source: http://www.kelvinhughes.com

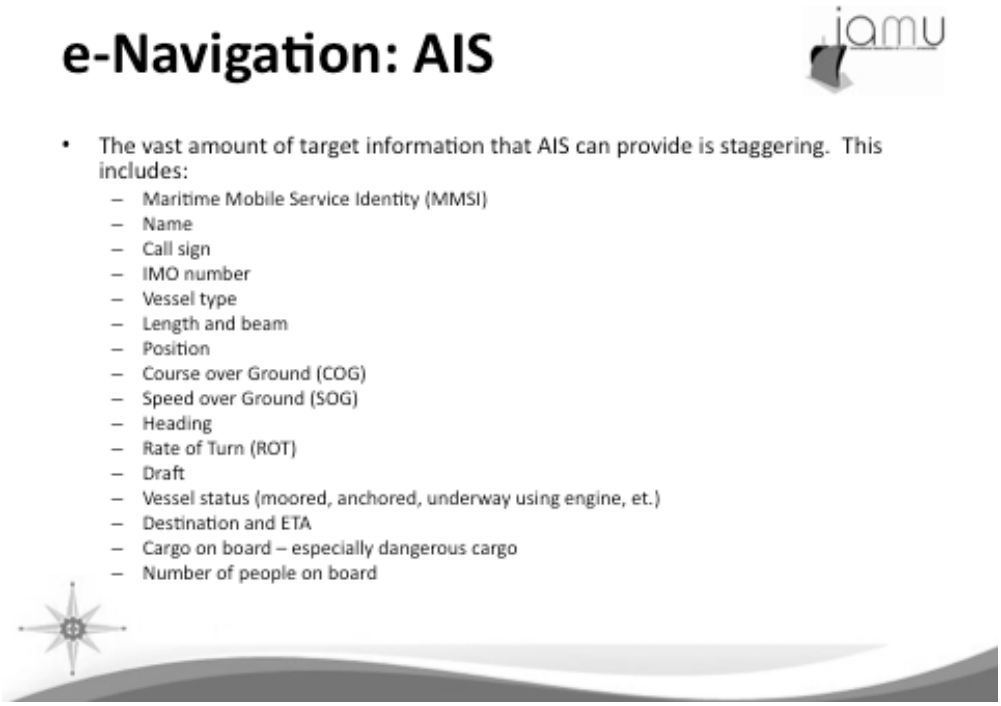
e-Navigation: Radar

Dual PPI

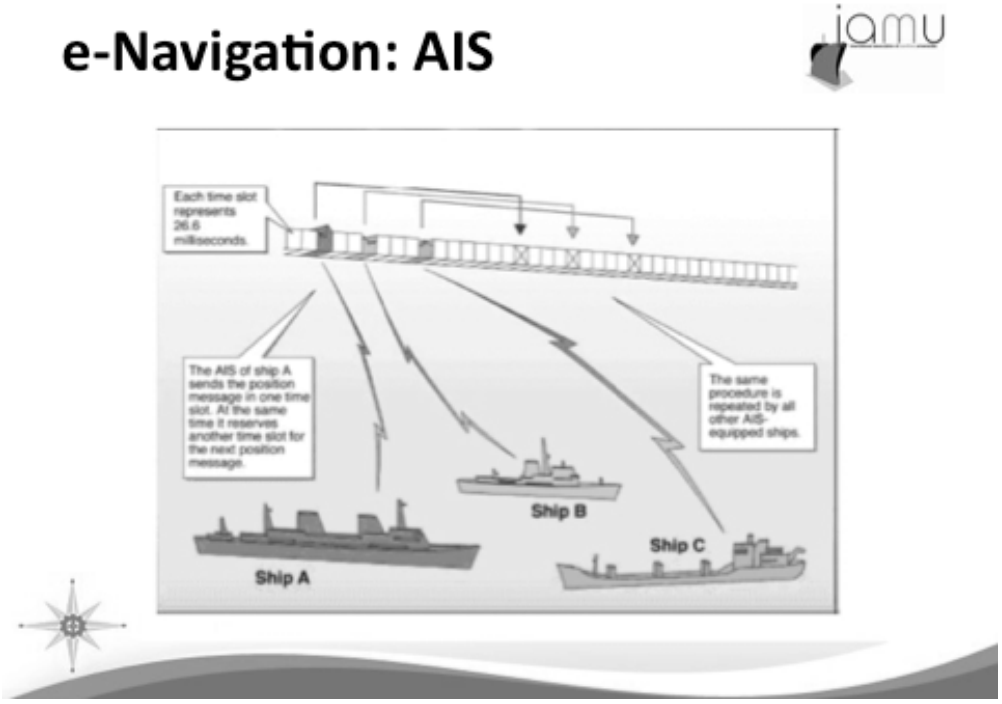
This secondary configurable display of Radar information is independent of the main radar PPI and can be used to provide simultaneous long and short range sitaution monitoring. The colour palette and amount of display data is controllable by the user. The window can also be used for vessel monitoring graphics and CCTV.



Source: http://www.kelvinhughes.com



With this information, you can call any ship over VHF radiotelephone by name, rather than by "ship off my port bow" or some other imprecise means. Or you can dial it up directly using GMDSS equipment. Or you can send to the ship, or receive from it, short safety-related email messages.
The AIS is a shipboard broadcast system that acts like a transponder, operating in the VHF maritime band, that is capable of handling well over 4,500 reports per minute and updates as often as every two seconds. It uses Self-Organizing Time Division Multiple Access (SOTDMA) technology to meet this high broadcast rate and ensure reliable ship-to-ship operation.

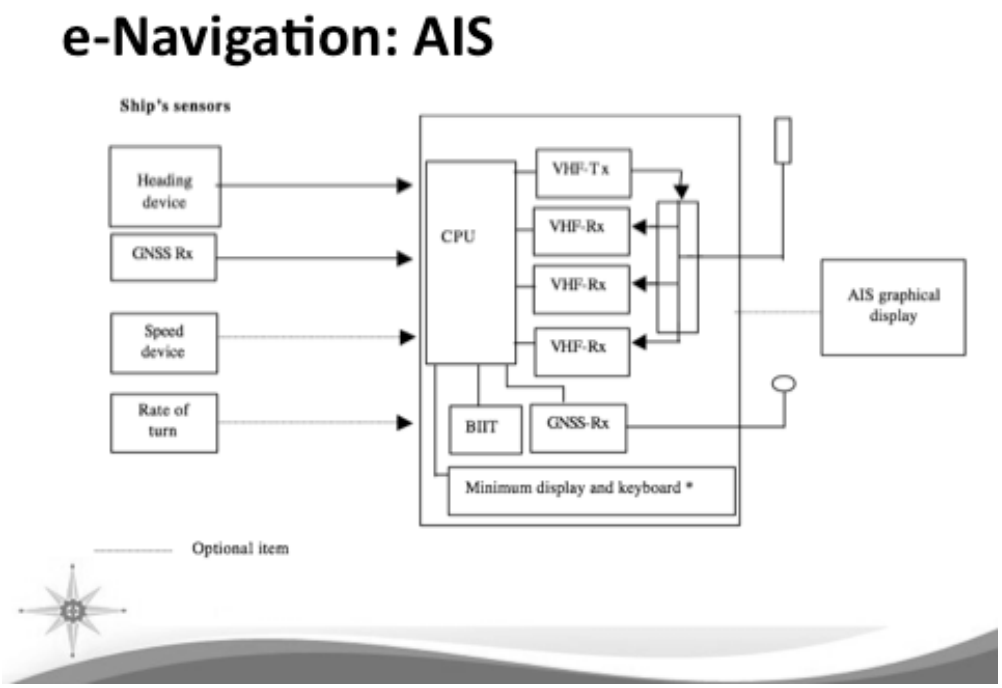


Each AIS system consists of one VHF transmitter, two VHF TDMA receivers, one VHF DSC receiver, and standard marine electronic communications links (IEC 61162/NMEA 0183) to shipboard display and sensor systems (AIS Schematic). Position and timing information is normally derived from an integral or external global navigation satellite system (e.g. GPS) receiver, including a medium frequency differential GNSS receiver for precise position in coastal and inland waters. Other information broadcast by the AIS, if available, is electronically obtained from shipboard equipment through standard marine data connections. All AIS-equipped ships would normally provide heading information and course and speed over ground. Other information, such as rate of turn, angle of heel, pitch and roll, and destination and ETA could also be provided.

The AIS transponder normally works in an autonomous and continuous mode, regardless of whether it is operating in the open seas or coastal or inland areas. Transmissions use 9.6 kb GMSK FM modulation over 25 or 12.5 kHz channels using HDLC packet protocols. Although only one radio channel is necessary, each station transmits and receives over two radio channels to avoid interference problems, and to allow channels to be shifted without communications loss from other ships. The system provides for automatic contention resolution between itself and other stations, and communications integrity is maintained even in overload situations.

Each station determines its own transmission schedule (slot), based upon data link traffic history and knowledge of future actions by other stations. A position

report from one AIS station fits into one of 2250 time slots established every 60 seconds. AIS stations continuously synchronize themselves to each other, to avoid overlap of slot transmissions. Slot selection by an AIS station is randomized within a defined interval, and tagged with a random timeout of between 0 and 8 frames. When a station changes its slot assignment, it pre-announces both the new location and the timeout for that location. In this way new stations, including those stations that suddenly come within radio range close to other vessels, will always be received by those vessels.



e-Navigation: AIS

- 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

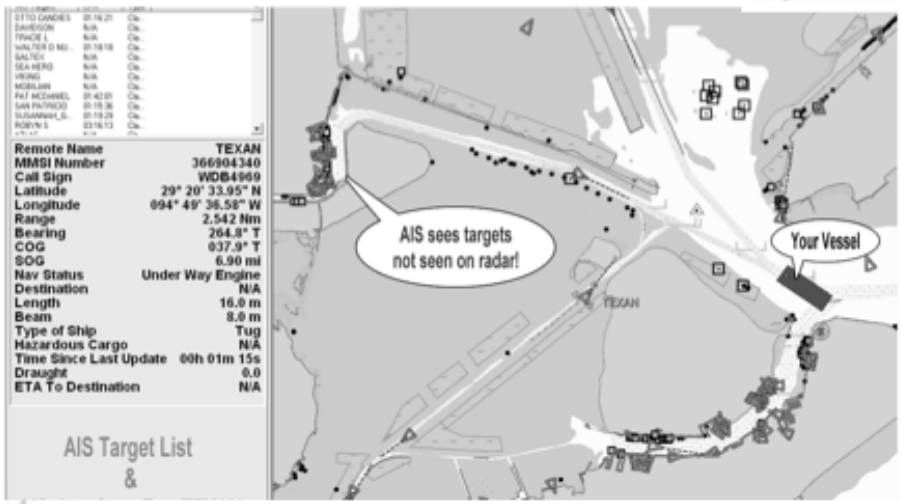
e-Navigation: AIS

- 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

e-Navigation: AIS

- 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

e-Navigation: AIS



Source: http://www.navcen.uscg.gov/?pageName=AISworks

e-Navigation: AIS

Type of ship	General reporting interval
Ship at anchor	3 min
Ship 0-14 knots	12 sec
Ship 0-14 knots and changing course	4 sec
Ship 14-23 knots	6 sec
Ship 14-23 knots and changing course	2 sec
Ship >23 knots	3 sec
Ship >23 knots and changing course	2 sec

Table 2 - Report rate of dynamic information

e-Navigation: AIS

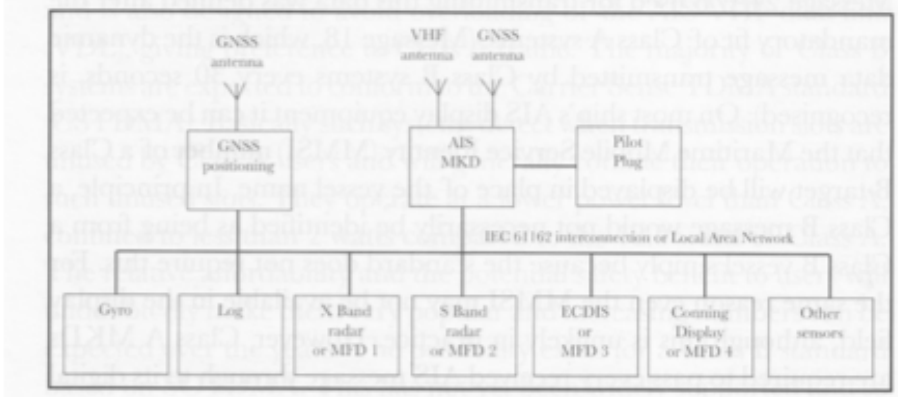


Figure 18 AIS within the IBS

Source: Radar and AIS, Norris

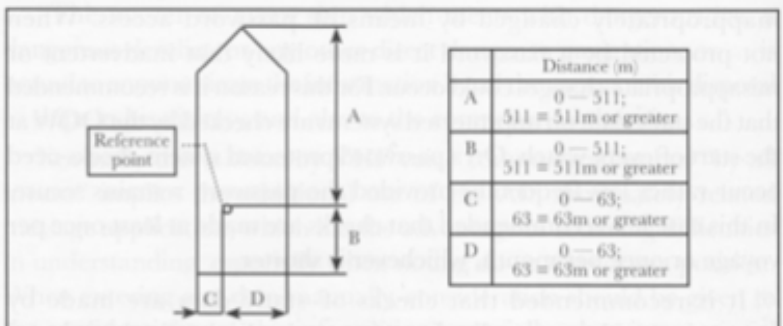
e-Navigation: AIS

Topic	Symbol	Description
AIS Target (sleeping)		An isosceles, acute-angles triangle should be used. The triangle should be oriented by heading, or COG if heading missing. The reported position should be located at centre and half the height of the triangle. The symbol of the sleeping target should be smaller than that of the activated target.
Activated AIS Target including Dangerous Target		An isosceles, acute-angles triangle should be used. The triangle should be oriented by heading, or COG if heading missing. The reported position should be located at centre and half the height of the triangle. The COG/SOG vector should be displayed as a dashed line with short dashes with spaces approximately twice the line width. Optionally, time increments may be marked along the vector. The heading should be displayed as a solid line thinner than speed vector line style, length twice the length of the triangle symbol. Origin of the heading line is the apex of the triangle. The turn should be indicated by a flag of fixed length added to the heading line. A path predictor may be provided as a curved vector. For a "**Dangerous AIS Target**", bold, red (on colour display) solid triangle with course and speed vector, flashing until acknowledged.

Figure 21 AIS symbology

Source: Radar and AIS, Norris

e-Navigation: AIS



	Distance (m)
A	0 — 511; 511 = 511m or greater
B	0 — 511; 511 = 511m or greater
C	0 — 63; 63 = 63m or greater
D	0 — 63; 63 = 63m or greater

The dimension A should be in the direction of the transmitted heading information (bow)

Reference point of reported position not available, but dimensions of ship are available:

A = C = 0 and B ≠ 0 and D ≠ 0. Neither reference point of reported position nor dimensions of ship available: A = B = C = D = 0 (= default).

For use in the message table, A = most significant field, D = least significant field.

Figure 26 AIS antenna coordinates (courtesy IMO)

Source: Radar and AIS, Norris

e-Navigation: AIS

Table 2: Tracked Radar Target Symbols

Topic	Symbol	Description
Tracked Target including Dangerous Target		Solid filled or unfilled circle located at target position. The course and speed vector should be displayed as dashed line, with short dashes with spaces approximately twice the line width. Optionally, time increments, may be marked along the vector. For a **"Dangerous Target"**, bold, red (on colour display) solid circle with course and speed vector, flashing until acknowledged.
Target in Acquisition State		Circle segments in the acquired target state. For automatic acquisition, bold circle segments, flashing and red (on colour display) until acknowledged.
Lost Target		Bold lines across the circle, flashing until acknowledged.
Selected Target		A square indicated by its corners centred around the target symbol.
Target Past Positions		Dots, equally spaced by time.
Tracked Reference Target	R	Large R adjacent to designated tracked target. Multiple reference targets should be marked as R1, R2, R3, etc.

Source: Radar and AIS, Norris

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e-Navigation

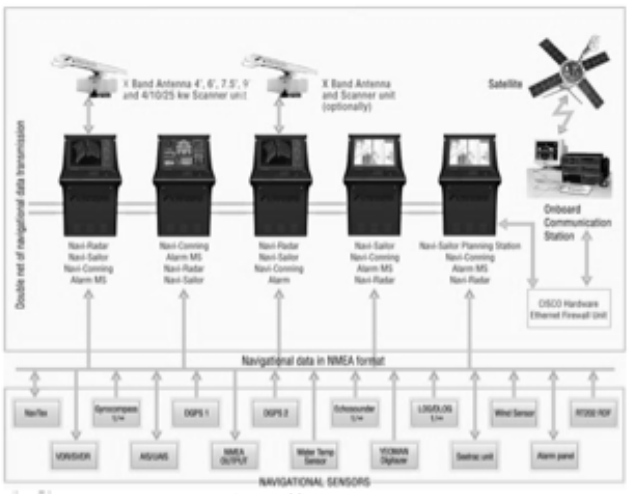
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Lecture 6

e-Navigation: INS and IBS

- 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.'

e-Navigation: INS and IBS



Source: http://www.transas.com

e-Navigation: INS and IBS



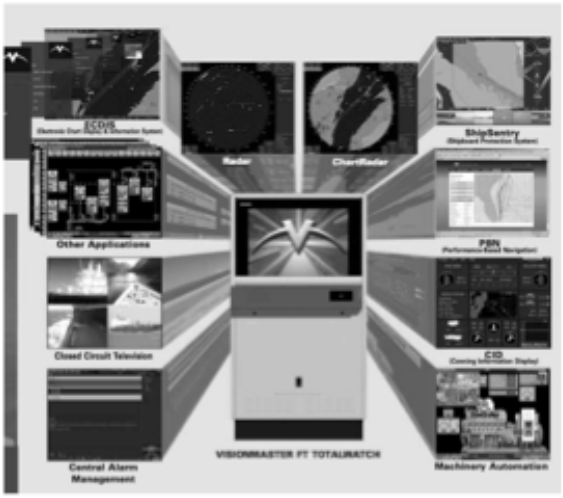
Source: http://www.transas.com

e-Navigation: INS and IBS

- Integration benefits
  - Navigator-friendly environment for One Man Bridge operation reduces workload and stress
  - Enhanced functional integration of navigational data
  - Master Station status changeover to any INS station
  - X-Band or S-Band Scanner control takeover to any INS station with Radar Application
  - Sensor redundancy and double network ensuring data integrity and reliability
  - Integral monitoring of essential navigational data quality
  - Intelligent and efficient alarm management
  - Chart correction, route and user database synchronization at all workstations and applications
  - Distribution of radar pictures from all available radars within INS
  - Configuration Display utility for real-time presentation of system hardware and software component status
  - Online ordering of charts, charts corrections and weather forecasts via ship communication

Source: http://www.transas.com

e-Navigation: INS and IBS



Source: http://www.sperrymarine.northropgrumman.com

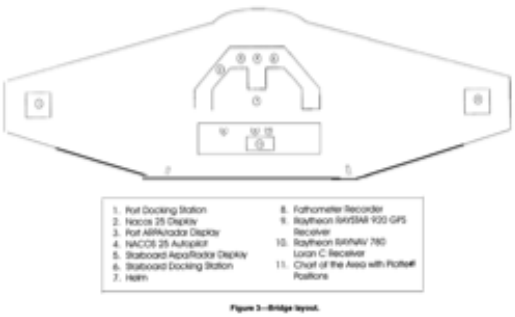
e-Navigation: INS and IBS

- INS advantages
  - **For Shipowners**
    - Flexibility in layout and design of the Bridge
    - Standardization of hardware platform and software
    - Reduces the amount of onboard spare parts
    - Ease of repair
    - Excellent maintainability
    - Simple upgrade throughout life cycle
    - No single point of failure
    - Dual network redundancy
    - Multifunction redundancy in navigation system
    - Availability of single-installation Electronic Charts for all Multifunction Workstations
  - **For Shipyards**
    - Flexibility in choice of equipment
    - Bespoke displays and computers according to customer preference
    - Attractive ergonomic consoles
    - Reduced cabling (cost efficient)
    - Reduced number of control panels, keyboards and switches.
    - Smaller consoles
    - Easy design, installation and maintenance
    - Competitive price

Source: http://www.transas.com

e-Navigation: INS and IBS

- M/V Royal Majesty
  - Bermuda to Boston
  - INB
    - GPS and Loran
  - GPS Antenna
  - Fathometer



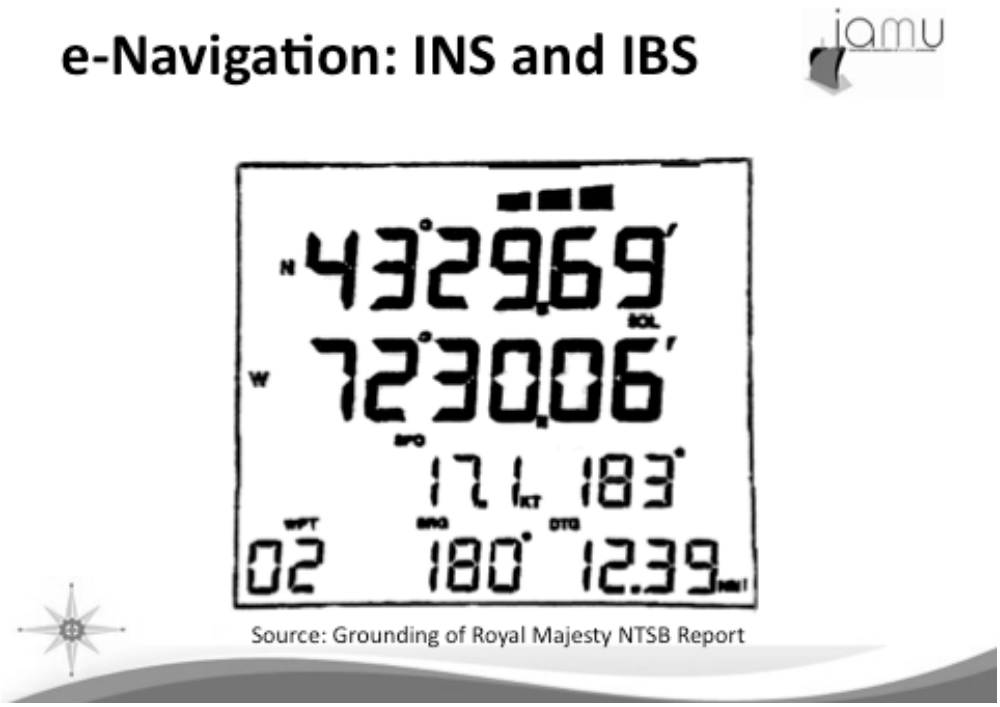
Source: Grounding of Royal Majesty NTSB Report

The ship had radars either side of the bridge equipped with automatic radar plotting aid, an ARPA, which overlaid an electronic map image supplied by the autopilot.
When the GPS lost satellite signal, it sounded a rather feeble alarm, the sort of thing you might have on a wristwatch, for just one second. An external alarm could have been fitted, but wasn't.
Because of a problem with satellite reception the GPS antenna had been moved from its original position and the cable ran across the roof of the bridge and wasn't fixed where it could not be accidentally kicked free.
One other bit of equipment is worth noting, the echo sounder, referred to in the official report as a fathomometer. Normally, this was set to sound an alarm if the depth under the keel was less than three meters, except in port, when it was adjusted to zero meters.

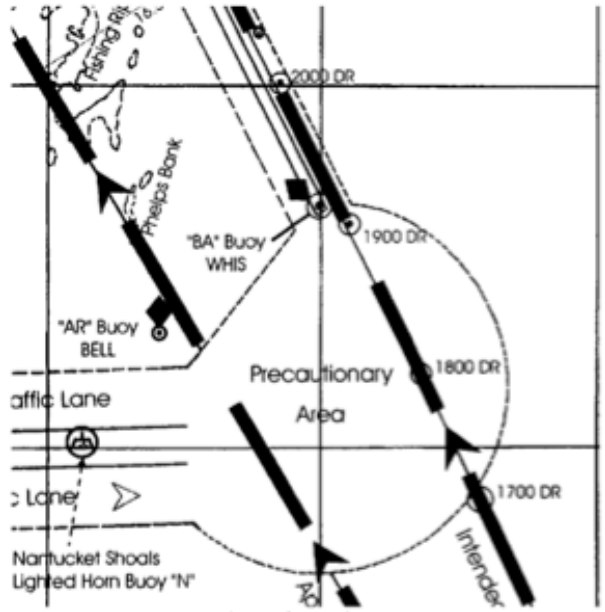
At 1200 on June 9, 1995, The Royal Majesty left the dock at St. Georges, Bermuda, on the 667 mile return leg of a cruise to Boston, Massachusetts with good weather and clear visibility. Joe checked the GPS and Loran-C equipment, it was working.
Nobody had reset the echo-sounder alert to three meters from its in-port setting of zero.
About 52 minutes after taking to sea the GPS antenna was somehow disconnected, possibly kicked loose by a crewman. The GPS receiver defaulted to dead reckoning. No one heard the alarm.

Harry took the watch at 20.00. Half an hour later a lookout reported a yellow light to port and a few moments later both the port and starboard lookouts

reported high red lights. Harry took no action. These lights were not mentioned to the master when he came to the bridge for the first time during that watch.
The Royal Majesty was not alone on the sea. Two fishing boats with Portuguese-speaking crews saw her. They tried to call her in English on Channel 16 but got no reply. The two boats discussed the out-of-place cruise liner.
Tom was on the bridge again at 2200. He didn't check the vessel's position because the second officer had told him they were already past the second buoy of the Boston traffic lane, buoy BB. In fact, he hadn't seen the BB buoy, either visually or on radar but based his assumption on the GPS reading.
The vessel was already moving over shoal that would have triggered the depth alarm if the fathomometer had been correctly set.



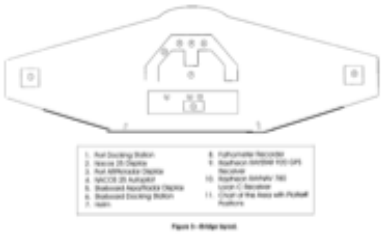
e-Na



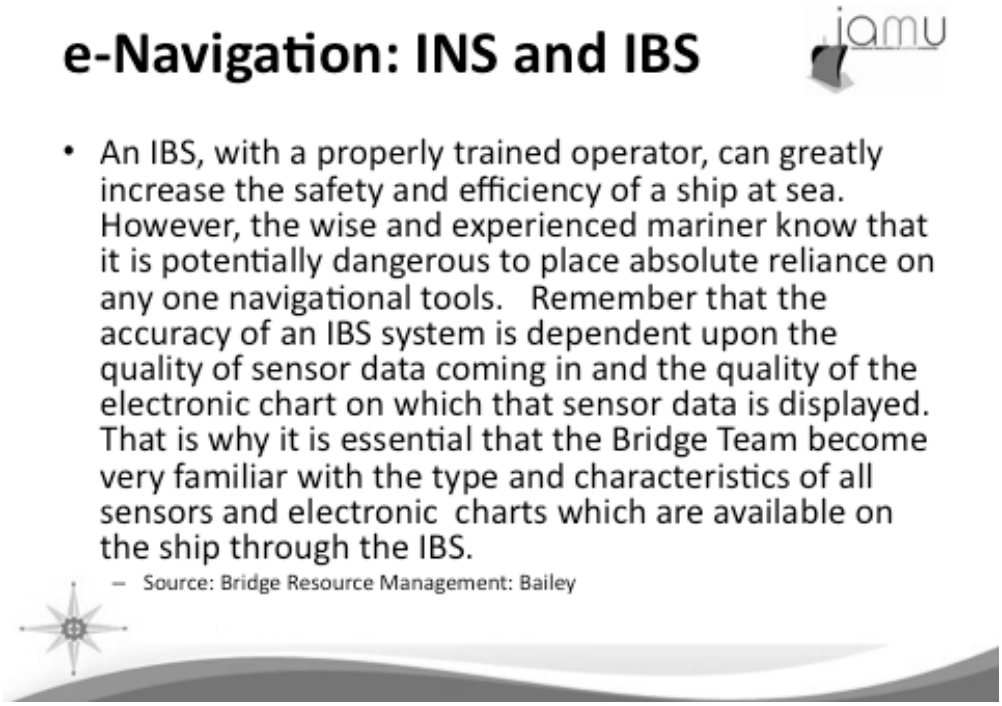
Source: Grounding of Royal Majesty NTSB Report

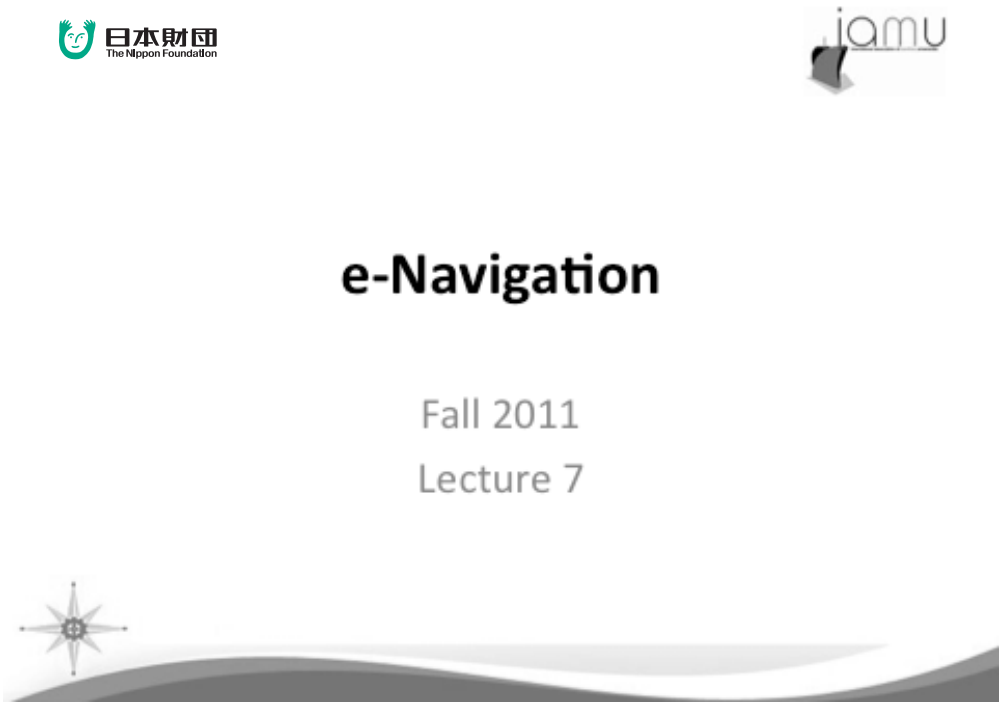
e-Navigation: INS and IBS

- Error Chain
  - GPS Position
  - Fathometer
  - Visual Lookout
  - Confirmation Bias
  - BRM



Source: Grounding of Royal Majesty NTSB Report


e-Navigation: INS and IBS
iamu
• An IBS, with a properly trained operator, can greatly increase the safety and efficiency of a ship at sea. However, the wise and experienced mariner know that it is potentially dangerous to place absolute reliance on any one navigational tools. Remember that the accuracy of an IBS system is dependent upon the quality of sensor data coming in and the quality of the electronic chart on which that sensor data is displayed. That is why it is essential that the Bridge Team become very familiar with the type and characteristics of all sensors and electronic charts which are available on the ship through the IBS.
– Source: Bridge Resource Management: Bailey


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Lecture 7

e-Navigation: VTS and LRIT

- 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."

e-Navigation: VTS and LRIT

- 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.

e-Navigation: VTS and LRIT



Note: VTS Louisville is only operational during high water.

Source: http://www.uscg.mil

e-Navigation: VTS and 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.

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e-Navigation

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Lecture 8

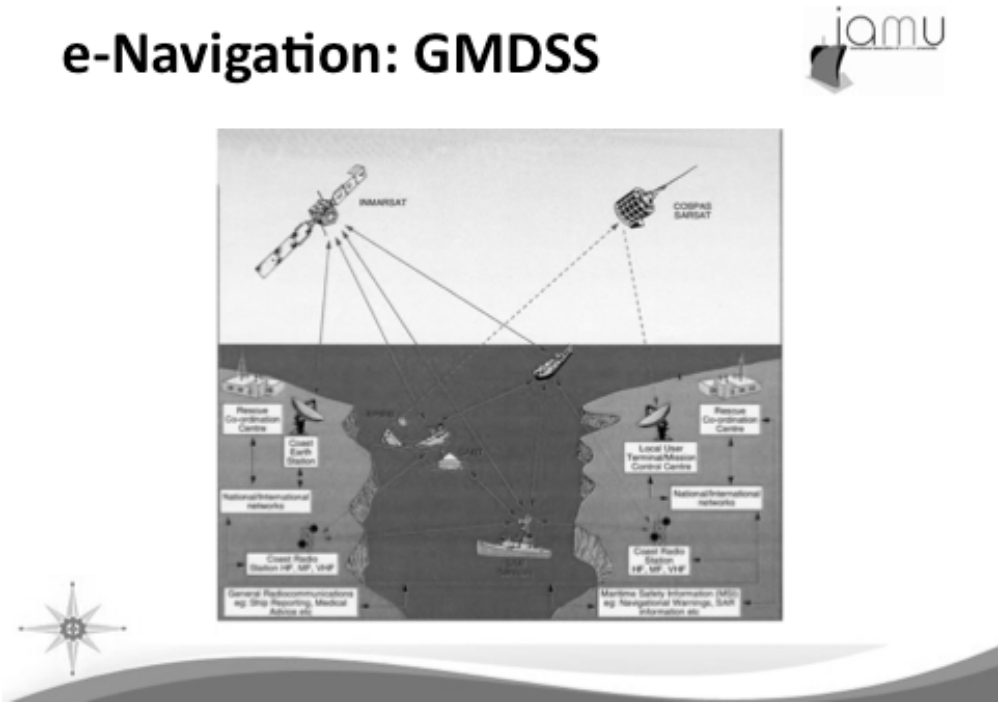
e-Navigation: GMDSS

jamu

- 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.

jamu (CMA)

As the Coast Guard's new marine radio network, Rescue 21, becomes operational throughout the U.S., rescue centers will have the ability to receive instant distress alerts from commonly used DSC-capable VHF marine radios; however, approximately 90% of VHF DSC distress alerts received by the Coast Guard do not contain position information, and approximately 60% do not contain a registered identity. The Coast Guard cannot effectively respond to a DSC distress alert sent from such a radio. As a result, search and rescue efforts may normally be suspended when:
no communications with the distressed vessel can be established;
no further information or means of contacting the vessel can be obtained from other sources; and, no position information is known.



e-Navigation: GMDSS



Source: http://www.transas.com

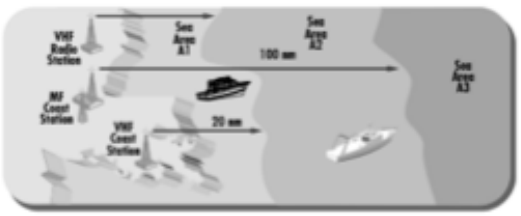
e-Navigation: GMDSS

Sea Area A1 – within range of a shore-based VHF-FM/DSC coast station (typically 20 NM from shore)

Sea Area A2 – within range of a shore-based MF/DSC coast station (typically 100 NM from shore, excluding Sea Area A1)

Sea Area A3 – within INMARSAT satellite coverage, between 70N and 70S, excluding Sea Areas A1 and A2

Sea Area A4 – the Polar Regions excluding Sea Areas A1, A2 and A3



(CMA)

e-Navigation: GMDSS



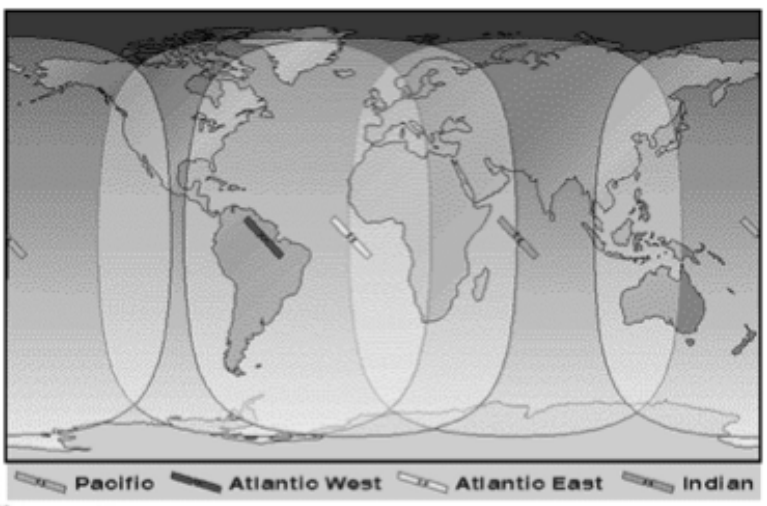
e-Navigation: GMDSS



e-Navigation: GMDSS



e-Navigation: GMDSS



e-Navigation: GMDSS

- 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.

e-Navigation: GMDSS

- 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

e-Navigation: GMDSS

- 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

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Lecture 9

e-Navigation: Education

- 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

e-Navigation: Education





e-Navigation: Education

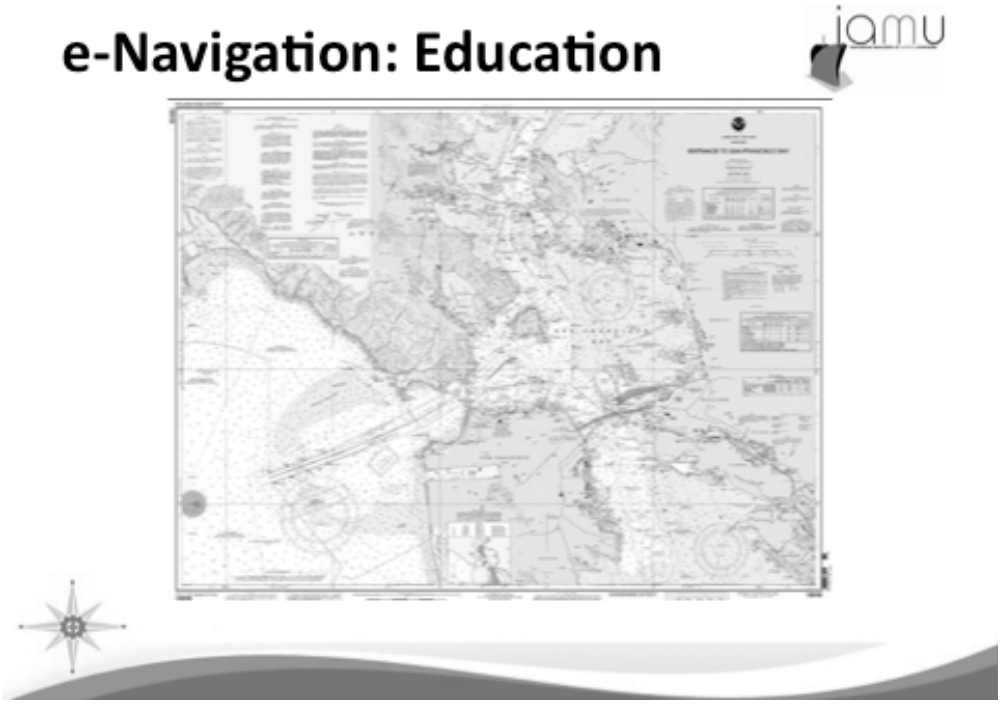
- Effectiveness of traditional navigation as an e-Navigation backup



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?



e-Navigation: Education



- 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.



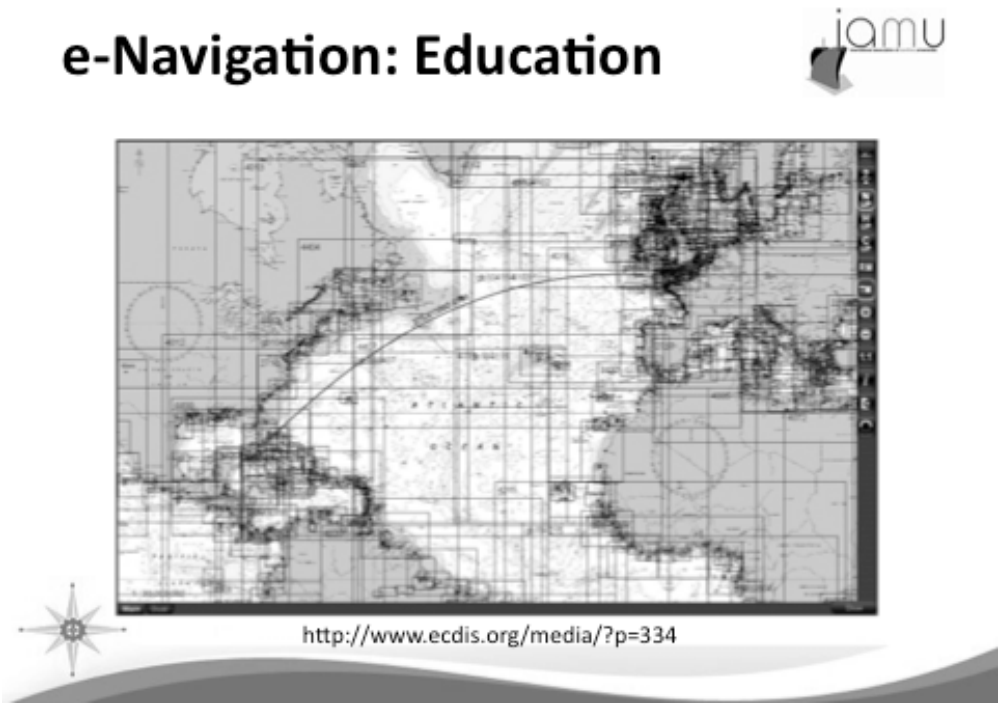
e-Navigation: Education



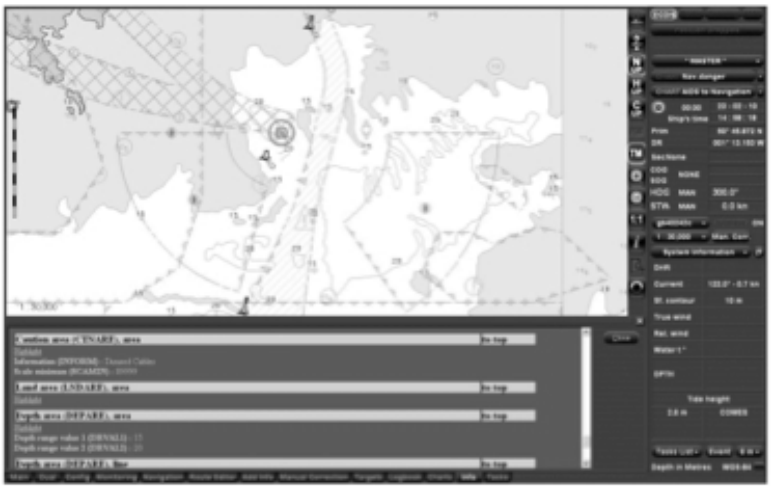
- Effectiveness of electronic equipment redundancy as an e-Navigation backup



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.

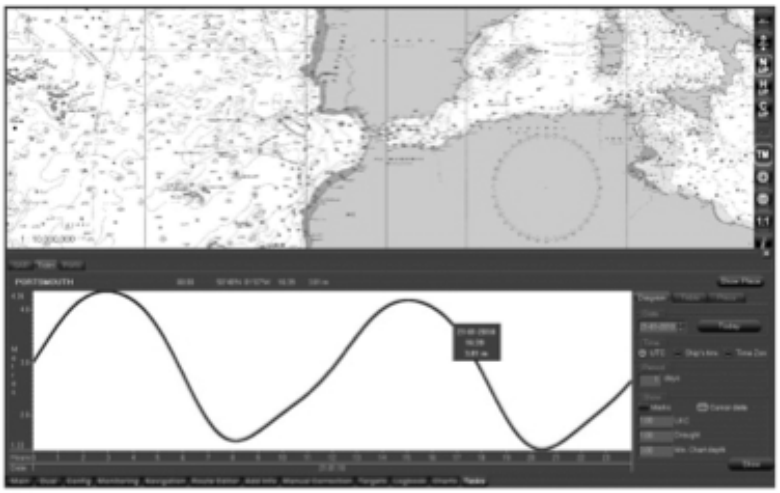


e-Navigation: Education



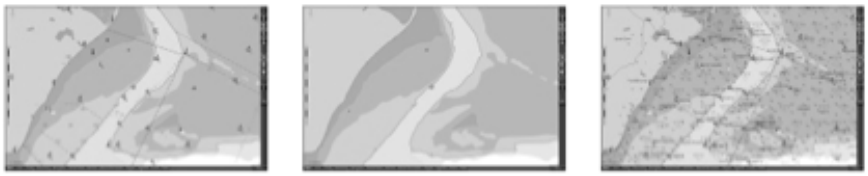
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e-Navigation: Education



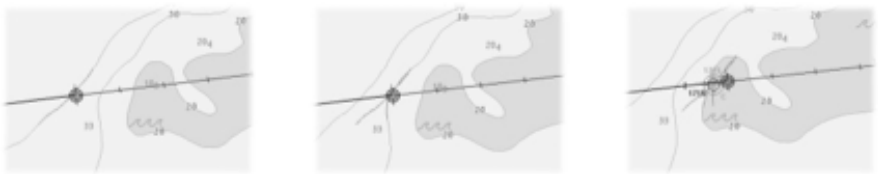
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e-Navigation: Education



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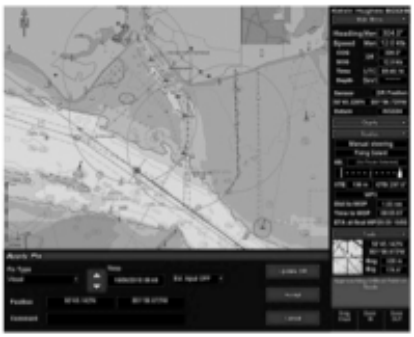
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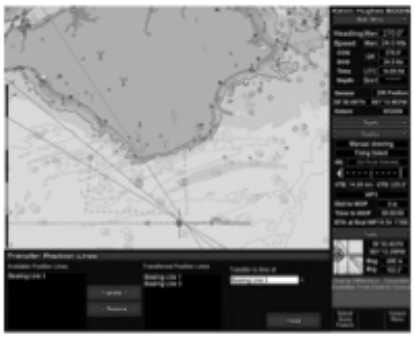
Bottom Contour Fixing using OSI ECPINS

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e-Navigation: Education



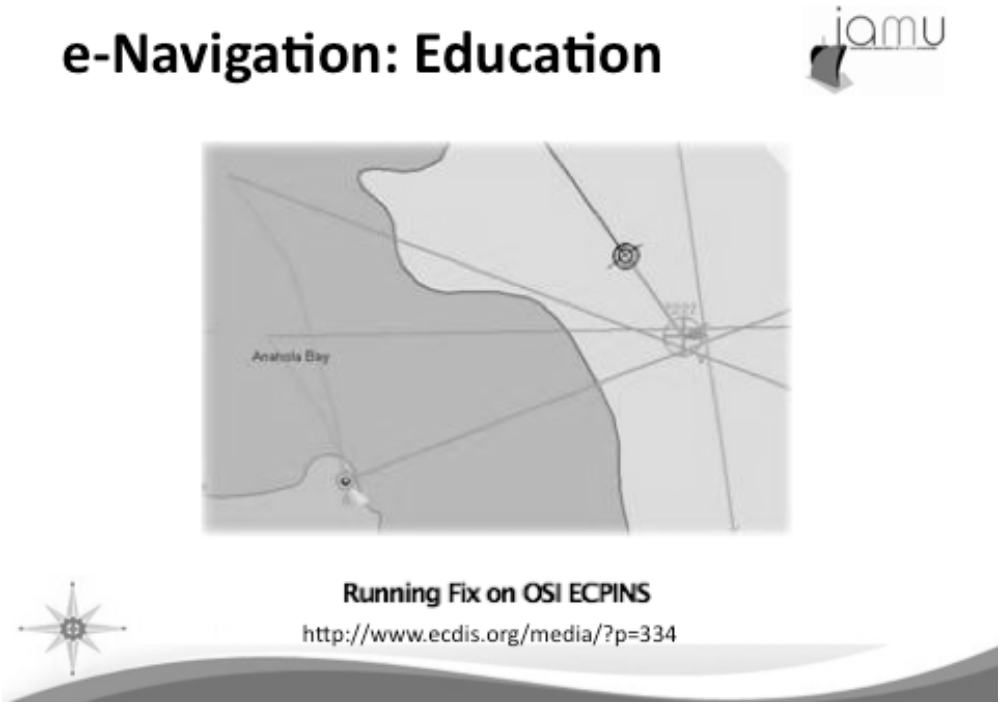
Fixing by HSA on Kelvin Hughes



Transferring Position Lines on Kelvin Hughes

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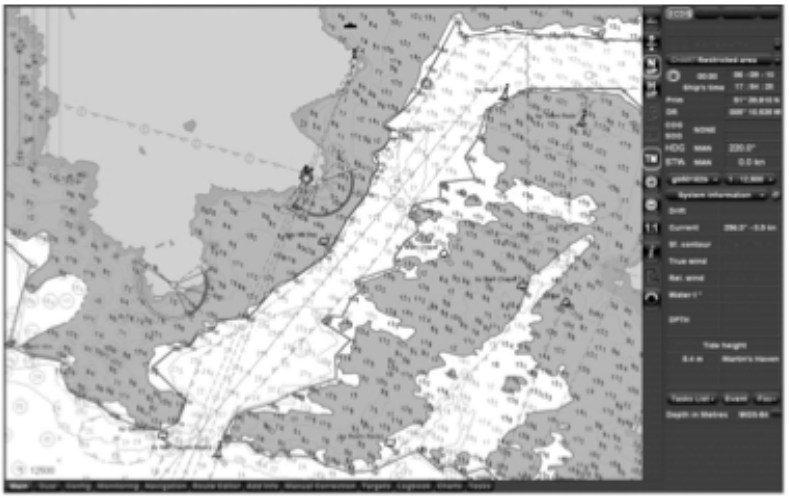
It is not enough to rely solely on GPS or RADAR to provide fix information. An ECDIS does not have to have a RADAR overlay under performance standards, but if it does have this facility, it is prudent to utilize it in its entirety. This is the subject of another element on the course and should further information be required, please call us. However, for GPS denial, the mindset you need to be in is not a case of 'if you lose GPS' but very much a case of 'when you lose GPS'. The mariner must therefore utilize the ECDIS like any other NavAid and question the accuracy of the data in order to quality control the information. The premise here is twofold – that manual fixing should be used to cross-reference GPS and that loss of GPS does not mean loss of ECDIS. I therefore recommend that manual fixing is incorporated by operators to prove the GPS position correct and good practice in case of ECDIS failure. Plotting a fix in ECDIS (Lines of Position) is a requirement under the performance standards and executing this function can be very quick. However, it does depend on the software and just as on paper, practice, practice, practice. It can easily be quicker to plot a fix on an ECDIS than on a paper chart so there should be no excuse for not doing it if needed!



The importance in being able to perform this task swiftly is threefold, one; it should not detract from looking out the window and driving the ship safely using all nav aids, two; the task is performed as a quick check at an appropriate time and three; operators should be able to comfortably manage long periods of relative navigation for areas of the world that require it and in case of sudden need.

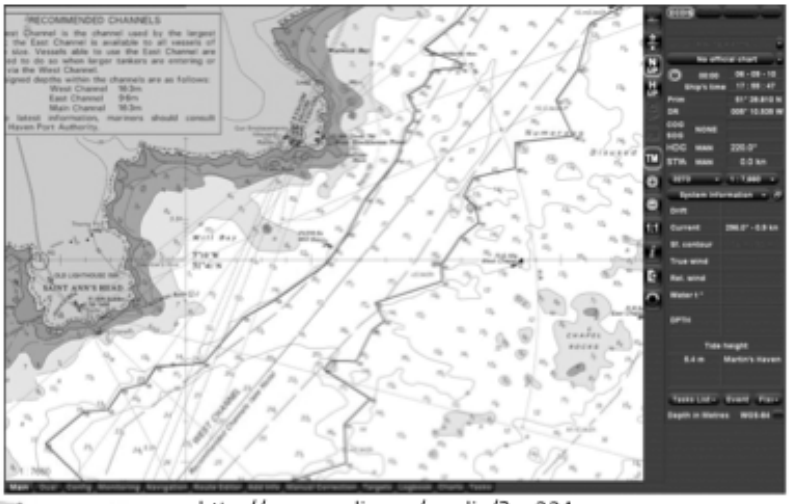
In event of GPS failure, the operator can utilize the DR function in ECDIS and revert to traditional fixing skills in order to provide accurate positional data. Note that loss of GPS may also mean loss of positional information on your RADAR. Furthermore, the environment you find yourself in may preclude or limit visual fixing to such an extent that the operator may have to use transferred position lines or fix by a line of soundings. Some systems can perform beyond the minimum performance standards in this regard by allowing the operator to plot visual bearings, radar ranges and other techniques accordingly. As well as being quick and easy to plot, the operator also benefits from a system that automatically calculates DR and EP based upon last known values such as set and drift, COG and SOG, when in 'DR mode'. It can be seen therefore that manually entered positional information can very quickly establish where you are and where you will be to a high degree of accuracy.

e-Navigation: Education



Transas ECDIS

e-Navigation: Education



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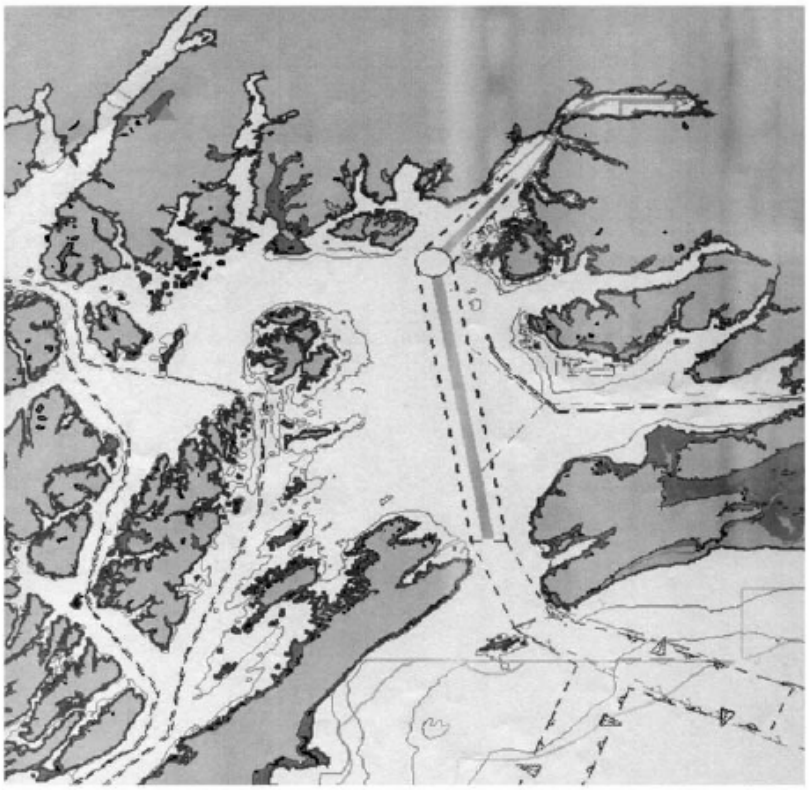
8.2 e-Navigation course lab instructions

NAU 395 e-Navigation

Fall 2011

Lab 2 Instructions

Name: _____ Name: _____



Prince William Sound

Purpose of lab:

1) Understand the benefits of e-Navigation to mariners, the maritime community, and the public through an analysis of the grounding incident of the Exxon Valdez.
2) Practice using e-Navigation concepts to conduct an outbound trip through the Valdez Arm.

Specific objective:

Navigate your vessel safely using Visual Watchstanding, Radar/ARPA, ECDIS, VHF and AIS.

Scenario:

Your vessel is departing the Alyeska Marine Terminal, Valdez, Alaska and will proceed through Valdez Narrows to the outbound lane of the Traffic Separation Scheme. Chart 16708 may be used as a reference:

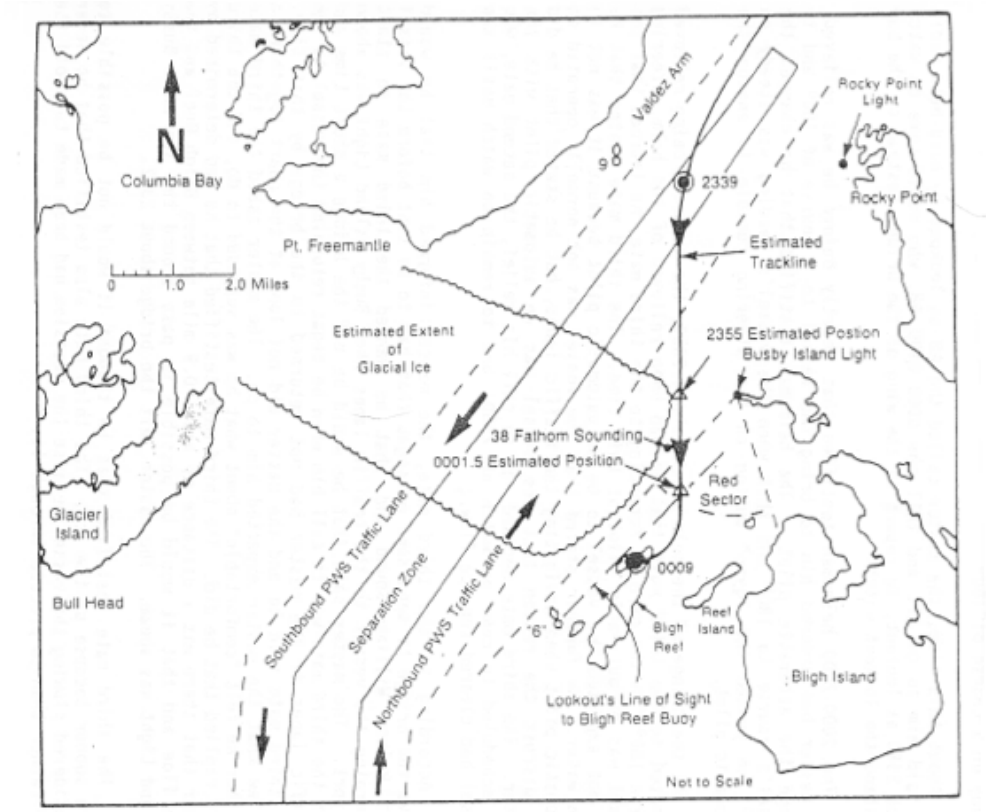


Figure 3.--Trackline of EXXON VALDEZ.

Task 1: Outbound trip of Exxon Valdez recreated using simulation.

Task 2: Create an outbound route via the Traffic Separation Scheme using ECDIS.

Scenario Parameters:

The following instructions and restrictions apply to this scenario:

(1) Monitoring your route: create a route with ECDIS. Pay particular attention to hazards along the route. Deviation from the route may be necessary given the ice conditions in the Valdez Arm

(2) Monitoring your route: Maneuver your vessel based on information provided to you from the VTS

(3) Bridge Team: Mate, Navigator, Helmsman, Lookout, and Extra

(4) The speed has been set to 12 knots. Speed shall be reduced if entering the ice field.

Vessel Characteristics:

Displacement: 321260 tons
Length: 1089.2 ft.
Beam: 190.3 ft.
Forward Draft: 68.3 ft.
After Draft: 68.3 ft.
Height of Eye: 97 ft.

Excerpts from the Prince William Sound VTS User's Manual

(1) At all times, no **VMRS User** shall enter the Valdez Arm VTS Special Area TSS, during periods of "Ice Routing Measures" when another VMRS User is transiting the Valdez Arm Special Area.
(2) During periods of closure due to excessive ice inside the Valdez Arm VTS Special Area, no tank vessel shall transit the special area, until the Valdez Arm is reopened by Valdez VTS.
(3) With permission from PWSVTS, users may deviate from the lanes as necessary to avoid ice (this permission is automatically granted when "Ice Routing Measures" are in place). Users are to remain inside the boundaries of the TSS; however, should it become necessary to leave the TSS, PWSVTS must be notified

Task 3: Use the ECDIS to create a User Chart Object (Line) with the Add Info panel to document the extent of ice coverage in the Valdez Arm.

Valdez VTS Ice Report provided via AIS message:

Waypoint	Latitude	Longitude	Name
1			
2			
3			
4			
5			

Debrief Notes:

Question 1: When comparing the ice report provided by the Valdez VTS and Radar ice returns, do you believe that the Add Info chart aids in your situational awareness while proceeding outbound through the TSS?

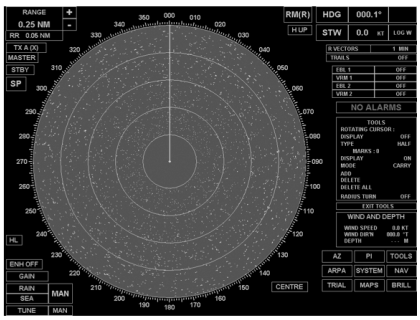
Question 2: When comparing the demonstration of the Exxon Valdez incident and your transit, do you feel that the addition of ECDIS contributed to your situational awareness?

NAU 395 e-Navigation

Fall 2011

Lab 3 Instructions

Name: _____ Name: _____





Bridge Resource Management

Purpose of lab:

1) Understand and develop methods of cross-checking electronic navigation equipment during route monitoring
2) Practice using a Constant Radius Turn with the Radar, which takes advantage of the range detection capabilities of Radar without gyro input.

Specific objective:

Navigate your vessel safely using Radar/ARPA and ECDIS.

Scenario(s):

1) Your vessel is departing Tacoma, WA bound for sea. Chart 18474 may be used as a reference.
2) Your vessel in transiting the Valdez Arm and proceeding to an anchorage. Chart 16708 may be used as a reference.

Task 1: Outbound trip from Tacoma, WA using Radar/ECDIS to monitor your turn.

VRM offset _____ @ 090°R (Turn Radius)
VRM distance _____ nm (Reference Point Distance)

Task 2: Transiting the Valdez Arm to anchorage using ECDIS/Radar to monitor your turn.

VRM offset _____ @ 090°R (Turn Radius)
VRM distance _____ nm (Reference Point Distance)

Scenario Parameters:

The following instructions and restrictions apply to this scenario:

(1) Monitoring your turn with Radar. Use autopilot until just prior to the turn. When your vessel is one shiplength before the turn shift to Follow-up steering and follow the radius turn while monitoring with the VRM. Pay particular attention to hazards along the route. There may be traffic, maintain a 1 mile CPA on large vessels and a .5 mile CPA on small vessels.

(2) Monitoring your turn with ECDIS. Use autopilot until just prior to the turn. When your vessel is one shiplength before the turn shift to Follow-up steering and follow the ECDIS route with radius turn. Pay particular attention to hazards along the route. There may be traffic, maintain a 1 mile CPA on large vessels and a .5 mile CPA on small vessels.

(3) Bridge Team: Mate, Navigator, Helmsman, Lookout, and Observer

(4) The speed has been set to 13.0 knots. Maintain this speed throughout the exercises.

Vessel Characteristics:

Displacement: 37560tons
Length: 730 ft.
Beam: 75 ft.
Forward Draft: 26ft.
After Draft: 26ft.
Height of Eye: 79ft

Debrief Notes:

Question 1: When comparing the monitoring of the turns using Radar and ECIDIS, which do your feel aided in your situational awareness the most and why?

_____
_____
_____
_____

Question 2: In your own words, do you feel it is important to cross-check the electronic navigation equipment such as Radar and ECDIS during route monitoring?

_____
_____
_____

NAU 395 e-Navigation

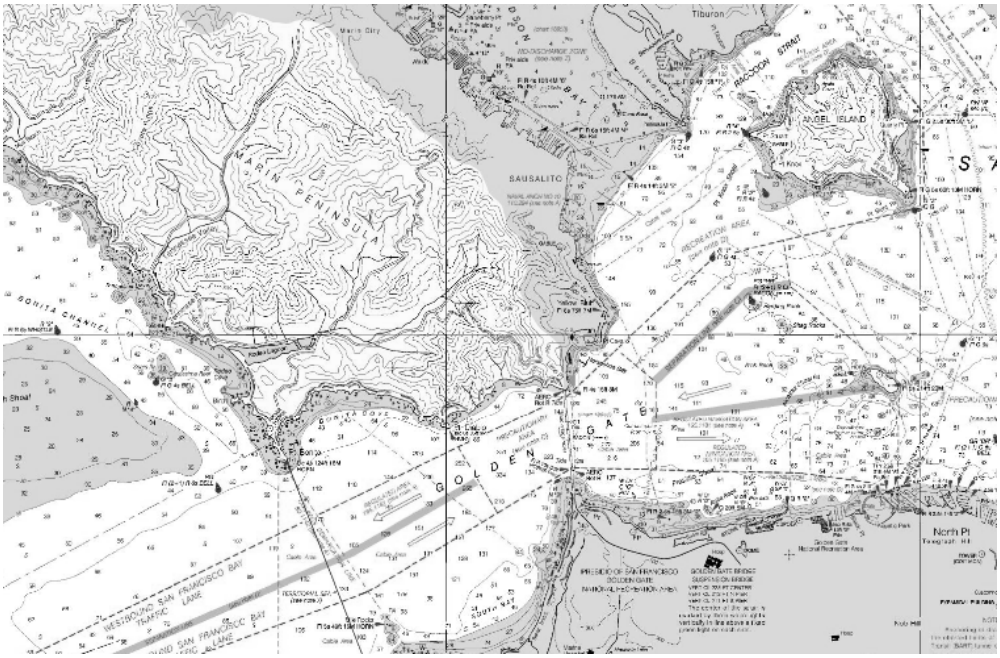
Fall 2011

Lab 4 Instructions

Name: _____ Name: _____

Purpose of lab: Continue the use of ECDIS in route planning/monitoring, GPS in position determination and Radar/ARPA in Collision Avoidance

Specific objectives: Integrate the use of Radar/ARPA, ECDIS, and AIS
Introduction of the Head-Up Display



Scenario(s):

1) Your vessel is inbound San Francisco bound for Martinez/Benicia. Chart 18649 may be used as a reference.
2) Your vessel outbound San Francisco bound for sea. Chart 18649 may be used as a reference.

Scenario Parameters:

The following instructions and restrictions apply to this scenario:

(1) From your vessel's position, create a route using ECDIS. Perform a route check and revise as necessary.

Radar Setup:

Presentation mode: North UP
Pulse Length: Short
Vectors: True
Band: X-Band
Range scale: Various (3, 1.5. and .75nm)
Speed input: Nav/Log W
Parallel Index Lines:
CPA: _____nm

ECDIS Setup: Safety Values:

Safety depth -		20 M
Safety contour -	20 M	
CPA -		_____ NM
TCPA -	5 min	
Safety vector -	5 min	
Safety circle -		0.25 NM

Debrief Notes:

Answer the following questions concerning this exercise:

1) Which range scale is most useful from waypoint 1 to the Golden Gate Bridge?

_____

2) Plot all ship targets. How do you differentiate between floating aids to navigations and ship targets?

_____

_____

_____

_____

_____

3) What are the advantages of using true vectors for in confined waterways such as in this exercise? What information does relative vector provide?

_____

_____

_____

_____

NAU 395 e-Navigation

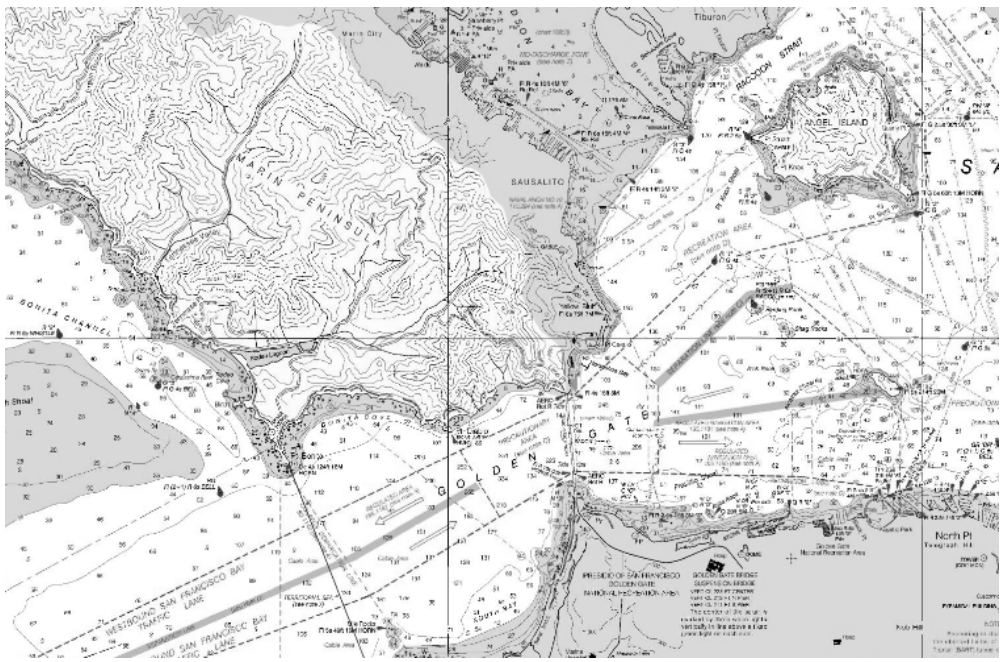
Fall 2011

Lab 5 Instructions

Name: _____ Name: _____

Purpose of lab: Introduce the use of marine HUD in route monitoring and greater use of AIS

Specific objectives: Integrate the use of HUD, Radar/ARPA, ECDIS, and AIS



Scenario(s):

1) Your vessel is inbound San Francisco bound for Oakland. Chart 18649 may be used as a reference.

.

Scenario Parameters:

The following instructions and restrictions apply to this scenario:

(1) From your vessel's position, create a route using ECDIS. Perform a route check and revise as necessary.

(2) Pay particular attention to AIS in this exercise. Identify and confirm the information being transmitted by both your vessel and the other vessels is correct. Notify VTS of any discrepancies.

Radar Setup:

Presentation mode: North UP
Pulse Length: Short
Vectors: True
Band: X-Band
Range scale: Various (3, 1.5. and .75nm)
Speed input: Nav/Log W
Parallel Index Lines:
CPA: _____nm

ECDIS Setup: Safety Values:

Safety depth -		20 M
Safety contour -	20 M	
CPA -		_____ NM
TCPA -	5 min	
Safety vector -	5 min	
Safety circle -		0.25 NM

Debrief Notes:

Answer the following questions concerning this exercise:

1) In your own words, what impact could the misidentification of the vessels in and near the traffic separation scheme have on your inbound transit?

_____

_____

_____

2) Plot all ship targets using the Radar/ARPA. How do you differentiate between floating aids to navigations and ship targets?

_____

_____

_____

_____

_____

3) What are the advantages of using true vectors for in confined waterways such as in this exercise? What information does relative vector provide?

_____

_____

_____

_____

4) What are the limitations of the information provided by AIS?

_____

_____

_____

_____

NAU 395 e-Navigation

Fall 2011

Lab 8 Instructions

Purpose of lab:

Learn proper procedures of ship-to-ship and ship-to-shore communication while safely navigating a vessel within a mandatory Vessel Traffic Service (VTS) area. This lab will look at how mandatory VTS can both impact and influence vessel movement into and out of a large port.



Specific objectives:

(1) Navigate safely by complying with vessel control orders issued by VTS
(2) Communicate effectively by VHF/AIS Text Messaging with VTS and other vessels in system
(3) Determine if and when it might be necessary to deviate from VTS controlled maneuvers

Scenario: Six separate ownships transiting in and out of Los Angeles/Long Beach Harbor

Ownship numbers, names and destinations:

1) *Petrochem Express* (tanker) – outbound for San Francisco
2) *Catalina* (fast ferry) – outbound for Avalon Harbor, Catalina Island
3) CSX *Baltimore* (containership) – outbound for New Orleans via Panama Canal
4) LNG *Aquarius* (LNG tanker) – inbound for inner anchorage area B-8
5) *Newport Beach* (fast ferry) – inbound for Berth 93A San Pedro
6) *Cadillac* (bulk carrier) – inbound for Pier 300, Berth 301

Vessel particulars:

See vessel characteristics information on conning display

Environment:

Time: 1630, 9 November 11
Visibility: good
Sea conditions: moderate chop, Beaufort Force 4

Traffic:

Mandatory VTS vessel control situation is in effect by order of the Captain of the Port of Los Angeles/Long Beach

Call VTS ("San Pedro Traffic") on Ch. 13/ AIS Text Messaging for traffic report and:

1 – getting underway outbound
2 – passing through breakwater
3 – departing or entering precautionary area
4 – arriving at destination inbound

When first contacting traffic before getting underway, give vessel name and call sign, deep draft, and destination. Request that VTS load a preferred route for the conning officer to inspect prior to getting underway. Once the route is loaded into ECDIS and approved by conning officer, request permission from VTS to get underway. VTS may permit the routes of other vessels to be displayed on your ECDIS.

Route

Follow the route provided by VTS unless deviation is necessary for collision avoidance or the route is deemed unsafe for any reason. Inform VTS immediately of any deviation from the route.

Night Orders:

Keep a 0.2 mi CPA on all contacts unless meeting or overtaking other vessels.
Use no more than 15 knots when inside precautionary area, 8 knots inside breakwater.

Make certain running lights are on.
Sound fog signal if visibility drops below 1 mile.
Call all other vessels by VHF Ch 13/AIS Text Messaging if crossing, overtaking or meeting within 1 mile

Bridge Team:

Conning Officer, Radar, Navigator (ECDIS), Helmsman (con)

VTS Standing Orders for Mandatory Vessel Control Situations:

1) Maintain a constant radio watch on VHF Ch. 13
2) Answer VTS immediately when hailed
3) Comply immediately with any VTS order to change course or speed
4) Hail other vessels on VHF Ch. 13 for meeting agreements unless already specified by VTS

Bridge teams: Watch Officer, Helmsman, and Lookout

Notes:

1. Only the team leader may talk on the radio.
2. Listen for an open channel before you begin your radio calls. Do not talk over other vessels or VTS.
3. A professional demeanor on the radio and AIS Text Messaging must be maintained at all times.
4. This likely to be a very difficult scenario that will require you to listen to the radio at all times and carry out the orders of VTS to the best of your ability.

8.3 eNavigation Conference 2011 presentation

日本財団 The Nippon Foundation

Alternative Displays



Nov 2011 Navigation Conference 2011

A Critical Problem for e-Navigation:

- The well-worn e-Navigation definition:
- "*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.*"
- But just how do we harmonize, integrate, present, and analyze marine information displays onboard vessels in the most efficient manner?
- The Maritime Head-Up Display may be an effective way

Nov 2011 Navigation Conference 2011

Problems with Existing Displays

- Too much 'head down' time with standard displays should make mariners uncomfortable
- Looking out the window is essential for proper lookout but not encouraged by radar, ARPA, and ECDIS displays
- HUD may be the solution to this problem
- Several other applications already exist

Aviation HUD



Automotive HUD



Non-conformal information



Conformal information

Maritime HUD

- What would a maritime HUD look like?
- What features should it have?
- How would it be used?
- Would it really be useful?
- Before these questions can be answered, some assumptions must be made.

Maritime HUD Similarities

- Conformal information required:
  - planned route
  - safe boundaries
  - upcoming turn points
  - potential dangers
- Non-conformal information required:
  - vehicle status, heading, speed, etc.



Maritime HUD Differences

- Operator movement (walking around bridge)
- Larger display surface (windows) available
- Slower pace of operation (except on HSV)
- More sluggish vehicle response
- Fewer visual cues than automobile
- Less room for error than aircraft (other than on landing)



Maritime HUD Evaluation

- **Purpose of study - define for Maritime HUD**:

  1) CONOPS (Concept of Operations)

  2) Essential information, applications, concerns

  3) Variations by vessel, crew, and task



Maritime HUD Evaluation

- **Process**
- During first e-Navigation course (Spring 2010), collect CMA students' initial impressions of HUD mockup (n =24)

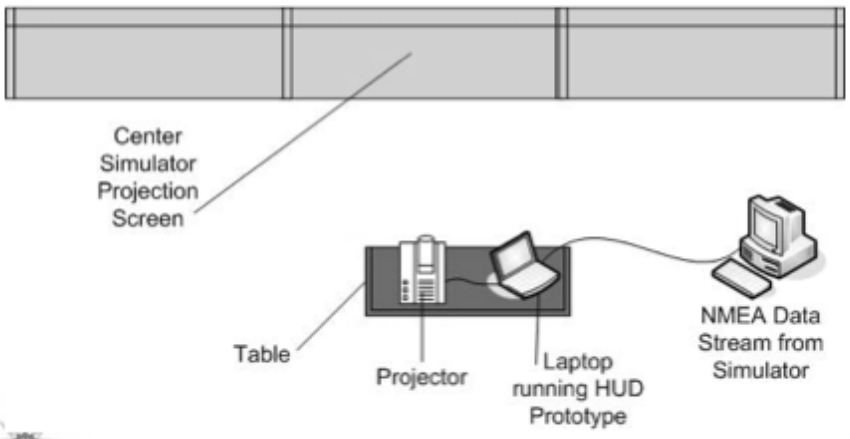




Evaluation Materials

- HUD mock-up
- CMA Advanced Simulation Facilities
- Surveys
  - Before interaction with HUD
  - After interaction with HUD
- Instructor Observation

Evaluation Materials (Simulator Prototype Set-Up)



Data Collected

- Ratings of 14 items on 1-5 Likert Scale
  - with comments
- Open ended questions:
  - Benefits
  - concerns
  - appropriate/inappropriate tasks and situations
  - appropriate/inappropriate vessel types
  - desired additional features
- Sketch of ideal HUD design

Key Results (ratings)

- HUD very useful in confined waters (4.25)
- Comments
  - Augmented with additional information
    - Stationary long-term objects
    - Highlighting channels and TSS
  - Concerns
    - Pilot acceptance
    - Clutter and distraction



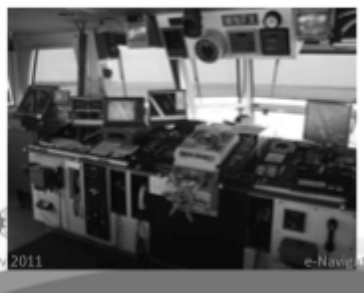
Key Results (ratings)

- HUD useful in restricted visibility (4.08)
- Comments
  - Allows for quick assessment of the situation
  - Can make the invisible visible
  - Confident maneuvering
  - Keeps eyes out the window
  - Would require properly integrated collision avoidance information



Key Results (ratings)

- Reduced navigational workload (3.96)
- Comments
  - Provides increased Situational Awareness (SA)
  - No significant reduction unless data entry processes changed
  - Still need to cross-check data





Key Results (ratings)

- Reduced Head-Down Time (HDT) compared to ECDIS and radar (4.29)
- Comments:
  - Reduced HDT was seen as one of the primary benefits of HUD



Key Results (Open-Ended)

HUD good for:

- Staying on track, quick indication of XTE
- Range and bearing assessments to next waypoint
- High-speed vessels with confined bridge layouts
  - Rapidly changing information

Key Results

HUD Unnecessary for:

- Coastal Navigation & Open Ocean

HUD Inadequate for:

- Docking or Dredging
  - Without task-specific information
- Primary Collision Avoidance
  - Further testing/features required

Key Results

HUD Primary Benefits:

- Increased SA
  - Reduced Stress
- Connects trackline to reality outside of window
- Potential to turn electronic navigation back into visual navigation



Key Results

HUD Primary Concerns:

- Obscuring outside information (targets, buoys) & distraction
- Potential for clutter and information overload
- Encouragement of poor Bridge Resource Management
- Another system to cross-check
- Training issues
- On-ship proof of concept
- Cost

Conclusions

- HUD demonstrated significant value-added, but
- More research is needed
- Focus future testing on confined waters, reduced visibility, high-speed vessels
- Compare different bridge equipment configurations
- Validate standard information requirements across additional situations
- Validate the benefits of providing task-specific information

Conclusions

- For complete discussion of study results see Royal Institute of Navigation's *Journal of Navigation,* Vol. 64, Issue 4, 1 Oct 2011



Ongoing Research

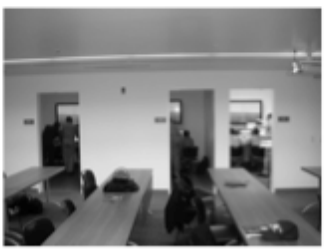
- Continued offerings of e-Navigation courses at CMA
- Funded by $120,000 grant from IAMU
- Final report for Phase 1



Ongoing Research

- **2nd *e*-Nav Course** (Fall 2010):
  - High enthusiasm (33 students)
  - Validated requirements and CONOPS developed in preliminary evaluation
  - Continued prototype development and testing
  - Incorporated additional objective and subjective measures
  - Used part-task simulators (8 stations running simultaneously) instead of FMB

E-Nav Fall 2010



E-Nav Fall 2010

- **HUD development**
- New features added to program through the Fall 2010 e-navigation course
- The last feature added was the ability to show AIS targets in 3-D



Ongoing Research

- **3rd e-Nav Course** (Fall 2011):
  - Produce a college level course in e-Navigation using guidance from last year's model course
  - Continue examining the role of HUD in the future of e-Navigation
  - Compare HUD to ARVCOP for alternative display utility
  - Explore the use of computerized training devices (Stanford's "Intelligent Tutor") in teaching e-Navigation concepts

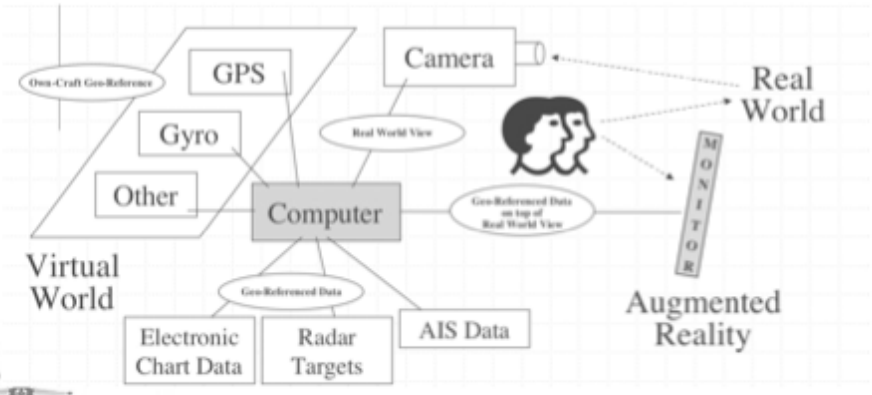
Ongoing Research

- **ARVCOP** (Augmented Reality Visualization of the Common Operational Picture)
- An AR 3-D navigation device produced by Technology Systems, Inc. of Brunswick, ME
- Tested in e-Navigation course both on CMA's crewboat and in the simulator



Ongoing Research

- **ARVCOP operating diagram**



ARVCOP in Action

- Testing on crewboat *URSA*



ARVCOP Evaluation

- Initial student impressions, while generally positive, showed concerns with ARVCOP pulling operator attention away from outside view in much the same way as radar and ECDIS
- Only a true AR Head-Up display conformal with outside view can prevent this

Future Directions: Manufacturer Partner

- Groundwork has been laid
  - CONOPS produced and tested
  - Results suggest value of HUD
- Manufacturer partner needs to have:
  - Familiarity with marine nav equipment
  - Familiarity with HUD applications
  - Familiarity with emerging technologies

The Ultimate Goal:

A working unit



Questions?



Contact for Further Information

Captain Samuel R. Pecota, AFRIN, MNI
California Maritime Academy, Vallejo, CA, USA

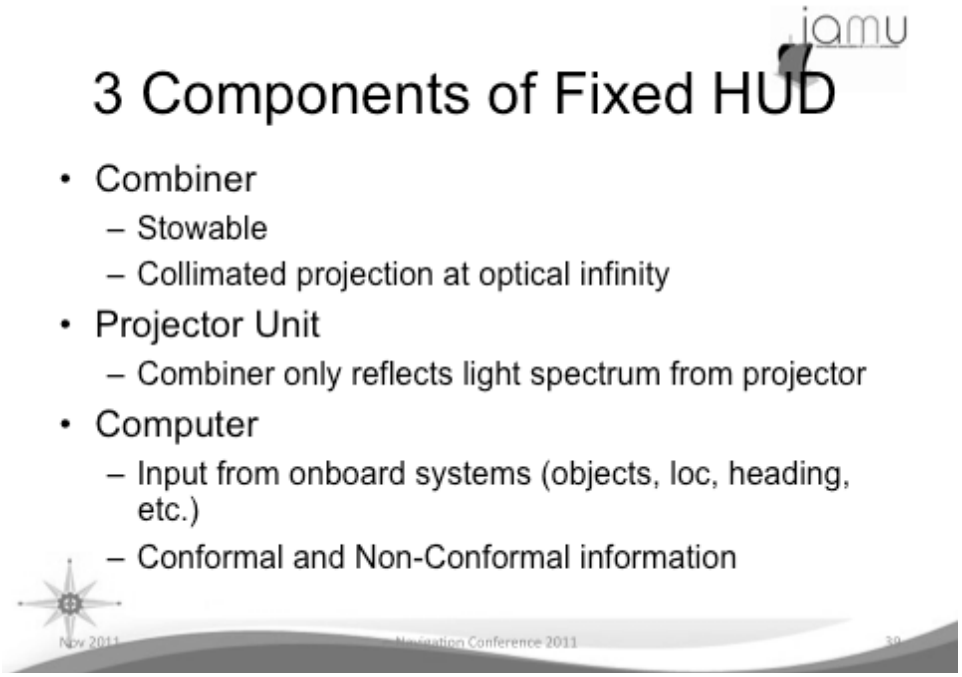
- Email: Specota@csum.edu
- Phone: (707) 654-1164
- Website: www.csum.edu

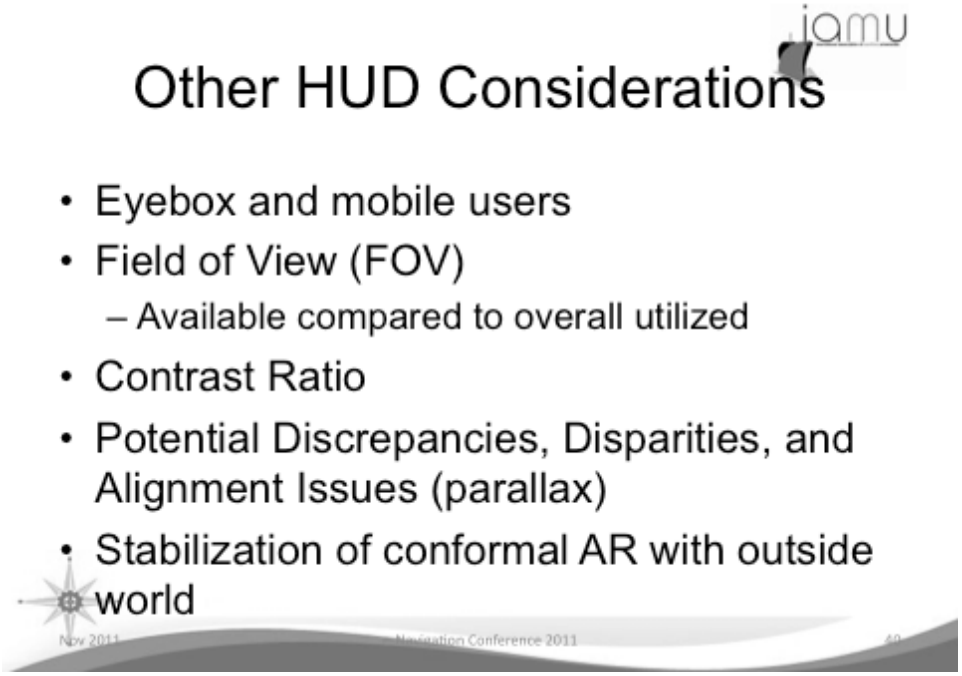
And furthermore…

- The previous slide is the end of the presentation. The following two slides contain extra points of discussion.

HUD in Action




3 Components of Fixed HUD
• Combiner
– Stowable
– Collimated projection at optical infinity
• Projector Unit
– Combiner only reflects light spectrum from projector
• Computer
– Input from onboard systems (objects, loc, heading, etc.)
– Conformal and Non-Conformal information


Other HUD Considerations
• Eyebox and mobile users
• Field of View (FOV)
– Available compared to overall utilized
• Contrast Ratio
• Potential Discrepancies, Disparities, and Alignment Issues (parallax)
• Stabilization of conformal AR with outside world

2011 eNavigation Conference Attendees

(November 29 & 30, 2011)

	FIRST	LAST	ORGANIZATION
1.	Dr. Lee	Alexander	Center of Coastal and Ocean Mapping - Joint Hydrographic Center
2.	Tom	Allison	Transas USA
3.	Capt. Paul D.	Amos	Columbia River Pilots
4.	Brad	Anthenat	Raven Marine
5.	Jorge	Arroyo	USCG
6.	Thor	Banks	USCG
7.	Duane	Bennett	Sabine Pilots Association
8.	Capt. Lee	Berrow	British Columbia Coast Pilots
9.	Lora	Blackburn	USCG
10.	Dave	Boldt	Royal Caribbean Cruises Ltd
11.	Karthik	Bollepalli	Raven Marine
12.	Diego	Bonfim	Fundacao Homem do Mar
13.	Peg	Brandon	Maine Maritime Academy
14.	Helen	Brohl	U.S. Dept. of Trans., Committee for the Marine Transportation System
15.	Capt. Doug	Burrows	Columbia River Pilots
16.	Steve	Burtchaell	Pacific Maritime Institute
17.	Becky	Butner	USCG NAIS
18.	Ron	Carey	British Columbia Coast Pilots
19.	Brad	Christian	Rose Point Navigation Systems
20.	Ken	Cirillo	Jeppesen Marine/C-Map
21.	Andy	Coe	Puget Sound Pilots
22.	Steve	Cole	Maine Maritime Academy
23.	Tom	Crane	USCG
24.	Capt. Dave	Crawford	Horizon Lines
25.	Michaela	Demuth	Shipping Institute Warnemuende
26.	Clay	Diamond	American Pilots Association
27.	Pete	Dolan	Automatic Power, Inc.
28.	Mike	Doupe	Radio Holland
29.	Cato	Eliassen	Kongsberg
30.	Don	English	ARINC
31.	Bob	Febos	Pacific Maritime Institute
32.	Capt. Sean	Gabe	San Francisco Bar Pilots
33.	Dom	Glithero	Aerobytes
34.	Irene	Gonin	USCG - RDC
35.	Sander	Groothuis	Windstar Cruises
36.	John Erik	Hagen	Norwegian Coastal Administration
37.	Capt. Erv	Hagerup	SE Alaska Pilots Association
38.	Dale	Hansen	British Columbia Coast Pilots
39.	Chris	Hicks	Marine Exchange
40.	Mark	Hiet	USCG
41.	Himeh	Horoufchin	Fraunhofer FKIE
42.	Bill	Hughes	Washington State Ferries
43.	Peter	Hyams	STAR Center
44.	Dave	Jackson	Canadian Hydrographic Service
45.	Greg	Johnson	Alion (USCG RDC)
46.	Capt. Prash	Karnik	Holland America Line
47.	Dan	Kerrigan	USCG NAIS
48.	Stan	Kim	USCG NAIS
49.	Jaeson	Kim	ETRI
50.	Dustin	King	USCG NAIS
51.	Fred	King	Cal Marine Electronics
52.	Paul	Kirchner	American Pilots' Association
53.	LCDR James	Larson	USCG
54.	Gregory	Lee	USCG - OSC
55.	LT Dave	Lewald	USCG
56.	Jeff	Lillycrop	US Army Corp of Engineers
57.	Markus	Ljungqvist	Norwegian Mapping Authority

2011 eNavigation Conference Attendees
Page 2 of 2

	FIRST	***LAST***	***ORGANIZATION***
58.	Jeff	Lynch	USCG
59.	David	Marjoribanks	Fraser River Pilots
60.	Capt. Ed	Marmol	Puget Sound Pilots
61.	Kevin	Martin	Aerobytes
62.	Mike	McBrady	USCG
63.	Kevin	Miller	USCG
64.	Ben	Minichino	CLS America
65.	Soo Jong	Mo	MEIPA
66.	Capt. Bob	Moore	Conference Co-Chair
67.	Mike	Morris	Houston Pilots
68.	Doug	Morrison	Cartel Communication Systems, Inc.
69.	Florian	Motz	Research Establishment for Applied Science
70.	Reinhard	Mueller	Shipping Institute Warnemuende
71.	Robert	Page	USCG
72.	Su Hyun	Park	
73.	Capt. Sam	Pecota	California Maritime Academy
74.	Capt. Simon	Pelletier	Canadian Marine Pilots Association
75.	Ken	Pike	Seaspan Marine
76.	Cesar	Pimenta	Fundacao Homem do Mar
77.	Barry	Poole	Seaspan Marine
78.	Fred	Pot	Conference Co-Chair
79.	LT Larry	Prewitt	USCG
80.	Bill	Rall	UW School of Oceanography
81.	Darryl	Randolph	USCG
82.	Sumita	Roy	Maritime Services Ltd.
83.	Tom	Rutter	Virginia Pilots' Association
84.	Capt. Victor	Schisler	California Maritime Academy
85.	Pankaj	Sharma	Institute for Infocomm Research, Singapore
86.	Mike	Sollosi	USCG & IMO Subcommittee on the Safety of Navigation
87.	Doug	Sowdon	Washington State Ferries
88.	Paul	Stanley	Navicom Dynamics Ltd.
89.	Sang Hyun	Suh	KORDI
90.	RADM Keith	Taylor	USCG
91.	Brian	Tetreault	ERDC/Coastal & Hydraulics Lab
92.	Adam	Tucker	Royal Caribbean Cruises Ltd
93.	Kevin	Vail	Canadian Marine Pilots Association
94.	Alan	Weigel	Blank Rome
95.	Bob	Whetsell	Aerobytes
96.	Mike	Young	British Columbia Coast Pilots

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

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