Simulation Training To Meet Advances in Shipboard Automation

Brian D. Long, STAR Center Director

We all know that the maritime industry does not adapt quickly to new technologies. Gradually, however, the shipboard environment has advanced to include such technologies as Automatic Radar Plotting Aids (ARPA), Electronic Chart Display Information System (ECDIS), Integrated Bridge Systems (IBS), Voyage Management Systems (VMS), joystick controllers, automated Engine and Cargo control rooms. These advancements have been developed in an attempt to increase safety, reduce the workload on the watch officer, and increase the quality of watchkeeping, however, it is important to note that if training is not provided for the operators of this equipment the opposite may result; decreased safety, increased workload, and decreased quality of watchkeeping.

One important phase of this training can be provided at a maritime simulation facility. These facilities provide a controlled environment where students can gradually learn, through a structured curriculum, the capabilities, limitations and operation of specific automation equipment without the obvious risk to the crew, vessel, environment, and passengers, if applicable. The simulators also provide an excellent "test bed" for designers and users to determine how to best utilize a particular piece of equipment or to evaluate between different manufacturers of the same type of equipment.

Recently, the Conference on Maritime Simulation (MARSIM) met in Copenhagen, Denmark, and discussions were held regarding the present status of simulation training and research. This international conference, which is held every three years, attracted over 200 participants from 25 countries. From this conference and subsequent visits to several European simulation facilities, it is evident to me that excellent simulation training and research capabilities exist world-wide and that the current state of simulation technology (hardware, software, courseware) can provide operators and designers of automated shipboard equipment with tremendous benefits. These facilities are constantly adapting their simulators and programs to incorporate new shipboard technologies and to meet new training regulations.

TRAINING METHOD

Obviously, when introducing a new piece of automated equipment into an existing training program, a training objective must first be clearly defined and then the training program built from that objective. You can not, for example, simply throw an ECDIS on the bridge simulator and continue the training courses as usual. By the way, this principle also applies to the ship itself; a shipping company should not expect to add new automation technology to the vessel without a clear objective of how and when this automation should be utilized.

When addressing training for operation of automated systems, it should kept in mind that the training requirements for the operators actually increase when automation is introduced. This is due to the fact that the individual needs to be trained in the use of the automation and also needs to be proficient in manual and backup procedures.

We all know the problems which can arise from relying solely on automation. A cruise ship grounding last year involved a failure of the position fixing input to an Integrated Bridge System, which went undetected for numerous hours. Although still under investigation, one can speculate that there may have been a sense of complacency on the bridge since the system had worked flawlessly in the past. This may have led to a relaxing of cross checking procedures with other navigation information.

As we all know from the Prevention Through People (PTP) program the vast majority of maritime casualties are the result of human error. It is important to realize, however, that the human who is responsible for the error is not necessarily the human operating the equipment. In some cases the error can be traced back to the people who designed the equipment or the overall system which incorporates the equipment. The error can even be traced back to the company in some cases for not providing an adequate level of training or not providing guidelines for when and how to use the equipment.

AVIATION COMPARISON

In the area of maritime training we are constantly looking to the aviation industry for comparisons since it has been quicker to adapt new technologies. In referencing Cockpit Resource Management, which is a compilation of papers on aviation training, some good lessons can be found. For example, in aviation it is interesting to note that initially when automation systems were added to training and check ride sessions, it resulted in an increase in the student failure rate. This was attributed to the fact that the students were not adequately trained on the automated systems before the sessions. This resulted in a revised training evolution which included:

- Generic automation training
- Simulator sessions without automation
- Extensive training on specific automation
- Simulator sessions with the use of automation at the pilots discretion

Several airline companies have adopted an automation philosophy which spells out what the company's stance is on the use of automation. A company may decide to leave it up the operator to determine in which situations the automation will be best suited and during which time it is better to use a more traditional method.

JOYSTICK EXAMPLE

As far as the training goes, we need to determine which training device should be used during which stage of the program. If we use the example above, it is best to train an individual on a piece of equipment in a stand alone mode prior to incorporating that system in a much larger system and complex training exercise on a full mission simulator.

As mentioned earlier, maritime simulators can be used to train on specific automated shipboard systems. Since equipment varies significantly from one ship to the other, unlike aviation, this usually involves hardware and software integration to the existing simulator. One example of customized integration to meet customer requirements is the installation of a joystick controller for a cruise company's training program at STAR Center. This controller combines the separate controls of the engines, rudders, and thrusters in a single control device.

Continued

STAR Center's 360° Bridge Simulator equipped with Joystick Controller (inset)

To try and imagine how the officers might feel when a new piece of automation is added onboard their vessel, an analogy that almost everyone can identify with follows: Suppose you rent a car and instead of a steering wheel, accelerator, and break pedal, the car is fitted with a joystick which incorporates all of those separate controls. You are told that this makes driving the car much easier and safer. I think you would agree that without training, this device would definitely decrease the safety of the operation. An what could be said about your confidence level in using this device; I think it is safe to say that it would not be very high. If given the choice, I am sure that you would opt to abort the joystick if possible and use the traditional and familiar controls.

The cruise company saw the tremendous benefit to training their senior officers on this device in a controlled environment; the simulator. To meet this goal, an authentic joystick identical to that which is on board the vessel was integrated into the existing simulator. In conjunction with this, a maneuvering model based on the actual ship maneuvering data was prepared. This allowed a recreation of the entire shipboard environment for the officers participating in the training.

Once the joystick was installed, the validation of the system was conducted. First the ship model was validated separately by one of the captains to insure that the modeled vessel behaved as the actual ship. Then the joystick was validated by someone with experience with the device as well as the technical representative for the equipment. Also visual and environmental models utilized in the training were validated in a similar manner.

To incorporate this device into our training curriculum, first, lecture modules were presented on the theory and operation of the joystick. Then simple “experiments” were conducted where the students were placed offshore on the simulated vessel to get a feel for how the joystick behaved under various conditions. The exercises were developed so they would

FLIR-1015.202

incrementally build to eventually include complex maneuvers in authentic and generic ports under adverse environmental conditions. The training evolution would then culminate in an exercise involving a failure of the system and a review of abort and backup procedures. Throughout the course, extensive maneuvers utilizing traditional controls were also conducted.

From our observations of the training it was obvious that the officers' proficiency on the joystick increased dramatically as the week progressed and from their comments, the students' confidence in using the system had increased significantly. I believe, as do the students who have attended these courses, that this is an ideal use of simulation technology. To realize the benefit of the joystick training example one needs only to consider the alternative; onboard experimentation in a real port with a ship full of passengers. I think everyone would agree that this is not the time to try a radically different maneuvering device.

SUMMARY

The joystick is just one example of the right way to introduce a new piece of shipboard automation but this philosophy can translate to other equipment such as ECDIS, IBS, portable Vessel Traffic Systems (VTS), etc. Any of this equipment can be integrated into a simulator so that it may be evaluated or used for training in a controlled environment. Other centers world wide have also integrated joysticks, ECDIS units, voyage management systems (VMS), as well as other specific equipment to conduct research or to meet specific customer requirements with similar results.

Shipping companies must keep in mind that if the people are not trained properly on these automated systems, the majority of them will simply not use the equipment, or even worse, misuse it. This could lead to "automation assisted" casualties as was seen with the introduction of RADAR and ARPA. With adequate structured training programs, however, these automated systems can achieve the desired results of increased safety, reduced workload, and an improved quality of watchkeeping.

Brian D. Long is the Director of RTM STAR Center, a Simulation Training and Research organization with locations in Dania, Florida and Toledo, Ohio. Mr. Long has worked in the simulation field in various capacities since 1984. Mr. Long is a graduate of SUNY Maritime College and holds an engineering degree and an unlimited mates license.

MARINER'S SEABAG

PC-Based Radar Simulators in Coast Guard Approved Courses

Innovative technology has provided a variety of useful tools for the mariner; thereby, making the task of safe navigation much less burdensome. Radio, Radar, and D-GPS are potentially tremendous assets in any pilothouse or ship's bridge.

Unfortunately, simple installation of such equipment does not make vessels any safer to operate. Numerous reviews of marine accident reports suggest that mere installation of equipment is just not enough. However, timely application of knowledge and skills in the proper use of these navigational aids is essential. This was certainly a key factor in the most deadly marine incident on U.S. waters in recent memory.

Well past midnight, on September 22, 1993, a radar-equipped towboat pushing several barges was not where its operator believed it was. The MAUVILLA was lost in the blanketing fog of Big Bayou Canot and headed for the tragic consequences of a chain of events beginning with the allision of a railroad bridge. This incident became the driving force in changes to regulations designed to prevent a repeat of circumstances surrounding the fatal disaster.

More than a decade ago, technology—in the form of marine-radar simulators—was identified as essential to improve marine safety through training, testing, and certifying mariners' competency in radar observation and plotting. Back then the emphasis was on collision avoidance, and the training requirements were directed primarily at masters and mates on vessels of at least 200 gross tons. Radar Schools offered courses based on the MARAD model, as this was the standard adopted by the USCG. Computers running simulation programs provided inputs to actual radar units and displays. Since the implementation of revised regulations as noted above, the scope of Coast Guard approved radar training courses has broadened to also emphasize position determination. Advisory Committee members, public comments, and marine educators provided information useful in the development of NVIC 9-94, the current guidelines for USCG approved radar-observer training courses.

To have radar courses approved today, or to have them remain approved, radar schools must show their curricula complies with the new standards. In addition to dealing with multiple targets (vessels) in collision avoidance, this means incorporating learning objectives on position determination, and using radar simulators with land-masses, coastline, or riverbanks that the students may observe and/or measure. Schools without the requisite simulator capability began searching for upgrades and alternatives. In an effort to keep their costs down, several schools have chosen desk-top, PC-based radar simulation to conduct the required practice and demonstrations of skills. While earlier attempts to offer radar training on desktop devices were unsatisfactory or marginal, this option is now viable due to the significant leaps in power and capability of hardware, as well as the development of software generating the visual elements needed to accomplish the training and testing. Factors leading to the Coast Guard's acceptance of PC-based radar simulators include:

1. A survey of currently available marine-radar units. Reflection plotters appear to have been largely phased-out. They are certainly obsolete for units with ARPA capabilities, or redundant where electronic marking features are used. Consequently, mandating exercises or demonstrations of proficiency in this type of "scope" plotting would be, at best, questionable;

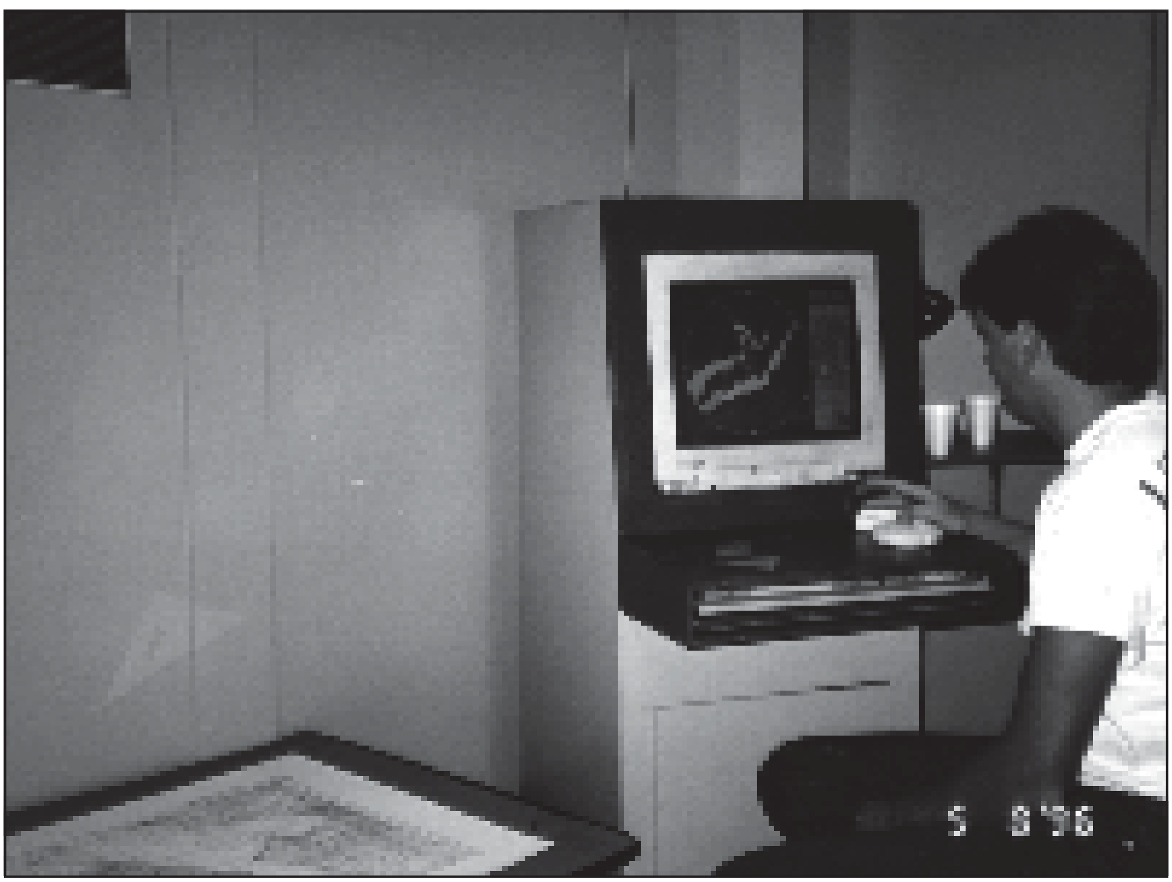
2. The ability of today's PC hardware and software to effectively emulate key marine-radar functions and performance; and,

3. The need to emphasize the focus on developing and demonstrating watchkeeping skills which will positively reduce the likelihood of mishaps, and thereby improve safety.

In addition, the typical deck-license candidate seeking a radar-observer endorsement must have at least two years of underway experience. In that time, he or she should have gained some familiarity with the radar units installed on their vessels. Further, many of today's license applicants may in fact have experience with PCs on the job and/or in education and training environments. The Coast Guard expects mariners will find that PC-based radar-simulators used in approved courses will improve their ability to use the particular radar-units installed on their vessels in determining risk of collision, avoiding collisions and allisions, and monitoring own-ship's position.

Future training in ARPA, GMDSS, and the use of other navigational safety devices may be delivered using PC-based simulators. While validation of simulator-based training has largely relied on manufacturers, schools, and/or Coast Guard personnel, in order to conform with the 1995 amendments to the STCW Convention, it is expected standard-setting organizations will be involved in establishing a more structured process for validating simulators used in future approved courses to come.

A key element in all simulator-based courses must be the danger of over-reliance on radar, ARPA, and the other tools technology delivers; for the importance of non-technical and "low-tech" watchkeeping skills remain as important as ever, and must be understood and practiced.



NAUTICAL QUERIES

DECK

1. Fusible-link fire dampers are operated by ____________________.

   A. a mechanical arm outside the vent duct
   B. electrical controls on the bridge
   C. the heat of a fire melting the link
   D. a break-glass and pull-cable system

2. A sextant having an index error that is "off the arc" has a _____________.

   A. positive correction
   B. dip error
   C. negative correction
   D. semidiameter error

3. What is the effect of heated intake air on a diesel engine?

   A. Increases efficiency
   B. Increases engine horsepower
   C. Increases engine life
   D. Reduces engine horsepower

4. The great circle on the celestial sphere that passes through the zenith and the north and south poles is the ___________________.

   A. hour circle
   B. prime vertical
   C. principal vertical
   D. ecliptic

5. How should you signal the crane operator to stop?

   A. Place both fists in front of your body with the thumbs pointing outward.
   B. Extend both arms out with the palms down and move arms back and forth.
   C. Extend arm with the palm down and hold this position rigidly.
   D. Clasp hands in front of your body.

6. Which statement is correct concerning the carriage of coal in bulk?

   A. Coal should be vented with surface ventilation only.
   B. Because of its inherent vice, coal should not be loaded wet.
   C. Dunnage should be placed against ship's sides and around stanchions.
   D. Through ventilation, as well as surface ventilation, should be provided whenever possible.

7. The dividing meridian between zone descriptions - 4 and -5 is ______.

   A. 60°00'E
   B. 67°30'E
   C. 75°00'E
   D. 60°00'W

8. When towing another vessel astern, the length of the towline should be ________.

   A. as long as possible
   B. such that one vessel will be on crest while the other is in a trough
   C. such that the vessel will be "in step"
   D. not over two wave lengths in seas up to 10 feet

9. While providing assistance to a victim of an epileptic seizure, it is most important to ________.

   A. give artificial respiration
   B. prevent patient from hurting himself
   C. keep the patient awake and make him/her walk if necessary to keep him/his awake
   D. remove any soiled clothing and put the patient in a clean bed

10. Considering manning requirements for US flag vessels, your 2 watch cargo vessel has a deck crew of 20 people, exclusive of officers. How many of these people do the manning regulations require to be able seamen?

    A. 13
    B. 10
    C. 7
    D. 5

DECK ANSWERS

1-C, 2-A, 3-D, 4-C, 5-C, 6-A, 7-B, 8-C, 9-B, 10-B ***If you have any questions concerning this quiz, please contact the National Maritime Center at (703) 235-1368.***

FLIR-1015.206

ENGINEERING

1. The auxiliary exhaust system is typically supplied by steam directly from ______________.

   A. the main engine
   B. turbine and reciproacting pumps
   C.Spring bearings
   D. all of the above

2. When completing the ballasting operation of a contaminated tank, which of the following problems must be guarded against?

   A. Back flow of contaminated water
   B. Loss of pump suction
   C. Excessive tank pressure due to closed vents
   D. Motor overload due to high discharge head

3. If an oil fire occurs in the double casing of a steming boiler, you should________________.

   A. increase the forced draft fan speed
   B. secure the feedwater supply to the boiler
   C. secure the fuel oil supply to the burners
   D. apply water with a smooth bore nozzle

4. Excessive exhaust temperatures in a two-stroke/cycle diesel engine can be caused by a/an _________.

   A. high injection pressure
   B. high firing pressure
   C. overheated air starting line
   D. carbon build up in the exhaust ports

5. Which statement is true concerning a split-phase induction motor?

   A. Motor rotation can be reversed without changing the windings or leads.
   B. Motor speed can be readily adjusted from zero to full speed.
   C. The motor will run as a generator with the proper wiring.
   D. Motor rotation can be reversed by reversing the leads on the starting winding.

6. Which of the listed fire extinguishers would be most effective to use on a fire in a small electric motor?

   A. Soda acid
   B. Foam
   C. C02
   D. Light water

7. Boiler efficiency and its ability to absorb heat is limited by the need to ________.

   A. maintain an excess of CO during transient firing rates
   B. prevent excess air density at low load conditions
   C. protect the safety valves from excessive temperature
   D. maintain uptake gas temperature above the dew point

8. The cooling water flow from an air ejector intercondenser and aftercondenser is discharged directly into the ________________.

   A. main condenser hotwell
   B. auxiliary condenser hotwell
   C. condensate and feed system
   D. atmospheric drain tank

9. When hydrogen sulfide has been encountered on a MODU, or is anticipated, monitoring devices must sound an alarm (differing from the lower concentration alarm) or otherwise warn employees when the concentration of the gas reaches or exceeds how many parts per million?

   A. 20
   B. 50
   C. 100
   D. 200

10. Mechanical foam used for firefighting, is produced by ___________________.

   A mechanically mixing and agitating foam chemical, water, and air
   B. a chemical reaction of foam components and air
   C. gas bubbles liberated when the foam chemical contacts fire
   D. chemical reaction of foam components and water

ENGINEERING ANSWERS

1-B, 2-A, 3-C, 4-D, 5-D, 6-C, 7-D, 8-C, 9-B, 10-A ***If you have any questions concerning this quiz, please contact the National Maritime Center at (703) 235-1368.***

FLIR-1015.207

INVESTIGATOR'S CORNER

SAVING SECONDS

by Tim Farley

It's a clear, calm sunny day, not a cloud in the sky. You've just cleaned the pool, the water's clean and clear and it's time to grab a cool one. Life is oh ... so good. As you meander back from the fridge you gasp as you catch a glimpse of what looks like your two year old face down and floating in the pool. Your heart drops to the deck, you become flush and fired up all at once, tunnel vision sets in focusing on the only thing that matters; getting to your baby. You drop your drink, heave your body into action blind to the fact you just stepped barefoot on your shattered glass, hurdle the lawn chairs and launch yourself into the water convinced that this is not really happening.

The Chief mate aboard the foreign chemical tanker M/V CHEMBULK SINGAPORE might have felt similarly one beautiful September day in Texas City, Texas. The Mate was on deck overseeing the routine bulk loading operations of Polybutene cargo, a water white combustible/flammable liquid. This cargo was described as benign in appearance, producing no fumes or foul odors. Because of this cargo's volatility and sensitivity to water contamination, the ship's cargo tank receiving it had been thoroughly purged of oxygen with nitrogen, a colorless, odorless inert gas. The oxygen content of the cargo tank was tested prior to loading and found to be two percent.

As the loading operations progressed the Chief Mate suddenly signaled the dock for an emergency shutdown of the transfer procedures and disappeared from sight. Once operations were secured a cargo inspector boarded the vessel to investigate the unexpected stoppage and found the cargo deck completely abandoned. Finally, after rustling out a member of the crew the inspector was informed that two crewmembers were missing, one of which was the Chief Mate. A search of the ship was initiated and the two missing crewmembers were found floating face down in the Polybutene cargo tank.

The investigation into the events that led up to this tragedy revealed that, apparently, a crewman had been stationed near the open cargo tank top in order to monitor the progress of the 1oadinq operations. As the loading progressed the nitrogen atmosphere in the tank was displaced, somehow overcoming the crewman who subsequently fell into the tank through the open tank top.

The Chief Mate, having either noticed the crewman missing or having actually seen him fall into the cargo tank, immediately ordered an emergency shutdown of the cargo operations and rushed to the scene. Whether the Chief Mate entered the tank directly or placed his head into the cargo tank trunk to got a better view of the crewman, we can only speculate. However, the Mate was also overcome by the nitrogen gas and fell into the cargo tank with tragic results.

Many questions are called to mind when looking at this incident. Was the crewman attending the tank fully aware of the hazards involved with loading this cargo? Did he understand that the tank was devoid of oxygen, and the cargo tank had been thoroughly purged with nitrogen, a colorless, odorless gas? Did he understand that, as the tank was filled with product, the atmosphere in the tank would pour out of the tank top?

Why was the crewman overcome? Why was he even near the cargo tank top. Did he put his head in the tank to get a good gauge of the cargo ullage? What was he actually instructed to do? What were his duties? Why wasn't the automatic tank gauging system used? Sufficient precautions were taken to place a barrier between the cargo and any water vapor or ignition source that might be found. Tragically, no consideration was given to the personnel hazards.

Code of Federal Regulation 46, at Section 35.30-10 allows cargo tank 'hatches (tank tops), ullage holes, or Butterworth plates to be open without flame screens fitted as long as the operation is under the supervision of the senior members of the crew or if the opened tank is gas free. Clearly, the open tank top in this case was permitted under the current rules. However, were personnel protected from falling into the tank as is the intent of 46 CFR Section 32.02-15 - Guards at Dangerous Places? This section requires all exposed and dangerous places be properly protected with covers, guards, or rails in order that the danger of accidents may be minimized. If a person can fall into a cargo tank shouldn't the area around the tank top have been secured?

How often do we see cases where someone, rushing to the aid of another, also becomes a victim thus exacerbating the situation. Why does this happen? How could the Chief Mate not be fully aware of the hazards of entering this cargo tank? He would have been intimately familiar with the hazardous atmosphere within the tank as he would have overseen the nitrogen gas purge and the removal of all the oxygen in the tank. Most certainly the Chief Mate experienced an overwhelming need to help, to actively do something for his fallen crewman. Amplify this by a scene described by the investigator's on scene as almost surreal, tranquil, and very benign. There were no apparent indications of danger; no fumes or foul odors. The water-like cargo itself shimmered with a transparent, almost Caribbean blue hue given off by the cargo tank coating. Overcome by events, one can easily understand why the Chief Mate, the Officer on board most responsible for the deck crew and who is accustomed to "getting things done", may have momentarily overlooked the grave nature of the situation and peeked his head into the tank. Unfortunately, this brief lapse of attention may have caused his death.

Certainly, the Chief Mate was one of the best suited crewmembers to understand the hazardous nature of the situation he was in. The question begs, how do we prevent this from happening again? Should tank top's always be fully secured and the atmosphere only released through the vent system? Although preferred, this solution is not always practical. However, had this been the case the final outcome may have been quite different. Someone may still have been overcome by the nitrogen gas (or lack of oxygen) but the chance they would have fallen into the cargo tank itself would have been eliminated. Further, had some type of rail or other physical barrier existed to keep personnel away from the edge of the tank top, it would be quite unlikely this accident would have happened as it did.

A conspicuous sign or signal in close proximity to the hazardous area also might have allowed the Chief Mate just a brief reminder that the cargo tank contained a dangerous, oxygen deficient atmosphere. This might have helped him to take a brief moment to reassess the situation and could have minimized the tragic results of this accident. When the Mate saw one of his crew in distress he acted instinctively to help–went on 'autopilot' so to say. One of his crew, his shipmate, his ward was in trouble and he most likely immediately reacted to the situation without any thought for his safety. Added to the sense of urgency was the fact that the scene was tranquil and had a benign appearance. Had a clear indication of the danger been present, the Chief Mate's memory may have been jogged. This might have him a brief moment to get control of his reactions and respond more appropriately.

The Coast Guard investigating officer who responded to this accident also relayed the following regarding the shoreside rescue team that responded to the incident. Apparently, the rescue team appeared to be ill prepared, not very well trained to handle this type of situation, and were in poor physical condition. They had no apparent awareness of the hazards they were dealing with. They mounted a rescue effort when there was absolutely no hope for rescue. The crewmembers were floating face down in Polybutene in an atmosphere of less than 2% oxygen. The response to this accident was mounted well after any reasonable rescue could be expected. The concentration of the effort should have been the retrieval of the bodies. This would have considerably reduced the unnecessary risk to each of the rescuers.

As it was, the rescuer's hastily responded with ill fitting equipment. The bodies were eventually retrieved but two squad members subsequently collapsed–one on deck, another on the gangway while exiting the vessel. One rescuer actually went for a dip in the product without actually knowing the hazards associated with it.

Exactly twelve days after this accident a similar tragedy occurred near Philadelphia, PA on board the foreign flag bulk carrier, M/V SAGA WAVE. During discharge operations of cut timber, an alarm was raised that a body had been found lying-in the after access trunk of the #8 cargo hold. As the crew mustered to mount a rescue attempt, the Chief Mate arrived obscene and immediately attempted a rescue on his own. By the time the rescue party arrived two bodies were observed in the space. A longshoreman and the Chief Mate were later removed from the space, transported to the hospital, and pronounced dead due to hypoxia caused by exposure to an oxygen deficient atmosphere.

Air samples of the cargo spaces and access trunks revealed that the atmosphere in the opened #8 cargo hold was normal but the after access trunk where the victim's were found contained 14% oxygen as well as an elevated level of carbon monoxide. Similarly, the after access trunk to the #10 cargo hold contained 10% oxygen and a high concentration of carbon monoxide. The cargo contained in holds #8 and #10 was the same and both cargo holds had been loaded and sealed five weeks earlier in Vancover, British Columbia.

Although the cause of the oxygen deficient atmosphere in the access trunks cannot be conclusively determined, it was theorized that a fungicide treatment the timber received during its cultivation sped the natural decay of the wood. Further, this intensified natural reaction when combined with the five week transit through a moist/humid environment (Panama Canal) and the lack of any ventilation, allowed for the depletion of the oxygen supply in the sealed cargo hold and adjacent access trunks.

Since the cargo holds themselves contained little oxygen due to the load configuration, it was felt that the oxygen used for the reaction most likely originated in the

FLIR-1015.209

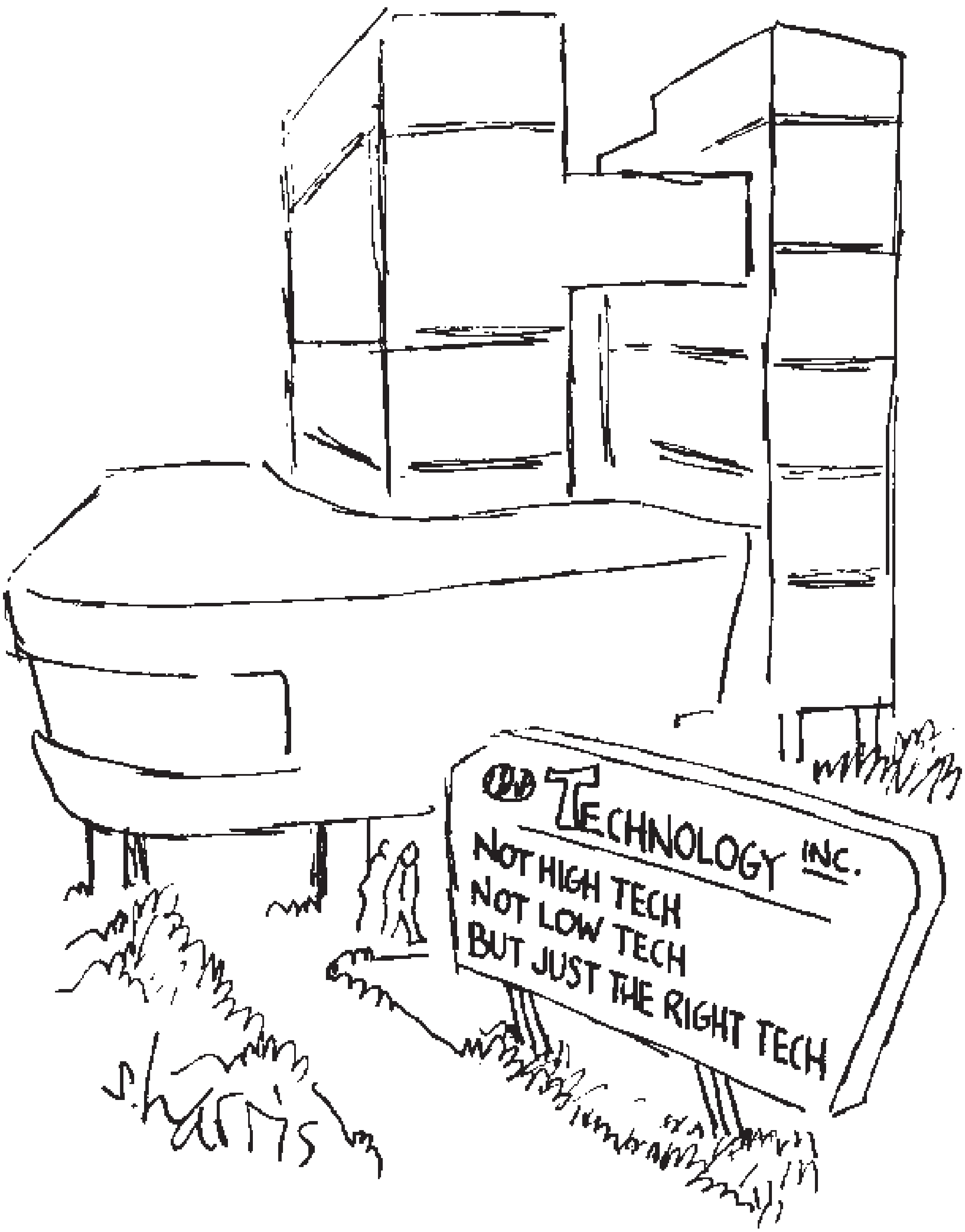
access trunks. These trunks provide cargo hold entry and are separated from the cargo spaces by non airtight doors. The particular access trunks with deficient levels of oxygen were located on the aft end of the cargo holds and, unlike the forward access trunks that have several doors and permit entry to each deck in the cargo hold, the aft access trunks only permitted access to the lower hold area.

Although these two incidents occurred under different circumstances they both illustrate the hazards of working in and around oxygen deficient atmospheres. More importantly, they demonstrate the tremendous risks of responding to a confined space entry accident without taking the opportunity to fully assess the situation at hand in each case a knowledgeable, experienced individual rushed to the aid of another in distress and was caught up in the situation–a natural reaction. Unfortunately, their response put them at great risk.

Had each of the Chief Mate's involved here been able to take a moment to think the situation through, the outcomes of these accidents, although still tragic, may not have been so severe. Although every second counts when responding to a confined space accident, taking several of them for yourself may ultimately save you a lifetime.

Tim Farley
USCG(3 Licensed Master, Any Gross Tons, Oceans
Works as a Safety Specialist in the Investigations and Office, Marine Safety and Environmental Protection - *Commandant (G-MOA)*
Captain Farley has sailed deep sea
Board Oil and Chemical Tankers

FLIR-1015.210



Reprint permission thanks to Sidney Harris.
U.S. Government Printing Office 1996-405-533/20004

FLIR-1015.212

Attachment 3g: Publication citing Document 3

Marine Safety Council

PROCEEDINGS

U.S. Department of Transportation

United States Coast Guard

The Coast Guard Journal of Safety at Sea

July-September 1996

Volume 53, Number 3

How Technology is Affecting the Maritime World

FLIR-1015.215

Attachment 3g: Publication citing Document 3

Front cover photo:
????

Back cover photo:
????

FLIR-1015.216

U.S. Government Printing Office 1996-405-533/20002

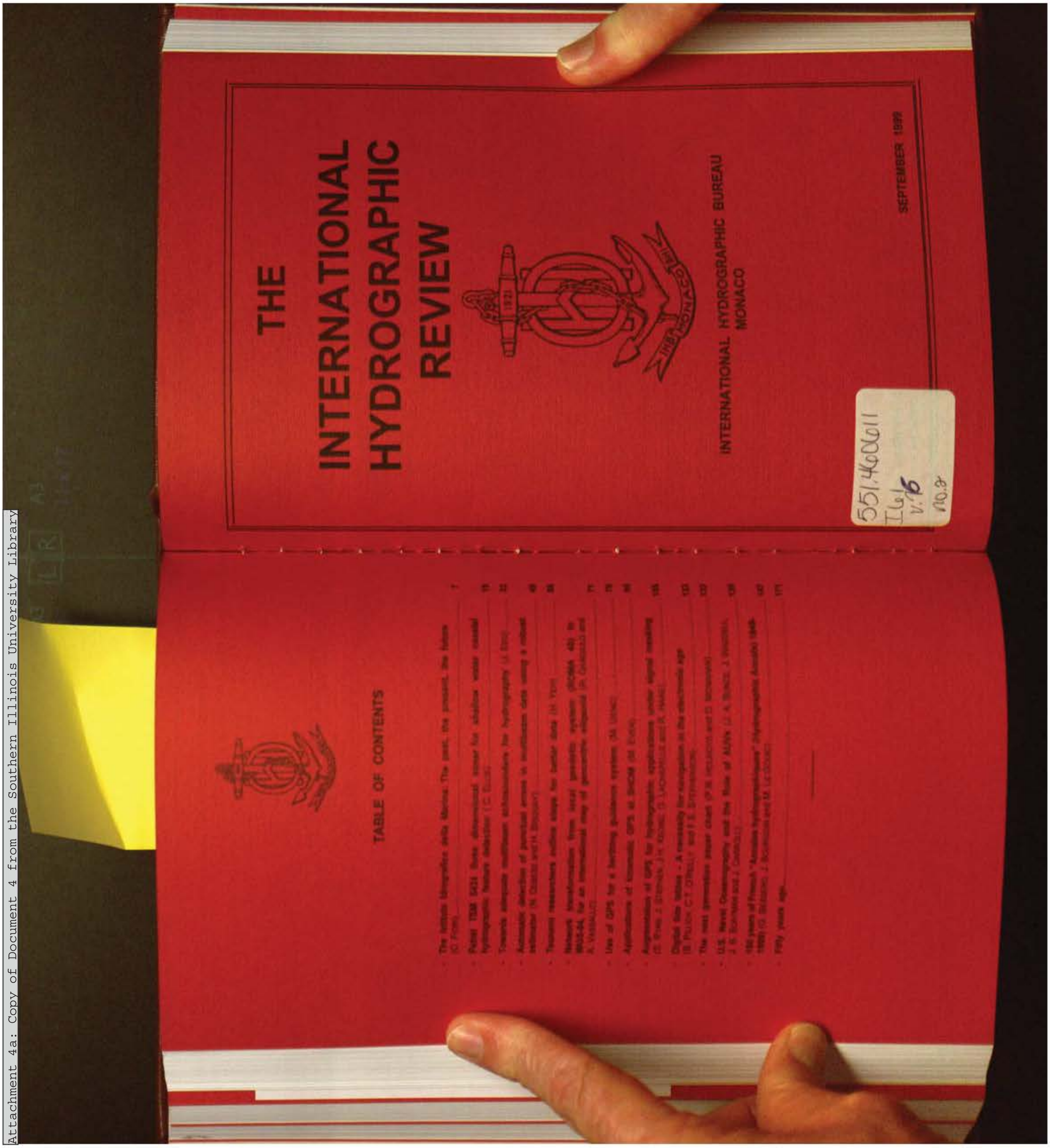
U.S. Department
of Transportation

**United States
Coast Guard**

National Maritime Center
4200 Wilson Blvd., Suite 510
Arlington, VA 22203-1804

Official Business
Penalty for Private Use $300

Attachment 4a: Copy of Document 4 from the Southern Illinois University Library



FLIR-1015.219

AUTRES PUBLICATIONS DU BUREAU HYDROGRAPHIQUE INTERNATIONAL

Pour ce qui concerne les publications de l'OHI et les prix le Catalogue des publications de l'OHI peut être obtenu gratuitement en s'adressant au BHI et à travers INTERNET WEB Home Page <http://www.iho.shom.fr> ou <http://www.ohi.shom.fr>)

PUBLICATIONS PERIODIQUES

P-3 Bulletin hydrographique international
Contient des nouvelles d'actualité, rend compte des travaux effectués par le Bureau H.I. et par la communauté hydrographique mondiale, couvre les développements récents concernant les instruments hydrographiques et les programmes de formation, décrit les nouveaux bâtiments hydrographiques, etc. Une liste de cartes marines et de publications diffusées par les services hydrographiques paraît tous les mois ainsi qu'une bibliographie complète sur l'hydrographie et les sujets connexes (trilingue anglais/français/espagnol).

P-5 Annuaire de l'OHI
Renseignements et adresses des Services hydrographiques du monde entier. Paraît tous les ans (bilingue anglais/français).

PUBLICATIONS MIXTES

M-4 Spécifications de l'OHI pour les cartes marines et règlement de l'OHI pour les cartes internationales (INT)
Fournit les spécifications de l'OHI pour les cartes marines nécessaires à la compilation des cartes marines ainsi que les signes conventionnels et abréviations généralement adoptés par les Etats membres (anglais, français et espagnol).

M-5 Normes de compétence pour les hydrographes - 8e édition
Décrit le niveau auquel on peut accorder l'homologation aux programmes de formation en catégorie A et en catégorie B. Donne les procédures de soumission, la documentation etc. et les programmes complets (anglais, français et espagnol).

M-11 Catalogue des cartes internationales (INT), Directives à l'usage des coordonnateurs régionaux de programmes des cartes INT
Décrit, au moyen d'index, de textes et de cartes, la série des cartes internationales de l'OHI à grandes, moyennes et petites échelles et fournit des directives,à l'usage des coordonnateurs conformément aux principes établis pour les cartes INT (bilingue anglais/français).

FOREWORD

The *International Hydrographic Review* is published twice a year (March and September) in separate English and French editions.

Original articles are welcomed on hydrography, oceanography, cartography, geodesy, navigation, photogrammetry, radio aids, automation, new instruments, equipment and hydrographic vessels, as well as on the history and organization of hydrographic offices.

The latest date for receipt of manuscripts is:

- 1 January for the March issue,
- 1 July for the September issue.

Articles should be addressed to: The Directing Committee, International Hydrographic Bureau, B.P. 445, MC 98011 MONACO Cedex (Principality of Monaco).

Up to 50 reprints per article can be supplied free to the author(s). They must be ordered prior to publication, and may be in either language or a proportion in each. Further copies ordered are charged at cost price, plus postage.

The Directing Committee does not hold itself responsible for statements or opinions expressed by contributors to the Review.

Notes for contributors

Papers should be as concise as possible and an abstract of up to 150 words is desirable. Uncommon expressions or constructions and particularly professional jargon should be avoided since a large proportion of readers are necessarily reading the Review in a language that is not their mother tongue.

Any permission needed to incorporate material published elsewhere is the responsibility of authors, and it will be assumed that such permission has been obtained.

Texts should be submitted in English or French (or both), though by special arrangement articles in Spanish could be accepted for translation in the Bureau.

Articles should be provided in floppy disk, in Wordperfect or Word for WINDOWS. The floppy disk should be accompanied by a typed copy of the article.

Bibliographic references should be listed at the end of the article in the standard Harvard form. Footnotes should be kept to a minimum, and metric measures used throughout.

Illustrations, already numbered and titled, should be supplied ready for reproduction by the offset method and for reduction to 12.5 x 21 cm, the effective size of a Review page. Positive transparencies (repromats) are preferred. Photographs should be black and white with good definition and be limited to those necessary for an understanding of the text. Colour transparencies cannot be accepted. Coloured photographs and plates can only be accepted under special terms that must be discussed directly with the Editor. Reproduction of charts and maps must provide clear definition of the features to be portrayed.

As the Review is a two-language publication a minimum of wording should be shown on the illustrations themselves, explanations being confined to the legend beneath.

Printer's proofs are corrected in the Bureau and are not normally sent to authors.

THE INTERNATIONAL HYDROGRAPHIC REVIEW

Vol. LXXVI N° 2

(N° 145 OF THE SERIES)

PUBLISHED AND PRINTED BY THE

INTERNATIONAL HYDROGRAPHIC BUREAU
B.P. 445 - 4, quai Antoine 1er
MC 98011 MONACO Cedex
PRINCIPALITY OF MONACO

SEPTEMBER 1999

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

MEMBERS OF THE IHO

ALGERIA
ARGENTINA
AUSTRALIA
BAHRAIN
BELGIUM
BRAZIL
CANADA
CHILE
CHINA
COLOMBIA
CUBA
CROATIA
CYPRUS
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EGYPT
ESTONIA
FIJI
FINLAND
FRANCE
GERMANY
GREECE
GUATEMALA
ICELAND
INDIA
INDONESIA
IRAN
ITALY
JAPAN
MALAYSIA
MONACO
MOZAMBIQUE
NETHERLANDS
NEW ZEALAND
NIGERIA
NORWAY
OMAN
PAKISTAN
PAPUA NEW GUINEA
PERU
PHILIPPINES
POLAND
PORTUGAL
REPUBLIC OF KOREA
REPUBLIC OF SOUTH AFRICA
RUSSIAN FEDERATION
SINGAPORE
SPAIN
SRI LANKA
SURINAME
SWEDEN
SYRIAN ARAB REPUBLIC
THAILAND
TONGA
TRINIDAD AND TOBAGO
TUNISIA
TURKEY
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED STATES OF AMERICA
URUGUAY
VENEZUELA
YUGOSLAVIA

INTERNATIONAL HYDROGRAPHIC BUREAU

DIRECTING COMMITTEE

President: Rear Admiral Giuseppe ANGRISANO (Ret.) (Italy)
Directors: Rear Admiral Neil GUY (Republic of South Africa)
Commodore John LEECH (Australia)

For conditions of sale see *Catalogue of IHO Publications*.

TABLE OF CONTENTS

International Hydrographic Review, Monaco, LXXVI(2), September 1999

VOYAGE PLANNING IN ECDIS

by Hein SABELIS [1]

This paper was first presented at the SASMEX Conference, 12-14 April 1999, Rotterdam, The Netherlands.

1. INTRODUCTION

The **aim** of this paper is to emphasize the need for a structured approach to the development of tools for navigation support in ECDIS. To this purpose this paper focuses on voyage planning in ECDIS, outlining a more formal approach, to provide a basis for the development of tools for automated navigation support.

The outline of this paper is as follows:

First it will present some considerations regarding the development of ECDIS functionality,

- then it will get into a definition of voyage **planning,**
- followed by a conceptual framework of **integrated navigation**, which is then used as
- the basis for a more detailed look into the **voyage-planning** process.
- This is followed by an impression of what could be envisaged as automated support tools for voyage planning.
- Some concluding remarks are made in the final paragraph.

2. ECDIS AND NAVIGATION SUPPORT

The electronic chart development started with the sole purpose of replacing the paper chart. Soon it was realised that the electronic chart functionality

[1] Royal Netherlands Naval College, Department of Nautical Sciences, Den Helder, The Netherlands. E-mail: H.Sabelis@kim.nl.

could be expanded to a navigation information system; the name changed from electronic chart into electronic chart display and information system, ECDIS. However, the term 'information system' can still be interpreted as a system which is simply able to display the stored data. In that case the discussion is reduced to the selection of data to be stored, the data structure and the symbology or display format. This basic interpretation does not lead to much added value. The added value improves significantly when the system integrates the available data into improved information products. This synergistic approach usually requires the data to be structured into objects and attributes which can be used in processing algorithms. The real value of ECDIS is determined by its synergism.

When designing support tools we tend to ask the practitioner what he requires. Often however the practitioner is focused on the current procedures and the workload involved. The result may easily be the development of a support tool which in essence is an automated replica of the manual procedure, thus failing to improve the solution because the underlying issue was not identified. Development of support tools should therefore be based on a thorough analysis of the problem to be solved. It should also be borne in mind that the tool should fit into the logical process it is supposed to support, i.e. the tool should provide the required information with the information available in that phase of the process.

The latest report of the workshop on development of Marine Information Objects (MIO) for ECDIS [ECDIS/MIO] showed some of the aforementioned in the resulting recommendations.

The point that is made here, however, is that the development of navigation support tools for ECDIS is rather a result of individual ideas than the results of a structured analysis of the navigation process. It is the author's view that the development of new ECDIS functionality should be founded on some reference-model of the navigation process, identifying logical structure and processes eligible for automated support, possibly including agreed priorities. Manufacturers could then focus their efforts to substantiate the identified functionality, standardisation forums could concentrate on the required data structures, and data suppliers could focus on providing the required data in the required structure in order of the agreed priorities.

The next paragraphs will focus on voyage planning as an area eligible for automated support by ECDIS.

3. VOYAGE PLANNING

3.1 Voyage Planning defined

Voyage planning can be defined as:

> *the systematic process in which a sailing order is translated into an optimal navigation plan and detailed navigation scenario to fulfil the mission, having considered all relevant information.*

The sailing order may differ for the different user groups: transport, fishery, offshore, navy, coastguard et cetera, but there will generally be a mission element and a constraints element that are to be satisfied by the voyage plan. Often the constraints are defined in terms of time, or economy, but they may also include criteria such as ship's motion or temperature constraints.

Voyage Planning is meant to provide:

- Prevention of potential conflicts or dangerous situations;
- Optimisation of planning for specific planning factors;
- A detailed scenario for the execution;
- A reference to compare the actual voyage progression with the planned progression.

Typical of voyage planning is the great diversity of data to be collected, consulted and integrated into both the overall voyage plan, and the detailed navigation scenario for every watch.

3.2 Voyage Plan and Integrated Navigation

This paragraph aims to identify voyage planning in the context of an integrated navigation system. Navigation can be defined as the process of controlling the movement of a craft from one state (position, course, speed, etc.) to another state, under predefined conditions.

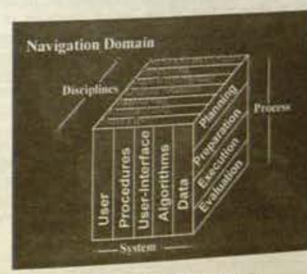


Fig. - 1: The Navigation Domain

From the perspective of elementary **navigation disciplines** (Fig. 1), this definition encompasses a broad variety of subjects, ranging from positioning, meteorology, tides, tidal stream, ocean current, hydrography and topography to anti-collision regulations, communication and ship manoeuvring.

From the **process perspective** navigation is comprised of the consecutive phases of planning, watch preparation, watch execution, and evaluation.

There is also the **system perspective** where we can discern the elements of data, algorithms, user-interface, procedures and the navigator.

With this cube-like model (Fig.1) of the navigation domain in mind we can discern various sorts of system integration. First there is integration of different navigation disciplines, which we could refer to as synergistic integration. Then there is the integration across the various phases of the navigation process, where the products of each navigation phase could be transferred to the next phases. In the system dimension integration is concerned with the allocation of tasks to either the system or the user, based on human factors methodology. In the data segment integration is concerned with data models, data standards and data quality.

In view of the focus of this presentation I will not go into a detailed discussion of integrated navigation. The remainder of this presentation will focus on voyage planning, being the first two phases of the navigation process, across all the disciplines and all segments of the system perspective.

3.3 Voyage Planning Process

The present standard for voyage planning is laid down in the IMO Guide to the Planning and Conduct of passages. This standard discerns the phases of Appraisal, Planning, Execution and Monitoring. Reading this document provides a good impression of the factors to take into consideration. However, the document does not provide a clear picture of the logical structure of the process, the interrelationships of the various aspects to consider, the questions to be answered, and the products resulting from each phase. It is a listing of reminders and things-to-do without logical structure or sequence. Therefore the document does not provide a basis which is sufficient for the development of coherent automated support tools for voyage planning.

Voyage planning is not a straightforward process which leads to the correct answer. It is much more a search through a wide variety of, often time-variant, information in many different publications. The navigator's task is to identify and comprehend the most important aspects to develop his voyage plan. In doing so he is repeatedly revisiting these aspects at an increasing level of detail while at the same time the voyage plan develops.

Fig. - 2: Voyage Planning Process

Voyage planning can be seen as an iterative cyclical process, (Fig.-2) as represented by a spiral model, with a standard logical structure and a clearly defined product for every cycle. Each product serves as a directive for the next cycle. The first cycle, *route planning*, is concerned with selecting the best route; the product is the **route plan**, an outline description of the route which is feasible within the constraints provided in the sailing order.

The second cycle, *navigation planning*, is concerned with the question how to navigate the selected route: the precise track to follow, the associated safety margins, track deviation tolerances, the overall time schedule and the navigation procedures for the different phases of the voyage (Fig.2).

The resulting **navigation plan** should provide guidance for every officer of the watch to independently carry out his *watch preparation* resulting in a fully detailed **navigation scenario** for his watch.

Theoretically speaking each cycle as aforementioned consists of the consecutive phases of *analysis, synthesis, decision*, and *direction* for the next cycle. The analysis-phase starts with the basic issues such as: what is required, within which constraints, which information is required, what does that information indicate. In the synthesis-phase options are generated and considered. Next the plan is finalised in the decision-phase and worked out to the required detail in the direction phase in order to serve as a reference directive for the next phase.

This formal description of the voyage planning process may seem very theoretical to the navigation practitioner. However, the experienced navigator may well recognise the essential ingredients in the procedure he personally developed over the years. This theoretical procedure is not meant to be formally implemented in full detail in the daily navigation practice. It is meant to provide the basis for development of automated tools to support the voyage planning process.

4. VOYAGE PLANNING SUPPORT OUTLINE

The following paragraphs provide an outline description of voyage planning support as envisaged for ECDIS. It is based on the aforementioned analysis. It is not meant to provide a complete picture. It is an extract, just to provide an impression of the required functionality that would result from a proper analysis.

4.1 Cycle-1: Route planning

The aim here is to select the best route fulfilling the mission within the constraints as prescribed. The system requests the ports of departure and arrival to be identified on an overview map, including the basic planning constraints in terms of ETD and ETA, speed characteristics and maximum draught, cargo class. The system searches a predefined route network, to come up with an **outline of feasible route options**. 'Feasible' in this stage indicates that the basic ship's constraints have been verified against the route constraints. Therefore the attributes of each leg of the route network include the basic parameters of that leg, such as distance, maximum allowable draught, speed limitations and prohibited cargo classes. Attributes may also provide references to other limitations that should be brought to the attention of the mariner on presenting the route as a feasible option.
Next the presented route options are verified against a climatologicl and oceanographic database for critical and significant environmental factors as defined by the operator in terms of wind-speed and –direction, seastate, ice, ocean currents. Unfeasible route options (e.g. through ice) are then deleted and significant environmental characteristics are assigned to the remaining route options. The result is an overview of feasible route options with their specific characteristics in terms of distance, time, economy, and environmental factors, providing the necessary information to make an initial route selection. The result is a route defined by Route points and connecting legs, with an associated bandwidth for detailed track planning, together with an initial time-schedule and possibly some pointers urging for more detailed planning, such as tidal time-slots.

4.2 Cycle 2: Navigation planning

The main questions to be answered in this cycle are concerning the definition of navigation track, its subdivision into phases of navigation (e.g. ocean, coastal, confined waters, inshore conditions), the associated safety margins and cross-track tolerances, the associated navigation procedures, and the detailed planning of critical elements of the voyage (e.g. tidal time-slots, critical passages, etc.). Before the course lines are drawn the system should mark areas of unsafe waterspace (within the defined route bandwidth). Then it highlights the vessel traffic data along the route such as TSSs and recommended tracks and routes. With this information the navigator can draw the initial course lines. Next, the system provides an initial subdivision of the track into the standardised phases of navigation. Assigning these phases of navigation automatically assigns specific (standardised) navigation procedures (positioning procedures, manoeuvrability, bridge manning,

etc.) to each phase of the route. Then the track is tested for critical points, as defined by the user, based on a combination of criteria such as safe water margin, positioning accuracy, tidal stream and water depth, prompting the navigator to adjust the track or to define additional measures and criteria in a decision point.

Then the system generates associated information regarding traffic management (reporting point, procedures etc.), pilotage (procedures, positions etc.) and communication, based on the fairways and traffic management regions that are passed. The resulting Navigation plan provides all information for every officer of the watch (OOW) to do the planning of his next watch in full detail.

4.3 Cycle-3: Watch preparation

The aim of this cycle is to produce a fully detailed navigation scenario for the next four to six hours.

Upon starting his preparations the OOW will require a geographical overview of the voyage with a small window indicating the area of interest for the hours of his watch. From here the OOW will focus on the area within this window to familiarise with details of the navigation plan for his watch. The system recalculates the planned time schedule in case of any significant deviation from the route or time schedule. This may also involve recalculation of tidal streams UKCs etc. Now the OOW will need to review the weather situation for his watch. To this purpose the system provides a comprehensive graphical presentation of the weather situation, based on actual data (own sensors), nowcast- and forecast-data, focused on: wind, seastate, visibility and precipitation. The OOW draws conclusion on impact on speed limitations, positioning options and collision avoidance. The next step is for the OOW to plan every course alteration in full detail under the anticipated circumstances of tidal stream, visibility and traffic.

Then the OOW attempts to picture the visual environment in terms of both general and navigation specific characteristics. The system may provide support by detailed pictures, annotated aerial overviews and possibly a video impression. This information may be augmented by a textual description, which is kept to a minimum.

The navigation plan, together with the detailed complementary information can be seen as the detailed navigation scenario in which the track and the associated time schedule are leading for the actions to take, in terms of manoeuvres, radio communication, ship's procedures, navigation procedures and decisions on feasibility.

Once again this description is far from complete, it is just an extract, meant to provide a picture of logical structure derived from analysis of the underlying process, resulting in options and requirements for automated support.

5. CONCLUDING REMARKS

Modelling the process to be supported provides a clear insight into the logical sequence of questions to be answered, with the data available in the specific phase of the process.

This can provide logic and structure into the supporting system, thus inviting the user to follow a structured process, at the same time ensuring that all relevant information is considered. A formal analysis of marine navigation and the processes involved could serve as a reference for manufacturers, data managers, researchers and regulators to provide coherence and purpose into the development of ECDIS as an information system. It could also serve as a reference for the customer to compare and contrast different systems.

Bibliography

IMO, International Maritime Organization; *Guide to the Planning and Conduct of Passages*; IMO Circular SN/CIRC. 92; London, 23 October 1978.

IMO, International Maritime Organization; *Performance Standards for Electronic Chart Display and Information Systems (ECDIS)*; Resolution A.817(19) adopted at the 19th session of the IMO general Assembly, London, 23 November 1995.

STCW-95, Standards for Training Certification and Watchkeeping 1995; *Voyage Planning*; STCW Convention of 1995, Section A - VIII/2; London 1995.

International Hydrographic Review, Monaco, LXXVI(2), September 1999

A COMMERCIALLY BASED SERVICE FOR THE DISTRIBUTION OF ELECTRONIC CHART UPDATES

by Dr Andy NORRIS [1]

This paper was first presented at the SASMEX Conference, 12-14 April 1999, Rotterdam, The Netherlands.

. A new service to mariners is now available that can broadcast both electronic and paper chart updates directly to vessels at sea. This gives the mariner an affordable and future-proof path to immediate access to the latest data available from hydrographic offices, enhancing safety and easing the job of the mariner in keeping charts properly updated. The broadcast service also provides the mariner with other navigational data such as precision position fixing, weather and sea state forecasts.

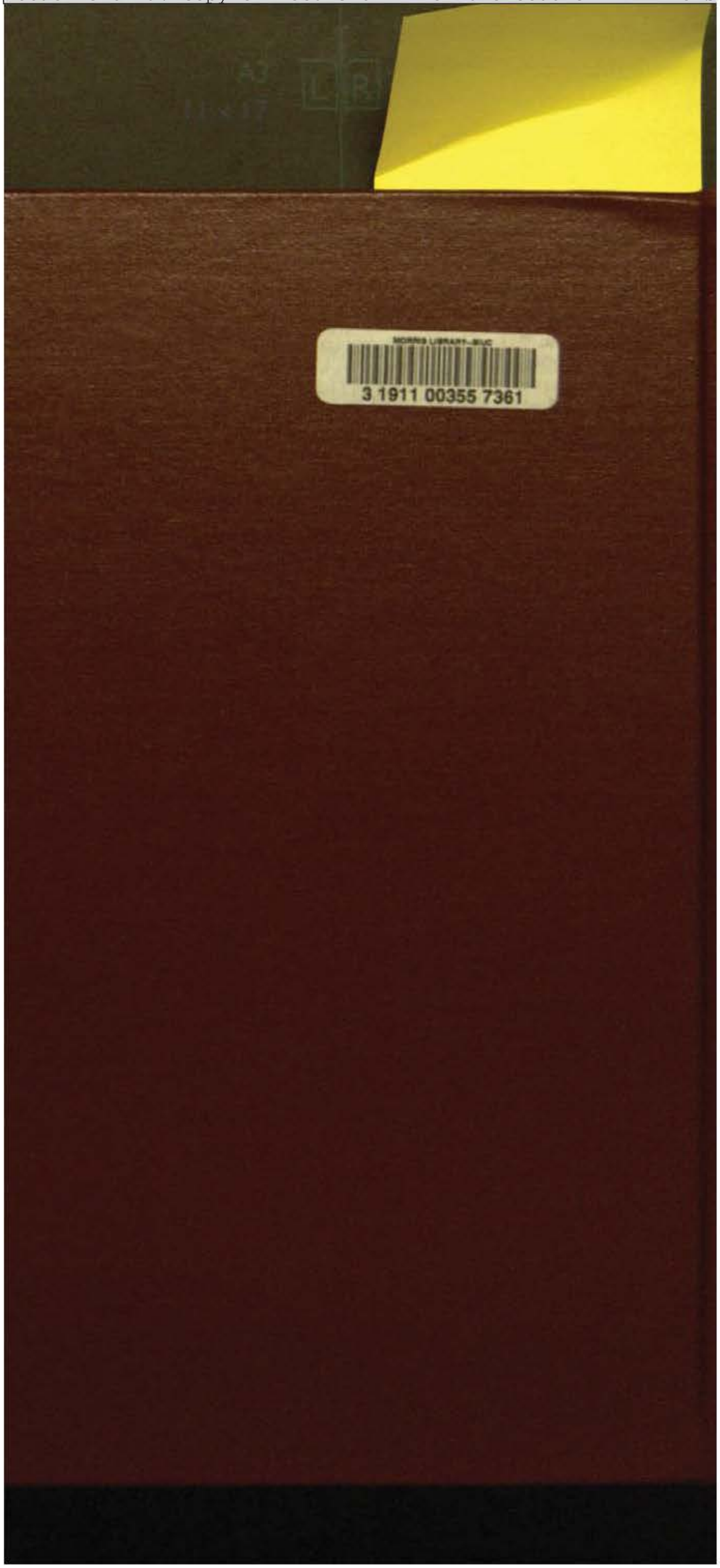
INTRODUCTION

It has always been recognised that an important advantage of electronic charts is in the relative ease of getting up-to-date chart information directly to the mariner by telecommunications. Hence charts may be updated easily and accurately to the latest information supplied by hydrographic offices with minimum effort by the mariner.

In the more distant future we can envisage that when a mariner wishes to use a particular chart, either for planning or route monitoring purposes, then the latest (fully updated) copy available from the relevant hydrographic office will be immediately 'down-loaded' to the vessel. The vessel would not need to carry a local

[1] Managing Director ChartCo.

Attachment 4a: Copy of Document 4 from the Southern Illinois



Attachment 4b: Southern Illinois University Library catalog record for the International Hydrographic Review

The International hydrographic review.

Published: Monaco, International Hydrographic Bureau, 1947-

Topics: Hydrography - Bibliography - Periodicals. | Hydrography - Periodicals.

Tags: No Tags, Be the first to tag this record!   Add

More Details | Location & Availability | User Reviews | Request Item

Southern Illinois University Carbondale

Location:	Dewey Books, Basement
Call Number:	551.460611 I61 Text me this call number
Copy:	1
Library Has (Volumes):	v.75-76 (1998-1999) c.1
	v.73-74 (1996-1997) c.1
	v.71-72 (1994-1995) c.1
	v.69-70 (1992-1993) c.1
	v.67-68 (1990-1991) c.1
	v.65-66 (1988-1989) c.1
	v.63-64 (1986-1987) c.1
	v.61-62 (1984-1985) c.1
	v.59-60 (1982-1983) c.1
	v.57-58 (1980-1981) c.1
	v.55-56 (1978-1979) c.1
	v.53-54 (1976-1977) c.1
	v.51-52 (1974-1975) c.1
Status:	v.75-76(1998-1999) c.1 - Checked out (Due: February 6, 2017)

Attachment 4c: Scopus index record for Document 4

Document details

International Hydrographic Review
Volume 76, Issue 2, 1999, Pages 41-48

Voyage planning In Ecdis (Conference Paper)

Sabelis, H.
Department of Nautical Sciences, Royal Netherlands Naval College, Den Helder, Netherlands

View references (3)

Abstract
[No abstract available]

ISSN: 00206946 Source Type: Journal Original language: English
Document Type: Conference Paper

References (3)

View in search results format

All Text export | Print | E-mail | Create bibliography

1 (1978) *Guide to the Planning and Conduct of Passages*, 92.
IMO, International Maritime Organization, IMO Circular SN/CIRC. London, 23 October

2 (1995) *Performance Standards for Electronic Chart Display and Information Systems (ECDIS)*. Cited 7 times.
IMO, International Maritime Organization, Resolution A.817(19) adopted at the 19th session of the IMO general Assembly, London, 23 November

3 (1995) *Voyage Planning*
STCW-95, Standards for Training Certification and Watchkeeping 1995, STCW Convention of 1995, Section A - VIII/2; London

Sabelis, H.; Department of Nautical Sciences, Royal Netherlands Naval College, Netherlands; email:H.Sabelis@kim.nl

Attachment 4d: Statewide Illinois Library Catalog record for the International Hydrographic Review

The International hydrographic review.

International Hydrographic Bureau.

1947-2008
English Serial Publication : Periodical : Semiannual (twice a year) volumes : illustrations ; 28 cm
Monte-Carlo, Monaco Principality : International Hydrographic Bureau,

GET THIS ITEM

Availability: **FirstSearch indicates your institution subscribes to this publication.**
- Libraries worldwide that own item: 150 UNIV OF ILLINOIS
- Search the catalog at the Library of University of Illinois at Urbana-Champaign

External Resources:
- Discover full text Discover UIUC Full Text
- Interlibrary Loan Request
- Cite This Item

FIND RELATED

More Like This: Advanced options ...
Browse Journal: Available Issues (ArticleFirst)
Find Items About: International Hydrographic Bureau. (51)

Title: **The International hydrographic review.**
Corp Author(s): International Hydrographic Bureau.
Publication: Monte-Carlo, Monaco Principality : International Hydrographic Bureau,
Year: 1947-2008
Frequency: Semiannual, 1948-; **Former:** Annual, 1947
Description: Vol. 24 (1947)-v. 76, no. 2 (Sept. 1999) = no 42-no 145 ; new ser., vol. 1, no. 1 (July 2000)-new ser., vol. 9, no. 2 (Aug. 2008).; volumes : illustrations ; 28 cm
Language: English; In English and French.
Standard No: **ISSN:** 0020-6946; **CODEN:** IHYRA4; **National Library:** 012266167; 410971-5; **LCCN:** 26-20627 ; sn 85-19358

SUBJECT(S)

Descriptor: Hydrography -- Periodicals.
Hydrography -- Bibliography -- Periodicals.
Hydrographie -- Périodiques.
Hydrographie -- Bibliographie -- Périodiques.
Hydrography.
Hydrografie.

Genre/Form: Bibliography.
Periodicals.

Note(s): Published: Lemmer [Netherlands] : GITC bv, 2000-/ Vol. 27-v. include section: International hydrographic bibliography (title varies)./ Also issued on microfilm./ **Supplement:** International hydrographic bulletin/ 0020-6938
General Info: Vols. 19-47.
Class Descriptors: **LC:** VK798; **Dewey:** 551.460611
Other Titles: Int. hydrogr. rev.; The International hydrographic review
Preceding Title: Hydrographic review; (DLC)sn 85019357; (OCoLC)1775808
Material Type: Government publication (gpb); International government publication (igp); Periodical (per)
Document Type: Serial
Entry: 19760828
Update: 20160512
Accession No: **OCLC:** 2401183
Database: WorldCat

FLIR-1015.231

Attachment 4d: Statewide Illinois Library Catalog record for the International Hydrographic Review

ANNUAL OF NAVIGATION 3/2001

Zdzisław Kopacz, Wacław Morgaś, Józef Urbański
Naval University of Gdynia

AN ATTEMPT OF THE SPECIFICATION OF THE SHIP'S NAVIGATION PROCESS

ABSTRACT An attempt of the specification of main issues, such as the objectives, tasks, activities, etc. which are being solved and are being done while the ship is conducted at sea is undertaken in the paper. These issues constitute the substance of the ship's navigation process and all its sub process. The authors' belief is that the specification of these issues would enable the better understanding the matter of ship's navigation process. It could also facilitate the preparation of more precise algorithms of all navigation sub processes, i.e. even those which hardly could be expressed by the means of mathematical relations.

INTRODUCTION

The "integrated ship navigation systems" are composed of modules, such as navigation module, auto-sailing module and collision avoidance module. Many ships are also equipped with weather routing module. Each of theses modules fulfills one or several navigational functions, i.e. navigation's sub processes.

The heart of the navigation module, which realizes most of the navigational functions, will become soon the Electronic Chart Display and Information System (ECDIS).

The higher development's level of ship navigation systems constitute the "integrated ship's navigation and platform control systems", such as Integrated Bridge Systems. However the most advanced, although still being-under-development, are "the integrated ship's operation control systems"[Kopacz et al. 1998]. Probably the future intelligent and "almost unmanned" ships will be equipped with such system. Such systems will be composed of many expert systems which will control the realization of all ship's processes. Such system will be supervised by the captain-operator which can be situated at own ship, at shore, at accompanied ship, or his function can be performed by the properly programmed "computer-captain".

However, regardless of the advancement's degree of automation of ship's navigation system and integration with other ship's systems, i.e. platform control systems and command and combat management systems - the ship's navigation process and its sub processes remain almost unchanged. Therefore, the knowledge regarding the substance of ship's navigation process and its sub processes is getting more and more important.

This knowledge is essential:

- for educational process,
- for evaluation, approval and survey of navigational equipment and systems,
- for perfecting the above equipment and systems,

Below, there are presented two main issues:

- the ship's navigation process, its sub processes, phases and participants,
- the specification of all ship's navigation sub processes.

THE SHIP'S NAVIGATION PROCESS, ITS SUBPROCESSES, PHASES AND PARTICIPANTS

The term "ship's navigation process" means the process of safe and efficient conducting the ship at sea from one place to another.

The ship's navigational process (nav) is composed of several sub process, so-called also the "navigational functions" (Fig 1.) The ship's navigation process can be expressed as follows:

$$nav= [inf \wedge pln \wedge wea \wedge sta \wedge pos \wedge man \wedge col \wedge mco \wedge rec] \quad (1)$$

where: inf = information acquisition and storing,
pln = voyage planning,
wea = weather–damage minimizing,
sta = stabilizing ship's course or track,
pos = ship's positioning,
man = ship's maneuvering and handling,
col = collision avoidance,
mco = monitoring and controlling the ship's navigation process,
rec = ship- voyage/passage-data recording

While the passage preparation, there are activated and working three initial sub processes (Fig.1). Only while the voyage/passage execution, there are activated and performed all ship's navigation sub processes, i.e. only then the whole ship's navigation process is being performed.

The ship's navigation process can be expressed by the following transformation formula

$$nav: (Prin, Stpr) \rightarrow Napa \quad (2)$$

where [Prin] is the primary navigational information, [Stpr] are the standards and procedures concerning the ship's navigation process, and [Napa] are the navigational parameters.

Attachment 4e: Copy of a publication citing Document 4

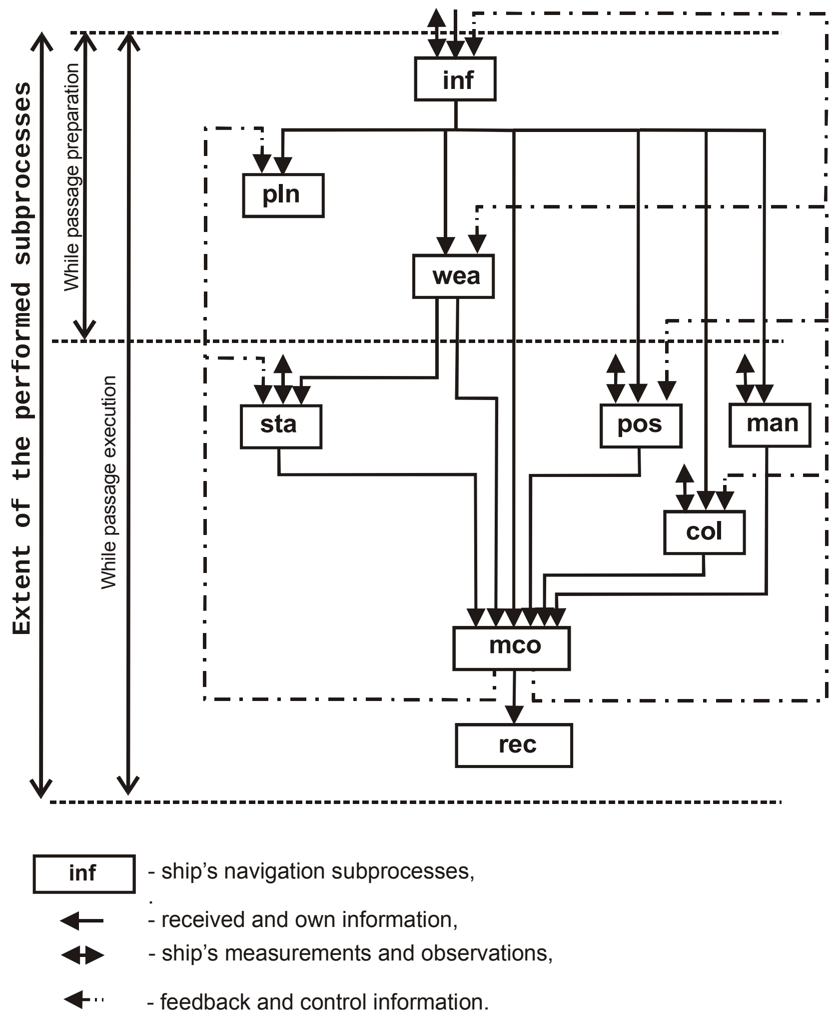


Fig. 1 The ship's navigation process and its subprocesses

Each ship's voyage (voya) include all or several of the following voyage phases:

- docking phases (dock),
- harbour phase(harb),
- restricted water phase (rest),
- ocean (open water) phase (ocea).

FLIR-1015.235

The ship's voyage (voya), which includes ocean phase (ocea), can be expressed as follows:

$$\text{voya} = [\text{dock} \wedge \text{harb} \wedge \text{rest} \wedge \text{ocea} \wedge \text{rest} \wedge \text{harb} \wedge \text{dock}] \quad (3)$$

The main participants of the ship's navigation process are (Fig. 2.):

- own ship and her navigation system,
- maritime geographical environment,
- other ships participating in the surrounding traffic,
- elements of the Maritime Navigation Safety System, i.e. the legal and operational ship's environment.

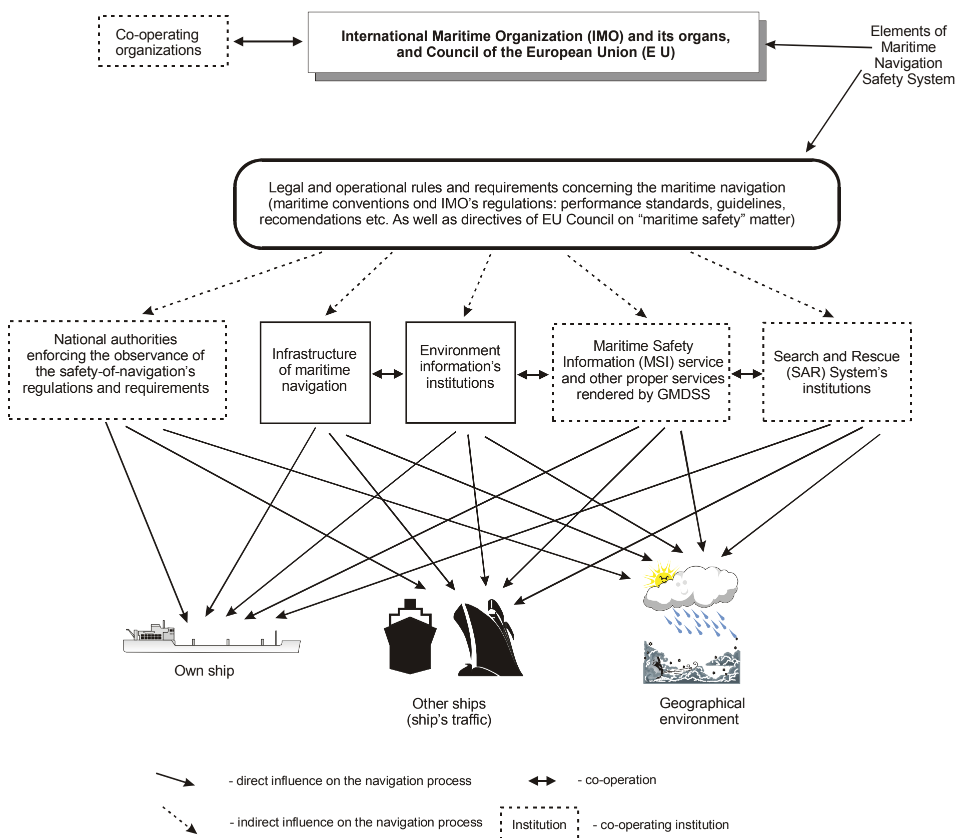


Fig. 2. The participants of the ship's navigation process.

Attachment 4e: Copy of a publication citing Document 4

THE SPECIFICATION OF THE SHIP'S "INFORMATION ACQUISITION AND STORING" SUBPROCESS

The ship's "information acquisition and storing" subprocess (inf), is the first navigation's subprocess (Fig.1).

The main subject of this subprocess is the ship - environment's information, i.e. geographic – environment's information and legal and operation-environment's information. The ship-environment's information must include also the information regarding ship's navigational characteristics and ship-tasks' characteristics.

The main objective of the ship's "information acquisition and storing" subprocess is to provide the ship timely with all kinds of necessary ship-environment's information, in proper amount, updated, and presented in suitable forms.

The first questions to answer is who and how are defined the kinds, forms of presentation, and amount of particular kinds of ship-environment's information.

The answer should be given taking into account the basic legal acts regarding the maritime navigation and its safety, i.e.:

- international maritime conventions such as SOLAS 74, COLREG 72, STCW 78/95 and SAR 79, but especially two chapters of SOLAS Convention, i.e. chapter IV: Radiocommunications, and chapter V: Safety of Navigation.,
- IMO's resolutions, i.e. General Assembly's resolutions and Maritime Safety Committee's resolutions regarding the "navigation's process", as well as directives of EU Council concerning navigation's matters,
- requirements of international institutions being responsible for supplying the ships with the maritime environmental information, i.e. World Meteorological Organization (WMO), International Hydrographic Organization (IHO), International Association of Lighthouse Authorities (IALA), and others,
- operational requirements concerning particular ship under discussion (merchant, naval or special ship) and the tasks performed by her (bulk goods or crude oil carriage; kind of performed warfare tasks, etc.).

The tasks to be realized by the "ship's information acquisition and storing "subprocess can be expressed as follows:

- give immediately the answer regarding the state of information being in ship's disposal,
- define what kinds and what amount of information is needed for realization of new ship's operational task,
- acquire the needed kinds and amounts of information (charts, nautical publications, etc.),
- store the whole necessary information at ship,
- ensure the up-dating the information stored at ship,
- retrieve the information without delay and in necessary forms of presentation.

FLIR-1015.237

The Main Kinds of Ship-Environment's Information.

The information regarding ship's environment contains the following kinds of information:

- information describing the navigational and operational characteristics of own ship [Ship],
- information describing the parameters of ship's task [Task],
- information describing the geographical (maritime) environment [Envi],
- information describing the legal and operational environment in which the navigation process is being realized (standards, procedures, etc.) [Loin].

The ship-environment's information [Senv] can be expressed as follows:

[Senv] = [Ship, Task, Envi, Loin] (4)

Because the contents of information regarding own ship [Ship] and ship's tasks [Task] are rather obvious, only two last kinds of information are subject of further considerations.

The Geographic-Environment's Information.

The set of geographic-environment's information (Envi) contains the following sets of information

[Envi] = [Char, Msin, Fore] (5)

where [Char] is the chart information, [Msin] is maritime safety information, and [Fore] is the long-term weather information.

The set of chart information [Char], i.e. the information which constitutes the content of paper charts and nautical publications, or content of the ECDIS data base, can be expressed as follows:

[Char] = [Hrol, Hgra, Infr] (6)

where [Hrol] is the hyrometeorological information, [Hgra] is the hydrographical information, and [Infr] is the information describing the navigational infrastructure.

The set of the hydrometeorological information [Hrol] can be expressed as follows

[Hrol] = [Clim, Sesu, Sewa] (7)

where [Clim] are the average values describing the sea climate, [Sesu] are the average values describing the sea surface, and [Sewa] are the average values describing the dynamic and static parameters of sea water being of importance for ship's navigation.

The set of the hydrographical information [Hgra] contains the following types of information

[Hgra] = [Dept, Isob, Grou, Obst, Tide, Curr, Vari, Topo] (8) where [Dept] are the sea depths, [Isob] are isobaths, [Grou] are the kinds of sea bottom grounds, [Obst] are the ship wrecks and other kinds of fixed obstacles, [Tide] are the parameters of sea tides, [Curr] are the parameters of sea currents, [Vari] is the variation, and [Topo] are topographic elements and features being of importance for ship's navigation.

The set of information regarding the navigational infrastructure [Infr] can be expressed as follows

[Infr] = [Aids, Ways, Assi] (9)

where [Aids] are aids to navigation (floating and fixed sea marks, electronic position-fixing systems, etc.), [Ways] are the sea ways (artificial canals, fairways, anchorages, passing areas, etc.), and [Assi] are the navigation assistance systems (pilotage services, traffic separation schemes, ship's reporting systems, Vessel Traffic Services, etc.).

The set of maritime safety information [Msin] contains the following types of information

[Msin] = [Warn, Weat, Sari] (10)

where [Warn] are the navigational warnings, [Weat] is the weather-forecast information, and [Sari] is the SAR-system information.

Legal - and Operation – Environment's Information.

The set of information regarding the ship–legal and-operation's environment [Loin] should contain these kinds of legal and operational constrains which influence passage planning and passage correcting and safe and efficient conducting the ship at sea.
The set of [Loin] information can be expressed as follows

[Loin] = [Leco, Opco] (11)

where [Leco] are the legal constraints regarding passage planning and monitoring, and [Opco] are the operational constraints regarding planning and execution of ship's navigation process.

The sources of the legal and operational constraints are given in subsection

THE SPECIFICATION OF THE "PASSAGE-PLANNING" SUBPROCESS

The problem of " voyage/passage-planning" subprocess are specified in two legal acts, i.e. (i) "Guide to the Planning and Conduct of the Passages" (IMO Circular SN/Circ. 92, 1978) and up-dating it: (ii) "Guidelines for voyage planning" (Resolution A.893 (21/1999). There are many elaboration's, also in Polish, regarding the voyage/passage planning and execution. The following considerations concern mainly the specification of this process and have rather the theoretical character.

Attachment 4e: Copy of a publication citing Document 4

They should be considered as an attempt to specify the logical sequence of consecutive items which could be used as the basis for preparation of algorithms and programs for ECDIS and which, consequently, could be used not only for rough but also for precise planning the ship's passage. Therefore, the authors present their own proposals regarding this question.

The main objective of the passage planning subprocess is:

- select, for given ship and her tasks, the most suitable route (passage) free from permanent navigational dangers,
- facilitate and make more effective the navigational watch process by preparing all necessary data, regarding navigational process, for use while the navigational watch is being performed.

The " voyage/passage planning" subprocess is being started and performed both before the ship's passage is begun and while ship's passage is performed (Fig.1). We constrain our considerations to the passage planning performed before passage execution.

The ship's "passage-planning" is being performed during two staged, i.e.:

- rough passage – planning stage,
- precise passage – planning stage.

The main aim of rough passage – planning is to select the safety ship's route, while the main aim of precise passage- planning is to prepare passage scenario, as the main aid for passage execution.

First Stage of Passage – Planning: Selection of Ship's Route.

The main aims to be achieved while performing this stage, are:

- select, for given ship and her tasks, the most suitable route free from permanent navigational dangers,
- obtain the rough data (times, distances, average speeds, etc.) for precise planning.

There are three kinds of constraints which should be taken into account while route selection:

- legal and operational constraints,
- own – ship characteristics' constraints,
- geographic – environment's constraints.

To the group of legal and operational constraints belong the following:

- prohibited areas,
- legal and operational constraints resulted from the kind of the ship and performed tasks (general cargo ship, crude oil tanker, fishery ship, naval ship, special ship, etc.), as well as estimated times of departure (ETDs) and arrivals (ETAs), and other.

To the group of constraints resulted from the own-ship characteristics belong ship's draught, horizontal dimensions of safety domain, speeds and ship's handling characteristics and seagoing characteristics,

FLIR-1015.240

To the group of geographic – environment's constraints belong areas with insufficient depths and other hazardous areas and areas where the hydrometeorological conditions, for given ship or her tasks, are (or could be) dangerous or highly unfavorable (ice, sea current, tides and tidal streams, sea state, wind parameters, etc.).

The selection of ship's route consists in choosing the successive route's legs - beginning from the position of unberthing, unmooring, or weighing anchor - and checking if the each route's leg is free from all of the above mentioned constraints. The selection of the ship's route is finished when all route's legs, between position of departure and arrival, had been chosen and each route's leg is free from constraints.

Second Stage of Passage – Planning: Passage Scenario Preparation.

The main aim to be achieved while performing this stage of passage – planning, is to prepare the passage scenario as reference data for using by the officers of navigational watch

The passage scenario should contain:

- graphical presentation, on charts, in proper scales, the whole ship's passage,
- timetable of all expected navigational events and relevant activities which should be performed by the officer of the watch.

The preparation of passage scenario should contain the realization of the following tasks (activities):

- exact outlying of the whole ship's track, having tacking into account the requirements of Traffic Separation Schemes (routes, recommended tracks, etc.),
- adjusting, if necessary and possible, the periods of passing the critical areas (restricted waters, straits, etc.) to the proper day's period (dark, day, twilight, etc.),
- adjusting, if necessary and possible, the moments of passing the important way points or hazardous areas (e.g. areas of excessive tidal effects, etc.),
- dividing the whole route into the proper voyage phases (docking phase, harbor phase, restricted-water phase, etc.), and division of each voyage phase into the day segments (day's segments, twilight's segments, etc.) and providing for each segment the proper positioning accuracy (and therefore method of positioning), way of steering, amount of bridge team, etc.,
- estimating the times of approaching all way points, values of course changes, as well as the time moment of beginning and ending of the turn,
- determining the times of passing, as well as the characteristics of all buoys and beacons,
- determining the times of approaching the ships reporting points and proper reporting procedures,
- determining the times of entering the vessel-traffic-vessels' zones, the proper communication procedures and ship's behavior,

- determining the times of approaching the points of pilot's call, embarking and disembarking, as well as communications procedures,
- checking the initial and final positions, times, courses, speeds and passage times of each route's leg,
- checking and determining the times of events, as well as proper activities of other important passage issues.

The passage scenario, besides the graphical presentation of the data on the charts of proper scales, should contain the time-table of all important navigation events, as well as activities (deeds, procedures) for the prospective realization by the officers of the watch.

THE SPECIFICATION OF THE "WEATHER - DAMAGE MINIMIZING" SUBPROCESS

Bad weather, including fog, was in the past one of the most important factors of ships wreckage. At the beginning of 19th century, bad weather was the reason of 46% ships catastrophes (collisions in foggy weather, grounding, beaching and foundering resulted from the heavy weather). Today, the situation changed dramatically. Nonetheless, even today, bad weather results in serious weather damages.

The term "weather damage" means all kinds of losses being the result of adverse weather conditions, i.e. from delays of ships arrivals or increased fuel consumption to damages of board equipment, hulls or even ships foundering.

The "weather - damage minimizing" subprocess is very mixed and complex. Therefore, only some it most general characteristics can here be mentioned.

There are two main ways of minimizing the weather damages, i.e. ships weather routing and proper maneuvering while in heavy weather.

The "ship weather routing" is much more effective, if the ship is equipped with Weather Routing System, or the ship is serviced by the "Ship Routing Agency". However, the deployment of the Global Maritime Distress and Safety System (GMDSS) and permanent progress in weather - forecast process make the weather - minimizing subprocess much more accessible and much more effective for each ship.

The second way of minimizing the weather damages, i.e. proper maneuvering while heavy weather, is the basic way of each ship's behavior while sailing in heavy weather. Therefore, our further considerations regard only the behavior of ships being endangered by heavy weather, or being in heavy weather.

The proper maneuvering the ship while in heavy weather can also be considered as an element of "ship's maneuvering and handling" subprocess.

There Exists the Danger of Tropical Storm

Below, there are given the successive steps which should be followed when in danger of tropical storm.

(i) if danger of tropical storm exists, then maneuvering to avoid eye of tropical storm,
(ii) if danger of encountering the eye of the tropical storm exists, then maneuvering to avoid the dangerous semicircle,
(iii) if danger of encountering the dangerous semicircle exists, then maneuvering to avoid the dangerous quarter,
(iv) if in dangerous quarter, then fighting against storm; however, most reasonable seams to be riding out the storm.

There Exists the Stormy Weather

Below, there are given the successive steps which should be followed when, for a given ship (because of her seagoing characteristics) the sea state is getting heavy weather, i.e. when occurs and persists a resonant rolling, heaving or slamming.

Then

(i) adjusting the ship's speed,
(ii) adjusting the ship's heading,
(iii) heaving to sea,
(iv) sterning the sea (if possible),
(v) riding out the sea,
(vi) using oil.

THE SPECIFICATION OF THE "STABILIZING THE SHIP'S COURSE OR TRACK" SUBPROCESS

By the term "course/track stabilizing" we understand keeping the established values of course/track, including course/track changes, without their fluctuating. Therefore, the term "course/track stabilizing" means such way of steering when established values of course/track including course/track changes, are being kept.

The term "course/track stabilizing" is used here to differ this way of steering from the way of steering when ship's maneuvers are being performed (collision avoidance maneuvers, search and rescue maneuvers, and many other kinds of maneuvers).

We assume that the whole ship's way at sea is composed of planned passage part or additional, i.e. unforeseen passage parts, performed while planned and unforeseen manoeuvres. We confine our further considerations only to the ship's planned passage. Each ship's passage i. e. each real ship's track is composed of straight segments (route's legs), and curve segments (the arcs of turn circles proceeded while changing the courses).

Each ship's passage can be performed in one of two stabilizing modes, i.e. stabilizing ship's course, or stabilizing ship's track. By the term "stabilizing the ship's track" we mean the conducting the ship at sea according to her planned courses.

Then the term "stabilization ship's/track" means the conducting the ships according to the planned track, i.e. strictly over the track line. The "course stabilization" can be realized either by the helmsman or by gyro-pilot. The "track stabilization" can be realized either by the helmsman (helped by the officer of the watch) or by the track control system.

The main objective of the "stabilizing ship's course or track" subprocess is to conduct the ship at sea according to her planned courses or strictly over the intendment-track's line. It should be stressed that the "stabilizing ship's course or track" subprocess is not an autonomous, i.e. self-contained subprocess. In respect of monitoring and controlling, this subprocess depends upon the subprocess of "monitoring and controlling the whole ship's navigation process", i.e. upon the subprocess (mco) (Fig.1).

The subprocess of "stabilizing ship's course or track" comprises the following activities:

- checking the readiness of ship's steering system and helmsmen's proficiencies concerning the changing procedures of ship's steering modes,
- transforming the speeds and courses made-good-values into the speeds and courses set values taking into account the actual hydrometeorological and hydrographical conditions,
- checking the set values of steering and propulsion systems, as well as, the work of these systems and work of the helmsman,
- matching the steering mode to the traffic conditions,
- maintaining and checking the dead-reckoning procedures.

THE SPECIFICATION OF THE "SHIP'S POSITIONING" SUBPROCESSS

The main objective of "ship-positioning" subprocess is to ensure the ship's safety against such dangers as grounding, beaching and colliding with fixed objects by the permanent checking ship positions against intendent track and against surrounding dangers, and by timely informing or alarming the imminent danger.

Ships positioning systems and, therefore, the ship-positioning subprocess were and are still the subject of very profound changes. The today's electronic position-fixing systems, esp. satellite position-fixing systems, enable the ship positioning in real time with relatively high accuracy. However, this accuracy does not fulfil still the ship accuracy requirements when in restricted waters and in harbour-phase of passage. Only the DGPSs fulfil these requirements when they are available.

Besides the electronic position-fixing systems, there are widely used piloting methods i.e. the terrestrial methods of positioning. In addition, in restricted waters, and while entering/leaving the harbours - there are used various danger - enclosing and danger - delimiting position lines. The last ways of positioning, even in the future, will be and should be used as the back-up positioning methods.

The required positioning accuracy depends upon passage phase, as it is specified by IMO's resolutions, and upon kinds of positioning systems being in ships disposal. The last must satisfy the regulation 12/V of SOLAS 74 Convention (shipborne navigational equipment).

It should be stressed that just as the subprocess of "stabilizing ship's course or track", also the "ship-positioning" subprocess is not self-contained, i.e. an independent subprocess. In respect of monitoring and controlling this subprocess depends upon the subprocess of "monitoring and controlling the whole ship's navigation process", i.e. upon the subprocess (mco) (cf. Fig.1).

The "ship-positioning" subprocess includes the realization of the following activities:

- checking the proposals prepared while "passage-planning" subprocess, regarding necessary accuracy for given passage phase and period of day, as well as chosen positioning systems or positioning methods,
- starting and maintaining the positioning subprocess by the means of required systems or methods,
- checking, at the chart in the available largest scale, the actual ship track against the intendent track, as well as, against the surrounding dangers, and, if any doubt regarding ships safety, inducing the change of ship-movement's vector,
- checking periodically the performed positioning subprocess by the means of the back-up system or method,
- checking the conformity of positions and characters of the passed buoys and beacons and recording these events; in case of any inconsistency, notifying the proper authority.

THE SPECIFICATION OF THE "SHIP'S MANEUVRING AND HANDLING" SUBPROECESS

The actual passage of each ship consists of the planned passage and some or several manoeuvres, accordingly to ship's task, traffic density, etc.

The term "manoeuvring" means often and sudden changes of ship movements which effect in changing mainly the ship's headings and speeds. One of the manoeuvring forms is "handling". The term "handling" means also often and sudden movement changes with often reversing the movement and using not only the rudder but also propeller(s) and thruster(s) for heading changes. However, in practice the terms "manoeuvring" and "handling" are being used interchangeably. We treat also both terms as synonyms.

The most often kinds of ship's maneuvering/handling are the following:

- berthing/unberthing,
- mooring/unmooring,
- anchoring/weighing the anchor,

- responding to own ship's navigational emergencies (after grounding, collision, etc.),
- man overboard,
- searching ships and /or persons being in distress,
- taking the survivors and survival craft on board,
- assisting or towing the damaged ship,
- pilot approaching, embarking and disembarking,
- sailing in ice,
- and many other (e.g. determining ship's manoeuvring characteristics, and others.)

The other ship's activities, such as "collision avoidance" and methods of "fighting against storm" can also be considered as the specific kinds of "ship's manoeuvring and handling" subprocess. However, because of their specificities and importance for ship's navigation there are considered as separate subprocesses.

The main properties of "ship's manoeuvring and handling" subprocess are the following:

- each kind of ship's manoeuvring/handling is strictly connected with the kind of ship's task being achieved trough this kind of handling. Therefore, each kind of manoeuvring/handling is different, i.e. adjusted to the aim of that maneuver,
- ship's maneuvering/handling is performed towards the object being the subject, substance, or task of this kind of maneuvering/handling,
- the sequence, and kind of successive movement changes are very often the result of achieved effects while preceding kind of movement.

The main objective of the "ship's manoeuvring and handling" subprocess is:

- enabling the realization of the task being the subject of this kind of ship's manoeuvring/handling.

The "ship's manoeuvring/handling" subprocess includes the following activities:

- checking the validities and up - dateness of particular maneuvring's/handling's procedures,
- activating, when necessary, the particular written or memorized maneuvering/handling procedure and acting according to it,
- steering the ship's courses and maintaining speeds according to master (first mate) orders,
- making allowances for the wind, current and tides while maneuvering/handling,
- keeping watch over surrounding traffic, as well as fixed navigational obstacles, and preventing and avoiding dangers,
- positioning the ship's movement at chart and alarming the master when actual movement can result in ship's accident,
- recording most important navigational events (times of changing the movement's elements, their values, etc.)

Attachment 4e: Copy of a publication citing Document 4

THE SPECIFICATION OF THE "COLLISION-AVOIDANCE" SUBPROCESS

The collision-danger, esp. in foggy weather, was in the past the seamen's nightmare. Even the employment of radars, in the past-World-War II period, did not diminish the amount of ships collisions, because in the same period the ships traffic grew permanently. Most of the collisions occurred in the restricted waters. Only deployment of the elements of ship-traffic control, such as "traffic separation schemes", and later, Vessel Traffic Services, as well as permanent perfection of radars use for collision avoidance – began to result in rush decreasing ships collisions.

Below, only some of very many factors influencing the state of collision-danger at sea are discussed, i.e. preventing collisions by following the rules of COLREG 72 Convention by ships, esp. rules regarding the use of radar for collision avoidance.

The main legal act regarding the prevention of collision at sea is the above-mentioned COLREG Convention. The requirements regarding ships equipment with radars and automatic radar plotting aids are specified by regulation 12/V of SOLAS 74 Convention, whereas the necessary competences of deck officers concerning collision avoidance, are specified with full particulars, in the STCW 78/95 Convention.

The main objective of "collision-avoidance" subprocess is ensuring the ship's safety against collision-danger. The main way of collision prevention, besides the strict following the rules and requirements provided by COLREG 72 Convention, such as light, shapes, conducting the ships in different visibility's conditions – is avoiding close-quarter situation and, therefore, collision of ships.

It should be remembered that the "collision-avoidance" subprocess, likewise the other navigation's subprocess, is not autonomous subprocess. In respect of monitoring and controlling, this subprocess depends upon the subprocess of "monitoring and controlling of the whole navigation process", i.e. upon the subprocess (mco) (Fig.1)

The "collision-avoiding' subprocess includes mainly the following activities:

- checking the fulfilment of COLREG 72 rules regarding lights, shapes, sound signals, distress signals, etc,
- following the COLREG 72 rules regarding the ship conduct in various visibility conditions and various states and conditions of ship's movement,
- maintaining the permanent observation of surrounding ships traffic,
- identifying the collision dangers,
- choosing proper avoidance maneuvers,
- fulfilling the avoidance maneuvers.

FLIR-1015.247

Attachment 4e: Copy of a publication citing Document 4

THE SPECIFICATION OF THE SUBPROCESS OF "MONITORING AND CONTROLLING THE SHIP'S NAVIGATION PROCESS"

The subprocess of "monitoring and controlling the ship's navigation process" is a special subprocess because it deals with all other subprocess, i.e. monitoring and controlling all other navigation's subprocesses (cf. Fig.1)

The main objective of this subprocess is monitor and control all navigation's subprocesses being realized in accordance with the ship's passage plan, her tasks, and actual situations, as well as in accordance with general safety requirements regarding the ships and their environment.

The "monitoring and controlling" subprocess contains three levels of activities (Fig.1.):

- monitoring the realization of all ship's navigation subprocess by the means of bridge's monitors an indicators, and personal observation,
- situation evaluating and, if or when necessary, decision making,
- supervising the decisions' fulfilling.

Ship-navigation-process' proceeding is being supervised by the master (captain) or by the officer of the navigational watch (being supervised by the captain).

The STCW 78/95 Convention provides that the officer in charge of the watch is the master's representative and is primary responsible at all times for the safe navigation and for complying with the International Regulations for Preventing Collision at Sea, 1972.

The subprocess of "monitoring and controlling the ship's navigation process" includes the following activities assuming that this subprocess is supervised by the officer of the watch:

- keeping watch over ship's external dangers, i.e. over the other ships, floating and fixed objects (buoys, beacons, etc.) by means of the indicators, monitors (radars, etc.) and by personal observation and, if necessary, undertaking preventive actions,
- checking on the chart, or ECDIS's monitor, the ship's current positions and track against planned (intendent) track and against the surrounding dangers (shallow waters, shoals, wrecks, etc.) and, if necessary, undertaking proper actions,
- checking the set values pointed by the indicators of the steering and propulsion systems, as well as error-values of the magnetic - and gyro-compasses,
- checking the state of realization of the items provided by the time-table of passage scenario, and fulfilling the consecutive planned activities,
- responding properly to all alarms generated by the navigational equipment and systems, as well as to events notified by the look-out or other bridge-team member,
- checking the correctness of the work of the bridge equipment and systems and bridge team,

FLIR-1015.248

- responding to own ship's emergencies according to the proper procedures, and notifying the captain, i.e. when:
  - man overboard,
  - fire on board,
  - sudden water ingress,
  - serious breakdown of ship's equipment or systems,
  - serious accident of the crew members, and in any other serious emergencies,
- notifying the captain if other ships or persons are in distress, or the danger to own ship is being arisen, i.e. when
  - distress signals have been received,
  - visibility is getting restricted,
  - surrounding ships are causing concern,
  - worsening weather can produce weather damage,
  - radio equipment is out of order,
  - any of difficulties or doubts concerning ship's navigation process and safety of ship have been arisen.

THE SPECIFICATION OF THE "SHIP-VOYAGE-DATA RECORDING" SUBPROCESS

The "ship-passage-data recording" subprocess is the technical subprocess which consists in recording the determined data at the determined times, regarding the navigation process, in way enabling the reconstruction this process.

The obligations of the recording ship-passage data are being specified by the being amended chapter V of the by the SOLAS 74 Convention (regulation 20/V and 28/V) and by the IMO Performance Standards for ECDIS".

The main objective of the "ship-passage-data recording" is:

- to assist in casualty investigation,
- to assist in operational evaluation of performed ship's passage and tasks,
- to preserve basic data, during fixed period, for the subsequent needs.

There exists the obligation of recording the ship-passage data in following way

(i) for short protection period of time (e.g. for 12 hours in ECDIS)
  - all navigational data allowing the reconstruction of all particulars of the ship' navigation process (e.g. at one minute intervals should be recorded: times, positions, headings and speeds).

(ii) for the protection period of time not shorter than the passage time:
  - the complete track of the whole passage, with time marks at the intervals not longer than 4 hours,
  - times and orders while ship's manoeuvrings,
  - times of the most important ship's activities and incidents

(iii) for the archival purpose of ship's passage
  - track with time marks at interval of one day,

Attachment 4e: Copy of a publication citing Document 4

- times of harbours' entries and leaves,
- most important events (grounding, collision, fatal incident of crew member, etc.)

However, the data recording for archival purpose is not the ship's navigation activity and, therefore, it is not the subject of concern or considerations of this paper.

The data for short-protection time (e.g. 12 hours), being-recorded at very short intervals, besides the times, positions, headings, and speeds, should also contain the data regarding the quality of chart data, or there should be preserved the actual navigational plots, drawn at the paper charts.

The data, for period of protection not shorter than passage time, are being recorded in the following way:

- by ECDIS or manually made navigational plot, drawn on the charts in small scales,
- by Voyage Data Recorder, if available,
- recorded in the logbook or preserved in another form approved by Administration.

It ought to be remembered that the recorded information which to be stored and kept until the passage is finished - should not and could not be manipulated, changed or removed.

The authors' belief is that their attempt of specification of ship's navigation process, although very far from perfection and also far from completeness, can fulfil the authors' expectations expressed in abstract of this paper.

REFERENCES

1. A. Felski, J. Urbański. Satellite Systems for Positioning and Ensuring the Safety of Navigation (in Polish). AMW, Gdynia, 1997.
2. D.F.H. Gracott. Shipwreck in the Revolutionary and Napoleonic Eras, 1795-1815. Casual Factors and Comments. The Journal of Navigation No 2, 1999.
3. IMO, International Maritime Organization, Guide to the Planning and Conduct of Passages, IMO Circular SN/Circ.92, 1978, and Guidelines for voyage planning, Resolution A.893 (21).
4. IMO, International Maritime Organization, Performance Standards for Electronic Chart Display and Information System (ECDIS). Resolution A.817(19), 1995.
5. The International Convention for the Safety of Life at Sea, 1974.
6. The International Convention on the International Regulation for Preventing Collision at Sea, 1972.
7. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978/1995.
8. The International Convention on Maritime Search and Rescue, 1979.
9. M. Jurdziński. Navigation Planning in Costal Waters (in Polish). WSM Gdynia, 1998.

Attachment 4e: Copy of a publication citing Document 4

10. Z. Kopacz, J. Urbański, The navigation at the beginning of the 21st Century. Geodezja i Kartografia, t. XLVII, z. 1-2, 1998.
11. Z. Kopacz, W. Morgaś, J. Urbański. The selected issues of the International Navigation Safety System (in Polish). AMW Gdynia, 1998.
12. Z. Kopacz, W. Morgaś, J. Urbański. The ship's navigation system and its integration with other ship's system into the integrated ship's operation control system. Zeszyty Naukowe AMW Nr 1, 1999.
13. Z. Kopacz, W. Morgaś, J. Urbański. The state of navigation's development in Poland at the turn of 20th Century. Annual of Navigation No 1, Gdynia 1999.
14. Z. Kopacz, W. Morgaś, J. Urbański. The Maritime Navigation Safety System and its participation in the process of safe and efficient conducting the ships at sea. Annual of Navigation No 2, Gdynia 2000.
15. Z. Kopacz, W. Morgaś, J. Urbański. An attempt of the specification of the ship's navigation subprocesses could be realized by ECDIS. Proceedings of Navigation Symposium, Szczecin, 2000.
16. R.H. Motte and all. Desing and Operation of Computerized, On-Board Weather Routing System. The Journal of Navigation No 1, 1994
17. H. Sabelis. Voyage Planning in ECDIS. International Hydrographic Review No 2, 1999.
18. Specification for Chart Content and Display Aspects of ECDIS. IHO/IHB, 1994.
19. J. Urbański, M. Holec. The ship's navigation process in the terms of the set theory. Archives of Transport. vol. 10, issue 1-2, 1998.

Received October 2000
Reviewed February 2001

Geo-spatial Information Science (Quarterly)

Volume 5, Issue 1, Page 7-11
March 5, 2002

Electronic Chart Display and Information System

WAN Xiaoxia GAN Chaohua

KEY WORDS ECDIS; ECS; display; key features; performance standards

ABSTRACT This paper introduces the most advanced form of electronic chart display and information systems (ECDIS) which complies with the Performance Standards for ECDIS established by the International Maritime Organization (IMO) and the International Hydrographic Organization (IHO). It also describes the key features and the important functions of ECDIS. Then the future development of ECDIS in marine is discussed.

1 Introduction

Electronic charts are new navigation aid that can provide significant benefits to maritime navigation, safety, and commerce. More than a simple computer graphics display, electronic chart systems combine both geographic and textual data into a readily useful operational tool. The electronic charts are a real-time navigation system that integrates a variety of information displayed and interpreted by the mariner. The most advanced form of electronic chart systems represents a new approach to maritime navigation[1].

2 ECDIS and ENC

There are two basic types of electronic charts. The most advanced form of electronic charts is the Electronic Chart Display and Information System (ECDIS). All other types of electronic charts can be regarded, in general, as Electronic Chart Systems (ECS).

2.1 *ECDIS and international performance standards*

To be considered as an ECDIS, an electronic chart must comply with the Performance Standards for ECDIS established by the International Maritime Organization (IMO). Under development for over 10 years, the IMO Performance Standards for ECDIS specify the components, features, functions of a system in which the primary function is to contribute to safe navigation[1]. They were formally adopted by IMO on 23 November 1995 and issued as IMO Resolution A. 817(19). Back-up arrangements for ECDIS were adopted by IMO in November 1996 and became Appendix 6 to the Performance Standards.

In conjunction with the IMO Performance Standards for ECDIS,

WAN Xiaoxia, professor, School of News and Communication, Wuhan University, 129 Luoyu Road, Wuhan 430079, China
E-mail: wan@wtusm.edu.cn

the International Hydrographic Organization (IHO) developed technical standards for the digital data format and display. IHO Special Publication 52 (IHO S-52) is the IHO specification for chart content and display of ECDIS[3]. It includes appendices describing the means/process for updating, colour and symbol specifications. The 4th edition of IHO S-52 was issued in December 1996. IHO Special Publication 57 (IHO S-57) is the IHO transfer standard for digital hydrographic data[4]. The current edition (Edition 3.0) was released in November 1996. Both IHO S-57 and S-52 are specified in the IMO Performance Standards for ECDIS.

The International Electromechanical Commission (IEC) developed its own ECDIS Performance Standard that describes the operational methods of testing and required test results for an IMO-compliant ECDIS[5]. In September 1997, Draft of IEC 61174 was completed, and a final draft of the international standard was issued on 30 March 1998. Following a formal voting process, IEC 61174 was officially published by IEC as an international standard in August 1998. IEC 61174 is the basis for type-approval/certification process for an IMO-compliant ECDIS.

2.2 *ECS*

An Electronic Chart System (ECS) can be considered as any other type of electronic charts that does not comply with the IMO Performance Standard for ECDIS. This general category can be further sub-divided into electronic charts that use either raster or vector data.

In a vector-based system, electronic chart data is comprised of a series of lines (vectors) in which different layers of information may be stored or displayed. This form of so-called intelligent spatial data is obtained by digitizing information from existing paper charts or by storing a list of instructions that define various position referenced features or objects. With a vector ECS, the user has considerable flexibility and discretion regarding the amount of information that is displayed for the task at hand.

2.3 *ECDIS components and data flow*

ECDIS components consists of:

- Computer processor
- digital database (i.e. electronic chart data)
- navigation sensor inputs (e.g. GPS, Loran)
- color display

Additional shipboard sensor inputs may include ship's gyrocompass, depth sounder, a marine radar/ARPA and shipboard automated identifications systems (AIS). Since ECDIS can function as the "Mariner's Window to the World", other navigation-related information could be displayed as well. This could include navigation-related information such as tides/water level, current flow, ice coverage, visibility, and the location of other vessels beyond visual or radar range. In this regard, IMO has recently adopted draft recommendation on Performance Standards for Universal Shipborne AIS that would operate in a ship-to-ship (transponder) and ship-to-shore/shore-to-ship (broadcast) mode of operation[6].

Fig. 1 shows the primary functional components of ECDIS.

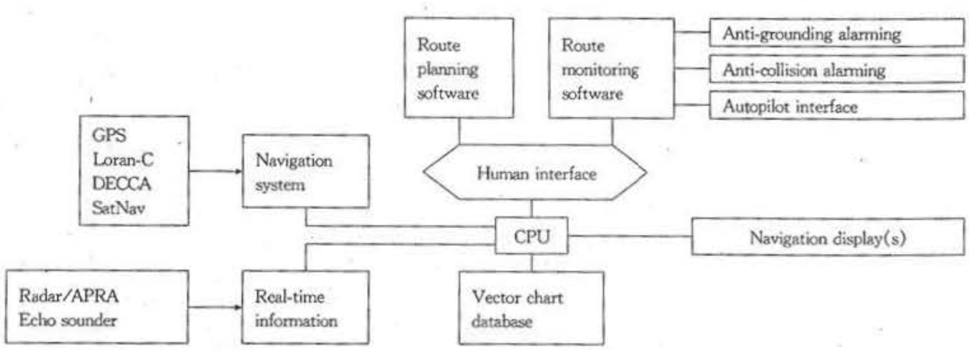


Fig. 1 ECDIS components and data flow

3 Key features for ECDIS

The IMO Performance Standards for ECDIS provide specific guidance regarding the various components, features, and functions which make up an ECDIS. As described in the various sections of the IMO Performance Standards for ECDIS, there are important features, functions, and capabilities provided by ECDIS. From 1998 to now, we have been developing the electronic chart display and information system which based on international standards. The following are the key features.

3.1 *Updating*

ECDIS must be capable of accepting official updates to the system data, provided in conformity with IHO standards. We have developed an ECDIS which can keep a record of updates including time of application, and allow the mariner to review their contents and ascertain that they have been included in the system data.

3.2 *Colours and symbols*

The colours and symbols used in an ECDIS display must conform to the specifications contained in IHO Special Publication 52. This includes a specified size and appearance of symbols, figures, and letters. A particularly useful feature is the Mariner's ability to select different color display schemes for daylight, nighttime, or twilight conditions.

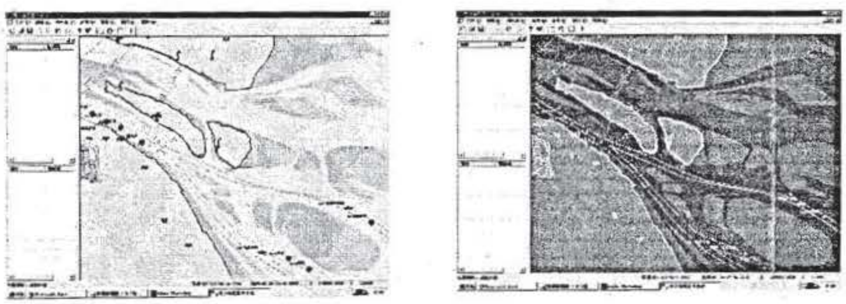


Fig. 2 ECDIS display in bright daylight and during dark time

3.3 *Standard display and display base*

This is the level of information that should be shown when a chart is first displayed. Depending upon the needs of the mariner, a amount of information may be modified by the mariner for route planning or route monitoring. However, an ECDIS must return to the standard display at any time by a selection operation. Thus, it is the mariner who decides what level of information is required during a particular situation or task at hand.

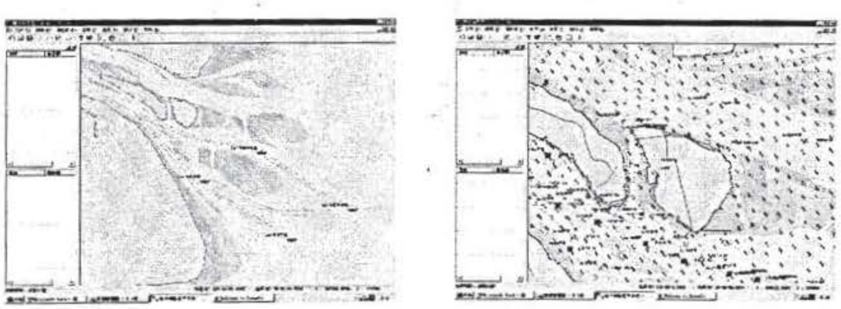


Fig. 3 Chart data in the overview display and the same data in detail

Display base is the layer of information which cannot be removed from the display, and includes information which is required in all geographic areas and during all circumstances. It is not intended to be sufficient for safe navigation.

Depending on the needs of the mariner, information may be displayed at different scales (i. e. zoom-in or zoom-out). This system will show us different details.

3.4 *Safety depth/contour*

With ECDIS the mariner can select a safety depth or safety contour. For a safety depth, all soundings less than or equal to the safety depth are emphasized. For a safety contour, ECDIS highlights this contour over other depth contours.

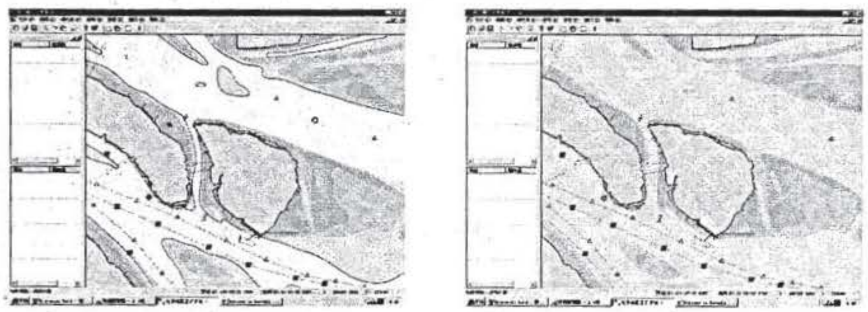


Fig. 4 Safety depth/contour in 5 meters and 30 meters

3.5 *Display orientation/mode*

With ECDIS, the mariner can select either a "north-up" or a "course-up" orientation. The ECDIS display can also be configured to operate in a true motion or relative motion mode of operation. In true motion, own ship's symbol moves across chart display. With a relative motion display, the own ship's symbol remains stationary in the center while the chart information appears to move.

3.6 *Other information*

Radar signal or other navigational information may be added to the display. However, it should not degrade the display and not obscure other electronic chart information. Different information is not simply superimposed together. Transferred radar information may contain both the radar image and ARPA (automated radar piloting aid) information. Those information can be crucial for collision avoidance.

4 Important functions for ECDIS

ECDIS is different from other GIS. It has not only it's own displaying features, but also some special important functions.

4.1 *Route planning*

With ECDIS the mariner should be able to perform route planning in a simple and reliable manner. It should be possible to add or delete waypoints, or to change the position or order of waypoints in a selected route. It should also be possible to plan both primary and alternate routes.

4.2 *Route monitoring*

During route monitoring, ECDIS must show own ship's position whenever the display covers that area. Key information provided during route monitoring includes a continuous indication of vessel position, course, and speed. Additional information that ECDIS can provide includes such information as distance right/left of intended track, time-to-run, distance-to-turn, position and past track history.

4.3 *Voyage recording*

After the voyage, ECDIS must be able to reconstruct the navigation and verify the official database used. Recorded at one minute intervals the information includes:

• own ship's past track including time, position, heading, and speed,

• a record of official ENC used including source, edition, date, cell and update history.

In addition, ECDIS must be able to record the complete track for the entire voyage with time marks. ECDIS should also have the capability to preserve the record of the voyage. Finally, it should not be allowed to manipulate or change the recorded information.

5 Conclusion

In order to gain type approval/certification by user, the ECDIS system which we are developing will need to comply fully with the IMO Performance Standard for ECDIS. Anything else (e. g. use of non-official data, different chart content/display, reduced functional capability, etc.) will likely be considered non-compliant.

Results from Shanghai Marine Administration's experiments and at-sea trials have showed that ECDIS is the most effective means of navigation comparing with more traditional methods (e. g. visual fixes, radar, or plotting fixes on paper charts). ECDIS has also showed that mental stress and workload on the bridge, and the portion of time spent on navigation-related tasks can be reduced. This in turn allows more time for the higher risk task of collision avoidance.

Since ECDIS is capable of continuously displaying own ship's position on the electronic chart, there is increasing benefit of having other real-time information available that can be used to increase the safety and efficiency of the voyage. Timely information on water levels and current flow can be of significant benefit to a mariner in terms of optimizing the timing of vessel transits, or the amount of vessel cargo loading.

6 The future

Looking forward to the future, it is evident that ECDIS offers enormous potential to improve the safety and efficiency of maritime navigation[7,8]. ECDIS will lead to dramatic changes in the type of navigation safety waterways services that will need to be provided in order to improve both the safety and efficiency of maritime commerce in the world's increasingly congested ports and waterways. Since ECDIS is a real-time navigation system, there are opportunities to improve upon the type of information that can be provided to the mariner in digital form.

ECDIS will be used in the following areas:

1) As an electronic nautical chart sytem ECDIS is used primarily by professional navigators in the shipping sector, and in particular on ferries in dangerous water areas and in bad weather (e. g. fog).

2) ECDIS will lead to dramatic changes in the types of Vessel Traffic Information Service (VTIS) that will be operated to benefit the efficiency and safety of maritime commerce. An important component of the VTIS in the future will be the increased employment of ECDIS-related technology[9].

3) Instead of relying primarily on voice communications, vessels will eventually have GPS/DGPS transponders (i. e. AIS) that will communicate with one another or to a VTIS center. With a standard format and protocol (e. g. vessel identification, location, course, speed, and time), it would be possible for each vessel to display the location and movement of other vessels on ECDIS.

4) ECDIS will be also employed for the national coastal and environmental protection, oil spill clearance duties, surveillance by aircraft and by the sea rescue service.

5) Simulation systems used for the basic and advanced training of navigators, pilots, et al. are equipped with ECDIS.

References

1 IMO (1995) Performance standards for electronic chart display and information systems (ECDIS), IMO Resolution A. 817 (19). International Maritime Organization, London.

2 International Convention for the Safety of Life at Sea (1986) Consolidated text of 1974 SOLAS Convention, the 1978 SOLAS Protocol, the 1981 and 1983 SOLAS Amendments. International Maritime Organization, London.

(Continued on Page 21)

As GPS furnishes 3D coordinates, some analyses concerning the course of the height of the calbeway are possible. On one hand it is possible to draw a side-face of the cableway, which emphasises the position of the tower(in Fig. 3). On the other hand it is possible to integrate this information in a GIS, e. g. about the obstacles for the aviation. Therewith, given the suitable software, 3D scenery representing the landscape and the cableway are computable(in Fig. 4).

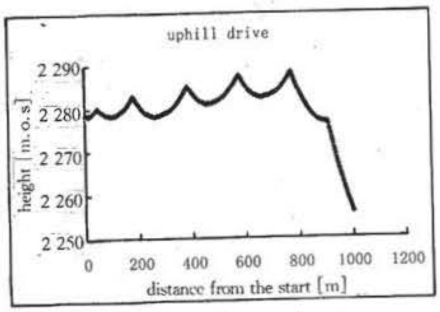


Fig. 3 Side-face of the cableway

5 Conclusion

From the described project, the following conclusions can be drawn:

1) Methods of satellite geodesy can be applied to determine the actual position of the axis of the cableway. As a consequence, also the deviations

Fig. 4 3D scenery

of the position of the tower, due to geodynamic process or mechanical movement, can be detected.

2) Compensation of GPS observations brings about better results, when a condition of linearity is taken into account.

3) Conditions of linearity allow to detect outliers.

4) The method is reliable and precise.

References

1 Salvini D. (1999) Ueberprüfung des Seilverlaufes bei Gondelbahnen und Sesselliften mit Methoden der Satellitengeodäsie. Zurich, Switzerland: IGP-Bericht Nr. 287, ETHZ(in German)

2 Salvini D. (1999) Dreidimensionale Modellierung von Seilbahnanlagen für eine geographische Datenbank der Luftfahrthindernisse. Zurich, Switzerland: IGP-Bericht Nr. 286, ETHZ(in German)

(Continued from Page 11)

3 IHO(1996) IHO Specification for Chart Content and Display of ECDIS, IHO Special Publication No. 52 (IHO S-52), 4th ed. Monaco.

4 IHO(1996) IHO Transfer Standard for Digital Hydrographic Data, IHO Special Publication No. 57 (IHO S-57), 3rd ed. Monaco.

5 IEC 61174: Maritime navigation and radiocommunication equipment systems—Electronic chart display and information system (ECDIS)—Operational and performance requirements, methods of testing, and required test results. International Electrotechnical Commission, Geneva.

6 IMO. Draft recommendation on performance standards for an universal shipborne automatic identification system (AIS). IMO Safety of Navigation Sub-committee Report NAV43/WP. 2, Annex 2, IMO London.

7 U. S. Coast Guard Research and Development Center (1996). Electronic chart display and information systems (ECDIS) test and evaluation — summary report. Report No. CG-D-20-97

8 Offshore Systems Ltd(1997) Canadian electronic chart pilot project — final report. Vancouver, BC.

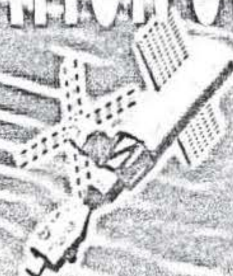
9 Lee A., Ganjon F. K. (1995) ECDIS: Current status/future expectations. *Sea Technology*, 36(3)

地球空间信息科学学报 DIQIU KONGJIAN XINXI KEXUE XUEBAO

ISSN 1009-5020

GEO-SPATIAL INFORMATION SCIENCE

QUARTERLY



VOL. 5 ISSUE 1

1
2002

EDITED BY

EDITORIAL BOARD OF GEOMATICS AND INFORMATION SCIENCE OF WUHAN UNIVERSITY

ISSN 1009-5020

04>

9 771009 502000

GEO-SPATIAL INFORMATION SCIENCE Quarterly

Volume 5, Issue 1

March 5, 2002

CONTENTS

Geo-spatial Information Science (ISSN 1009-5020), started in 1998, is published by Wuhan University Journals Press in March, June, September and December of every year, edited by Editorial Board of Geomatics and Information of Wuhan University and distributed by China International Book Trading Corporation (Code: 1556Q).

Attachment 5a: Copy of Document 5 from the Library of Congress

GEO-SPATIAL INFORMATION SCIENCE

Quarterly

Geo-spatial Information Science (Quarterly) Vol. 5 Issue 1, March 5, 2002

Sponsored by: Wuhan University

Chief Editor: Prof. Dr. LI Deren

Edited by: Editorial Board of Geomatics and Information Science of Wuhan University

Add: 129 Luoyu Road, Wuhan 430079, P. R. China; E-mail: journal@wtusm.edu.cn; Tel: +86-27-87885922-2465

Published by: Wuhan University Journals Press

Distributed by: China International Book Trading Corporation (Code 1556 Q)

(P. O. Box 399, Beijing, P. R. China)

ISSN 1009-5020/CN 42-1610/P Price: US$10.0

Attachment 5b: Library of Congress catalog record for Geo-spatial Information Science

MENU LIBRARY OF CONGRESS ONLINE CATALOG

LC Online Catalog Quick Search | SEARCH OPTIONS | LOGIN

Search Navigation | < | 4 of 8 | >

PERIODICAL OR NEWSPAPER

Geo-spatial information science = Diqui kongjian xinxi kexue xuebao

Full Record | MARC Tags

Main title

Geo-spatial information science = Diqui kongjian xinxi kexue xuebao / edited by Editorial Board of Geomatics and Information Science of Wuhan University.

Published/Created

Wuhan, China : Wuhan University Journals Press
<2016-> : Abingdon, UK : Taylor and Francis on behalf of Wuhan University

Request this Item | LC Find It | Where to Request

PERIODICAL OR NEWSPAPER

PRINT RECORD | SAVE RECORD | EMAIL RECORD | CITE RECORD

MARCXML Record
MODS Record

Report Record Errors
Ask a Librarian
Feedback

LCCN Permalink	https://lccn.loc.gov/2003202799
Publication history	Began in 1998.
Description	v. : ill. ; 30 cm.
Current frequency	Quarterly
ISSN	1009-5020
Linking ISSN	1009-5020
LC classification (full)	G70.212 .G425
LC classification (partial)	G70.212
Variant title	Spatial information science Diqui kongjian xinxi kexue xuebao
Serial key title	Geo-spatial information science
Abbreviated title	Geo-spat. info. sci.
Related names	Wuhan da xue. Editorial Board of Geomatics and Information Science.
Subjects	Geographic information systems--Periodicals. Geographic information systems.
Form/Genre	Periodicals.
Additional formats	Online version: Geo-spatial information science 1993-5153 (DLC) 2016203785 (OCoLC)67617759 Online version: Geo-spatial information science (OCoLC)754552327
LCCN	2003202799
Dewey class no.	526.0285
National bib no.	022097953
National bib agency no.	2053942-3 022097953
Other system no.	(OCoLC)ocm53126793

FLIR-1015.262

Attachment 5b: Library of Congress catalog record for Geo-spatial Information Science

Other system no.	[illegible]
Type of material	Periodical or Newspaper

Where to Request

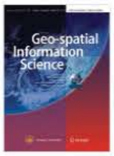
CALL NUMBER	G70.212 .G425 Set 1
Request in	Jefferson or Adams Building Reading Rooms
Status	Not Charged
Older receipts	v.4-v.6(2001-2003), v.7:no.2-v.14:no.1 (2004:June-2011:Mar.)

CALL NUMBER	G70.212 G425 Copy 1 Unbound issues
Request in	Newspaper & Current Periodical Reading Room (Madison LM133)
Older receipts	v.7:issue 1 (2004), v.14:issue 2-4 (2011:June-2011:Dec.)

Attachment 5c: SpringerLink index record for Document 5

Springer Link

Search Home • Contact Us • Log in



Geo-spatial Information Science
March 2002, Volume 5, Issue 1, pp 7–11

Electronic chart display and information system

Authors   Authors and affiliations

Wan Xiaoxia, Gan Chaohua

Article

DOI: 10.1007/BF02863487

Cite this article as:
Xiaoxia, W. & Chaohua, G. Geo-spat. Inf. Sci. (2002) 5: 7. doi:10.1007/BF02863487

Download PDF

Export citation

Share article

Article
Abstract
References
Copyright information
About this article

Article
Abstract
References
Copyright information
About this article

Article
Abstract
References
Copyright information
About this article

Article
Abstract
References
Copyright information
About this article

Article
Abstract
References
Copyright information
About this article

Article
Abstract
References
Copyright information
About this article

Article
Abstract
References
Copyright information

Abstract

This paper introduces the most advanced form of electronic chart display and information systems (ECDIS) which complies with the Performance Standards for ECDIS established by the International Maritime Organization (IMO) and the International Hydrographic Organization (IHO). It also describes the key features and the important functions of ECDIS. Then the future development of ECDIS in marine is discussed.

Key words

ECDIS ECS display key features performance standards

Download to read the full article text

References

1. IMO (1995) Performance standards for electronic chart display and information systems (ECDIS). IMO Resolution A. 817 (19). International Maritime Organization, London. Google Scholar
2. International Convention for the Safety of Life at Sea (1986) Consolidated text of 1974 SOLAS Convention, the 1978 SOLAS Protocol, the 1981 and 1983 SOLAS A-mendments. International Maritime Organization, London.
3. IHO (1996) IHO Specification for Chart Content and Display of ECDIS, IHO Special Publication No. 52 (IHO S-52), 4th ed. Monaco.
4. IHO (1996) IHO Transfer Standard for Digital Hydrographic Data, IHO Special Publication No. 57 (IHO S-57), 3rd ed. Monaco.
5. IEC 61174: Maritime navigation and radiocommunication equipment systems—Electronic chart display and information system (EODIS)—Operational and performance requirements, methods of testing, and required test results. International Electrotechnical Commission, Geneva.
6. IMO. Draft recommendation on performance standards for an universal shipborne automatic identification system (AIS). IMO Safety of Navigation Sub-committee Report NAV43/WP.2, Annex 2, IMO London.

Attachment 5c: SpringerLink index record for Document 5

7. U. S. Coast Guard Research and Development Center (1996). Electronic chart display and information systems (ECDIS) test and evaluation—summary report. Report No. CG-D-20-97

8. Offshore Systems Ltd (1997) Canadian electronic chart pilot project—final report. Vancouver, BC.

9. Lee A., Ganjon F. K. (1995) ECDIS: Current status/future expectations.*Sea Technology*, 36(3)

Copyright information

About this article

Print ISSN	Online ISSN	Publisher Name
1009-5020	1993-5153	Wuhan University of Technology

About this journal

Reprints and Permissions

Geo-spatial Information Science (Quarterly)
Volume 5, Issue 1, Page 7-11
March 5, 2002

Electronic Chart Display and Information System

WAN Xiaoxia GAN Chaohua

KEY WORDS ECDIS; ECS; display; key features; performance standards

ABSTRACT This paper introduces the most advanced form of electronic chart display and information systems (ECDIS) which complies with the Performance Standards for ECDIS established by the International Maritime Organization (IMO) and the International Hydrographic Organization (IHO). It also describes the key features and the important functions of ECDIS. Then the future development of ECDIS in marine is discussed.

1 Introduction

Electronic charts are new navigation aid that can provide significant benefits to maritime navigation, safety, and commerce. More than a simple computer graphics display, electronic chart systems combine both geographic and textual data into a readily useful operational tool. The electronic charts are a real-time navigation system that integrates a variety of information displayed and interpreted by the mariner. The most advanced form of electronic chart systems represents a new approach to maritime navigation[1].

2 ECDIS and ENC

There are two basic types of electronic charts. The most advanced form of electronic charts is the Electronic Chart Display and Information System (ECDIS). All other types of electronic charts can be regarded, in general, as Electronic Chart Systems (ECS).

2.1 *ECDIS and international performance standards*

To be considered as an ECDIS, an electronic chart must comply with the Performance Standards for ECDIS established by the International Maritime Organization (IMO). Under development for over 10 years, the IMO Performance Standards for ECDIS specify the components, features, functions of a system in which the primary function is to contribute to safe navigation[1]. They were formally adopted by IMO on 23 November 1995 and issued as IMO Resolution A. 817(19). Back-up arrangements for ECDIS were adopted by IMO in November 1996 and became Appendix 6 to the Performance Standards.

In conjunction with the IMO Performance Standards for ECDIS,

WAN Xiaoxia, professor, School of News and Communication, Wuhan University, 129 Luoyu Road, Wuhan 430079, China
E-mail: wan@wtusm.edu.cn

the International Hydrographic Organization (IHO) developed technical standards for the digital data format and display. IHO Special Publication 52 (IHO S-52) is the IHO specification for chart content and display of ECDIS[3]. It includes appendices describing the means/process for updating, colour and symbol specifications. The 4th edition of IHO S-52 was issued in December 1996. IHO Special Publication 57 (IHO S-57) is the IHO transfer standard for digital hydrographic data[4]. The current edition (Edition 3.0) was released in November 1996. Both IHO S-57 and S-52 are specified in the IMO Performance Standards for ECDIS.

The International Electromechanical Commission (IEC) developed its own ECDIS Performance Standard that describes the operational methods of testing and required test results for an IMO-compliant ECDIS[5]. In September 1997, Draft of IEC 61174 was completed, and a final draft of the international standard was issued on 30 March 1998. Following a formal voting process, IEC 61174 was officially published by IEC as an international standard in August 1998. IEC 61174 is the basis for type-approval/certification process for an IMO-compliant ECDIS.

2.2 *ECS*

An Electronic Chart System (ECS) can be considered as any other type of electronic charts that does not comply with the IMO Performance Standard for ECDIS. This general category can be further sub-divided into electronic charts that use either raster or vector data.

In a vector-based system, electronic chart data is comprised of a series of lines (vectors) in which different layers of information may be stored or displayed. This form of so-called intelligent spatial data is obtained by digitizing information from existing paper charts or by storing a list of instructions that define various position referenced features or objects. With a vector ECS, the user has considerable flexibility and discretion regarding the amount of information that is displayed for the task at hand.

2.3 *ECDIS components and data flow*

ECDIS components consists of:

- Computer processor
- digital database (i. e. electronic chart data)
- navigation sensor inputs (e. g. GPS, Loran)
- color display

Additional shipboard sensor inputs may include ship's gyrocompass, depth sounder, a marine radar/ARPA and shipboard automated identifications systems (AIS). Since ECDIS can function as the "Mariner's Window to the World", other navigation-related information could be displayed as well. This could include navigation-related information such as tides/water level, current flow, ice coverage, visibility, and the location of other vessels beyond visual or radar range. In this regard, IMO has recently adopted draft recommendation on Performance Standards for Universal Shipborne AIS that would operate in a ship-to-ship (transponder) and ship-to-shore/shore-to-ship (broadcast) mode of operation[6].

Fig. 1 shows the primary functional components of ECDIS.

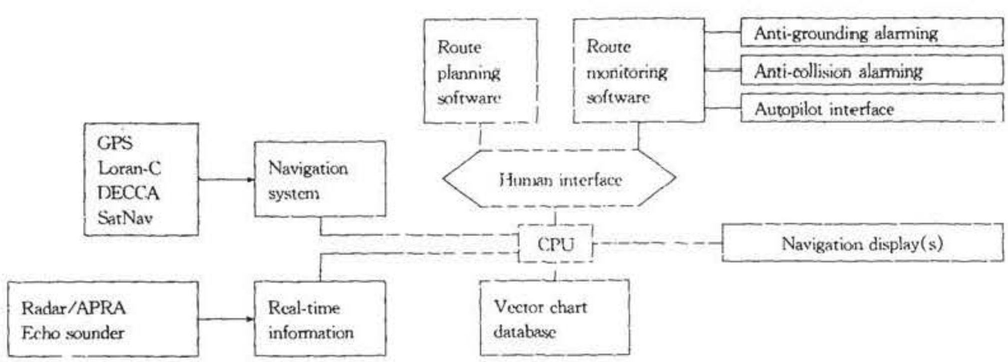


Fig. 1 ECDIS components and data flow

FLIR-1015.267

3 Key features for ECDIS

The IMO Performance Standards for ECDIS provide specific guidance regarding the various components, features, and functions which make up an ECDIS. As described in the various sections of the IMO Performance Standards for ECDIS, there are important features, functions, and capabilities provided by ECDIS. From 1998 to now, we have been developing the electronic chart display and information system which based on international standards. The following are the key features.

3.1 *Updating*

ECDIS must be capable of accepting official updates to the system data, provided in conformity with IHO standards. We have developed an ECDIS which can keep a record of updates including time of application, and allow the mariner to review their contents and ascertain that they have been included in the system data.

3.2 *Colours and symbols*

The colours and symbols used in an ECDIS display must conform to the specifications contained in IHO Special Publication 52. This includes a specified size and appearance of symbols, figures, and letters. A particularly useful feature is the Mariner's ability to select different color display schemes for daylight, nighttime, or twilight conditions.

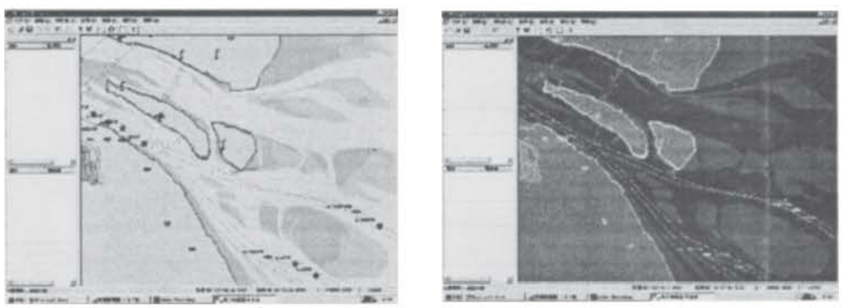


Fig. 2 ECDIS display in bright daylight and during dark time

3.3 *Standard display and display base*

This is the level of information that should be shown when a chart is first displayed. Depending upon the needs of the mariner, a amount of information may be modified by the mariner for route planning or route monitoring. However, an ECDIS must return to the standard display at any time by a selection operation. Thus, it is the mariner who decides what level of information is required during a particular situation or task at hand.

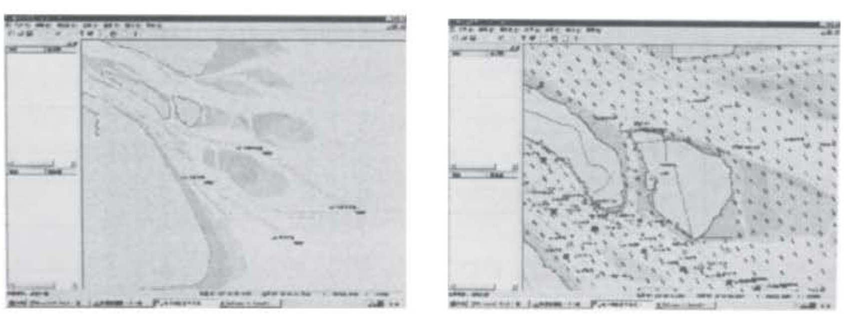


Fig. 3 Chart data in the overview display and the same data in detail

Display base is the layer of information which cannot be removed from the display, and includes information which is required in all geographic areas and during all circumstances. It is not intended to be sufficient for safe navigation.

Depending on the needs of the mariner, information may be displayed at different scales (i. e. zoom-in or zoom-out). This system will show us different details.

3.4 *Safety depth/contour*

With ECDIS the mariner can select a safety depth or safety contour. For a safety depth, all soundings less than or equal to the safety depth are emphasized. For a safety contour, ECDIS highlights this contour over other depth contours.

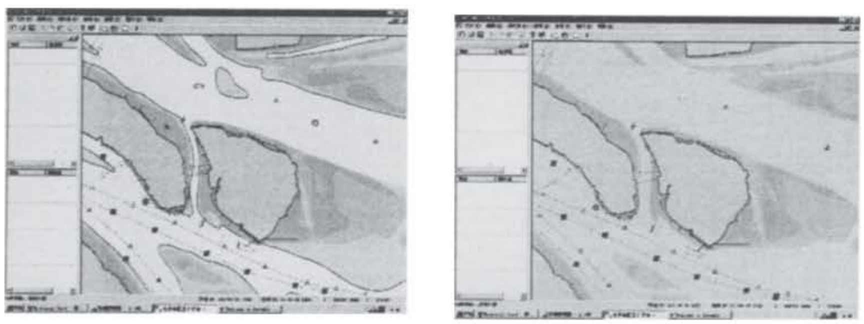


Fig. 4 Safety depth/contour in 5 meters and 30 meters

3.5 *Display orientation/mode*

With ECDIS, the mariner can select either a "north-up" or a "course-up" orientation. The ECDIS display can also be configured to operate in a true motion or relative motion mode of operation. In true motion, own ship's symbol moves across chart display. With a relative motion display, the own ship's symbol remains stationary in the center while the chart information appears to move.

3.6 *Other information*

Radar signal or other navigational information may be added to the display. However, it should not degrade the display and not obscure other electronic chart information. Different information is not simply superimposed together. Transferred radar information may contain both the radar image and ARPA (automated radar piloting aid) information. Those information can be crucial for collision avoidance.

4 Important functions for ECDIS

ECDIS is different from other GIS. It has not only it's own displaying features, but also some special important functions.

4.1 *Route planning*

With ECDIS the mariner should be able to perform route planning in a simple and reliable manner. It should be possible to add or delete waypoints, or to change the position or order of waypoints in a selected route. It should also be possible to plan both primary and alternate routes.

4.2 *Route monitoring*

During route monitoring, ECDIS must show own ship's position whenever the display covers that area. Key information provided during route monitoring includes a continuous indication of vessel position, course, and speed. Additional information that ECDIS can provide includes such information as distance right/left of intended track, time-to-run, distance-to-turn, position and past track history.

4.3 *Voyage recording*

After the voyage, ECDIS must be able to reconstruct the navigation and verify the official database used. Recorded at one minute intervals the information includes:

•own ship's past track including time, position, heading, and speed,

•a record of official ENC used including source, edition, date, cell and update history.

In addition, ECDIS must be able to record the complete track for the entire voyage with time marks. ECDIS should also have the capability to preserve the record of the voyage. Finally, it should not be allowed to manipulate or change the recorded information.

5 Conclusion

In order to gain type approval/certification by user, the ECDIS system which we are developing will need to comply fully with the IMO Performance Standard for ECDIS. Anything else (e. g. use of non-official data, different chart content/display, reduced functional capability, etc.) will likely be considered non-compliant.

Results from Shanghai Marine Administration's experiments and at-sea trials have showed that ECDIS is the most effective means of navigation comparing with more traditional methods (e. g. visual fixes, radar, or plotting fixes on paper charts). ECDIS has also showed that mental stress and workload on the bridge, and the portion of time spent on navigation-related tasks can be reduced. This in turn allows more time for the higher risk task of collision avoidance.

Since ECDIS is capable of continuously displaying own ship's position on the electronic chart, there is increasing benefit of having other real-time information available that can be used to increase the safety and efficiency of the voyage. Timely information on water levels and current flow can be of significant benefit to a mariner in terms of optimizing the timing of vessel transits, or the amount of vessel cargo loading.

6 The future

Looking forward to the future, it is evident that ECDIS offers enormous potential to improve the safety and efficiency of maritime navigation[7,8]. ECDIS will lead to dramatic changes in the type of navigation safety waterways services that will need to be provided in order to improve both the safety and efficiency of maritime commerce in the world's increasingly congested ports and waterways. Since ECDIS is a real-time navigation system, there are opportunities to improve upon the type of information that can be provided to the mariner in digital form.

ECDIS will be used in the following areas:

1) As an electronic nautical chart sytem ECDIS is used primarily by professional navigators in the shipping sector, and in particular on ferries in dangerous water areas and in bad weather(e. g. fog).

2) ECDIS will lead to dramatic changes in the types of Vessel Traffic Information Service (VTIS) that will be operated to benefit the efficiency and safety of maritime commerce. An important component of the VTIS in the future will be the increased employment of ECDIS-related technology[9].

3) Instead of relying primarily on voice communications, vessels will eventually have GPS/DGPS transponders (i. e. AIS) that will communicate with one another or to a VTIS center. With a standard format and protocol (e. g. vessel identification, location, course, speed, and time), it would be possible for each vessel to display the location and movement of other vessels on ECDIS.

4) ECDIS will be also employed for the national coastal and environmental protection, oil spill clearance duties, surveillance by aircraft and by the sea rescue service.

5) Simulation systems used for the basic and advanced training of navigators, pilots, et al. are equipped with ECDIS.

References

1 IMO(1995) Performance standards for electronic chart display and information systems (ECDIS), IMO Resolution A. 817 (19). International Maritime Organization, London.

2 International Convention for the Safety of Life at Sea (1986) Consolidated text of 1974 SOLAS Convention, the 1978 SOLAS Protocol, the 1981 and 1983 SOLAS Amendments. International Maritime Organization, London.

(Continued on Page 21)

As GPS furnishes 3D coordinates, some analyses concerning the course of the height of the calbeway are possible. On one hand it is possible to draw a side-face of the cableway, which emphasises the position of the tower(in Fig. 3). On the other hand it is possible to integrate this information in a GIS, e. g. about the obstacles for the aviation. Therewith, given the suitable software, 3D scenery representing the landscape and the cableway are computable(in Fig. 4).

Fig. 3 Side-face of the cableway

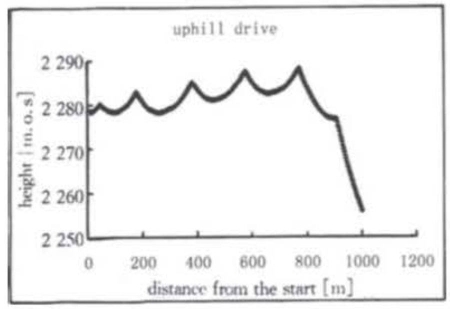


Fig. 4 3D scenery

5 Conclusion

From the described project, the following conclusions can be drawn:

1) Methods of satellite geodesy can be applied to determine the actual position of the axis of the cableway. As a consequence, also the deviations of the position of the tower, due to geodynamic process or mechanical movement, can be detected.

2) Compensation of GPS observations brings about better results, when a condition of linearity is taken into account.

3) Conditions of linearity allow to detect outliers.

4) The method is reliable and precise.

References

1 Salvini D. (1999) Ueberprüfung des Seilverlaufes bei Gondelbahnen und Sesselliften mit Methoden der Satellitengeodäsie. Zurich, Switzerland: IGP-Bericht Nr. 287, ETHZ(in German)

2 Salvini D. (1999) Dreidimensionale Modellierung von Seilbahnanlagen für eine geographische Datenbank der Luftfahrthindernisse. Zurich, Switzerland: IGP-Bericht Nr. 286, ETHZ(in German)

(Continued from Page 11)

3 IHO(1996) IHO Specification for Chart Content and Display of ECDIS, IHO Special Publication No. 52 (IHO S-52), 4th ed. Monaco.

4 IHO(1996) IHO Transfer Standard for Digital Hydrographic Data, IHO Special Publication No. 57 (IHO S-57), 3rd ed. Monaco.

5 IEC 61174: Maritime navigation and radiocommunication equipment systems—Electronic chart display and information system (ECDIS)—Operational and performance requirements, methods of testing, and required test results. International Electrotechnical Commission, Geneva.

6 IMO. Draft recommendation on performance standards for an universal shipborne automatic identification system (AIS). IMO Safety of Navigation Sub-committee Report NAV43/WP. 2, Annex 2, IMO London.

7 U. S. Coast Guard Research and Development Center (1996). Electronic chart display and information systems (ECDIS) test and evaluation — summary report. Report No. CG-D-20-97

8 Offshore Systems Ltd(1997) Canadian electronic chart pilot project — final report. Vancouver, BC.

9 Lee A. , Ganjon F. K. (1995) ECDIS: Current status/future expectations. *Sea Technology*, 36(3)

Attachment 5e: Statewide Illinois Library Catalog record for Geo-spatial Information Science

WorldCat Detailed Record

- Click on a checkbox to mark a record to be e-mailed or printed in Marked Records.

Geo-spatial information science =
Diqui kongjian xinxi kexue xuebao /

Wuhan da xue. Editorial Board of Geomatics and Information Science.

1998-
English Serial Publication : Periodical : Quarterly (every 3 months) v. : ill. ; 30 cm.
Wuhan, China : Wuhan University Journals Press Abingdon, UK : Taylor and Francis on behalf of Wuhan University

GET THIS ITEM

Availability: **Check the catalogs in your library.**
- Libraries worldwide that own item: 38
- Search the catalog at the Library of University of Illinois at Urbana-Champaign

External Resources:
- Discover full text Discover UIUC Full Text
- Interlibrary Loan Request
- Cite This Item

FIND RELATED

More Like This: Advanced options ...
Browse Journal: Available Issues (ArticleFirst)
Find Items About: Wuhan da xue. (82)

Title: **Geo-spatial information science = Diqui kongjian xinxi kexue xuebao /**
Corp Author(s): Wuhan da xue.; Editorial Board of Geomatics and Information Science.
Publication: Wuhan, China : Wuhan University Journals Press Abingdon, UK : Taylor and Francis on behalf of Wuhan University
Year: 1998-
Frequency: Quarterly
Description: Began in 1998.; v. : ill. ; 30 cm.
Language: English
Standard No: **ISSN:** 1009-5020; **Other format's ISSN:** 1993-5153; **National Library:** 2053942-3; 022097953; **LCCN:** 2003-202799

SUBJECT(S)

Descriptor: Geographic information systems -- Periodicals.
Geographic information systems.
Genre/Form: Periodicals.
Class Descriptors: **LC:** G70.212; **Dewey:** 526.0285
Other Titles: Geo-spat. info. sci.; Geo-spatial information science; Spatial information science; Diqui kongjian xinxi kexue xuebao
Responsibility: edited by Editorial Board of Geomatics and Information Science of Wuhan University.
Material Type: Periodical (per)
Document Type: Serial
Entry: 20031002
Update: 20161215
Accession No: **OCLC:** 53126793
Database: WorldCat

Subjects Libraries E-mail Bib Print Export Help

WorldCat results for: **ti: Geo-spatial and ti: Information and ti: Science and dt= "ser"** . Record **1** of **8**.

Gaudio-Hint, Laura

From: Ferdinand Cayongcong <ferdinand.cayongcong@springer.com>
Sent: Tuesday, January 03, 2017 1:46 PM
To: Gaudio-Hint, Laura
Subject: FD 01.03.2016 Article publication date Fc

Dear Laura,

This is to inform you that the article ***Electronic chart display and information system*** *was published online last March 5,2002. For further more information you may contact the Editor Ms. Annie Kang (annie.kang@springer.com).*

With kind regards / Mit freundlichen Grüßen

Ferdinand Cayongcong Jr. (Mr.)
Customer Service

Springer Nature

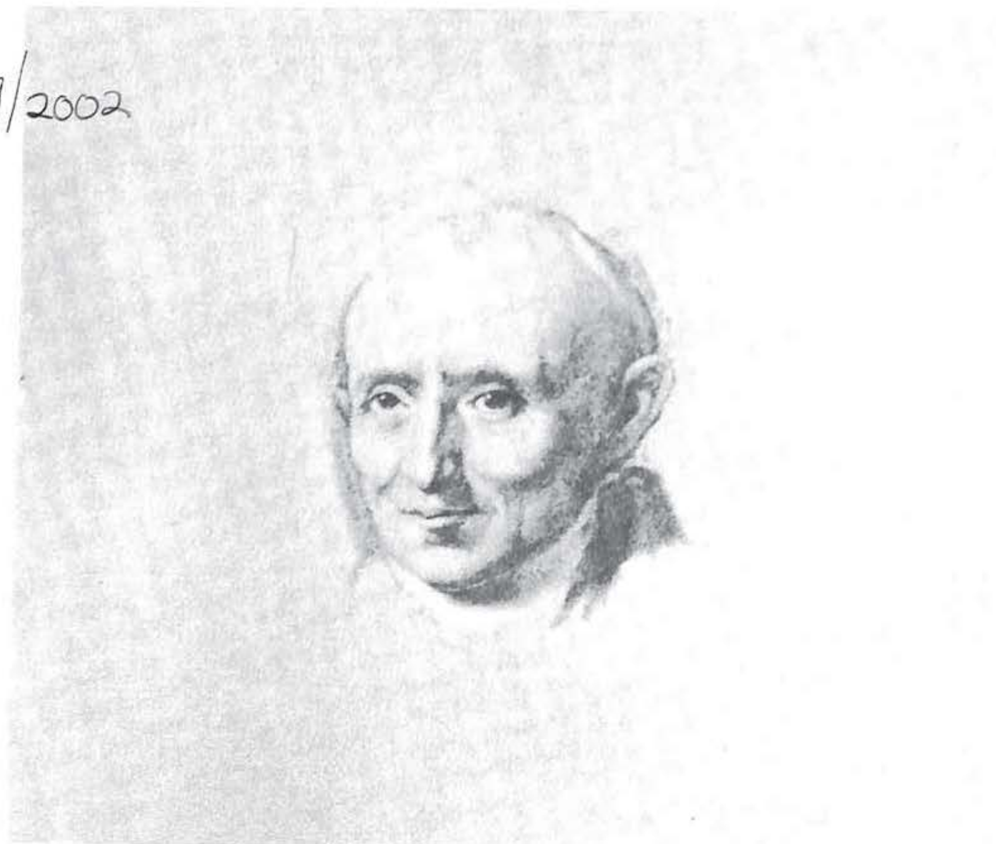
customerservice@springer.com

For the Americas:
Springer Customer Service Center LLC
233 Spring Street, New York, New York 10013, USA
T 1-800-SPRINGER (777-4643) or 212-460-1500
Weekdays 08:30 am – 05:30 pm ET

For any other country:
Springer Customer Service Center GmbH
Tiergartenstrasse 15-17, 69121 Heidelberg, Germany
T +49 6221 345-4301
F +49 6221 345-4229
Weekdays 08:00 am – 06:00 pm MEZ

www.springernature.com
Shop: www.springer.com or www.palgrave.com

When contacting us, please include all previous emails/attachments



Last painting by Gilbert Stuart (1828). Considered by the family of Bowditch to be the best of various paintings made, although it was unfinished when the artist died.

NATHANIEL BOWDITCH

(1773-1838)

Nathaniel Bowditch was born on March 26, 1773, in Salem, Mass., fourth of the seven children of shipmaster Habakkuk Bowditch and his wife, Mary.

Since the migration of William Bowditch from England to the Colonies in the 17th century, the family had resided at Salem. Most of its sons, like those of other families in this New England seaport, had gone to sea, and many of them became shipmasters. Nathaniel Bowditch himself sailed as master on his last voyage, and two of his brothers met untimely deaths while pursuing careers at sea.

Nathaniel Bowditch's father is said to have lost two ships at sea, and by late Revolutionary days he returned to the trade of cooper, which he had learned in his youth. This provided insufficient income to properly supply the needs of his growing family, who were often hungry and cold. For many years the nearly destitute family received an annual grant of 15 to 20 dollars from the Salem Marine Society. By the time Nathaniel had reached the age of 10, the family's poverty forced him to leave school and join his father in the cooper's trade to help support the family.

Nathaniel was unsuccessful as a cooper, and when he was about 12 years of age, he entered the first of two ship-chandlery firms by which he was employed. It was during the nearly 10 years he was so employed that his great mind first attracted public attention. From the time he began school Bowditch had an all-consuming interest in learning, particularly mathematics. By his middle teens he was recognized in Salem as an authority on that subject. Salem being primarily a shipping town, most of the inhabitants sooner or later found their way to the ship chandler, and news of the brilliant young clerk spread until eventually it came to the attention of the learned men of his day. Impressed by his desire to educate himself, they supplied him with books that he might learn of the discoveries of other men. Since many of the best books were written by Europeans, Bowditch first taught himself their languages. French, Spanish, Latin, Greek and German were among the two dozen or more languages and dialects he studied during his life. At the age of 16 he began the study of Newton's *Principia*, translating parts of it from the Latin. He even found an error in that classic text, and though lacking the confidence to announce it at the time, he later published his findings and had them accepted by the scientific community.

During the Revolutionary War a privateer out of Beverly, a neighboring town to Salem, had taken as one of its prizes an English vessel which was carrying the philosophical library of a famed Irish scholar, Dr. Richard Kirwan. The books were brought to the Colonies and there bought by a group of educated Salem men who used them to found the Philosophical Library Company, reputed to have been the best library north of Philadelphia at the time. In 1791, when Bowditch was 18, two Harvard-educated ministers, Rev. John Prince and Rev. William Bentley, persuaded the Company to allow Bowditch the use of its library. Encouraged by these two men and a third, Nathan Read, an apothecary and also a Harvard man, Bowditch studied the works of the great men who had preceded him, especially the mathematicians and the astronomers. By the time he became of age, this knowledge, acquired when not working long hours at the chandlery, had made young Nathaniel the outstanding mathematician in the Commonwealth, and perhaps in the country.

In the seafaring town of Salem, Bowditch was drawn to navigation early, learning the subject at the age of 13 from an old British sailor. A year later he began studying surveying, and in 1794 he assisted in a survey of the town. At 15 he devised an almanac reputed to have been of great accuracy. His other youthful accomplishments included the construction of a crude barometer and a sundial.

When Bowditch went to sea at the age of 21, it was as captain's writer and nominal second mate, the officer's berth being offered him because of his reputation as a scholar. Under Captain Henry Prince, the ship *Henry* sailed from Salem in the winter of 1795 on what was to be a year-long voyage to the Ile de Bourbon (now called Reunion) in the Indian Ocean.

Bowditch began his seagoing career when accurate time was not available to the average naval or merchant ship. A reliable marine chronometer had been invented some 60 years before, but the prohibitive cost, plus the long voyages without opportunity to check the error of the timepiece, made the large investment an impractical one. A system of determining longitude by "lunar distance," a method which did not require an accurate timepiece, was known, but this product of the minds of mathematicians and astronomers was so involved as to be beyond the capabilities of the uneducated seamen of that day. Consequently, ships were navigated by a combination of dead reckoning and parallel sailing (a system of sailing north or south to the latitude of the destination and then east or west to the destination). The navigational routine of the time was "lead, log, and lookout."

To Bowditch, the mathematical genius, computation of lunar distances was no mystery, of course, but he recognized the need for an easier method of working them in order to navigate ships more safely and efficiently. Through analysis and observation, he derived a new and simplified formula during his first trip.

John Hamilton Moore's *The Practical Navigator* was the leading navigational text when Bowditch first went to sea, and had been for many years. Early in his first voyage, however, the captain's writer-second mate began turning up errors in Moore's book, and before long he found it necessary to recompute some of the tables he most often used in working his sights. Bowditch recorded the errors he found, and by the end of his second voyage, made in the higher capacity of supercargo, the news of his findings in *The New Practical Navigator* had reached Edmund Blunt, a printer at Newburyport, Mass. At Blunt's request, Bowditch agreed to participate with other learned men in the preparation of an American edition of the thirteenth (1798) edition of Moore's work. The first American edition was published at Newburyport by Blunt in 1799. This edition corrected many of the errors that Moore had included.

Although most of the errors were of little significance to practical navigation because they were errors in the fifth and sixth places of logarithm tables, some errors were significant.The most significant mistake was listing the year 1800 as a leap year in the table of the sun's declination. The consequence was that Moore gave the declination for March 1, 1800, as 7°11'. Since the actual value was 7° 33', the calculation of a meridian altitude would be in error by 22 minutes of latitude, or 22 nautical miles.

Bowditch's principal contribution to the first American edition was his chapter "The Method of Finding the Longitude at Sea," which discussed his new method for computing lunar distances. Following publication of the first American edition, Blunt obtained Bowditch's services in checking the American and English editions for further errors. Blunt then published a second American edition of Moore's thirteenth edition in 1800. When preparing a third American edition for the press, Blunt decided that Bowditch had revised Moore's work to such an extent that Bowditch should be named as author. The title was changed to *The New American Practical Navigator* and the book was published in 1802 as a first edition. Bowditch vowed while writing this edition to "put down in the book nothing I can't teach the crew," and it is said that every member of his crew including the cook could take a lunar observation and plot the ship's position.

Bowditch made a total of five trips to sea, over a period of about nine years, his last as master and part owner of the three-masted *Putnam*. Homeward bound from a 13-month voyage to Sumatra and the Ile de France (now called Mauritius) the *Putnam* approached Salem harbor on December 25, 1803, during a thick fog without having had a celestial observation since noon on the 24th. Relying upon his dead reckoning, Bowditch conned his wooden-hulled ship to the entrance of the rocky harbor, where he had the good fortune to get a momentary glimpse of Eastern Point, Cape Ann, enough to confirm his position. The *Putnam* proceeded in, past such hazards as "Bowditch's Ledge" (named after a great-grandfather who had wrecked his ship on the rock more than a century before) and anchored safely at 1900 that evening. Word of the daring feat, performed when other masters were hove to outside the harbor, spread along the coast and added greatly to Bowditch's reputation. He was, indeed, the "practical navigator."

His standing as a mathematician and successful shipmaster earned him a well-paid position ashore within a matter of weeks after his last voyage. He was installed as president of a Salem fire and marine insurance company at the age of 30, and during the 20 years he held that position the company prospered. In 1823 he left Salem to take a similar position with a Boston insurance firm, serving that company with equal success until his death.

From the time he finished the "*Navigator*" until 1814, Bowditch's mathematical and scientific pursuits consisted of studies and papers on the orbits of comets, applications of Napier's rules, magnetic variation, eclipses, calculations on tides, and the charting of Salem harbor. In that year, however, he turned to what he considered the greatest work of his life, the translation into English of *Mecanique Celeste*, by Pierre Laplace. *Mecanique Celeste* was a summary of all the then known facts about the workings of the heavens. Bowditch translated four of the five volumes before his death, and published them at his own expense. He gave many formula derivations which Laplace had not shown, and also included further discoveries following the time of publication. His work made this information available to American astronomers and enabled them to pursue their studies on the basis of that which was already known. Continuing his style of writing for the learner, Bowditch presented his English version of *Mecanique Celeste* in such a manner that the student of mathematics could easily trace the steps involved in reaching the most complicated conclusions.

Shortly after the publication of *The New American Practical Navigator*, Harvard College honored its author with the presentation of the honorary degree of Master of Arts, and in 1816 the college made him an honorary Doctor of Laws. From the time the Harvard graduates of Salem first assisted him in his studies, Bowditch had a great interest in that college, and in 1810 he was elected one of its Overseers, a position he held until 1826, when he was elected to the Corporation. During 1826-27 he was the leader of a small group of men who saved the school from financial disaster by forcing necessary economies on the college's reluctant president. At one time Bowditch was offered a Professorship in Mathematics at Harvard but this, as well as similar offers from West Point and the University of Virginia, he declined. In all his life he was never known to have made a public speech or to have addressed any large group of people.

Many other honors came to Bowditch in recognition of his astronomical, mathematical, and marine accomplishments. He became a member of the American Academy of Arts and Sciences, the East India Marine Society, the Royal Academy of Edinburgh, the Royal Society of London, the Royal Irish Academy, the American Philosophical Society, the Connecticut Academy of Arts and Sciences, the Boston Marine Society, the Royal Astronomical Society, the Palermo Academy of Science, and the Royal Academy of Berlin.

Nathaniel Bowditch outlived all of his brothers and sisters by nearly 30 years. He died on March 16, 1838, in his sixty fifth year. The following eulogy by the Salem Marine Society indicates the regard in which this distinguished American was held by his contemporaries:

"In his death a public, a national, a human benefactor has departed. Not this community, nor our country only, but the whole world, has reason to do honor to his memory. When the voice of Eulogy shall be still, when the tear of Sorrow shall cease to flow, no monument will be needed to keep alive his memory among men; but as long as ships shall sail, the needle point to the north, and the stars go through their wonted courses in the heavens, the name of Dr. Bowditch will be revered as of one who helped his fellow-men in a time of need, who was and is a guide to them over the pathless ocean, and of one who forwarded the great interests of mankind."

THE NEW AMERICAN

PRACTICAL NAVIGATOR;

BEING AN

EPITOME OF NAVIGATION;

CONTAINING ALL THE TABLES NECESSARY TO BE USED WITH THE

NAUTICAL ALMANAC,

IN DETERMINING THE

LATITUDE;

AND THE

LONGITUDE BY LUNAR OBSERVATIONS;

AND

KEEPING A COMPLETE RECKONING AT SEA:

ILLUSTRATED BY

PROPER RULES AND EXAMPLES:

THE WHOLE EXEMPLIFIED IN A

JOURNAL,

KEPT FROM

BOSTON TO MADEIRA,

IN WHICH ALL THE RULES OF NAVIGATION ARE INTRODUCED:

ALSO

The Demonstration of the most useful Rules of Trigonometry: With many useful Problems in Mensuration, Surveying, and Gauging: And a Dictionary of Sea-Terms; with the Manner of performing the most common Evolutions at Sea.

TO WHICH ARE ADDED,

Some General Instructions and Information to Merchants, Masters of Vessels, and others concerned in Navigation, relative to Maritime Laws and Mercantile Customs.

FROM THE BEST AUTHORITIES.

ENRICHED WITH A NUMBER OF

NEW TABLES,

WITH ORIGINAL IMPROVEMENTS AND ADDITIONS, AND A LARGE VARIETY OF NEW AND IMPORTANT MATTER:

ALSO,

MANY THOUSAND ERRORS ARE CORRECTED,

WHICH HAVE APPEARED IN THE BEST SYSTEMS OF NAVIGATION YET PUBLISHED.

BY **NATHANIEL BOWDITCH,**

FELLOW OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.

ILLUSTRATED WITH COPPERPLATES.

First Edition.

J+ PRINTED AT NEWBURYPORT, (Mass.) 1802,

BY

EDMUND M. BLUNT, (Proprietor)

For CUSHING & APPLETON, Salem.

Sold by every Bookseller, Ship-Chandler, and Mathematical [illegible], in the United States and West-Indies.

Original title page of *The New American Practical Navigator*, First Edition, published in 1802.

PREFACE

The Naval Observatory library in Washington, D.C., is unnaturally quiet. It is a large circular room, filled with thousands of books. Its acoustics are perfect; a mere whisper from the room's open circular balcony can be easily heard by those standing on the ground floor. A fountain in the center of the ground floor softly breaks the room's silence as its water stream gently splashes into a small pool. From this serene room, a library clerk will lead you into an antechamber, beyond which is a vault containing the Observatory's most rare books. In this vault, one can find an original 1802 first edition of the *New American Practical Navigator*.

One cannot hold this small, delicate, slipcovered book without being impressed by the nearly 200-year unbroken chain of publication that it has enjoyed. It sailed on U.S. merchantmen and Navy ships shortly after the quasi-war with France and during British impressment of merchant seamen that led to the War of 1812. It sailed on U.S. Naval vessels during operations against Mexico in the 1840's, on ships of both the Union and Confederate fleets during the Civil War, and with the U.S. Navy in Cuba in 1898. It went around the world with the Great White Fleet, across the North Atlantic to Europe during both World Wars, to Asia during the Korean and Vietnam Wars, and to the Middle East during Operation Desert Storm. It has circled the globe with countless thousands of merchant ships for 200 years.

As navigational requirements and procedures have changed throughout the years, *Bowditch* has changed with them. Originally devoted almost exclusively to celestial navigation, it now also covers a host of modern topics. It is as practical today as it was when Nathaniel Bowditch, master of the *Putnam*, gathered the crew on deck and taught them the mathematics involved in calculating lunar distances. It is that practicality that has been the publication's greatest strength, and that makes the publication as useful today as it was in the age of sail.

Seafarers have long memories. In no other profession is tradition more closely guarded. Even the oldest and most cynical acknowledge the special bond that connects those who have made their livelihood plying the sea. This bond is not comprised of a single strand; rather, it is a rich and varied tapestry that stretches from the present back to the birth of our nation and its seafaring culture. As this book is a part of that tapestry, it should not be lightly regarded; rather, it should be preserved, as much for its historical importance as for its practical utility.

Since antiquity, mariners have gathered available navigation information and put it into a text for others to follow. One of the first attempts at this involved volumes of Spanish and Portuguese navigational manuals translated into English between about 1550 to 1750. Writers and translators of the time "borrowed" freely in compiling navigational texts, a practice which continues today with works such as Sailing Directions and Pilots.

Colonial and early American navigators depended exclusively on English navigation texts because there were no American editions. The first American navigational text, *Orthodoxal Navigation*, was completed by Benjamin Hubbard in 1656. The first American navigation text published in America was Captain Thomas Truxton's *Remarks, Instructions, and Examples Relating to the Latitude and Longitude; also the Variation of the Compass, Etc., Etc.*, published in 1794.

The most popular navigational text of the late 18th century was John Hamilton Moore's *The New Practical Navigator*. Edmund M. Blunt, a Newburyport publisher, decided to issue a revised copy of this work for American navigators. Blunt convinced Nathaniel Bowditch, a locally famous mariner and mathematician, to revise and update *The New Practical Navigator*. Several other learned men assisted in this revision. Blunt's *The New Practical Navigator* was published in 1799. Blunt also published a second American edition of Moore's book in 1800.

By 1802, when Blunt was ready to publish a third edition, Nathaniel Bowditch and others had corrected so many errors in Moore's work that Blunt decided to issue the work as a first edition of the *New American Practical Navigator*. It is to that 1802 work that the current edition of the *American Practical Navigator* traces its pedigree.

The *New American Practical Navigator* stayed in the Bowditch and Blunt family until the government bought the copyright in 1867. Edmund M. Blunt published the book until 1833; upon his retirement, his sons, Edmund and George, took over publication.The elder Blunt died in 1862; his son Edmund followed in 1866. The next year, 1867, George Blunt sold the copyright to the government for $25,000. The government has published *Bowditch* ever since. George Blunt died in 1878.

Nathaniel Bowditch continued to correct and revise the book until his death in 1838. Upon his death, the editorial responsibility for the *American Practical Navigator* passed to his son, J. Ingersoll Bowditch. Ingersoll Bowditch continued editing the *Navigator* until George Blunt sold the copyright to the government. He outlived all of the principals involved in publishing and editing the *Navigator*, dying in 1889.

The U.S. government has published some 52 editions since acquiring the copyright to the book that has come to be known simply by its original author's name, "*Bowditch.*" Since the government began production, the book has been known by its year of publishing, instead of by the edition number. During a revision in 1880 by Commander Phillip H. Cooper, USN, the name was changed to *American Practical Navigator*. Bowditch's original method of taking "lunars" was finally dropped from the book just after the turn of the 20th century. After several more revisions and printings through World Wars I and II, *Bowditch* was extensively revised for the 1958 edition and again in 1995.

Recognizing the limitations of the printed word, and that computers and electronic media permit us to think about the processes of both navigation and publishing in completely new ways, NIMA has, for the 2002 edition, produced the first official Compact Disk-Read Only Memory (CD-ROM) version of this work. This CD contains, in addition to the full text of the printed book, electronic enhancements and additions not possible in book form. Our goal is to put as much useful navigational information before the navigator as possible in the most understandable and readable format. We are only beginning to explore the possibilities of new technology in this area.

As much as it is a part of history, Bowditch is not a history book. As in past editions, dated material has been dropped and new methods, technologies and techniques added to keep pace with the rapidly changing world of navigation. The changes to this edition are intended to ensure that it remains the premier reference work for modern, practical marine navigation. This edition replaces but does not cancel former editions, which may be retained and consulted as to historical navigation methods not discussed herein.

PART 1, FUNDAMENTALS, includes an overview of the types and phases of marine navigation and the organizations which develop, support and regulate it. It includes chapters relating to the types, structure, use and limitations of nautical charts; a concise explanation of geodesy and chart datums; and a summary of various necessary navigational publications.

PART 2, PILOTING, emphasizes the practical aspects of navigating a vessel in restricted waters, using both traditional and electronic methods.

PART 3, ELECTRONIC NAVIGATION, explains the nature of radio waves and electronic navigation systems. Chapters deal with each of the several electronic methods of navigation--satellite, Loran C, and radar, with special emphasis on satellite navigation systems and electronic charts.

PART 4, CELESTIAL NAVIGATION, updates the former edition with more modern terminology, and discusses the use of calculators and computers for the solution of celestial navigation problems.

PART 5, NAVIGATIONAL MATHEMATICS, remains unchanged from the former edition.

PART 6, NAVIGATIONAL SAFETY, discusses recent developments in management of navigational resources, the changing role of the navigator, distress and safety communications, procedures for emergency navigation, and the increasingly complex web of navigation regulations.

PART 7, OCEANOGRAPHY, has been updated to reflect the latest science and terminology.

PART 8, MARINE WEATHER incorporates updated weather routing information and new cloud graphics.

The pronoun "he," used throughout this book as a reference to the navigator, refers to both genders.

The printed version of this volume may be corrected using the Notice to Mariners and Summary of Corrections. Suggestions and comments for changes and additions may be sent to:

NATIONAL IMAGERY AND MAPPING AGENCY
MARITIME SAFETY INFORMATION DIVISION
MAIL STOP D-44
4600 SANGAMORE RD.
BETHESDA, MARYLAND, 20816-5003
UNITED STATES OF AMERICA

This book could not have been produced without the expertise of dedicated personnel from many government organizations, among them: U.S. Coast Guard, U.S. Naval Academy, U.S. Naval Oceanographic Office, US Navy Fleet Training Center, the U.S. Naval Observatory, Office of the Navigator of the Navy, U.S. Merchant Marine Academy, U.S. Coast and Geodetic Survey, the National Ocean Service, and the National Weather Service. In addition to official government expertise, we must note the contributions of private organizations and individuals far too numerous to mention. Mariners worldwide can be grateful for the experience, dedication, and professionalism of the many people who generously gave their time in this effort. A complete list of contributors can be found in the "Contributor's Corner" of the CD-ROM version of this book.

THE EDITORS

TABLE OF CONTENTS

PART 7 — OCEANOGRAPHY

PART 8 — MARINE METEOROLOGY

NAVIGATION TABLES

MATHEMATICAL TABLES

CARTOGRAPHIC TABLES

PILOTING TABLES

CELESTIAL NAVIGATION TABLES

METEOROLOGICAL TABLES

GLOSSARIES

INDEX

1

FUNDAMENTALS

CHAPTER 1

INTRODUCTION TO MARINE NAVIGATION

DEFINITIONS

100. The Art And Science Of Navigation

Marine navigation blends both science and art. A good navigator constantly thinks strategically, operationally, and tactically. He plans each voyage carefully. As it proceeds, he gathers navigational information from a variety of sources, evaluates this information, and determines his ship's position. He then compares that position with his pre-voyage plan, his operational commitments, and his pre-determined "dead reckoning" position. A good navigator anticipates dangerous situations well before they arise, and always stays "ahead of the vessel." He is ready for navigational emergencies at any time. He is increasingly a manager of a variety of resources--electronic, mechanical, and human. Navigation methods and techniques vary with the type of vessel, the conditions, and the navigator's experience. The navigator uses the methods and techniques best suited to the vessel, its equipment, and conditions at hand.

Some important elements of successful navigation cannot be acquired from any book or instructor. The science of navigation can be taught, but the art of navigation must be developed from experience.

101. Types of Navigation

Methods of navigation have changed throughout history. New methods often enhance the mariner's ability to complete his voyage safely and expeditiously, and make his job easier. One of the most important judgments the navigator must make involves choosing the best methods to use. Each method or type has advantages and disadvantages, while none is effective in all situations. Commonly recognized types of navigation are listed below.

- **Dead reckoning (DR)** determines position by advancing a known position for courses and distances. A position so determined is called a dead reckoning (DR) position. It is generally accepted that only course and speed determine the DR position. Correcting the DR position for leeway, current effects, and steering error result in an **estimated position (EP)**.

- **Piloting** involves navigating in restricted waters with frequent or constant determination of position relative to nearby geographic and hydrographic features.

- **Celestial navigation** involves reducing celestial measurements taken with a sextant to lines of position using calculators or computer programs, or by hand with almanacs and tables or using spherical trigonometry.

- **Radio navigation** uses radio waves to determine position through a variety of electronic devices.

- **Radar navigation** uses radar to determine the distance from or bearing of objects whose position is known. This process is separate from radar's use in collision avoidance.

- **Satellite navigation** uses radio signals from satellites for determining position.

Electronic systems and integrated bridge concepts are driving navigation system planning. Integrated systems take inputs from various ship sensors, electronically and automatically chart the position, and provide control signals required to maintain a vessel on a preset course. The navigator becomes a system manager, choosing system presets, interpreting system output, and monitoring vessel response.

In practice, a navigator synthesizes different methodologies into a single integrated system. He should never feel comfortable utilizing only one method when others are also available. Each method has advantages and disadvantages. The navigator must choose methods appropriate to each situation, and never rely completely on only one system.

With the advent of automated position fixing and electronic charts, modern navigation is almost completely an electronic process. The mariner is constantly tempted to rely solely on electronic systems. But electronic navigation systems are always subject to failure, and the professional mariner must never forget that the safety of his ship and crew may depend on skills that differ little from those practiced generations ago. Proficiency in conventional piloting and celestial navigation remains essential.

102. Phases of Navigation

Four distinct phases define the navigation process. The mariner should choose the system mix that meets the accuracy requirements of each phase.

- **Inland Waterway Phase**: Piloting in narrow canals, channels, rivers, and estuaries.
- **Harbor/Harbor Approach Phase**: Navigating to a harbor entrance through bays and sounds, and negotiating harbor approach channels.
- **Coastal Phase**: Navigating within 50 miles of the coast or inshore of the 200 meter depth contour.
- **Ocean Phase**: Navigating outside the coastal area in the open sea.

The navigator's position accuracy requirements, his fix interval, and his systems requirements differ in each phase. The following table can be used as a general guide for selecting the proper system(s).

	Inland	*Harbor/ Approach*	*Coastal*	*Ocean*
DR	X	X	X	X
Piloting	X	X	X	
Celestial			X	X
Radio		X	X	X
Radar	X	X	X	
Satellite	X*	X	X	X

*Table 102. The relationship of the types and phases of navigation. * With SA off and/or using DGPS*

NAVIGATION TERMS AND CONVENTIONS

103. Important Conventions and Concepts

Throughout the history of navigation, numerous terms and conventions have been established which enjoy worldwide recognition. The professional navigator, to gain a full understanding of his field, should understand the origin of certain terms, techniques, and conventions. The following section discusses some of the important ones.

Defining a **prime meridian** is a comparatively recent development. Until the beginning of the 19th century, there was little uniformity among cartographers as to the meridian from which to measure longitude. But it mattered little because there existed no method for determining longitude accurately.

Ptolemy, in the 2nd century AD, measured longitude eastward from a reference meridian 2 degrees west of the Canary Islands. In 1493, Pope Alexander VI established a line in the Atlantic west of the Azores to divide the territories of Spain and Portugal. For many years, cartographers of these two countries used this dividing line as the prime meridian. In 1570 the Dutch cartographer Ortelius used the easternmost of the Cape Verde Islands. John Davis, in his 1594 *The Seaman's Secrets*, used the Isle of Fez in the Canaries because there the variation was zero. Most mariners paid little attention to these conventions and often reckoned their longitude from several different capes and ports during a voyage.

The meridian of London was used as early as 1676, and over the years its popularity grew as England's maritime interests increased. The system of measuring longitude both east and west through 180° may have first appeared in the middle of the 18th century. Toward the end of that century, as the Greenwich Observatory increased in prominence, English cartographers began using the meridian of that observatory as a reference. The publication by the Observatory of the first British *Nautical Almanac* in 1767 further entrenched Greenwich as the prime meridian. An unsuccessful attempt was made in 1810 to establish Washington, D.C. as the prime meridian for American navigators and cartographers. In 1884, the meridian of Greenwich was officially established as the prime meridian. Today, all maritime nations have designated the Greenwich meridian the prime meridian, except in a few cases where local references are used for certain harbor charts.

Charts are graphic representations of areas of the Earth, in digital or graphic form, for use in marine or air navigation. Nautical charts, whether in digital or paper form, depict features of particular interest to the marine navigator. Charts have probably existed since at least 600 B.C. Stereographic and orthographic projections date from the 2nd century B.C. In 1569 Gerardus Mercator published a chart using the mathematical principle which now bears his name. Some 30 years later, Edward Wright published corrected mathematical tables for this projection, enabling other cartographers to produce charts on the Mercator projection. This projection is still the most widely used.

Sailing Directions or ***pilots*** have existed since at least the 6th century B.C. Continuous accumulation of navigational data, along with increased exploration and trade, led to increased production of volumes through the Middle Ages. "Routiers" were produced in France about 1500; the English referred to them as "rutters." In 1584 Lucas Waghenaer published the *Spieghel der Zeevaerdt (The Mariner's Mirror)*, which became the model for such publications for several generations of navigators. They were known as "Waggoners" by most sailors.

The **compass** was developed about 1000 years ago. The origin of the magnetic compass is uncertain, but

Norsemen used it in the 11th century, and Chinese navigators used the magnetic compass at least that early and probably much earlier. It was not until the 1870s that Lord Kelvin developed a reliable dry card marine compass. The fluid-filled compass became standard in 1906.

Variation was not understood until the 18th century, when Edmond Halley led an expedition to map lines of variation in the South Atlantic. **Deviation** was understood at least as early as the early 1600s, but adequate correction of compass error was not possible until Matthew Flinders discovered that a vertical iron bar could reduce certain types of errors. After 1840, British Astronomer Royal Sir George Airy and later Lord Kelvin developed combinations of iron masses and small magnets to eliminate most magnetic compass error.

The **gyrocompass** was made necessary by iron and steel ships. Leon Foucault developed the basic gyroscope in 1852. An American (Elmer Sperry) and a German (Anshutz Kampfe) both developed electrical gyrocompasses in the early years of the 20th century. Ring laser gyrocompasses and digital flux gate compasses are gradually replacing traditional gyrocompasses, while the magnetic compass remains an important backup device.

The **log** is the mariner's speedometer. Mariners originally measured speed by observing a chip of wood passing down the side of the vessel. Later developments included a wooden board attached to a reel of line. Mariners measured speed by noting how many knots in the line unreeled as the ship moved a measured amount of time; hence the term **knot.** Mechanical logs using either a small paddle wheel or a rotating spinner arrived about the middle of the 17th century. The taffrail log still in limited use today was developed in 1878. Modern logs use electronic sensors or spinning devices that induce small electric fields proportional to a vessel's speed. An engine revolution counter or shaft log often measures speed aboard large ships. Doppler speed logs are used on some vessels for very accurate speed readings. Inertial and satellite systems also provide highly accurate speed readings.

The Metric Conversion Act of 1975 and the Omnibus Trade and Competitiveness Act of 1988 established the **metric system** of weights and measures in the United States. As a result, the government is converting charts to the metric format. Notwithstanding the conversion to the metric system, the common measure of distance at sea is the **nautical mile**.

The current policy of the National Imagery and Mapping Agency (NIMA) and the National Ocean Service (NOS) is to convert new compilations of nautical, special purpose charts, and publications to the metric system. All digital charts use the metric system. This conversion began on January 2, 1970. Most modern maritime nations have also adopted the meter as the standard measure of depths and heights. However, older charts still on issue and the charts of some foreign countries may not conform to this standard.

The **fathom** as a unit of length or depth is of obscure origin. Posidonius reported a sounding of more than 1,000 fathoms in the 2nd century B.C. How old the unit was then is unknown. Many modern charts are still based on the fathom, as conversion to the metric system continues.

The sailings refer to various methods of mathematically determining course, distance, and position. They have a history almost as old as mathematics itself. Thales, Hipparchus, Napier, Wright, and others contributed the formulas that permit computation of course and distance by plane, traverse, parallel, middle latitude, Mercator, and great circle sailings.

104. The Earth

The Earth is an irregular oblate spheroid (a sphere flattened at the poles). Measurements of its dimensions and the amount of its flattening are subjects of geodesy. However, for most navigational purposes, assuming a spherical Earth introduces insignificant error. The Earth's axis of rotation is the line connecting the north and south geographic poles.

A great circle is the line of intersection of a sphere and a plane through its center. This is the largest circle that can be drawn on a sphere. The shortest line on the surface of a sphere between two points on the surface is part of a great circle. On the spheroidal Earth the shortest line is called a geodesic. A great circle is a near enough approximation to

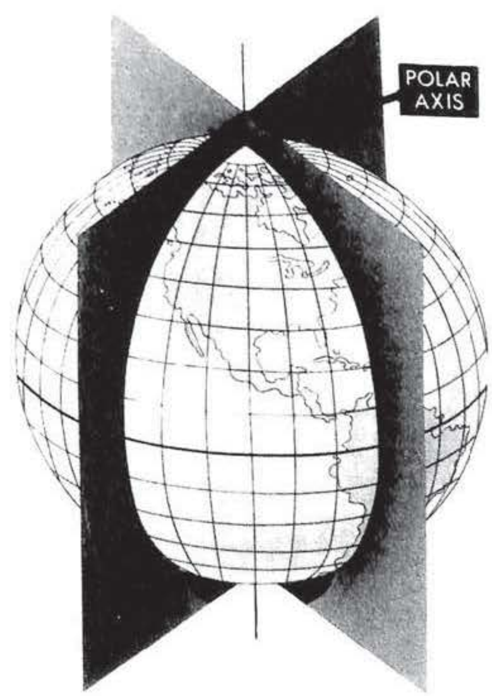


Figure 104a. The planes of the meridians at the polar axis.

a geodesic for most problems of navigation. A small circle is the line of intersection of a sphere and a plane which does not pass through the center. See Figure 104a.

The term **meridian** is usually applied to the **upper branch** of the half-circle from pole to pole which passes through a given point. The opposite half is called the **lower branch.**

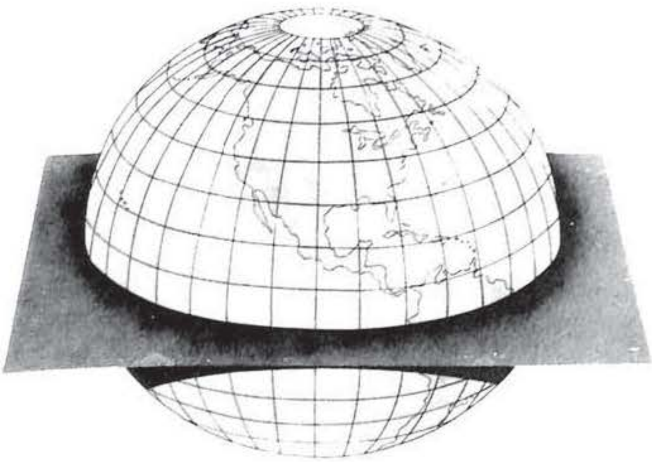


Figure 104b. The equator is a great circle midway between the poles.

A **parallel** or parallel of latitude is a circle on the surface of the Earth parallel to the plane of the equator. It connects all points of equal latitude. The equator is a great circle at latitude 0°. See Figure 104b. The poles are single points at latitude 90°. All other parallels are small circles.

105. Coordinates

Coordinates of latitude and longitude can define any position on Earth. **Latitude (L, lat.)** is the angular distance from the equator, measured northward or southward along a meridian from 0° at the equator to 90° at the poles. It is designated north (N) or south (S) to indicate the direction of measurement.

The **difference of latitude (*l*, DLat.)** between two places is the angular length of arc of any meridian between their parallels. It is the numerical difference of the latitudes if the places are on the same side of the equator; it is the sum of the latitudes if the places are on opposite sides of the equator. It may be designated north (N) or south (S) when appropriate. The middle or **mid-latitude (Lm)** between two places on the same side of the equator is half the sum of their latitudes. Mid-latitude is labeled N or S to indicate whether it is north or south of the equator.

The expression may refer to the mid-latitude of two places on opposite sides of the equator. In this case, it is equal to half the difference between the two latitudes and takes the name of the place farthest from the equator.

Longitude (l, long.) is the angular distance between the prime meridian and the meridian of a point on the Earth, measured eastward or westward from the prime meridian through 180°. It is designated east (E) or west (W) to indicate the direction of measurement.

The **difference of longitude (DLo)** between two places is the shorter arc of the parallel or the smaller angle at the pole between the meridians of the two places. If both places are on the same side (east or west) of Greenwich, DLo is the numerical difference of the longitudes of the two places; if on opposite sides, DLo is the numerical sum unless this exceeds 180°, when it is 360° minus the sum.

The distance between two meridians at any parallel of latitude, expressed in distance units, usually nautical miles, is called **departure (p, Dep.)**. It represents distance made good east or west as a craft proceeds from one point to another. Its numerical value between any two meridians decreases with increased latitude, while DLo is numerically the same at any latitude. Either DLo or p may be designated east (E) or west (W) when appropriate.

106. Distance on the Earth

Distance, as used by the navigator, is the length of the **rhumb line** connecting two places. This is a line making the same angle with all meridians. Meridians and parallels which also maintain constant true directions may be considered special cases of the rhumb line. Any other rhumb line spirals toward the pole, forming a **loxodromic curve** or **loxodrome**. See Figure 106. Distance along the great

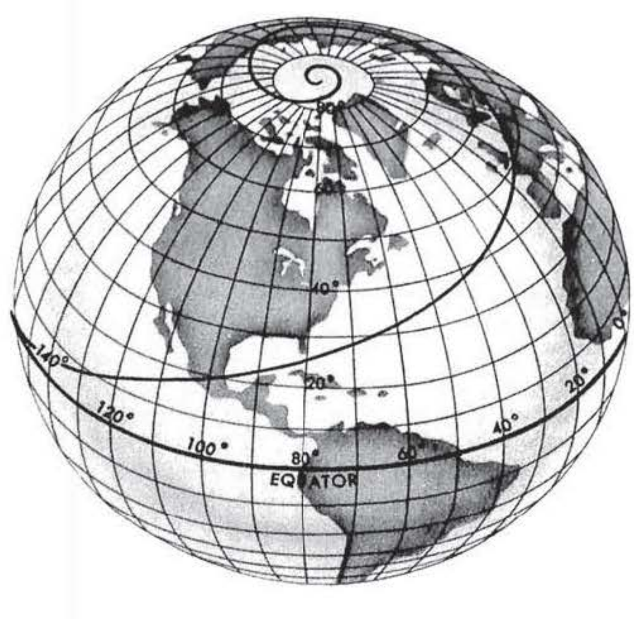


Figure 106. A loxodrome.

circle connecting two points is customarily designated **great-circle distance**. For most purposes, considering the nautical mile the length of one minute of latitude introduces no significant error.

Speed (S) is rate of motion, or distance per unit of time. A **knot (kn.)**, the unit of speed commonly used in navigation, is a rate of 1 nautical mile per hour. The expression **speed of advance (SOA)** is used to indicate the speed to be made along the intended track. **Speed over the ground (SOG)** is the actual speed of the vessel over the surface of the Earth at any given time. To calculate **speed made good (SMG)** between two positions, divide the distance between the two positions by the time elapsed between the two positions.

107. Direction on the Earth

Direction is the position of one point relative to another. Navigators express direction as the angular difference in degrees from a reference direction, usually north or the ship's head. **Course (C, Cn)** is the horizontal direction in which a vessel is intended to be steered, expressed as angular distance from north clockwise through 360°. Strictly used, the term applies to direction through the water, not the direction intended to be made good over the ground. The course is often designated as true, magnetic, compass, or grid according to the reference direction.

Track made good (TMG) is the single resultant direction from the point of departure to point of arrival at any given time. **Course of advance (COA)** is the direction intended to be made good over the ground, and **course over ground (COG)** is the direction between a vessel's last fix and an EP. A **course line** is a line drawn on a chart extending in the direction of a course. It is sometimes convenient to express a course as an angle from either north or south, through 90° or 180°. In this case it is designated course angle (C) and should be properly labeled to indicate the origin (prefix) and direction of measurement (suffix). Thus, C N35°E = Cn 035° (000° + 35°), C N155°W = Cn 205° (360° - 155°), C S47°E = Cn 133° (180° - 47°). But Cn 260° may be either C N100°W or C S80°W, depending upon the conditions of the problem.

Track (TR) is the intended horizontal direction of travel with respect to the Earth. The terms intended track and trackline are used to indicate the path of intended travel. See Figure 107a. The track consists of one or a series of course lines, from the point of departure to the destination, along which one intends to proceed. A great circle which a vessel intends to follow is called a **great-circle track**, though it consists of a series of straight lines approximating a great circle.

Heading (Hdg., SH) is the direction in which a vessel is pointed at any given moment, expressed as angular distance from 000° clockwise through 360°. It is easy to confuse heading and course. Heading constantly changes as a vessel yaws back and forth across the course due to sea, wind, and steering error.

Bearing (B, Brg.) is the direction of one terrestrial point from another, expressed as angular distance from 000° (North) clockwise through 360°. When measured through 90° or 180° from either north or south, it is called bearing angle (B). Bearing and azimuth are sometimes used interchangeably, but the latter more accurately refers to the horizontal direction of a point on the celestial sphere from a point on the Earth. A relative bearing is measured relative to the ship's heading from 000° (dead ahead) clockwise through 360°. However, it is sometimes conveniently measured right or left from 000° at the ship's head through 180°. This is particularly true when using the table for Distance of an Object by Two Bearings.

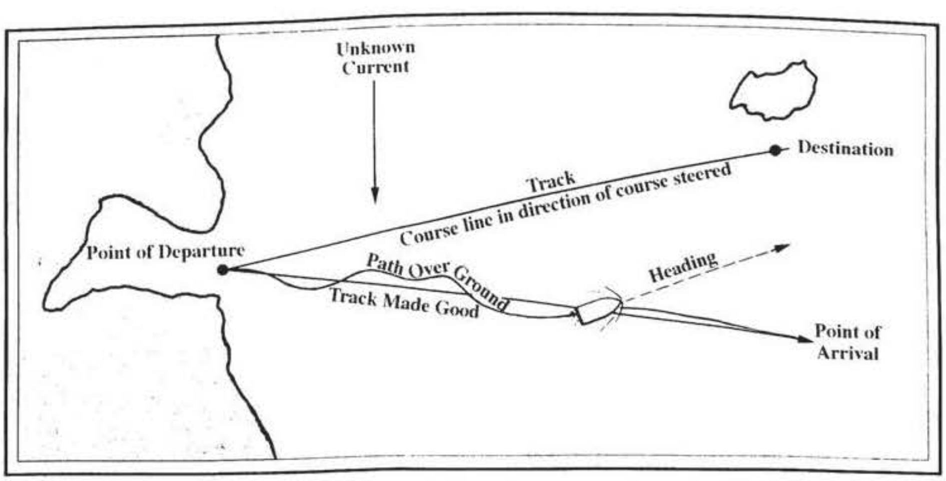


Figure 107a. Course line, track, track made good, and heading.

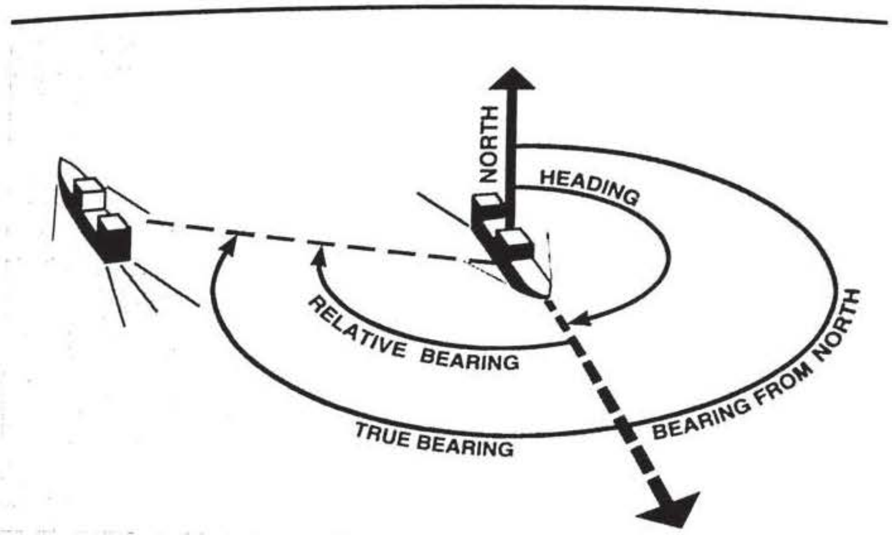


Figure 107b. Relative Bearing

To convert a relative bearing to a true bearing, add the true heading. See Figure 107b

True Bearing = Relative Bearing + True Heading.
Relative Bearing = True Bearing - True Heading.

108. Finding Latitude and Longitude

Navigators have made latitude observations for thousands of years. Accurate declination tables for the Sun have been published for centuries, enabling ancient seamen to compute latitude to within 1 or 2 degrees. Those who today determine their latitude by measuring the Sun at their meridian and the altitude of Polaris are using methods well known to 15th century navigators.

A method of finding longitude eluded mariners for centuries. Several solutions independent of time proved too cumbersome. Finding longitude by magnetic variation was tried, but found too inaccurate. The lunar distance method, which determines GMT by observing the Moon's position among the stars, became popular in the 1800s. However, the mathematics required by most of these processes were far above the abilities of the average seaman. It was apparent that the solution lay in keeping accurate time at sea.

In 1714, the British Board of Longitude was formed, offering a small fortune in reward to anyone who could provide a solution to the problem.

An Englishman, John Harrison, responded to the challenge, developing four chronometers between 1735 and 1760. The most accurate of these timepieces lost only 15 seconds on a 156 day round trip between London and Barbados. The Board, however, paid him only half the promised reward. The King finally intervened on Harrison's behalf, and at the age of 80 years Harrison received his full reward of £20,000.

Rapid chronometer development led to the problem of determining **chronometer error** aboard ship. **Time balls**, large black spheres mounted in port in prominent locations, were dropped at the stroke of noon, enabling any ship in harbor which could see the ball to determine chronometer error. By the end of the U.S. Civil War, telegraph signals were being used to key time balls. Use of radio signals to send time ticks to ships well offshore began in 1904, and soon worldwide signals were available.

109. The Navigational Triangle

Modern celestial navigators reduce their celestial observations by solving a **navigational triangle** whose points are the elevated pole, the celestial body, and the zenith of the observer. The sides of this triangle are the polar distance of the body (**codeclination**), its zenith distance (**coaltitude**), and the polar distance of the zenith (**colatitude** of the observer).

A spherical triangle was first used at sea in solving **lunar distance** problems. Simultaneous observations were made of the altitudes of the Moon and the Sun or a star near the ecliptic and the angular distance between the Moon and the other body. The zenith of the observer and the two celestial bodies formed the vertices of a triangle whose sides were the two coaltitudes and the angular distance between the bodies. Using a mathematical calculation the navigator "cleared" this distance of the effects of refraction and parallax applicable to each altitude. This corrected value was then used as an argument for entering the almanac. The almanac gave the true lunar distance from the Sun and several stars at 3 hour intervals. Previously, the navigator had set his watch or checked its error and rate with the local mean time determined by celestial observations. The local mean time of the watch, properly corrected, applied to the Greenwich mean time obtained from the lunar distance observation, gave the longitude.

The calculations involved were tedious. Few mariners could solve the triangle until Nathaniel Bowditch published his simplified method in 1802 in *The New American Practical Navigator*.

Reliable chronometers were available by 1800, but their high cost precluded their general use aboard most ships. However, most navigators could determine their longitude using Bowditch's method. This eliminated the need for parallel sailing and the lost time associated with it. Tables for the lunar distance solution were carried in the American nautical almanac into the 20th century.

110. The Time Sight

The theory of the **time sight** had been known to mathematicians since the development of spherical trigonometry, but not until the chronometer was developed could it be used by mariners.

The time sight used the modern navigational triangle. The codeclination, or polar distance, of the body could be determined from the almanac. The zenith distance (coaltitude) was determined by observation. If the colatitude were known, three sides of the triangle were available. From these the meridian angle was computed. The comparison of this with the Greenwich hour angle from the almanac yielded the longitude.

The time sight was mathematically sound, but the navigator was not always aware that the longitude determined was only as accurate as the latitude, and together they merely formed a point on what is known today as a **line of position**. If the observed body was on the prime vertical, the line of position ran north and south and a small error in latitude generally had little effect on the longitude. But when the body was close to the meridian, a small error in latitude produced a large error in longitude.

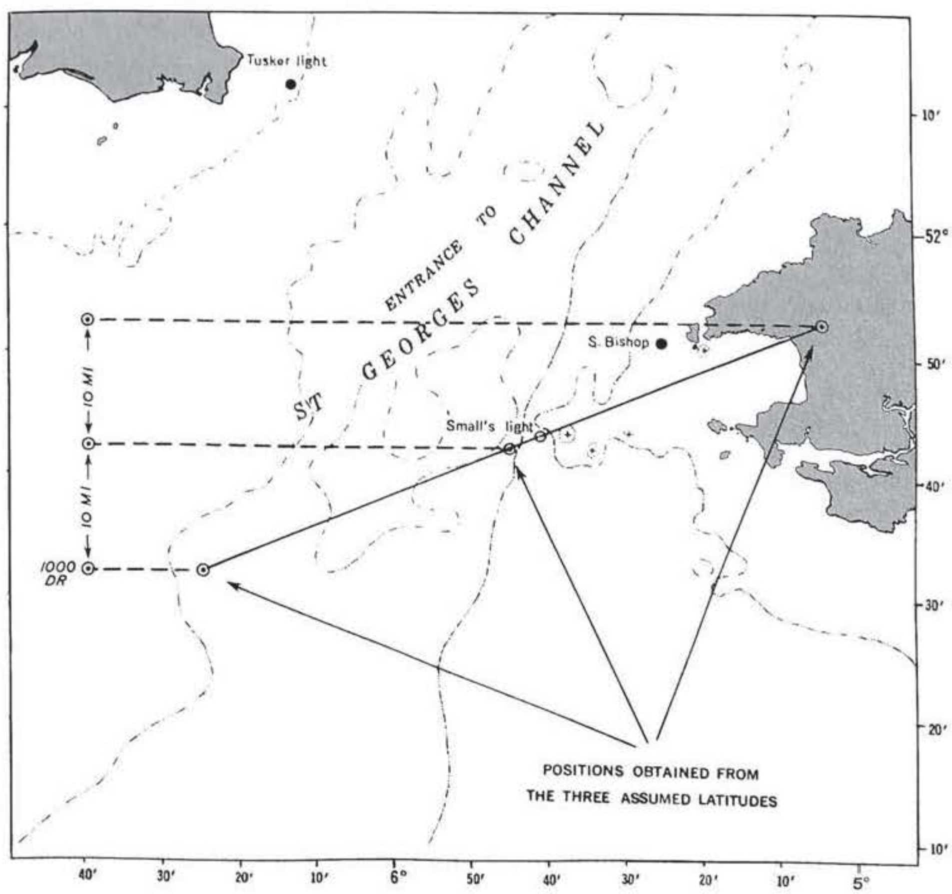


Figure 110. The first celestial line of position, obtained by Captain Thomas Sumner in 1837.

The line of position by celestial observation was unknown until discovered in 1837 by 30-year-old Captain Thomas H. Sumner, a Harvard graduate and son of a United States congressman from Massachusetts. The discovery of the "**Sumner line**," as it is sometimes called, was considered by Maury "the commencement of a new era in practical navigation." This was the turning point in the development of modern celestial navigation technique. In Sumner's own words, the discovery took place in this manner:

> *Having sailed from Charleston, S. C., 25th November, 1837, bound to Greenock, a series of heavy gales from the Westward promised a quick passage; after passing the Azores, the wind prevailed from the Southward, with thick weather; after passing Longitude 21° W, no observation was had until near the land; but soundings were had not far, as was supposed, from the edge of the Bank. The weather was now more boisterous, and very thick; and the wind still Southerly; arriving about midnight, 17th December, within 40 miles, by dead reckoning, of Tusker light; the wind hauled SE, true, making the Irish coast a lee shore; the ship was then kept close to the wind, and several tacks made to preserve her position as nearly as possible until daylight; when nothing being in sight, she was kept on ENE under short sail, with heavy gales; at about 10 AM an altitude of the Sun was observed, and the Chronometer time noted; but, having run so far without any observation, it was plain the Latitude by dead reckoning was liable to error, and could not be entirely relied on. Using, however, this Latitude, in finding the Longitude by Chronometer, it was found to put the ship 15' of Longitude E from her position by dead reckoning; which in Latitude 52° N is 9 nautical miles; this seemed to agree tolerably well with the dead reckoning; but feeling doubtful of the Latitude, the observation was tried with a Latitude 10' further N, finding this placed the ship ENE 27 nautical miles, of the former position, it was tried again with a Latitude 20' N of the dead reckoning; this also placed the ship still further ENE, and still 27 nautical miles further; these three positions were then seen to lie in the direction of Small's light. It then at once appeared that the observed altitude must have happened at all the three points, and at Small's light, and at the ship, at the same instant of time; and it followed, that Small's light must bear ENE, if the Chronometer was right. Having been convinced of this truth, the ship was kept on her course, ENE, the wind being still SE., and in less than an hour, Small's light was made bearing ENE 1/2 E, and close aboard.*

In 1843 Sumner published a book, A *New and Accurate Method of Finding a Ship's Position at Sea by Projection on Mercator's Chart.* He proposed solving a single time sight twice, using latitudes somewhat greater and somewhat less than that arrived at by dead reckoning, and joining the two positions obtained to form the line of position.

The Sumner method required the solution of two time sights to obtain each line of position. Many older navigators preferred not to draw the lines on their charts, but to fix their position mathematically by a method which Sumner had also devised and included in his book. This was a tedious but popular procedure.

111. Navigational Tables

Spherical trigonometry is the basis for solving every navigational triangle, and until about 80 years ago the navigator had no choice but to solve each triangle by tedious, manual computations.

Lord Kelvin, generally considered the father of modern navigational methods, expressed interest in a book of tables with which a navigator could avoid tedious trigonometric solutions. However, solving the many thousands of triangles involved would have made the project too costly. Computers finally provided a practical means of preparing tables. In 1936 the first volume of *Pub. No. 214* was made available; later, Pub. No. 249 was provided for air navigators. *Pub. No. 229, Sight Reduction Tables for Marine Navigation*, has replaced *Pub. No. 214*.

Electronic calculators are gradually replacing the tables. Scientific calculators with trigonometric functions can easily solve the navigational triangle. Navigational calculators readily solve celestial sights and perform a variety of voyage planning functions. Using a calculator generally gives more accurate lines of position because it eliminates the rounding errors inherent in tabular inspection and interpolation.

112. Development of Electronic Navigation

Perhaps the first application of electronics to navigation involved sending telegraphic time signals in 1865 to check chronometer error. Transmitting radio time signals for chronometer checks dates to 1904. Radio broadcasts providing navigational warnings, begun in 1907 by the U.S. Navy Hydrographic Office, helped increase the safety of navigation at sea.

By the latter part of World War I the directional properties of a loop antenna were successfully used in the radio direction finder. The first radiobeacon was installed in 1921. Early 20th century experiments by Behm and Langevin led to the U.S. Navy's development of the first practical echo sounder in 1922. Radar and hyperbolic systems grew out of WWII.

Today, electronics touches almost every aspect of navigation. Hyperbolic systems, satellite systems, and electronic charts all require an increasingly sophisticated electronics suite and the expertise to manage them. These systems' accuracy and ease of use make them invaluable assets to the navigator, but there is far more to using them than knowing which buttons to push.

113. Development of Radar

As early as 1904, German engineers were experimenting with reflected radio waves. In 1922 two American scientists, Dr. A. Hoyt Taylor and Leo C. Young, testing a communication system at the Naval Aircraft Radio Laboratory, noted fluctuations in the signals when ships passed between stations on opposite sides of the Potomac River. In 1935 the British began work on radar. In 1937 the USS Leary tested the first sea going radar, and in 1940 United States and British scientists combined their efforts. When the British revealed the principle of the multicavity magnetron developed by J. T. Randall and H. A. H. Boot at the University of Birmingham in 1939, microwave radar became practical. In 1945, at the close of World War II, radar became available for commercial use.

114. Development of Hyperbolic Radio Aids

Various hyperbolic systems were developed beginning in World War II. These were outgrowths of the British GEE system, developed to help bombers navigate to and from their missions over Europe. Loran A was developed as a long-range marine navigation system. This was replaced by the more accurate Loran C system, deployed throughout much of the world. Various short range and regional hyperbolic systems have been developed by private industry for hydrographic surveying, offshore facilities positioning, and general navigation.

115. Other Electronic Systems

The underlying concept that led to development of satellite navigation dates to 1957 and the first launch of an artificial satellite into orbit. The first system, NAVSAT, has been replaced by the far more accurate and widely available **Global Positioning System (GPS)**, which has revolutionized all aspects of navigation

The first **inertial navigation system** was developed in 1942 for use in the V2 missile by the Peenemunde group under the leadership of Dr. Wernher von Braun. This system used two 2-degree-of-freedom gyroscopes and an integrating accelerometer to determine the missile velocity. By the end of World War II, the Peenemunde group had developed a stable platform with three single-degree-of-freedom gyroscopes and an integrating accelerometer. In 1958 an inertial navigation system was used to navigate the USS *Nautilus* under the ice to the North Pole.

NAVIGATION ORGANIZATIONS

116. Governmental Role

Navigation only a generation ago was an independent process, carried out by the mariner without outside assistance. With compass and charts, sextant and chronometer, he could independently travel anywhere in the world. The increasing use of electronic navigation systems has made the navigator dependent on many factors outside his control. Government organizations fund, operate, and regulate satellites, Loran, and other electronic systems. Governments are increasingly involved in regulation of vessel movements through traffic control systems and regulated areas. Understanding the governmental role in supporting and regulating navigation is vitally important to the mariner. In the United States, there are a number of official organizations which support the interests of navigators. Some have a policy-making role; others build and operate navigation systems. Many maritime nations have similar organizations performing similar functions. International organizations also play a significant role.

117. The Coast and Geodetic Survey

The **U.S. Coast and Geodetic Survey** was founded in 1807 when Congress passed a resolution authorizing a survey of the coast, harbors, outlying islands, and fishing banks of the United States. President Thomas Jefferson appointed Ferdinand Hassler, a Swiss immigrant and professor of mathematics at West Point, the first Director of the "Survey of the Coast." The survey became the "Coast Survey" in 1836.

The approaches to New York were the first sections of the coast charted, and from there the work spread northward and southward along the eastern seaboard. In 1844 the work was expanded and arrangements made to simultaneously chart the gulf and east coasts. Investigation of tidal conditions began, and in 1855 the first tables of tide predictions were published. The California gold rush necessitated a survey of the west coast, which began in 1850, the year California became a state. *Coast Pilots*, or *Sailing Directions*, for the Atlantic coast of the United States were privately published in the first half of the 19th century. In 1850 the Survey began accumulating data that led to federally produced *Coast Pilots*. The 1889 *Pacific Coast Pilot* was an outstanding contribution to the safety of west coast shipping.

In 1878 the survey was renamed "Coast and Geodetic Survey." In 1970 the survey became the "National Ocean Survey," and in 1983 it became the "National Ocean Service." The Office of Charting and Geodetic Services accomplished all charting and geodetic functions. In 1991 the name was changed back to the original "Coast and Geodetic Survey," organized under the National Ocean Service along with several other environmental offices. Today it provides the mariner with the charts and coast pilots of all waters of the United States and its possessions, and tide and tidal current tables for much of the world. Its

CHAPTER 3

NAUTICAL CHARTS

CHART FUNDAMENTALS

300. Definitions

A **nautical chart** represents part of the spherical earth on a plane surface. It shows water depth, the shoreline of adjacent land, prominent topographic features, aids to navigation, and other navigational information. It is a work area on which the navigator plots courses, ascertains positions, and views the relationship of the ship to the surrounding area. It assists the navigator in avoiding dangers and arriving safely at his destination.

Originally hand-drawn on sheepskin, traditional nautical charts have for generations been printed on paper. **Electronic charts** consisting of a digital data base and a display system are in use and are replacing paper charts aboard many vessels. An electronic chart is not simply a digital version of a paper chart; it introduces a new navigation methodology with capabilities and limitations very different from paper charts. The electronic chart is the legal equivalent of the paper chart if it meets certain International Maritime Organization specifications. See Chapter 14 for a complete discussion of electronic charts.

Should a marine accident occur, the nautical chart in use at the time takes on legal significance. In cases of grounding, collision, and other accidents, charts become critical records for reconstructing the event and assigning liability. Charts used in reconstructing the incident can also have tremendous training value.

301. Projections

Because a cartographer cannot transfer a sphere to a flat surface without distortion, he must project the surface of a sphere onto a **developable surface**. A developable surface is one that can be flattened to form a plane. This process is known as **chart projection**. If points on the surface of the sphere are projected from a single point, the projection is said to be **perspective** or **geometric**.

As the use of electronic charts becomes increasingly widespread, it is important to remember that the same cartographic principles that apply to paper charts apply to their depiction on video screens.

302. Selecting a Projection

Each projection has certain preferable features. However, as the area covered by the chart becomes smaller, the differences between various projections become less noticeable. On the largest scale chart, such as of a harbor, all projections are practically identical. Some desirable properties of a projection are:

1. True shape of physical features
2. Correct angular relationships
3. Equal area (Represents areas in proper proportions)
4. Constant scale values
5. Great circles represented as straight lines
6. Rhumb lines represented as straight lines

Some of these properties are mutually exclusive. For example, a single projection cannot be both conformal and equal area. Similarly, both great circles and rhumb lines cannot be represented on a single projection as straight lines.

303. Types of Projections

The type of developable surface to which the spherical surface is transferred determines the projection's classification. Further classification depends on whether the projection is centered on the equator (equatorial), a pole (polar), or some point or line between (oblique). The name of a projection indicates its type and its principal features.

Mariners most frequently use a **Mercator projection**, classified as a **cylindrical projection** upon a plane, the cylinder tangent along the equator. Similarly, a projection based upon a cylinder tangent along a meridian is called **transverse** (or inverse) **Mercator** or **transverse** (or inverse) **orthomorphic**. The Mercator is the most common projection used in maritime navigation, primarily because rhumb lines plot as straight lines.

In a **simple conic projection**, points on the surface of the earth are transferred to a tangent cone. In the **Lambert conformal projection**, the cone intersects the earth (a secant cone) at two small circles. In a **polyconic projection**, a series of tangent cones is used.

In an **azimuthal** or **zenithal projection**, points on the earth are transferred directly to a plane. If the origin of the

CHAPTER 8

PILOTING

DEFINITION AND PURPOSE

800. Introduction

Piloting involves navigating a vessel in restricted waters and fixing its position as precisely as possible at frequent intervals. More so than in other phases of navigation, proper preparation and attention to detail are important. This chapter will discuss a piloting methodology designed to ensure that procedures are carried out safely and efficiently. These procedures will vary from vessel to vessel according to the skills and composition of the piloting team. It is the responsibility of the navigator to choose the procedures applicable to his own situation, to train the piloting team in their execution, and to ensure that duties are carried out properly.

These procedures are written primarily from the perspective of the military navigator, with some notes included where civilian procedures might differ. This set of procedures is designed to minimize the chance of error and maximize safety of the ship.

The military navigation team will nearly always consist of several more people than are available to the civilian navigator. Therefore, the civilian navigator must streamline these procedures, eliminating certain steps, doing only what is essential to keep his ship in safe water.

The navigation of civilian vessels will therefore proceed differently than for military vessels. For example, while the military navigator might have bearing takers stationed at the gyro repeaters on the bridge wings for taking simultaneous bearings, the civilian navigator must often take and plot them himself. While the military navigator will have a bearing book and someone to record entries for each fix, the civilian navigator will simply plot the bearings on the chart as they are taken and not record them at all.

If the ship is equipped with an ECDIS, it is reasonable for the navigator to simply monitor the progress of the ship along the chosen track, visually ensuring that the ship is proceeding as desired, checking the compass, sounder and other indicators only occasionally. If a pilot is aboard, as is often the case in the most restricted of waters, his judgement can generally be relied upon explicitly, further easing the workload. But should the ECDIS fail, the navigator will have to rely on his skill in the manual and time-tested procedures discussed in this chapter.

While an ECDIS is the legal equivalent of a paper chart and can be used as the primary plot, an ECS, (non-ECDIS compliant electronic chart system) cannot be so used. An ECS may be considered as an additional resource used to ensure safe navigation, but cannot be relied upon for performing all the routine tasks associated with piloting. The individual navigator, with knowledge of his vessel, his crew, and the capabilities they possess, must make a professional judgement as to how the ECS can support his efforts to keep his ship in safe water. The navigator should always remember that reliance on any single navigation system courts disaster. An ECS does not relieve the navigator of maintaining a proper and legal plot on a paper chart.

PREPARATION

801. Plot Setup

The navigator's job begins well before getting underway. Much advance preparation is necessary to ensure a safe and efficient voyage. The following steps are representative:

Ensure the plotting station(s) have the following instruments:

- **Dividers:** Dividers are used to measure distances between points on the chart.
- **Compasses:** Compasses are used to plot range arcs for radar LOP's. **Beam compasses** are used when the range arc exceeds the spread of a conventional compass. Both should be available at both plots.
- **Plotters:** Several types of plotters are available. The preferred device for large vessels is the parallel motion plotter (PMP) used in conjunction with a drafting table. Otherwise, use a transparent protractor plotter, or triangles, parallel rulers or rolling rulers in conjunction with the chart's compass rose. Finally, the plotter can use a one arm protractor. The plotter should use the device with which he can work the most quickly and accurately.
- **Sharpened Pencils and Erasers:** Ensure an adequate supply of pencils is available.

- **Fischer Radar Plotting Templates:** Fischer plotting is covered in Chapter 13. The plotting templates for this technique should be stacked near the radar repeater.

- **Time-Speed-Distance Calculator:** Given two of the three unknowns (between time, speed, and distance), this calculator allows for rapid computation of the third.

- **Tide and Current Graphs:** Post the tide and current graphs near the primary plot for easy reference during the transit. Give a copy of the graphs to the conning officer and the captain.

Once the navigator verifies the above equipment is in place, he tapes down the charts on the chart table. If more than one chart is required for the transit, tape the charts in a stack such that the plotter works from the top to the bottom of the stack. This minimizes the time required to shift the chart during the transit. If the plotter is using a PMP, align the arm of the PMP with any meridian of longitude on the chart. While holding the PMP arm stationary, adjust the PMP to read 000.0°T. This procedure calibrates the PMP to the chart in use. Perform this alignment every time the piloting team shifts charts.

Be careful not to fold under any important information when folding the chart on the chart table. Ensure the chart's distance scale, the entire track, and all important warning information are visible.

Energize and test all electronic navigation equipment, if not already in operation. This includes the radar and the GPS receiver. Energize and test the fathometer. Ensure the entire electronic navigation suite is operating properly prior to entering restricted waters.

802. Preparing Charts and Publications

- **Assemble Required Publications.** These publications should include *Coast Pilots*, *Sailing Directions*, *USCG Light Lists*, *NIMA Lists of Lights*, *Tide Tables*, *Tidal Current Tables*, *Notice to Mariners*, and *Local Notice to Mariners*. Often, for military vessels, a port will be under the operational direction of a particular squadron; obtain that squadron's port Operation Order. Civilian vessels should obtain the port's harbor regulations. These publications will cover local regulations such as speed limits and bridge-to-bridge radio frequency monitoring requirements. Assemble and review the Broadcast Notice to Mariners file.

- **Select and Correct Charts.** Choose the largest scale chart available for the harbor approach or departure. Often, the harbor approach will be too long to be represented on only one chart. For example, three charts are required to cover the waters from the Naval Station in Norfolk to the entrance of the Chesapeake Bay. Therefore, obtain all the charts required to cover the entire passage. Using the *Notice to Mariners*, verify that these charts have been corrected through the latest *Notice to Mariners*. Check the *Local Notice to Mariners* and the Broadcast Notice to Mariners file to ensure the chart is fully corrected. Annotate on the chart or a chart correction card all the corrections that have been made; this will make it easier to verify the chart's correction status prior to its next use. Naval ships may need to prepare three sets of charts. One set is for the primary plot, the second set is for the secondary plot, and the third set is for the conning officer and captain. Civilian vessels will prepare one set.

- **Mark the Minimum Depth Contour:** Determine the minimum depth of water in which the vessel can safely operate and outline that depth contour on the chart. Do this step before doing any other harbor navigation planning. Highlight this outline in a bright color so that it clearly stands out. Carefully examine the area inside the contour and mark the isolated shoals less than the minimum depth which fall inside the marked contour. Determine the minimum depth in which the vessel can operate as follows:

  Minimum Depth = Ship's Draft – Height of Tide + Safety Margin + Squat. (See Article 804 and Article 818.)

  Remember that often the fathometer's transducer is not located at the section of the hull that extends the furthest below the waterline. Therefore, the indicated depth of water is that below the fathometer transducer, not the depth of water below the vessel's deepest draft.

- **Highlight Selected Visual Navigation Aids (NAVAIDS).** Circle, highlight and label the main navigational aids on the chart. Consult the applicable *Coast Pilot* or *Sailing Directions* to determine a port's best NAVAIDS if the piloting team has not visited the port previously. These aids can be lighthouses, piers, shore features, or tanks; any prominent feature that is displayed on the chart can be used as a NAVAID. Label critical buoys, such as those marking a harbor entrance or a traffic separation scheme. Verify charted lights against the *Light List* or the *List of Lights* to confirm the charted information is correct. This becomes most critical when attempting to identify a light at night. Label NAVAIDS succinctly and clearly. Ensure everyone in the navigation team refers to a NAVAID using the same terminology. This will reduce confusion between the bearing taker, the bearing recorder, and plotter.

- **Highlight Selected Radar NAVAIDS.** Highlight radar NAVAIDS with a triangle instead of a circle. If the NAVAID is suitable for either visual or radar piloting, it can be highlighted with either a circle or a triangle.

- **Plot the Departure/Approach Track.** This process is critical for ensuring safe pilotage. Consult the *Fleet Guide* and *Sailing Directions* for recommendations on the best track to use. Look for any information or regulations published by the local harbor authority. Lacking any of this information, locate a channel or safe route on the chart and plot the vessel's track. Most U.S. ports have well-defined channels marked with buoys. Carefully check the intended track to ensure a sufficient depth of water under the keel will exist for the entire passage. If the scale of the chart permits, lay the track out to the starboard side of the channel to allow for any vessel traffic proceeding in the opposite direction. Many channels are marked by natural or man-made ranges. The bearings of these ranges should be measured to the nearest 0.1° or noted from the *Light List*, and this value should be marked on the chart. Not only are ranges useful in keeping a vessel on track, they are invaluable for determining gyro error. See Article 807.

- **Label the Departure/Approach Track.** Label the track course to the nearest 0.5°. Similarly, label the distance of each track leg. Highlight the track courses for easy reference while piloting. Often a navigator might plan two separate tracks. One track would be for use during good visibility and the other for poor visibility. Considerations might include concern for the number of turns (fewer turns for poor visibility) or proximity to shoal water (smaller margin for error might be acceptable in good visibility). In this case, label both tracks as above and appropriately mark when to use each track.

- **Use Advance and Transfer to Find Turning Points.** The distance the vessel moves along its original course from the time the rudder is put over until the new course is reached is called **advance**. The distance the vessel moves perpendicular to the original course during the turn is called **transfer**.The track determined above does not account for these. See Figure 802a. Use the advance and transfer characteristics of the vessel to determine when the vessel must put its rudder over to gain the next course. From that point, fair in a curve between the original course and the new course. Mark the point on the original course where the vessel must put its rudder over as the **turning point**. See Figure 802b.

- **Plot Turn Bearings and Ranges.** A **turn bearing** is a predetermined bearing to a charted object from the track point at which the rudder must be put over in order to make a desired turn. In selecting a NAVAID for a turn bearing, find one as close to abeam as possible at the turning point, and if possible on the inside elbow of the turn. Account for advance and transfer and label the bearing to the nearest 0.1°. A **turn range** is similar, but taken as a radar range to a prominent object ahead or astern. Ideally, both can be used, one as a check against the other.

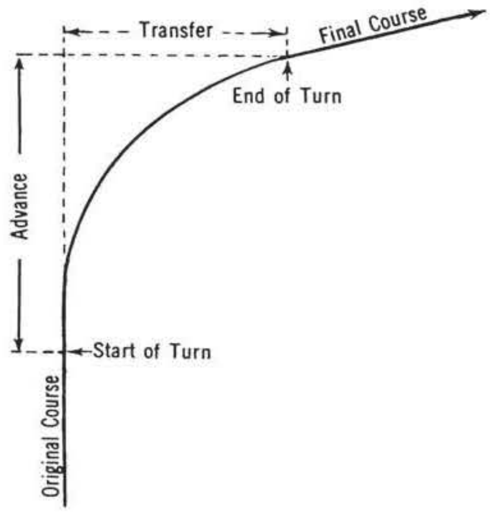


Figure 802a. Advance and transfer.

Example: *Figure 802b illustrates using advance and transfer to determine a turn bearing. A ship proceeding on course 100° is to turn 60° to the left to come on a range which will guide it up a channel. For a 60° turn and the amount of rudder used, the advance is 920 yards and the transfer is 350 yards.*

Required: *The bearing of flagpole "FP." when the rudder is put over.*

Solution:

1. *Extend the original course line, AB.*
2. *At a perpendicular distance of 350 yards, the transfer, draw a line A'B' parallel to the original course line AB. The point of intersection, C, of A'B' with the new course line is the place at which the turn is to be completed.*
3. *From C draw a perpendicular, CD, to the original course line, intersecting at D.*
4. *From D measure the advance, 920 yards, back along the original course line. This locates E, the point at which the turn should be started.*
5. *The direction of "FP." from E, 058°, is the bearing when the turn should be started.*

Answer: *Bearing 058°.*

FLIR-1015.297

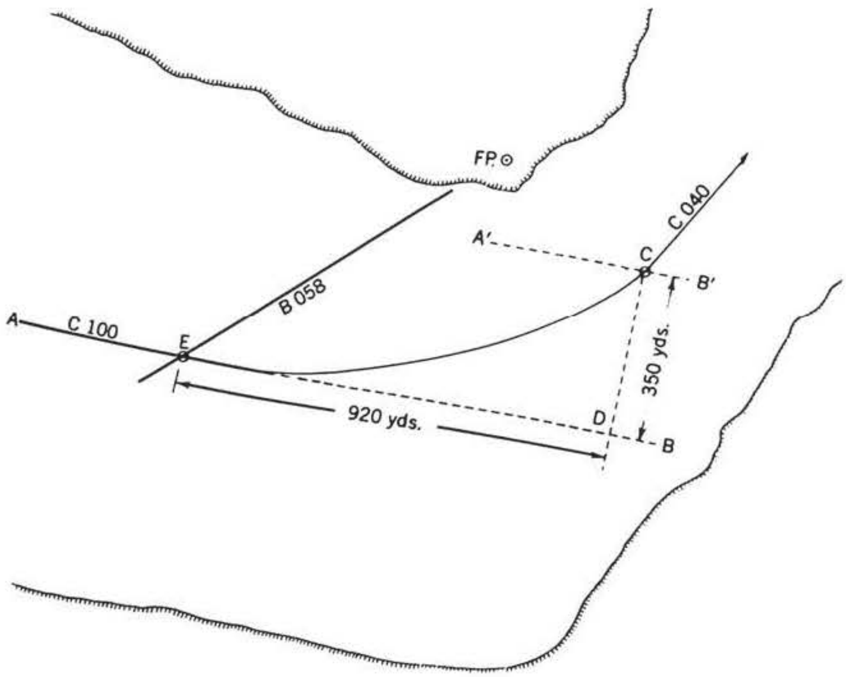


Figure 802b. Allowing for advance and transfer.

- **Plot a Slide Bar for Every Turn Bearing:** If the ship is off track immediately prior to a turn, a plotting technique known as the **slide bar** can quickly revise a turn bearing. See Figure 802c. A slide bar is a line drawn parallel to the new course through the turning point on the original course. The navigator can quickly determine a new turn bearing by dead reckoning ahead from the vessel's last fix position to where the DR intersects the slide bar. The revised turn bearing is simply the bearing from that intersection point to the turn bearing NAVAID. Draw the slide bar with a different color from that used for the track in order to see the slide bar clearly.

- **Label Distance to Go from Each Turn Point:** At each turning point, label the distance to go until either the ship moors (inbound) or the ship clears the harbor (outbound). For an inbound transit, a vessel's captain is usually more concerned about time of arrival, so assume a speed of advance and label each turn point with time to go until mooring.

- **Plot Danger Bearings:** Danger bearings warn a navigator he may be approaching a navigational hazard too closely. See Figure 802d. Vector AB indicates a vessel's intended track. This track passes close to the indicated shoal. Draw a line from the NAVAID H tangent to the shoal. The bearing of that tangent line measured from the ship's track is 074.0°T. In other words, as long as NAVAID H bears *less than* 074°T as the vessel proceeds down its track, the vessel will not ground on the shoal. Hatch the side of the bearing line on the side of the hazard and label the danger bearing NMT (no more than) 074.0°T. For an added margin of safety, the line does not have to be drawn exactly tangent to the shoal. Perhaps, in this case, the navigator might want to set an error margin and draw the danger bearing at 065°T from NAVAID H. Lay down a danger bearing from any appropriate NAVAID in the vicinity of any hazard to navigation. Ensure the track does not cross any danger bearing.

- **Plot Danger Ranges:** The danger range is analogous to the danger bearing. It is a standoff range from an object to prevent the vessel from approaching a hazard too closely.

- **Label Warning and Danger Soundings:** To determine the danger sounding, examine the vessel's proposed track and note the minimum expected sounding. The minimum expected sounding is the difference between the shallowest water expected on the transit and the vessel's maximum draft. Set 90% of this difference as the warning sounding and 80% of this difference as the danger sounding. There may be peculiarities about local conditions that will cause the navigator to choose another method of setting warning and danger soundings. Use the above method if no

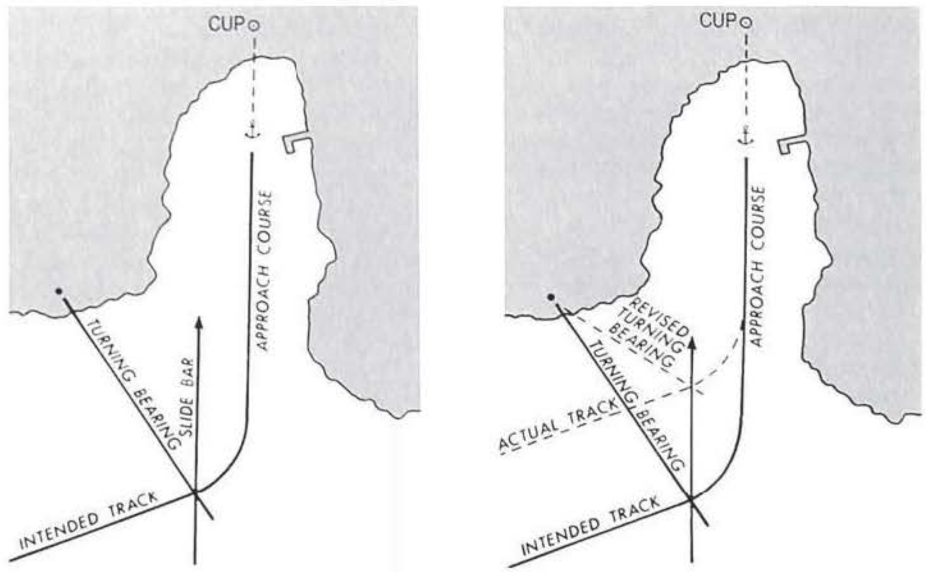


Figure 802c. The slide bar technique.

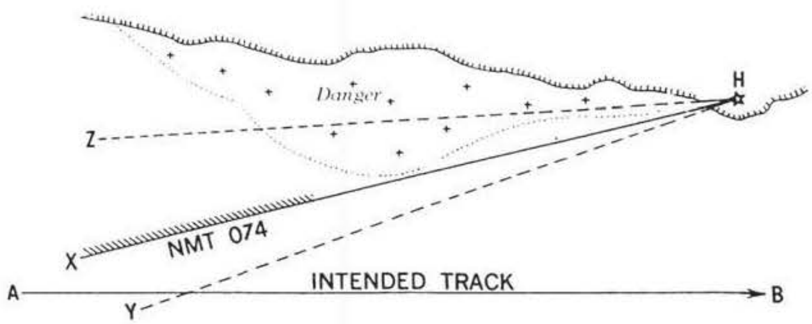


Figure 802d. A danger bearing, hatched on the dangerous side, labeled with the appropriate bearing.

other means is more suitable. For example: A vessel draws a maximum of 20 feet, and it is entering a channel dredged to a minimum depth of 50 feet. Set the warning and danger soundings at 0.9 (50ft. - 20ft) = 27ft and 0.8 (50ft. - 20ft.) = 24ft., respectively. Re-evaluate these soundings at different intervals along the track, when the minimum expected sounding may change. Carefully label the points along the track between which these warning and danger soundings apply.

- **Label Demarcation Line:** Clearly label the point on the ship's track where the Inland and International Rules of the Road apply. This is applicable only when piloting in U.S. ports.
- **Mark Speed Limits Where Applicable:** Often a harbor will have a local speed limit in the vicinity of piers, other vessels, or shore facilities. Mark these speed limits and the points between which they are applicable on the chart.
- **Mark the Point of Pilot Embarkation:** Some ports require vessels over a certain size to embark a pilot. If this is the case, mark the point on the chart where the pilot is to embark.
- **Mark the Tugboat Rendezvous Point:** If the vessel requires a tug to moor, mark the tug rendezvous point on the chart.
- **Mark the Chart Shift Point:** If more than one chart

will be required to complete the passage, mark the point where the navigator should shift to the next chart.

- **Harbor Communications:** Mark the point on the chart where the vessel must contact harbor control. Also mark the point where a vessel must contact its parent squadron to make an arrival report (military vessels only).

- **Tides and Currents:** Mark the points on the chart for which the tides and currents were calculated.

803. Records

Ensure the following records are assembled and personnel assigned to maintain them:

- **Bearing Record Book:** The bearing recorders for the primary and secondary plots should record all the bearings used on their plot during the entire transit. The books should clearly list what NAVAIDS are being used and what method of navigation was being used on their plot. In practice, the primary bearing book will contain mostly visual bearings and the secondary bearing book will contain mostly radar ranges and bearings.

- **Fathometer Log:** In restricted waters, monitor soundings continuously and record soundings every five minutes in the fathometer log. Record all fathometer settings that could affect the sounding display.

- **Deck Log:** This log is the legal record of the passage. Record all ordered course and speed changes. Record all the navigator's recommendations and whether the navigator concurs with the actions of the conning officer. Record all buoys passed, and the shift between different Rules of the Road. Record the name and embarkation of any pilot. Record who has the conn at all times. Record any casualty or important event. The deck log combined with the bearing log should constitute a complete record of the passage.

804. Tides and Currents

Determining the tidal and current conditions of the port is crucial. This process is covered in depth in Chapter 9. In order to anticipate early or late transit, plot a graph of the tidal range for the 24-hour period centered on the scheduled time of arrival or departure. Depending on a vessel's draft and the harbor's depth, some vessels may be able to transit only at high tide. If this is this case, it is critically important to determine the time and range of the tide correctly.

The magnitude and direction of the current will give the navigator some idea of the **set and drift** the vessel will experience during the transit. This will allow him to plan in advance for any potential current effects in the vicinity of navigational hazards.

While printed tide tables can be used for predicting and plotting tides, it is far more efficient to use a computer with appropriate software, or the internet, to compute tides and print out the graphs. These graphs can be posted on the bridge at the chart table for ready reference, and copies made for others involved in the piloting process. NOAA tide tables for the U.S. are available at the following site http://co-ops.nos.noaa.gov/tp4days.html. Always remember that tide tables give predicted data, but that actual conditions may be quite different due to weather or other natural phenomena.

805. Weather

The navigator should obtain a weather report covering the route which he intends to transit. This will allow him to prepare for any adverse weather by stationing extra lookouts, adjusting speed for poor visibility, and preparing for radar navigation. If the weather is thick, consider standing off the harbor until it clears.

The navigator can receive weather information any number of ways. Military vessels may receive weather reports from their parent squadrons prior to coming into port. Marine band radio carries continuous weather reports. Many vessels are equipped with weather facsimile machines. Some navigators carry cellular phones to reach shoreside personnel and harbor control; these can also be used to get weather reports from NOAA weather stations. If the ship is using a weather routing service for the voyage, it should provide forecasts when asked. Finally, if the vessel has an internet connection, this is an ideal source of weather data. NOAA weather data can be obtained at: http://www.nws.noaa.gov. However he obtains the information, the navigator should have a good idea of the weather before entering piloting waters.

806. The Piloting Brief

Assemble the entire navigation team for a piloting brief prior to entering or leaving port. The vessel's captain and navigator should conduct the briefing. All navigation and bridge personnel should attend. The pilot, if he is already on board, should also attend. If the pilot is not onboard when the ship's company is briefed, the navigator should immediately brief him when he embarks. The pilot must know the ship's maneuvering characteristics before entering restricted waters. The briefing should cover, as a minimum, the following:

- **Detailed Coverage of the Track Plan:** Go over the planned route in detail. Use the prepared and approved chart as part of this brief. Concentrate especially on all the NAVAIDS and soundings which are being used to indicate danger. Cover the buoyage system in use and the port's major NAVAIDS. Point out the radar NAVAIDS for the radar operator. Often, a *Fleet Guide* or *Sailing Directions* will have pictures of a port's NAVAIDS. This is especially important for the piloting party that has never transited a particular port before. If no pictures are available, consider stationing a photographer to take some for submission to NIMA.

- **Harbor Communications:** Discuss the bridge-to bridge radio frequencies used to raise harbor control. Discuss what channel the vessel is supposed to monitor on its passage into port and the port's communication protocol.

- **Duties and Responsibilities:** Each member of the piloting team must have a thorough understanding of his duties and responsibilities. He must also understand how his part fits into the whole. The radar plotter, for example, must know if radar will be the primary or secondary source of fix information. The bearing recorder must know what fix interval the navigator is planning to use. Each person must be thoroughly briefed on his job; there is little time for questions once the vessel enters the channel.

807. Evolutions Prior to Piloting

The navigator should always accomplish the following evolutions prior to piloting:

- **Testing the Shaft on the Main Engines in the Astern Direction:** This ensures that the ship can answer a backing bell. If the ship is entering port, no special precautions are required prior to this test. If the ship is tied up at the pier preparing to get underway, exercise extreme caution to ensure no way is placed on the ship while testing the main engines.

- **Making the Anchor Ready for Letting Go:** Make the anchor ready for letting go and station a watchstander in direct communications with the bridge at the anchor windlass. Be prepared to drop anchor immediately when piloting if required to keep from drifting too close to a navigational hazard.

- **Calculate Gyro Error:** An error of greater than 1.0° T indicates a gyro problem which should be investigated prior to piloting. There are several ways to determine gyro error:

  1. Compare the gyro reading with a known accurate heading reference such as an inertial navigator. The difference in the readings is the gyro error.

  2. Mark the bearing of a charted range as the range NAVAID's come into line and compare the gyro bearing with the charted bearing. The difference is the gyro error.

  3. Prior to getting underway, plot a dockside fix using at least three lines of position. The three LOP's should intersect at a point. Their intersecting in a "cocked hat" indicates a gyro error. Incrementally adjust each visual bearing by the same amount and direction until the fix plots as a pinpoint. The total correction required to eliminate the cocked hat is the gyro error.

  4. Measure a celestial body's azimuth or amplitude, or Polaris' azimuth with the gyro, and then compare the measured value with a value computed from the *Sight Reduction Tables* or the *Nautical Almanac*. These methods are covered in detail in Chapter 17.

Report the magnitude and direction of the gyro error to the navigator and captain. The direction of the error is determined by the relative magnitude of the gyro reading and the value against which it is compared. When the compass is least, the error is east. Conversely, when the compass is best, the error is west. See Chapter 6.

808. Inbound Voyage Planning

The vessel's planned estimated time of arrival (ETA) at its mooring determines the vessel's course and speed to the harbor entrance. Arriving at the mooring site on time may be important in a busy port which operates its port services on a tight schedule. Therefore, it is important to plan the arrival accurately. Take the desired time of arrival at the mooring and subtract from that the time it will take to navigate to it from the entrance. The resulting time is when you must arrive at the harbor entrance. Next, measure the distance between the vessel's present location and the harbor entrance. Determine the speed of advance (SOA) the vessel will use to make the transit to the harbor. Use the distance to the harbor and the SOA to calculate what time to leave the present position to make the mooring ETA, or what speed must be made good to arrive on time.

Consider these factors which might affect this decision:

- **Weather:** This is the single most important factor in harbor approach planning because it directly affects the vessel's SOA. The thicker the weather, the more slowly the vessel must proceed. Therefore, if heavy fog or rain is in the forecast, the navigator must allow more time for the transit.

- **Mooring Procedures:** The navigator must take more than distance into account when calculating how long it will take him to pilot to his mooring. If the vessel needs a

CHAPTER 12

LORAN NAVIGATION

INTRODUCTION TO LORAN

1200. History and Role of Loran

The theory behind the operation of hyperbolic navigation systems was known in the late 1930's, but it took the urgency of World War II to speed development of the system into practical use. By early 1942, the British had an operating hyperbolic system in use designed to aid in long-range bomber navigation. This system, named Gee, operated on frequencies between 30 MHz and 80 MHz and employed "master" and "slave" transmitters spaced approximately 100 miles apart. The Americans were not far behind the British in development of their own system. By 1943, the U. S. Coast Guard was operating a chain of hyperbolic navigation transmitters that became Loran A (The term Loran was originally an acronym for LOng RAnge Navigation). By the end of the war, the network consisted of over 70 transmitters providing coverage over approximately 30% of the earth's surface.

In the late 1940's and early 1950's, experiments in low frequency Loran produced a longer range, more accurate system. Using the 90-110 kHz band, Loran developed into a 24-hour-a-day, all-weather radionavigation system named Loran C. From the late 1950's, Loran A and Loran C systems were operated in parallel until the mid 1970's when the U.S. Government began phasing out Loran A. The United States continued to operate Loran C in a number of areas around the world, including Europe, Asia, the Mediterranean Sea, and parts of the Pacific Ocean until the mid 1990's when it began closing its overseas Loran C stations or transferring them to the governments of the host countries. This was a result of the U.S. Department of Defense adopting the Global Positioning System (GPS) as its primary radionavigation service. In the United States, Loran serves the 48 contiguous states, their coastal areas and parts of Alaska. It provides navigation, location, and timing services for both civil and military air, land, and marine users. Loran systems are also operated in Canada, China, India, Japan, Northwest Europe, Russia, Saudi Arabia, and South Korea.

The future role of Loran depends on the radionavigation policies of the countries and international organizations that operate the individual chains. In the United States, the Federal Government plans to continue operating Loran in the short term while it evaluates the long-term need for the system. The U.S. Government will give users reasonable notice if it concludes that Loran is no longer needed or is not cost effective, so that users will have the opportunity to transition to alternative navigation aids and timing services.

Current information on the U.S. Loran system, including Notices to Mariners, may be obtained at the U.S. Coast Guard Navigation Center World Wide Web site at http://www.navcen.uscg.gov/.

LORAN C DESCRIPTION

1201. Summary of Operation

The Loran C (hereafter referred to simply as Loran) system consists of **transmitting stations**, which are placed several hundred miles apart and organized into **chains**. Within a Loran chain, one station is designated as the **master station** and the others as **secondary stations**. Every Loran chain contains at least one master station and two secondary stations in order to provide two lines of position.

The master and secondary stations transmit radio pulses at precise time intervals. A Loran receiver measures the **time difference** (TD) between when the vessel receives the master signal and when it receives each of the secondary signals. When this elapsed time is converted to distance, the locus of points having the same TD between the master and each secondary forms the hyperbolic LOP. The intersection of two or more of these LOP's produces a fix of the vessel's position.

There are two methods by which the navigator can convert this information into a geographic position. The first involves the use of a chart overprinted with a Loran **time delay lattice** consisting of hyperbolic TD lines spaced at convenient intervals. The navigator plots the displayed TD's by interpolating between the lattice lines printed on the chart, manually plots the fix where they intersect and then determines latitude and longitude. In the second method, computer algorithms in the receiver's software convert the TD's to latitude and longitude for display.

As with other computerized navigation receivers, a typical Loran receiver can accept and store **waypoints**.

Waypoints are sets of coordinates that describe either locations of navigational interest or points along a planned route. Waypoints may be entered by visiting the spot of interest and pressing the appropriate receiver control key, or by keying in the waypoint coordinates manually, either as a TD or latitude-longitude pair. If using waypoints to mark a planned route, the navigator can use the receiver to monitor the vessel's progress in relation to the track between each waypoint. By continuously providing parameters such as cross-track error, course over ground, speed over ground, and bearing and distance to next waypoint, the receiver continually serves as a check on the primary navigation plot.

1202. Components of the Loran System

For the marine navigator, the components of the Loran system consist of the land-based transmitting stations, the Loran **receiver** and **antenna**, the **Loran charts.** In addition to the master and secondary transmitting stations themselves, land-based Loran facilities also include the primary and secondary **system area monitor** sites, the **control station** and a precise time reference. The transmitters emit Loran signals at precisely timed intervals. The monitor sites and control stations continually measure and analyze the characteristics of the Loran signals received to detect any anomalies or out-of-specification conditions. Some transmitters serve only one function within a chain (i.e., either master or secondary). However, in many instances, one transmitter transmits signals for each of two adjacent chains. This practice is termed **dual rating**.

Loran receivers exhibit varying degrees of sophistication, but their signal processing is similar. The first processing stage consists of **search and acquisition**, during which the receiver searches for the signal from a particular Loran chain and establishes the approximate time reference of the master and secondaries with sufficient accuracy to permit subsequent settling and tracking.

After search and acquisition, the receiver enters the **settle** phase. In this phase, the receiver searches for and detects the front edge of the Loran pulse. After detecting the front edge of the pulse, it selects the correct cycle of the pulse to track.

Having selected the correct tracking cycle, the receiver begins the **tracking and lock** phase, in which the receiver maintains synchronization with the selected received signals. Once this phase is reached, the receiver displays either the time difference of the signals or the computed latitude and longitude.

1203. The Loran Signal

The Loran signal consists of a series of 100 kHz pulses sent first by the master station and then, in turn, by the secondary stations. Both the shape of the individual pulse and the pattern of the entire pulse sequence are shown in Figure 1203a. As compared to a carrier signal of constant amplitude, pulsed transmission allows the same signal range to be achieved with a lower average output power. Pulsed transmission also yields better signal identification properties and more precise timing of the signals.

The individual sinusoidal Loran pulse exhibits a steep rise to its maximum amplitude within 65 μsec of emission and an exponential decay to zero within 200 to 300 μsec. The signal frequency is nominally defined as 100 kHz; in actuality, the signal is designed such that 99% of the radiated power is contained in a 20 kHz band centered on 100 kHz.

The Loran receiver is programmed to track the signal on the cycle corresponding to the carrier frequency's third positive crossing of the x-axis. This occurrence, termed the **standard zero crossing**, is chosen for two reasons. First, it is late enough for the pulse to have built up sufficient signal strength for the receiver to detect it. Second, it is early enough in the pulse to ensure that the receiver is detecting the transmitting station's ground wave pulse and not its sky wave pulse. Sky wave pulses are affected by atmospheric refraction and if used unknowingly, would introduce large errors into positions determined by a Loran receiver. The pulse architecture described here reduces this major source of error.

Another important parameter of the pulse is the **envelope-to-cycle difference (ECD)**. This parameter indicates how propagation of the signal causes the pulse shape envelope (i.e., the imaginary line connecting the peak of each sinusoidal cycle) to shift in time relative to the zero crossings. The ECD is important because receivers use the precisely shaped pulse envelope to identify the correct zero crossing. Transmitting stations are required to keep the ECD within defined limits. Many receivers display the received ECD as well.

Next, individual pulses are combined into sequences. For the master signal, a series of nine pulses is transmitted, the first eight spaced 1000 μsec apart followed by a ninth transmitted 2000 μsec after the eighth. Secondary stations transmit a series of eight pulses, each spaced 1000 μsec apart. Secondary stations are given letter designations of U, W, X, Y, and Z; this letter designation indicates the order in which they transmit following the master. If a chain has two secondaries, they will be designated Y and Z. If a chain has three secondaries, they are X, Y and Z, and so on. Some exceptions to this general naming pattern exist (e.g., W, X and Y for some 3-secondary chains).

The spacing between the master signal and each of the secondary signals is governed by several parameters as illustrated in Figure 1203b. The general idea is that each of the signals must clear the entire chain coverage area before the next one is transmitted, so that no signal can be received out of order. The time required for the master signal to travel to the secondary station is defined as the average **baseline travel time (BTT)**, or **baseline length (BLL)**. To this time interval is added an additional delay defined as the **secondary coding delay (SCD)**, or simply **coding delay (CD)**. The total of these two delays is termed the **emission delay**

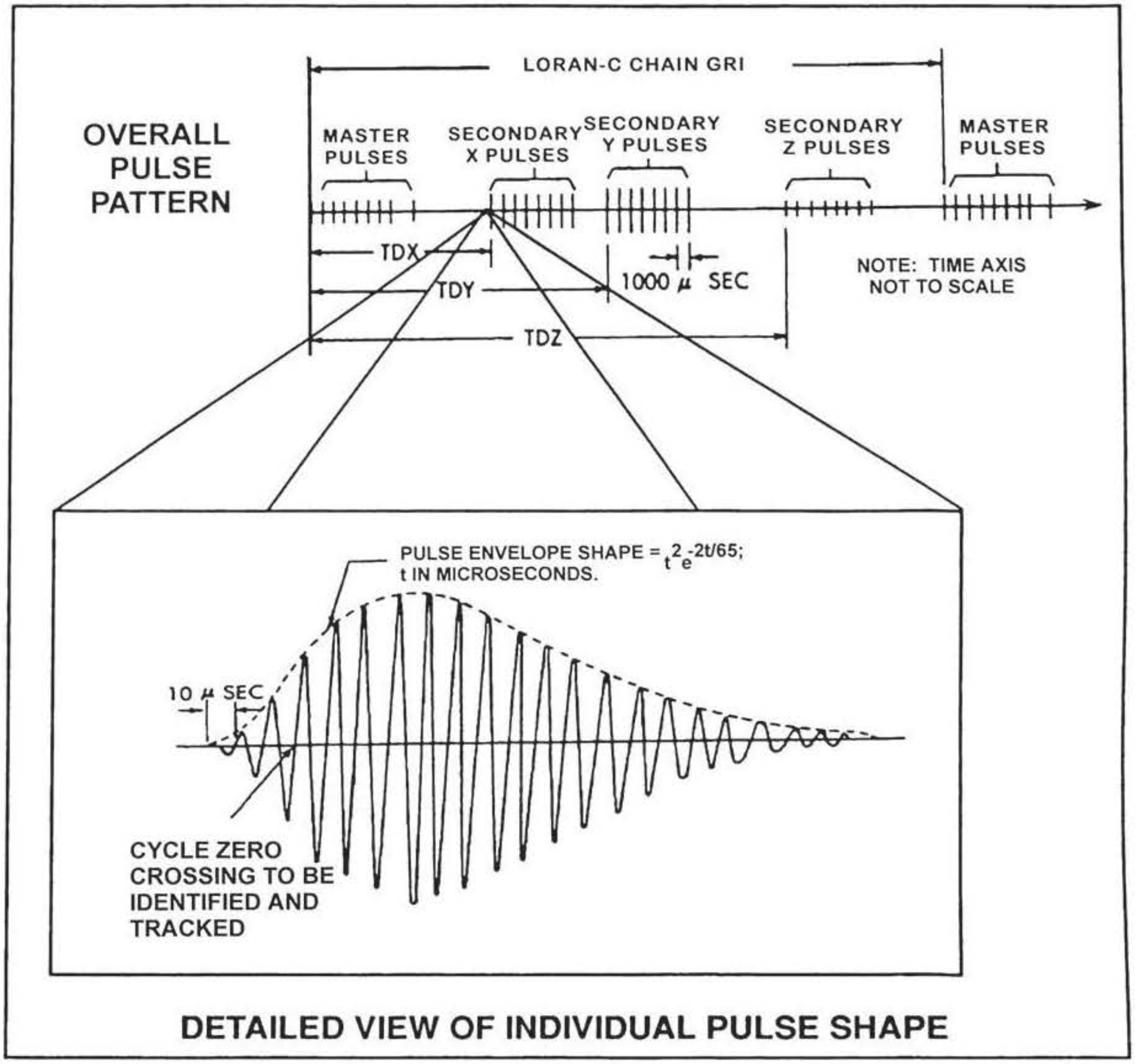


Figure 1203a. Pulse pattern and shape for Loran C transmission.

(ED), which is the exact time interval between the transmission of the master signal and the transmission of the secondary signal. Each secondary station has its own ED value. In order to ensure the proper sequence, the ED of secondary Y is longer than that of X, and the ED of Z is longer than that of Y.

Once the last secondary has transmitted, the master transmits again, and the cycle is repeated. The time to complete this cycle of transmission defines an important characteristic for the chain: the **group repetition interval (GRI)**. The group repetition interval divided by ten yields the chain's numeric designator. For example, the interval between successive transmissions of the master pulse group for the northeast U.S. chain is 99,600 μsec, just less than one tenth of a second. From the definition above, the GRI designator for this chain is defined as 9960. As mentioned previously, the GRI must be sufficiently large to allow the signals from the master and secondary stations in the chain to propagate fully throughout the region covered by the chain before the next cycle of pulses begins.

Two additional characteristics of the pulse group are **phase coding** and **blink coding**. In phase coding, the phase of the 100 kHz carrier signal is reversed from pulse to pulse in a preset pattern that repeats every two GRI's. Phase coding allows a receiver to remove skywave contamination from the groundwave signal. Loran C signals travel away

CHAPTER 14

ELECTRONIC CHARTS

INTRODUCTION

1400. The Importance of Electronic Charts

Since the beginning of maritime navigation, the desire of the navigator has always been to answer a fundamental question: "Where, exactly, is my vessel?" To answer that question, the navigator was forced to continually take fixes on celestial bodies, on fixed objects ashore, or using radio signals, and plot the resulting lines of position as a fix on a paper chart. Only then could he begin to assess the safety of the ship and its progress toward its destination. He spent far more time taking fixes, working out solutions, and plotting the results than on making assessments, and the fix only told him where the ship was at the time that fix was taken, not where the vessel was some time later when the assessment was made. He was always "behind the vessel." On the high seas this is of little import. Near shore, it becomes vitally important.

Electronic charts automate the process of integrating real-time positions with the chart display and allow the navigator to continuously assess the position and safety of the vessel. Further, the GPS/DGPS fixes are far more accurate and taken far more often than any navigator ever could. A good piloting team is expected to take and plot a fix every three minutes. An electronic chart system can do it once per second to a standard of accuracy at least an order of magnitude better.

Electronic charts also allow the integration of other operational data, such as ship's course and speed, depth soundings, and radar data into the display. Further, they allow automation of alarm systems to alert the navigator to potentially dangerous situations well in advance of a disaster.

Finally, the navigator has a complete picture of the instantaneous situation of the vessel and all charted dangers in the area. With a radar overlay, the tactical situation with respect to other vessels is clear as well. This chapter will discuss the various types of electronic charts, the requirements for using them, their characteristics, capabilities and limitations.

1401. Terminology

Before understanding what an electronic chart is and what it does, one must learn a number of terms and definitions. We must first make a distinction between official and unofficial charts. Official charts are those, and only those, produced by a government hydrographic office (HO). Unofficial charts are produced by a variety of private companies and may or may not meet the same standards used by HO's for data accuracy, currency, and completeness.

An **electronic chart system (ECS)** is a commercial electronic chart system not designed to satisfy the regulatory requirements of the IMO Safety of Life at Sea (SOLAS) convention. ECS is an aid to navigation and when used on SOLAS regulated vessels is to be used in conjunctions with corrected paper charts.

An **electronic chart display and information system (ECDIS)** is an electronic chart system which satisfies the IMO SOLAS convention carriage requirements for corrected paper charts when used with an ENC or its functional equivalent (e.g. NIMA Digital Nautical Chart.)

An **electronic chart (EC)** is any digitized chart intended for display on a computerized navigation system.

An **electronic chart data base (ECDB)** is the digital database from which electronic charts are produced.

An **electronic navigational chart (ENC)** is an electronic chart issued by a national hydrographic authority designed to satisfy the regulatory requirements for chart carriage.

The **electronic navigation chart database (ENCDB)** is the hydrographic database from which the ENC is produced.

The **system electronic navigation chart (SENC)** is the database created by an ECDIS from the ENC data.

A **raster navigation chart (RNC)**is a raster-formatted chart produced by a national hydrographic office.

A **raster chart display system (RCDS)** is a system which displays official raster-formatted charts on an ECDIS system. Raster charts cannot take the place of paper charts because they lack key features required by the IMO, so that when an ECDIS uses raster charts it operates in the ECS mode.

Overscale and **underscale** refer to the display of electronic chart data at too large and too small a scale, respectively. In the case of overscale, the display is "zoomed in" too close, beyond the standard of accuracy to which the data was digitized. Underscale indicates that larger scale data is available for the area in question. ECDIS provides a warning in either case.

Raster chart data is a digitized "picture" of a chart comprised of millions of "picture elements" or "pixels." All data is in one layer and one format. The video display simply reproduces the picture from its digitized data file. With raster data, it is difficult to change individual elements of the chart since they are not separated in the data file. Raster data files tend to be large, since a data point with associated color and intensity values must be entered for every pixel on the chart.

Vector chart data is data that is organized into many separate files or layers. It contains graphics files and programs to produce certain symbols, points, lines, and areas with associated colors, text, and other chart elements. The programmer can change individual elements in the file and link elements to additional data. Vector files of a given area are a fraction the size of raster files, and at the same time much more versatile. The navigator can selectively display vector data, adjusting the display according to his needs. Vector data supports the computation of precise distances between features and can provide warnings when hazardous situations arise.

1402. Components of ECS's and ECDIS's

The terms ECS and ECDIS encompasses many possible combinations of equipment and software designed for a variety of navigational purposes. In general, the following components comprise an ECS or ECDIS.

- **Computer processor, software, and network:** These subsystems control the processing of information from the vessel's navigation sensors and the flow of information between various system components. Electronic positioning information from GPS or Loran C, contact information from radar, and digital compass data, for example, can be integrated with the electronic chart data.

- **Chart database:** At the heart of any ECS lies a database of digital charts, which may be in either raster or vector format. It is this dataset, or a portion of it, that produces the chart seen on the display screen.

- **System display:** This unit displays the electronic chart and indicates the vessel's position on it, and provides other information such as heading, speed, distance to the next waypoint or destination, soundings, etc. There are two modes of display, **relative** and **true**. In the relative mode the ship remains fixed in the center of the screen and the chart moves past it. This requires a lot of computer power, as all the screen data must be updated and re-drawn at each fix. In true mode, the chart remains fixed and the ship moves across it. The display may also be north-up or course-up, according to the availability of data from a heading sensor such as a digital compass.

- **User interface:** This is the user's link to the system. It allows the navigator to change system parameters, enter data, control the display, and operate the various functions of the system. Radar may be integrated with the ECDIS or ECS for navigation or collision avoidance, but is not required by SOLAS regulations.

1403. Legal Aspects of Using Electronic Charts

Requirements for carriage of charts are found in SOLAS Chapter V, which states in part: "All ships shall carry adequate and up-to-date charts... necessary for the intended voyage." As electronic charts have developed and the supporting technology has matured, regulations have been adopted internationally to set standards for what constitutes a "chart" in the electronic sense, and under what conditions such a chart will satisfy the chart carriage requirement.

An extensive body of rules and regulations controls the production of ECDIS equipment, which must meet certain high standards of reliability and performance. By definition, **only an ECDIS can replace a paper chart.** No system which is not an ECDIS relieves the navigator of the responsibility of maintaining a plot on a corrected paper chart. Neither can the presence of an electronic chart system substitute for good judgement, sea sense, and taking all reasonable precautions to ensure the safety of the vessel and crew.

An electronic chart system should be considered as an aid to navigation, one of many the navigator might have at his disposal to help ensure a safe passage. While possessing revolutionary capabilities, it must be considered as a tool, not an infallible answer to all navigational problems. The rule for the use of electronic charts is the same as for all other aids to navigation: The prudent navigator will never rely completely on any single one.

CAPABILITIES AND PERFORMANCE STANDARDS

1404. ECDIS Performance Standards

The specifications for ECDIS consist of a set of interrelated standards from three organizations, the International Maritime Organization (IMO), the International Hydrographic Organization (IHO), and the International Electrotechnical Commission (IEC). The IMO published a resolution in November 1995 to establish performance standards for the general functionality of ECDIS, and to define the conditions for its replacement of paper charts. It consisted of a 15-section annex and 5 original appendices. Appendix 6 was adopted in 1996 to define the backup requirements for ECDIS. Appendix 7 was adopted in 1998 to define the operation of ECDIS in a raster chart mode. Previous standards related only to vector data.

The IMO performance standards refer to IHO Special

Publication S-52 for specification of technical details pertaining to the ECDIS display. Produced in 1997, the 3rd edition of S-52 includes appendices specifying the issue, updating, display, color, and symbology of official electronic navigational charts (ENC), as well as a revised glossary of ECDIS-related terms. The IMO performance standards also refer to IEC International Standard 61174 for the requirements of type approval of an ECDIS. Published in 1998, the IEC standard defines the testing methods and required results for an ECDIS to be certified as compliant with IMO standards. Accordingly, the first ECDIS was given type approval by Germany's classification society (BSH) in 1999. Since then, several other makes of ECDIS have gained type approval by various classification societies.

The IMO performance standards specify the following general requirements: Display of government-authorized vector chart data including an updating capability; enable route planning, route monitoring, manual positioning, and continuous plotting of the ship's position; have a presentation as reliable and available as an official paper chart; provide appropriate alarms or indications regarding displayed information or malfunctions; and permit a mode of operation with raster charts similar to the above standards.

The performance standards also specify additional functions, summarized as follows:

- Display of system information in three selectable levels of detail
- Means to ensure correct loading of ENC data and updates
- Apply updates automatically to system display
- Protect chart data from any alteration
- Permit display of update content
- Store updates separately and keep records of application in system
- Indicate when user zooms too far in or out on a chart (over- or under-scale) or when a larger scale chart is available in memory
- Permit the overlay of radar image and ARPA information onto the display
- Require north-up orientation and true motion mode, but permit other combinations
- Use IHO-specified resolution, colors and symbols
- Use IEC-specified navigational elements and parameters (range & bearing marker, position fix, own ship's track and vector, waypoint, tidal information, etc.)
- Use specified size of symbols, letters and figures at scale specified in chart data
- Permit display of ship as symbol or in true scale
- Display route planning and other tasks
- Display route monitoring
- Permit display to be clearly viewed by more than one user in day or night conditions
- Permit route planning in straight and curved segments and adjustment of waypoints
- Display a route plan in addition to the route selected for monitoring
- Permit track limit selection and display an indication if track limit crosses a safety contour or a selected prohibited area
- Permit display of an area away from ship while continuing to monitor selected route
- Give an alarm at a selectable time prior to ship crossing a selected safety contour or prohibited area
- Plot ship's position using a continuous positioning system with an accuracy consistent with the requirements of safe navigation
- Identify selectable discrepancy between primary and secondary positioning system
- Provide an alarm when positioning system input is lost
- Provide an alarm when positioning system and chart are based on different geodetic datums
- Store and provide for replay the elements necessary to reconstruct navigation and verify chart data in use during previous 12 hours
- Record the track for entire voyage with at least four hour time marks
- Permit accurate drawing of ranges and bearings not limited by display resolution
- Require system connection to continuous position-fixing, heading and speed information
- Neither degrade nor be degraded by connection to other sensors
- Conduct on-board tests of major functions with alarm or indication of malfunction
- Permit normal functions on emergency power circuit
- Permit power interruptions of up to 45 seconds without system failure or need to reboot
- Enable takeover by backup unit to continue navigation if master unit fails.

Before an IMO-compliant ECDIS can replace paper charts on vessels governed by SOLAS regulations, the route of the intended voyage must be covered completely by ENC data, that ENC data must include the latest updates, the ECDIS installation must be IMO-compliant including the master-slave network with full sensor feed to both units, and the national authority of the transited waters must allow for paperless navigation through published regulations. The latter may also include requirements for certified training in the operational use of ECDIS.

The first type approval was earned in 1999 and since the finalization of the standards in 1998, many manufacturers of ECDIS equipment have gained such certification.

The certifying agency issues a certificate valid for two years. For renewal, a survey is conducted to ensure that systems, software versions, components and materials used comply with type-approved documents and to review possible changes in design of systems, software versions, components, materials performance, and make sure that such changes do not affect the type approval granted.

Manufacturers have been willing to provide type-approved ECDIS to vessel operators, but in a non-compliant installation. Without the geographical coverage of ENC data, the expensive dual-network installation required by ECDIS will not eliminate the requirement to carry a corrected portfolio of paper charts. These partial installations range from approved ECDIS software in a single PC, to ECDIS with its IEC-approved hardware. In these instances, plotting on paper charts continues to be the primary means of navigation. As more ENC data and updates become available, and as governments regulate paperless transits, vessel operators are upgrading their installations to meet full IMO compliance and to make ECDIS the primary means of navigation.

1405. ECS Standards

Although the IMO has declined to issue guidelines on ECS, the Radio Technical Commission for Maritime Services (RTCM) in the United States developed a voluntary, industry-wide standard for ECS. Published in December 1994, the RTCM Standard called for ECS to be capable of executing basic navigational functions, providing continuous plots of own ship position, and providing appropriate indicators with respect to information displayed. The RTCM ECS Standard allows the use of either raster or vector data, and includes the requirement for simple and reliable updating of information, or an indication that the electronic chart information has changed.

In November 2001, RTCM published Version 2.1 of the "RTCM Recommended Standards for Electronic Chart Systems." This updated version is intended to better define requirements applicable to various classes of vessels operating in a variety of areas. Three general classes of vessels are designated:

Large commercial vessels (oceangoing ships)
Small commercial vessels (tugs, research vessels. etc.)
Smaller craft (yachts, fishing boats, etc.)

The intent is that users, manufacturers, and regulatory authorities will have a means of differentiating between the needs of various vessels as relates to ECS. In concept, an ECS meeting the minimum requirements of the RTCM standard should reduce the risk of incidents and improve the efficiency of navigating for many types of vessels.

However, unlike IMO-compliant ECDIS, an ECS is not intended to comply with the up-to-date chart requirements of SOLAS. As such, an ECS must be considered as a single aid to navigation, and should always be used with a corrected chart from a government-authorized hydrographic office.

Initially, IMO regulations require the use of vector data in an ECDIS: raster data does not have the flexibility needed to do what the ECDIS must do. But it soon became clear that the hydrographic offices of the world would not be able to produce vector data for any significant part of the world for some years. Meanwhile, commercial interests were rasterizing charts as fast as they could for the emerging electronic chart market, and national hydrographic offices began rasterizing their own inventories to meet public demand. The result was a rather complete set of raster data for the most heavily travelled waters of the world, while production of man-power intensive vector data lagged far behind. IMO regulations were then amended to allow ECDIS to function in an RCDS mode using official raster data in conjunction with an appropriate portfolio of corrected paper charts. Nations may issue regulations authorizing the use of RCDS and define what constitutes an appropriate folio of paper charts for use in their waters.

In general, an ECS is not designed to read and display the S-57 format, and does not meet the performance standards of either ECDIS or RCDS. But an ECDIS can operate in ECS mode when using raster charts or when using non-S-57 vector charts. When a type-approved ECDIS is installed without being networked to a backup ECDIS, or when it is using non-official ENC data, or ENC data without updates, it can be said to be operating in an ECS mode, and as such cannot be used as a substitute for official, corrected paper charts.

1406. Display Characteristics

While manufacturers of electronic chart systems have designed their own proprietary colors and symbols, the IMO Performance Standard requires that all IMO approved ECDIS follow the International Hydrographic Organization (IHO) Color & Symbol Specifications. These specifications are embodied in the ECDIS Presentation Library. Their development was a joint effort between Canada and Germany during the 1990s. In order for ECDIS to enhance the safety of navigation, every detail of the display should be clearly visible, unambiguous in its meaning, and uncluttered by superfluous information. The unofficial ECS's continue to be free to develop independent of IHO control. In general they seek to emulate the look of the traditional paper chart.

To reduce clutter, the IMO Standard lays down a permanent display base of essentials such as depths, aids to navigation, shoreline, etc., making the remaining information selectable. The navigator may then select only what is essential for the navigational task at hand. A black-background display for night use provides good color contrast without compromising the mariner's night vision. Similarly, a "bright sun" color table is designed to output maximum luminance in order to be daylight visible, and the colors for details such as buoys are made as contrasting as possible.

The symbols for ECDIS are based on the familiar paper chart symbols, with some optional extras such as simplified buoy symbols that show up better at night. Since the ECDIS can be customized to each ship's requirements, new symbols were added such as a highlighted, mariner selectable, safety contour and a prominent isolated danger symbol.

The Presentation Library is a set of colors and symbols together with rules relating them to the digital data of the ENC, and procedures for handling special cases, such as priorities for the display of overlapping objects. Every feature in the ENC is first passed through the look-up table of the Presentation Library that either assigns a symbol or line style immediately, or, for complex cases, passes the object to a symbology procedure. Such procedures are used for objects like lights, which have so many variations that a look-up table for their symbolization would be too long. The Presentation Library includes a Chart 1, illustrating the symbology. Given the IHO S-57 data standards and S-52 display specifications, a waterway should look the same no matter which hydrographic office produced the ENC, and no matter which manufacturer built the ECDIS.

The overwhelming advantage of the vector-based ECDIS display is its ability to remove cluttering information not needed at a given time. By comparison, the paper chart and its raster equivalent is an unchangeable diagram. A second advantage is the ability to orient the display course-up when this is convenient, while the text remains screen-up.

Taking advantage of affordable yet high-powered computers, some ECDIS's now permit a split screen display, where mode of motion, orientation and scale are individually selectable on each panel. This permits, for example, a north-up small-scale overview in true motion alongside a course-up large-scale view in relative motion. Yet another display advantage occurs with zooming, in that symbols and text describing areas center themselves automatically in whatever part of the area appears on the screen. None of these functions are possible with raster charts.

The display operates by a set of rules, and data is arranged hierarchically, For example, where lines overlap, the less important line is not drawn. A more complex rule always places text at the same position relative to the object it applies to, no matter what else may be there. Since a long name or light description will often over-write another object, the only solution is to zoom in until the objects separate from each other. Note that because text causes so much clutter, and is seldom vital for safe navigation, it is written automatically when the object it refers to is on the display, but is an option under the "all other information" display level.

Flexibility in display scale requires some indication of distance to objects seen on the display. Some manufacturers use the rather restrictive but familiar radar range rings to provide this, while another uses a line symbol keyed to data's original scale. The ECDIS design also includes a one-mile scalebar at the side of the display, and an optionally displayed course and speed made good vector for own ship. There may be a heading line leading from the vessel's position indicating her future track for one minute, three minutes, or some other selectable time.

To provide the option of creating manual chart corrections, ECDIS includes a means of drawing lines, adding text and inserting stored objects on the display. These may be saved as user files, called up from a subdirectory, and edited on the display. Once loaded into the SENC, the objects may be selected or de-selected just as with other objects of the SENC.

Display options for ECDIS include transfer of ARPA-acquired targets and radar image overlay. IMO standards for ECDIS require that the operator be able to deselect the radar picture from the chart with a single operator action for fast "uncluttering" of the chart presentation.

1407. Units, Data Layers and Calculations

ECDIS uses the following units of measure:

- **Position:** Latitude and longitude will be shown in degrees, minutes, and decimal minutes, normally based on WGS-84 datum.
- **Depth:** Depths will be indicated in meters and decimeters.
- **Height:** Meters
- **Distance:** Nautical miles and tenths, or meters
- **Speed:** Knots and tenths

ECDIS requires data layers to establish a priority of data displayed. The minimum number of information categories required and their relative priority from highest to lowest are listed below:

- ECDIS warnings and messages
- Hydrographic office data
- *Notice to Mariners* information
- Hydrographic office cautions
- Hydrographic office color-fill area data
- Hydrographic office on demand data
- Radar information
- User's data
- Manufacturer's data
- User's color-fill area data
- Manufacturer's color-fill area data

FLIR-1015.309

As a minimum, an ECDIS system must be able to perform the following calculations and conversions:

- Geographical coordinates to display coordinates, and display coordinates to geographical coordinates.
- Transformation from local datum to WGS-84.
- True distance and azimuth between two geographical positions.
- Geographic position from a known position given distance and azimuth.
- Projection calculations such as great circle and rhumb line courses and distances.

1408. Warnings and Alarms

Appendix 5 of the IMO Performance Standard specifies that ECDIS must monitor the status of its systems continuously, and must provide alarms and indications for certain functions if a condition occurs that requires immediate attention. Indications may be either visual or audible. An alarm must be audible and may be visual as well.

An alarm is required for the following:

- Exceeding cross-track limits
- Crossing selected safety contour
- Deviation from route
- Position system failure
- Approaching a critical point
- Chart on different geodetic datum from positioning system

An alarm or indication is required for the following:

- Largest scale for alarm (indicates that presently loaded chart is too small a scale to activate anti-grounding feature)
- Area with special conditions (means a special type of chart is within a time or distance setting)
- Malfunction of ECDIS (means the master unit in a master-backup network has failed)

An indication is required for the following:

- Chart overscale (zoomed in too close)
- Larger scale ENC available
- Different reference units (charted depths not in meters)
- Route crosses safety contour
- Route crosses specified area activated for alarms
- System test failure

As these lists reveal, ECDIS has been programmed to constantly "know" what the navigation team should know, and to help the team to apply its experience and judgment through the adjustment of operational settings.

This automation in ECDIS has two important consequences: First, route or track monitoring does not replace situational awareness; it only enhances it. The alarm functions, while useful, are partial and have the potential to be in error, misinterpreted, ignored, or overlooked.

Secondly, situational awareness must now include, especially when ECDIS is used as the primary means of navigation, the processes and status of the electronic components of the system. This includes all attached sensors, the serial connections and communication ports and data interfaces, the computer processor and operating system, navigation and chart software, data storage devices, and power supply. Furthermore, these new responsibilities must still be balanced with the traditional matters of keeping a vigilant navigational watch.

ECDIS or not, the windows in the pilothouse are still the best tool for situational awareness. Paradoxically, ECDIS makes the navigator's job both simpler and more complex.

1409. ECDIS Outputs

During the past 12 hours of the voyage, ECDIS must be able to reconstruct the navigation and verify the official database used. Recorded at one minute intervals, the information includes:

- Own ship's past track including time, position, heading, and speed
- A record of official ENC used including source, edition, date, cell and update history

It is important to note that if ECDIS is turned off, such as for chart management or through malfunction, voyage recording ceases, unless a networked backup system takes over the functions of the master ECDIS. In that case, the voyage recording will continue, including an entry in the electronic log for all the alarms that were activated and reset during the switchover. Voyage files consist of logbook files, track files and target files. The file structure is based on the date and is automatically created at midnight for the time reference in use. If the computer system time is used for that purpose, the possibility exists for overwriting voyage files if the system time is manually set back. Allowing GPS time as the system reference avoids this pitfall.

In addition, ECDIS must be able to record the complete track for the entire voyage with time marks at least once every four hours. ECDIS should also have the capability to preserve the record of the previous 12 hours of the voyage. It is a requirement that the recorded information be inaccessible to alteration. Preserving voyage files should follow procedures for archiving data. Unless radar overlay data is being recorded, voyage files tend to be relatively small, permitting backup onto low-capacity media, and purging from system memory at regular intervals. (This form of backing up should not be confused with the network master-slave backup system.)

Adequate backup arrangements must be provided to ensure safe navigation in case of ECDIS failure. This includes provisions to take over ECDIS functions so that an ECDIS failure does not develop into a critical situation, and a means of safe navigation for the remaining part of the voyage in case of complete failure.

1410. Voyage Data Recorder (VDR)

The purpose of the voyage data recorder VDR is to provide accurate historical navigational data in the investigation of maritime incidents. It is additionally useful for system performance monitoring. A certified VDR configuration records all data points, as per IMO Resolution A.861(20) & EC Directive 1999/35/EC. Some of the voyage data can be relayed through ECDIS. A fully IEC compliant data capsule passes fire and immersion tests.

The implementation of a secure "black box" and comprehensive Voyage Data Recorder (VDR) is now a carriage requirement on passenger and Ro-Ro vessels over 3000 GT (1600 GRT) engaged in international passages. Existing vessels must be retrofitted by July 2004, and all vessels built after July 2002 must be fitted with a VDR. Retrofit regulations for other vessels built before July 2002 are still in development. Non-RO-RO passenger vessels built before July 2002 may be exempted from carriage where an operator can show that interfacing a VDR with the existing equipment on the ship is unreasonable and impracticable. The European Union requires that all RO-RO ferries or high speed craft engaged on a regular service in European waters (domestic or international) be fitted with a VDR if built before February 2003, and otherwise retrofitted by July 2004.

VDR features include:

- Radar video capture: Radar video is captured and compressed every 15 seconds to comply with IEC performance standards.
- I/O subsystem: To collect a wide variety of data types, a sensor interface unit provides signal conditioning for all analog, digital and serial inputs. All data is converted and transmitted to a data acquisition unit via an ethernet LAN.
- Audio compression: An audio module collects analog signals from microphone preamplifiers. The data is digitized and compressed to meet Lloyds of London 24-hour voice storage requirements.
- Integral uninterruptible power supply (UPS) IEC requires a UPS backup for all components of the data acquisition unit and for the data capsule to provide two hours continuous recording following a blackout.
- Hardened fixed data capsule: IEC 61996 compliant data capsules fitted with ethernet connections provide fast download as well as fast upload to satellite links.
- Remote data recovery and shoreside playback: Options available in several systems.
- Annual system certification: The IMO requires that the VDR system, including all sensors, be subjected to an annual performance test for certification.

DATA FORMATS

1411. Official Vector Data

How ECDIS operates depends on what type of chart data is used. ENC's (electronic navigational charts) and RNC's (raster nautical charts) are approved for use in ECDIS. By definition both ENC's and RNC's are issued under the authority of national hydrographic offices (HO's). ECDIS functions as a true ECDIS when used with corrected ENC data, but ECDIS operates in the less functional raster chart display system (RCDS) mode when using corrected RNC data. When ECDIS is used with non-official vector chart data (corrected or not), it operates in the ECS mode.

In vector charts, hydrographic data is comprised of a series of files in which different layers of information are stored or displayed. This form of "intelligent" spatial data is obtained by digitizing information from existing paper charts or by storing a list of instructions that define various position-referenced features or objects (e.g., buoys, lighthouses, etc.). In displaying vector chart data on ECDIS, the user has considerable flexibility and discretion regarding the amount of information that is displayed.

An ENC is vector data conforming to the IHO S-57 ENC product specification in terms of content, structure and format. An ENC contains all the chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart. In general, an S-57 ENC is a structurally layered data set designed for a range of hydrographic applications. As defined in IHO S-57 Edition 3, the data is comprised of a series of points, lines, areas, features, and objects. The minimum size of a data set is a cell, which is a spherical rectangle (i.e., bordered by meridians and latitudes). Adjacent cells do not overlap. The scale of the data contained in the cell is dependent upon the navigational purpose (e.g., general, coastal, approach, harbor).

Under S-57, cells have a standard format but do not have a standard coverage size. Instead, cells are limited to 5mb of data. S-57 cells are normally copy protected and therefore require a permit before use is allowed. These permits are delivered as either a file containing the chart permits or as a code. In both cases the first step is to install the chart permit into the ECDIS. Some hydrographic offices deliver S-57 cells without copy protection and therefore permits are not required.

Any regional agency responsible for collecting and distributing S-57 data, such as PRIMAR for Northern Europe, will also maintain data consistency. National hydrographic offices are responsible for producing S-57 data for their own country area. Throughout the world HO's have been slow to produce sufficient quantities of ENC data. This is due to the fact that the standards evolved over several years, and that vector data is much harder to collect than raster data.

In 1996 the IHO S-57 data standard and IHO S-52 specifications for chart content and display were "frozen." It took three versions of S-57 before the issue was finally settled as to what actually comprises an ENC (i.e., ENC Product Specification) and what is required for updating (ENC Updating Profile). The ENC Test Dataset that the International Electrotechnical Commission (IEC) requires for use in conjunction with IEC Publication 61174 (IEC 1997) was finalized by IHO in 1998. It was not possible to conduct ECDIS type-approval procedures without a complete and validated IHO ENC Test Dataset.

Major areas of ENC coverage now include most of Canadian and Japanese waters, the Baltic and North Sea, and important waterways such as the Straits of Malacca, Singapore Strait, and the Straits of Magellan (Chile).

At the same time, many countries including the United States, are stepping up their production of ENC's where issues of port security require the collection of baseline data of submerged hazards. In the U.S., NOAA plans to complete its portfolio of large-scale charts of 42 ports in ENC format by mid-2003, with smaller scale chart completion by 2005. As the chart cells are completed, the data is being made available on the World Wide Web at no cost. Beginning in 2003, NOAA will post critical notice to mariner corrections without restrictions in monthly increments. At that point the status of NOAA's available ENC data will be changed from provisional to official.

ENC data is currently available from the HO's of most Northern European countries, Japan, Korea, Hong Kong, Singapore, Canada, Chile, and the United States, although the coverage and updating process is incomplete. Most ENC is available only through purchase, permits or licensing.

1412. Vector Data Formats Other Than IHO S-57

The largest of the non-S-57 format databases is the Digital Nautical Chart (DNC). The National Imagery and Mapping Agency (NIMA) produces the content and format for the DNC according to a military specification. This allows compatibility among all U.S. Defense Department assets. The DNC is a vector-based digital product that portrays significant maritime features in a format suitable for computerized marine navigation. The DNC is a general-purpose global database designed to support marine navigation and Geographic Information System (GIS) applications. DNC data is only available to the U.S. military and selected allies. It is designed to conform to the IMO Performance Standard and IHO specifications for ECDIS.

Several commercial manufacturers have developed vector databases beyond those that have been issued by official hydrographic offices. These companies are typically manufacturers of ECDIS or ECS equipment or have direct relationships with companies that do, and typically have developed data in proprietary format in order to provide options to raster charts in the absence of ENC data. HO-issued paper charts provide the source data for these formats, although in some cases non-official paper charts are used. In some cases, ECS manufacturers provide a regular updating and maintenance service for their vector data, resulting in added confidence and satisfaction among users. The manufacturer's source of the updates is through HO's. Hence, these two particular non-official formats allows for a very high degree of confidence and satisfaction among mariners using this data.

ECS systems sometimes apply rules of presentation similar to officially specified rules. Thus information is displayed or removed automatically according to scale level to manage clutter. The same indications pertinent to overscaling ENC apply to private vector data. Since the chart data is not ENC, the systems must display that non-official status when used in an ECDIS.

1413. Raster Data

Raster navigational chart (RNC) data is stored as picture elements (pixels). Each pixel is a minute component of the chart image with a defined color and brightness level. Raster-scanned images are derived by scanning paper charts to produce a digital photograph of the chart. Raster data are far easier to produce than vector data, but raster charts present many limitations to the user.

The official raster chart formats are:

ARCS (British Admiralty)
Seafarer (Australia)
BSB (U.S., NOAA/Maptech)

These charts are produced from the same raster process used to print paper charts. They are accurate representations of the original paper chart with every pixel geographically referenced. Where applicable, horizontal datum shifts are included with each chart to enable referencing to WGS84. This permits compatibility with information overlaid on the chart. *Note: Not all available charts have WGS84 shift information.* Extreme caution is necessary if the datum shift cannot be determined exactly.

Raster nautical charts require significantly larger amounts of memory than vector charts. Whereas a world portfolio of more than 7500 vector charts may occupy about 500mb, a typical coastal region in raster format may consist of just 40 charts and occupy more than 1000mb of memory.

For practical purposes, most of a portfolio of raster charts should be left on the CD and not loaded into the ECDIS hard drive unless one is route planning or actually sailing in a given region. Of course, updates can only be performed on charts that are loaded onto the hard drive.

Certain non-official raster charts are produced that cover European and some South American waters. These are scanned from local paper charts. Additionally, some ECDIS and ECS manufacturers also produce raster charts in proprietary formats.

In 1998 the IMO's Maritime Safety Committee (MSC 70) adopted the Raster Chart Display System (RCDS) as Appendix 7 to the IMO Performance Standards. The IMO-IHO Harmonization Group on ECDIS (HGE) considered this issue for over three years. Where IHO S-57 Ed. 3 ENC data coverage is not available, raster data provided by official HO's can be used as an interim solution. But this RCDS mode does not have the full functionality of an otherwise IMO-compliant ECDIS using ENC data. Therefore, RCDS does not meet SOLAS requirements for carriage of paper charts, meaning that when ECDIS equipment is operated in the RCDS mode, it must be used together with an appropriate portfolio of corrected paper charts.

Some of the limitations of RCDS compared to ECDIS include:

- Chart features cannot be simplified or removed to suit a particular navigational circumstance or task.
- Orientation of the RCDS display to course-up may affect the readability of the chart text and symbols since these are fixed to the chart image in a north-up orientation.
- Depending on the source of the raster chart data, different colors may be used to show similar chart information, and there may be differences between colors used during day and night time.
- The accuracy of the raster chart data may be less than that of the position-fixing system being used.
- Unlike vector data, charted objects on raster charts do not support any underlying information.
- RNC data will not trigger automatic alarms. (However, some alarms can be generated by the RCDS from user-inserted information.).
- Soundings on raster charts may be in fathoms and feet, rather than meters.

The use of ECDIS in RCDS mode can only be considered as long as there is a backup folio of appropriate up-to-date paper charts.

INTEGRATED BRIDGE SYSTEMS

1414. Description

An Integrated Bridge System (IBS) is a combination of equipment and software which uses interconnected controls and displays to present a comprehensive suite of navigational information to the mariner. Rules from classification societies such as Det Norske Veritas (DNV) specify design criteria for bridge workstations. Their rules define tasks to be performed, and specify how and where equipment should be sited to enable those tasks to be performed. Equipment carriage requirements are specified for ships according to the requested class certification or notation. Publication IEC 61029 defines operational and performance requirements, methods of testing, and required test results for IBS.

Classification society rules address the total bridge system in four parts: technical system, human operator, man/machine interface, and operational procedures. The DNV classifies IBS with three certifications: NAUT-C covers bridge design; W1-OC covers bridge design, instrumentation and bridge procedures; W1 augments certain portions of W1-OC.

An IBS generally consists of at least:

- Dual ECDIS installation – one serving master and the other as backup and route planning station
- Dual radar/ARPA installation
- Conning display with a concentrated presentation of navigational information (the master ECDIS)
- DGPS positioning
- Ship's speed measuring system
- Auto-pilot and gyrocompass system
- Full GMDSS functionality

Some systems include full internal communications, and a means of monitoring fire control, shipboard status alarms, and machinery control. Additionally, functions for the loading and discharge of cargo may also be provided.

An IBS is designed to centralize the functions of monitoring collision and grounding risks, and to automate navigation and ship control. Control and display of component systems are not simply interconnected, but often share a proprietary language or code. Several instruments and indicators are considered essential for safe and efficient performance of tasks, and are easily readable at the navigation workstation, such as heading, rudder angle, depth, propeller speed or pitch, thruster azimuth and force, and speed and distance log.

Type approval by Det Norske Veritas for the DNV-W1-ANTS (Automatic Navigation and Track-Keeping

Attachment 6b: Southern Illinois University, Edwardsville, Library catalog record for Document 6

Keyword ▾ | Local Catalog Only ▾ | Find

Your Account | Log Out

Ask A Librarian

Logged in as Helen Sullivan
(Not Helen?)

Advanced Search | Course Reserves | Search History

« Back to Search Results | Cite this | Email this | Add to favorites | Staff view

American practical navigator.

Names:	Bowditch, Nathaniel, | Bowditch, Jonathan Ingersoll,
Published:	Washington, D.C. : U.S. Navy Hydrographic Office under the authority of the Secretary of the Navy,
Series:	H.O. pub. ; no. 9
Topics:	Nautical astronomy - Periodicals. | Navigation - Periodicals.
Tags:	No Tags, Be the first to tag this record! Add

More Details | Location & Availability | User Reviews | Request Item

Southern Illinois University Edwardsville

Location:	Book Collection
	2002 (CD-ROM) c.1 Temporarily Shelved at: SIUE ACCESS SERVICES
Call Number:	VK555 .A48
	Text me this call number
Copy:	1
Library Has (Volumes):	2002 (text) c.1
	2002 (CD-ROM) c.1
	1977:1 c.1
	1975:2 c.1
Status:	2002 c.1 - In Transit On Hold

Keyword ▾ | Local Catalog Only ▾ | Find

Advanced Search | Course Reserves | Search History

Attachment 6c: Catalog of U.S. Government Publications record for Document 6

CATALOG OF U.S. GOVERNMENT PUBLICATIONS (CGP)

Full View of Record

Choose format: Standard | Short | MARC

Record 1 out of 6

Previous Record | Next Record

Title	The **American practical navigator** : an **epitome** of **navigation** /
Internet Access	http://purl.access.gpo.gov/GPO/LPS22411
Author	Bowditch, Nathaniel, 1773-1838.
Publisher Info.	Bethesda, Maryland : The Agency ; Washington, DC : For sale by the Supt. of Docs., U.S. G.P.O., 2002.
SuDoc Number	D 5.317:9/2002
ISBN	0160511259 : $65.00
Item Number	0378-D
	0378-D (online)
Edition	2002 bicentennial ed.
Description	xi, 879 p., [2] p. of plates : ill.(some col.), maps (some col.) ; 29 cm. + 1 CD-ROM.
Series	(Pub. (United States. National Imagery and Mapping Agency); 9.)
General Note	"NIMA ref. no. NVPUB9."
	First published under title: The new American practical navigator.
	Includes index.
	Shipping list no.: 2002-0042-S.
Additional Form	Also available via Internet from the NIMA web site. Address as of 9/23/02: http://pollux.nss.nima.mil/pubs/pubsjapnsections.html?rid=187; current access is available via PURL.
Subject - LC	Nautical astronomy.
	Navigation -- United States.
Added Entry	United States. National Imagery and Mapping Agency.

Attachment 6c: Catalog of U.S. Government Publications record for Document 6

Stock Number/Avail.	008-000-00882-5 GPO NSN 7642014014652 NIMA
CGP Record Link	https://catalog.gpo.gov/F/?func=direct&doc_number=000546470&local_base=GPO01PUB
Holdings	All items
Locate in a Library	(paper, online) http://catalog.gpo.gov/fdlpdir/locate.jsp?ItemNumber=0378-D&SYS=000546470
OCLC Number	(OCoLC)50648886
	ocm50648886
System Number	000546470

Previous Record Next Record

End Session - Preferences - Feedback - Help - Browse - Search - Results List - Previous Searches - Catalogs to Search - Bookshelf

Pub. No. 9

THE AMERICAN PRACTICAL NAVIGATOR

AN EPITOME OF NAVIGATION

ORIGINALLY BY

NATHANIEL BOWDITCH, LL.D.

2002 BICENTENNIAL EDITION

Prepared and published by the
NATIONAL IMAGERY AND MAPPING AGENCY
Bethesda, Maryland

NSN 7642014014652

Attachment 6e: Statewide Illinois Library Catalog record for Document 6

Statewide Illinois Library Catalog UNIV OF ILLINOIS

Libraries that Own Item

| Ask A Librarian

- This screen shows libraries that own the item you selected.

Home | Databases | Searching | Results

Staff View | My Account | Options | Comments | Exit | Hide tips

List of Records | Detailed Record | Marked Records | Saved Records | Go to page

E-mail Print Return Help

Current database: **WorldCat** Total Libraries: **214**

WorldCat

Title: The American practical navigator : an epitome of navigation **Author:** Bowditch, Nathaniel **Accession Number:** 50648886

Other libraries hold this item; please check with your librarian for more information.

Libraries with Item: "The American practical na..."(Record for Item | Get This Item)

Location	Library	Local Holdings	Code
US,IL	CHICAGO PUB LIBR		CGP
US,IL	EASTERN ILLINOIS UNIV		IAD
US,IL	HANSON PROF SERV, INC		AP5
US,IL	NORTHERN ILLINOIS UNIV		JNA
US,IL	NORTHWESTERN UNIV		INU
US,IL	POPLAR CREEK PUB LIBR DIST		JJG
US,IL	UNIV OF ILLINOIS, CHICAGO		IAY
US,IL	WESTERN ILLINOIS UNIV		IAZ
US,IA	IOWA STATE UNIV	Local Holdings Availa...	IWA
US,IN	ALLEN CNTY PUB LIBR		IMF
US,IN	BALL STATE UNIV LIBR		IBS
US,IN	INDIANA STATE LIBR		ISL
US,IN	INDIANA UNIV, E		IE0
US,IN	INDIANA UNIV, KOKOMO		IU0
US,IN	INDIANA UNIV, NORTHWEST		IN0
US,IN	INDIANA UNIV, PURDUE UNIV, FT WAYNE		HV6
US,IN	INDIANA UNIV, PURDUE UNIV, INDIANAPOLIS		IUP
US,IN	INDIANA UNIV, S BEND		I3U
US,IN	INDIANA UNIV, SOUTHEAST		XUN
US,IN	TIPPECANOE CNTY PUB LIBR		XWE
US,IN	UNIV LIBR OF COLUMBUS		XPJ
US,IN	UNIV OF NOTRE DAME		IND
US,KY	UNIV OF KENTUCKY LIBR		KUK
US,MO	MISSOURI UNIV OF SCI & TECH		UMR
US,MO	MOBIUS MERLIN CLUSTER		ZM@
US,MO	SAINT CHARLES CITY-CNTY LIBR DIST		ZAC
US,MO	SAINT LOUIS PUB LIBR		SVP
US,MO	SHOOK HARDY & BACON		E49
US,MO	UNIV OF MISSOURI, ST LOUIS		UMS
US,MO	UNIV OF MISSOURI--COLUMBIA		MUU
US,MO	WASHINGTON UNIV		WTU
US,WI	EASICAT/EASTERN SHORES LIBR SYST		WSD
US,WI	MENOMONEE FALLS LIBR		WMF
US,WI	UNIV OF WISCONSIN, GREEN BAY		GZW
US,WI	WISCONSIN HISTORICAL SOCIETY		WIH

Record for Item: "The American practical na..."(Libraries with Item)

GET THIS ITEM

Access: http://purl.access.gpo.gov/GPO/LPS22411

Availability: Check the catalogs in your library.
- Libraries worldwide that own item: 214
- Search the catalog at the Library of University of Illinois at Urbana-Champaign

External Resources:
- Discover full text Discover UIUC Full Text
- Interlibrary Loan Request
- Cite This Item

FIND RELATED

More Like This: Search for versions with same title and author | Advanced options ...

Find Items About: Bowditch, Nathaniel, (max: 298); United States. (8,113,514)

Title: **The American practical navigator : an epitome of navigation /**

Author(s): Bowditch, Nathaniel, 1773-1838

Corp Author(s): United States : National Imagery and Mapping Agency

Attachment 6e: Statewide Illinois Library Catalog record for Document 6

Corp Author(s): United States., National Imagery and Mapping Agency.

Publication: Bethesda, Md. : The Agency ; Washington, DC : For sale by the Supt. of Docs., U.S. G.P.O.,
Edition: 2002 bicentennial ed.

Year: 2002

Description: xi, 879 pages, [2] pages of plates : illustrations (some color), maps (some color) ; 29 cm + 1 CD-ROM.

Language: English

Series: Pub. ;; no. 9; **Variation:** Pub. (United States. National Imagery and Mapping Agency) ;; 9.

Standard No: **ISBN:** 0160511259; 9780160511257; 0939837544; 9780939837540; **LCCN:** 2004-356318

Contents: Part 1: Fundamentals --; Introduction to marine navigation --; Geodesy and datums in navigation --; Nautical charts --; Nautical publications --; Part 2: Piloting --; Short range aids to navigation --; Compasses --; Dead reckoning --; Piloting --; Tides and tidal currents --; Part 3:Electronic navigation --; Radio waves --; Satellite --; Loran navigation --; Radar navigation --; Electronic charts --; Part 4: Celestial navigation --; Navigational astronomy --; Instruments for celestial navigation --; Azimuths and amplitudes --; Time --; The almanacs --; Sight reduction --; Part 5:Navigational mathematics --; Navigational mathematics --; Calculations and conversions --; Navigational errors --; The sailings --; Part 6: Navigational safety --; Navigation processes --; Emergency navigation --; Navigation regulations --; Maritime safety systems --; Hydrography --; Part 7: Oceanography --; The Oceans --; Ocean Currents --; Waves, breakers and surf --; Ice navigation --; Part 8: Marine Meteorology --; Weather elements --; Tropical cyclones --; Weather observations --; Weather routing --; Navigation tables --; Mathematical tables --; Explanation of navigation tables --; Mathematical tables --; Cartographic tables --; Piloting tables --; Celestial navigation tables --; Meteorological tables --; Glossaries.

Access: http://purl.access.gpo.gov/GPO/LPS22411
http://pollux.nss.nima.mil/pubs/pubsjapnsections.html?rid=187

SUBJECT(S)

Descriptor: Navigation -- United States.
Nautical astronomy.
Nautical astronomy.
Navigation.

Geographic: United States.

System Info: System requirements for accompanying CD-ROM: PC or compatible; Pentium I+ processor; 64+ MB memory; 150 MB hard drive space; Windows NT 4.0, SP 4.0 or Windows 2000.

Note(s): Originally published under title: The new American practical navigator./ Shipping list no.: 2002-0042-S./ Includes index./ "NIMA ref. no. NVPUB9."/ Also available via Internet from the NIMA web site. Address as of 9/23/02: http://pollux.nss.nima.mil/pubs/pubsjapnsections.html?rid=187; current access is available via PURL./ **Report:** NIMA ref. no. NVPUB 9

Class Descriptors: **LC:** VK555; **Dewey:** 623.89; **GovDoc:** D 5.317:9/2002; **GPO Item No:** 0378-D; 0378-D (online)

Responsibility: originally by Nathaniel Bowditch ; prepared and published by the National Imagery and Mapping Agency.

Vendor Info: Baker & Taylor Baker & Taylor Brodart Baker and Taylor Ingram YBP Library Services (BKTY BKTY BROD BTCP INGR YANK) 68.50 49.95 $49.95 **Status:** active active

Material Type: Government publication (gpb); National government publication (ngp); Internet resource (url)

Document Type: Book; Internet Resource

Date of Entry: 20020923

Update: 20150115

Accession No: **OCLC:** 50648886

Database: WorldCat

E-mail Print Return Help

Current database: **WorldCat** Total Libraries: **214**

WorldCat

English | Español | Français | عربي | 日本語 | 한국어 | 中文(繁體) | 中文(简体) | Options | Comments | **Exit**

For Publishers

Bookwire™ by Bowker

All | Enter your query here

Return to Search Results

Buy Now

American Practical Navigator

An Epitome of Navigation, 2002

☆☆☆☆☆ (be the first to rate this)

Author:	Bowditch, Nathaniel
ISBN:	978-0-16-051125-7
Publication Date:	Aug 2002
Publisher:	United States Government Printing Office
Book Format:	CD-ROM Hardback
List Price:	USD $68.50

See more details about this Book

Book Seller	Condition	Price	Shipping	Total	
amazon.com marketplace	New Book	$60.00	$3.99	**$63.99**	Buy
alibris	New Book	$79.99	$3.99	**$83.98**	Buy
AbeBooks.com	New Book	$84.96	$0.00	**$84.96**	Buy

The American Practical Navigator : An Epitome Of Navigation

LEADER 00000cam##2200000#a#4500
oldings ##
root ##
001 ## 50648886
007 ## cr#mnu|||uuaun
008 ## 020923s2002####mduabf#######f001#0#eng#c
010 ## $a 2004356318
019 ## $a 50683922 $a 51530140 $a 53449566
020 ## $a 0160511259
020 ## $a 9780160511257
020 ## $a 0939837544
020 ## $a 9780939837540
029 1# $a AU@ $b 000025902055
029 1# $a IG# $b 0160511259
029 1# $a IG# $b 0939837544
029 1# $a NZ1 $b 8484260
029 1# $a NZ1 $b 8574186
037 ## $a 008-000-00882-5 $b GPO
037 ## $a NSN 7642014014652 $b NIMA
040 ## $a COO $b eng $c COO $d JUA $d DLC $d GPO $d BUF $d BAKER $d UPP $d BTCTA $d IG# $d OCLCG $d B2A $d YDXCP $d BDX $d OCLCO $d OCLCF $d OCLCQ
042 ## $a pcc
043 ## $a n-us---
050 00 $a VK555 $b .B7297 2002
074 ## $a 0378-D
074 ## $a 0378-D (online)
082 00 $a 623.89 $2 22
086 0# $a D 5.317:9/2002
088 ## $a NIMA ref. no. NVPUB 9
100 1# $a Bowditch, Nathaniel, $d 1773-1838.
245 14 $a The American practical navigator : $b an epitome of navigation / $c originally by Nathaniel Bowditch ; prepared and published by the National Imagery and Mapping Agency.
250 ## $a 2002 bicentennial ed.
260 ## $a Bethesda, Md. : $b The Agency ; $a Washington, DC : $b For sale by the Supt. of Docs., U.S. G.P.O., $c 2002.
300 ## $a xi, 879 pages, [2] pages of plates : $b illustrations (some color), maps (some color) ; $c 29 cm + $e 1 CD-ROM.
336 ## $a text $b txt $2 rdacontent
337 ## $a unmediated $b n $2 rdamedia
338 ## $a volume $b nc $2 rdacarrier

490 1# $a Pub. ; $v no. 9
500 ## $a Originally published under title: The new American practical navigator.
500 ## $a Shipping list no.: 2002-0042-S.
500 ## $a Includes index.
500 ## $a "NIMA ref. no. NVPUB9."
505 00 $g Part 1: Fundamentals -- $t Introduction to marine navigation -- $t Geodesy and datums in navigation -- $t Nautical charts -- $t Nautical publications -- $g Part 2: Piloting -- $t Short range aids to navigation -- $t Compasses -- $t Dead reckoning -- $t Piloting -- $t Tides and tidal currents -- $g Part 3:Electronic navigation -- $t Radio waves -- $t Satellite -- $t Loran navigation -- $t Radar navigation -- $t Electronic charts -- $g Part 4: Celestial navigation -- $t Navigational astronomy -- $t Instruments for celestial navigation -- $t Azimuths and amplitudes -- $t Time -- $t The almanacs -- $t Sight reduction -- $g Part 5:Navigational mathematics -- $t Navigational mathematics -- $t Calculations and conversions -- $t Navigational errors -- $t The sailings -- $g Part 6: Navigational safety -- $t Navigation processes -- $t Emergency navigation -- $t Navigation regulations -- $t Maritime safety systems -- $t Hydrography -- $g Part 7: Oceanography -- $t The Oceans -- $t Ocean Currents -- $t Waves, breakers and surf -- $t Ice navigation -- $g Part 8: Marine Meteorology -- $t Weather elements -- $t Tropical cyclones -- $t Weather observations -- $t Weather routing -- $t Navigation tables -- $t Mathematical tables -- $t Explanation of navigation tables -- $t Mathematical tables -- $t Cartographic tables -- $t Piloting tables -- $t Celestial navigation tables -- $t Meteorological tables -- $t Glossaries.
530 ## $a Also available via Internet from the NIMA web site. Address as of 9/23/02: http://pollux.nss.nima.mil/pubs/pubsjapnsections.html?rid=187; current access is available via PURL.
538 ## $a System requirements for accompanying CD-ROM: PC or compatible; Pentium I+ processor; 64+ MB memory; 150 MB hard drive space; Windows NT 4.0, SP 4.0 or Windows 2000.
650 #0 $a Navigation $z United States.
650 #0 $a Nautical astronomy.
650 #7 $a Nautical astronomy. $2 fast $0 (OCoLC)fst01034759
650 #7 $a Navigation. $2 fast $0 (OCoLC)fst01035085
651 #7 $a United States. $2 fast $0 (OCoLC)fst01204155
710 1# $a United States. $b National Imagery and Mapping Agency.
830 #0 $a Pub. (United States. National Imagery and Mapping Agency) ; $v 9.
856 41 $u http://purl.access.gpo.gov/GPO/LPS22411
856 41 $u http://pollux.nss.nima.mil/pubs/pubsjapnsections.html?rid=187
938 ## $a Baker & Taylor $b BKTY $c 68.50 $d 68.50 $i 0160511259 $n 0004297155 $s active
938 ## $a Baker & Taylor $b BKTY $c 49.95 $d 37.46 $i 0939837544 $n 0004179114 $s active
938 ## $a Brodart $b BROD $n 02802686 $c $49.95
938 ## $a Baker and Taylor $b BTCP $n 2004356318
938 ## $a Ingram $b INGR $n 9780160511257
938 ## $a YBP Library Services $b YANK $n 8173026

Attachment 6h: Internet Archive capture of a NIMA Web site providing access to Document 6

NIMA www

The American Practical Navigator - Pub. 9
The American Practical Navigator, 2002

Current Edition:
Corrected through U.S. Notice to Mariners No. 43/2002 (26 October 2002)

This publication contains the following sections. Click the link to view a section on-line or download the file using your web browser's download mechanism. All documents are in **PDF format**. In order to view them on-line, you must have the Adobe Acrobat Reader© plug-in installed in your browser. For help on viewing/downloading, click here.

View/Download File

Publications Home

Maritime Safety Home Page

If you have questions or comments pertaining to the information provided on this website or if you are experiencing technical difficulties, please contact:

Attachment 6h: Internet Archive capture of a NIMA Web site providing access to Document 6

webmaster_nss@nima.mil

HTML last updated 27 Mar 2002