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ECDIS Development Laboratory and Navigation Technology Demonstration Center

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ECDIS Development Laboratory and Navigation Technology Demonstration Center

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Abstract - The U.S. Navy is undergoing a major transition from traditional, paper chart navigation to computer-based electronic charting. The Chief of Naval Operations (CNO) has mandated that all Navy ships will navigate strictly through electronic means by FY07. However, due to some recent groundings, the Navy is now striving to accelerate the full implementation of electronic navigation by FY04. The Naval Oceanographic Office (NAVOCEANO) is making a concerted effort to support this transition with upgrades to state-of-the-art survey ships, instrumentation, and data processing equipment. NAVOCEANO is increasing its capability to rapidly collect and process hydrographic survey data, and to quickly produce new electronic navigational charts in co-production with NIMA. In addition to ensuring safe navigation, these new products will include tactical digital overlays for battlespace awareness.

At NAVOCEANO, a new program is under development to expand these capabilities in a joint effort with University of Southern Mississippi's new Hydrographic Sciences Research Program. In September 2001, an ECDIS Development Laboratory and Navigation Technology Demonstration Center will be established. This facility will conduct quality assurance (QA) and test and evaluation (T&E) of electronic chart products from NAVOCEANO and other hydrographic/oceanographic data providers. This facility will also assist Navy ship personnel in gaining a greater understanding of electronic charting, as well as increased technical proficiency in properly using these systems to safely navigate – particularly in the shallow littoral areas of the world. The ECDIS Development Laboratory is envisioned to become an information clearinghouse and demonstration center on electronic charting technological development. In addition to explaining the range of currently available government data products and services,

The Navigation Technology Demonstration Center will showcase the use of electronic charts and its capability when used to avoid groundings and collisions at sea. The Center will

have commercial-off-the-shelf ECDIS and other electronic chart-based systems. A major focus will be to provide a better appreciation of the limitations electronic chart data produced by both the government and private sector that are derived from century-old hydrographic source data. Another important aspect will be to explain the capability and limitations of using very precise electronic navigation positioning systems (e.g., GPS and Differential GPS) with electronic charting systems. The Navigation Technology Center will also demonstrate the use of tactical digital overlays to provide naval vessels with critical military information that contributes to both safe navigation and increased warfighting mission capability.

I. BACKGROUND

A. What is an Electronic Chart?

Electronic charting is a new technology capable of providing significant benefits in terms of navigation safety, operational efficiency, and improved mission capability. As shown in Figure 1, an electronic chart is much more than simply computer display. In reality, an electronic chart is a real-time navigation system that integrates a variety of hydrographic and geospatial information including chart, positioning system (e.g., GPS), radar/Automatic Radar Plotting Aids (ARPA), and shipboard Automated Identification System (AIS). As an automated decision aid capable of continuously determining a vessel's position in relation to land, charted objects, unseen hazards and other vessels, the electronic chart represents an entirely new approach to maritime navigation and Warfighting in the Littoral Zone.

In terms of system components, features and functional capability, 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, generically, as Electronic Chart Systems (ECS).

For an electronic chart to be considered an ECDIS, it must comply with the Performance Standards for ECDIS established by the International Maritime Organization (IMO). [1] 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.

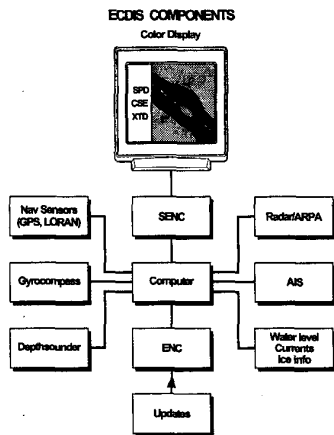


Figure 1 – ECDIS is an integrated navigation system capable of displaying a variety of information from different sources.

As defined in the IMO Performance Standards, ECDIS is a "navigation information system which with adequate back-up arrangements can be accepted as complying with the up-to-date chart required by Regulation V, Chapter 20 of the 1974 Safety of Life-at-Sea (SOLAS¹) Convention. Further, by displaying selected information from an electronic navigational chart (ENC) and positional information from navigation sensors ECDIS should "assist the mariner in route planning and route monitoring, and if required, display additional navigation-related information." As an automated decision aid capable of continuously determining a vessel's position in relation to land, charted objects, aids-to-navigation, and unseen hazards, ECDIS represents an entirely new approach to maritime navigation.

An Electronic Chart System (ECS) can be considered any other type of electronic chart that does not comply fully with the IMO Performance Standards for ECDIS. In the United States, the Radio Technical Commission for Maritime Services (RTCM) developed a voluntary, industry-wide standard for ECS. The RTCM Recommended Minimum Standards for ECS [2] require that ECS 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. Three general classes of vessels are designated (large commercial vessels, small commercial vessels operating in coastal waters or inland rivers, and smaller vessels). 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 an IMO-compliant ECDIS, an ECS is not intended to comply with the up-to-date chart requirement of V/20 of SOLAS 1974. As such, an ECS is an aid-to-navigation that should always be used with an up-to-date chart from a government-authorized hydrographic office.

Whether an ECDIS or a less capable ECS, electronic chart systems can be categorized as capable of using vector, raster, or both raster and 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 (e.g., floating buoys). With a vector ECS, the user has considerable flexibility and discretion regarding the amount of information that is displayed for the task at hand. For raster-based systems, the 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 video or digital scanning techniques that result in a computer photograph of existing paper charts. Although a raster data does not have the same "intelligence" as a vector data, raster data are far easier to produce.

B. U.S. Navy ECDIS-N

On 17 March 1998, the U.S. Navy issued a policy letter for ECDIS-N [3]. It set a goal that all Navy ships be equipped and trained to use ECDIS-N by FY07. The letter described an ECDIS-N Performance Standard that generally follows the IMO Performance Standards except as modified to meet U.S. Department of Defense (DoD) requirements. The policy also stipulated that ECDIS-N will be the central component of how the Navy will navigate in the 21st Century.

The primary source of navigational data for ECDIS-N will be the Digital Nautical Chart (DNC®) issued by the National Imagery and Mapping Agency (NIMA). The DNC® conforms to the U.S. DoD standard (VPF) that is an implementation of the NATO DIGEST C Vector Relational Format. Since interoperability between the maps and charts of air, land, and sea forces, is essential for joint military operations, NIMA decided to use the NATO Digital Geographic Information Exchange Standard (DIGEST) instead of the IHO S-57 data exchange standard.

¹ SOLAS 1974 applies to all ocean-going vessels, except warships and vessels operating solely in the Gt. Lakes – St. Lawrence Seaway System.

The DNC® is an unclassified, vector-based, relational, digital database containing significant maritime features essential for safe marine navigation and is distributed on 29 CD-ROMs. The DNC® portfolio was initially produced by digitizing approximately 5000 paper charts and consists of over 2400 digital chart libraries. The database is structured using the NIMA Vector Product Format (VPF), which distributes the data into 12 thematic layers and uses the Feature Attribute Coding Catalog (FACC) to encode chart features and associated attributes. Currently the DNC® cannot be used for navigation because it has not been brought into routine updating. The current technique under development for updating the DNC® is the "patch" method. This is a binary difference file, estimated to be 2KB to 1MB in size, that is created by differencing an updated DNC®, called the "Gold Copy" with the base DNC®. Patch files will be "pushed" to the end user or "pulled" from the NIMA Navigational Safety System website for application to the ships' ECDIS-N systems.²

C. NATO Warship ECDIS (WECDIS)

Performance Standards for "Warship" ECDIS (WECDIS) were approved by the North Atlantic Treaty Organization (NATO) in February 1999 and issued as STANAG 4564.[4] The core functionality of WECDIS is an IMO-compliant ECDIS. Beyond the minimum performance requirements for ECDIS, WECDIS has the ability to use a variety of geospatial data from both civilian and military sources. For navigational data, WECDIS uses both IHO S-57 ENCs and data conforming to NATO Digital Geographic Information (DIGEST) standards. This includes such products as Vector Product Format (VPF™) and Digital Nautical Chart (DNC™). In addition to Core Navigation Information (e.g., IHO S-57 ENC and VPF-DNC™), WECDIS will also use Raster Nautical Charts (RNCs), such as Admiralty Raster Chart Service (ARCS) or NOAA/Maptech ChartKit®. The ability to use different types of navigational data from a variety sources is often referred to as "multi-fuel." [5] Additional geospatial data to supplement the Core Navigation Information in WECDIS will be provided as Additional Military Layers (AML). This fusion of information will greatly improve the battle space awareness of the ship's crew, particularly in support of littoral warfare missions, such as mine and amphibious warfare.

III. Status of Electronic Chart Development

A. ECDIS

In conjunction with the IMO Performance Standards for ECDIS, 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. [6] It includes appendices describing the means/process for updating, colour and symbol specifications, and a glossary of ECDIS-related terms. IHO Special Publication 57 (IHO S-57) is the IHO Transfer Standard for Digital Hydrographic Data. [7] It includes an object catalog, DX-90 format, an ENC Product Specification, and ENC updating profile. Both IHO S-57 and S-52 are specified in the IMO Performance Standards for ECDIS.

In November 1996, Back-up arrangements for ECDIS were adopted by IMO and became Appendix 6 to the Performance Standards. In December 1998, a Raster Chart Display System (RCDS) was adopted by IMO and became Appendix 7. As a simplified "mode of operation" for an otherwise IMO-compliant ECDIS, official HO-provided raster data can be used as an interim type of electronic chart data where official Electronic Navigational Chart (ENC) coverage is not yet available. However, in order to conform to SOLAS regulations, ECDIS equipment operated in the RCDS mode must be used together with appropriate folio of up-to-date paper charts.

In March 1999, the IHO developed a Raster Navigational Chart (RNC) Product Specification and published it as IHO Special Publication No. 61 (IHO S-61). [8] IHO S-61 defines the minimum requirements that a RNC is required to meet for the RCDS Mode of Operation in ECDIS. There are two raster formats that meet IHO S-61 specifications:

Admiralty Raster Chart Service (ARCS) – HCRF Format
NOAA – BSB/Maptech File Format

In January 1999, IMO approved a standardized IMO Model Training Course on the Operational Use of ECDIS (IMO Model Course 1.27). [9] The primary objective of the Model Course is to ensure proper use and operation of ECDIS in terms of a thorough understanding and appreciation of its capabilities and limitations. The one-week Model Course syllabus includes classroom lecture, hands-on training, and exercise scenarios to be conducted in a ship's bridge simulator facility. In December 2000, the U.S. Coast Guard issued a Certificate of Approval to the Maritime Institute of Training and Graduate Studies as the first Coast Guard approved Operational ECDIS Training Course in the USA. [10]

In July 2002, a new Chapter V to SOLAS 1974 will go into effect. Revision was considered necessary as a result of new technologies and performance standards that IMO had adopted to improve navigation safety. While ECDIS is specifically mentioned as an important new shipborne navigation system, it is not listed as a mandatory carriage requirement. For the foreseeable future, ECDIS will not likely become a mandatory shipborne navigation system under SOLAS until greater worldwide electronic chart data coverage and associated updating services are achieved.

B. Electronic Chart Systems (ECS)

Increasingly, ECS systems are being used by many

² Additional information is available at the NIMA website (www.nima.mil/dncpublic).

vessels – both commercial and military, to improve navigation safety and efficiency. For U.S. Navy operations, there was a “Tiger Team” that performed an Analysis of Alternatives (AoA) for ECDIS-N. This study included three phases:

- 1) Determine fleet requirements for electronic charting systems
- 2) Determine which ships require what type of systems
- 3) Conduct a market survey of currently available commercial-off-the-shelf (COTS) and government-off-the-shelf (GOTS) electronic charting systems.

The results of this study are being used to provide an interim solution that will help facilitate the transition to full ECDIS-N by FY 2007. [11]

IV. New Navigator of the Navy

On 31 January 2001, the Vice CNO issued a Navy-wide message that designated the Oceanographer of the Navy (N096) to also become the “Navigator of the Navy” [11].³ As outlined in the message:

Navigator of the Navy will establish standards for navigation used by all Navy units with a goal of improving safety, efficiency, and interoperability with other DOD systems, allies and the international maritime community.

Included in his responsibilities are:

- analysis and assessment of navigation systems and emerging technologies
- performance standards for navigation systems
- technical specifications to attain ECDIS-N certification
- provide advice on navigation training
- formulate navigation policy decisions

Some of the more specific tasks related to electronic charting include:

- specify performance standards for Situational Awareness (S/A) related to the use of electronic chart systems
- transition plan to full ECDIS-N certification
- coordinate joint, interagency and international data and display standards

Affected by several highly publicized groundings, such as, the USS LEYTE GULF (CG-55) grounding in Virginia Beach in January 2001 and the USS LA MOURE COUNTY (LST 1194) grounding in Chile in September 2000, the Navy has decided on an “Acceleration Plan” developed with the goal to achieve ECDIS-N certified systems on all U.S. Navy ships by FY04. Included in the “Acceleration Plan” is a plan to deploy in FY02, two carrier battle groups, one to the Atlantic theater and one to the

Pacific theater, with certified ECDIS-N systems. It is intended for these two battle groups to navigate electronically wherever possible. One serious constraint will be that only 1014 DNC libraries (or 48%) are projected to be under maintenance by end-FY02.

V. NAVOCEANO Initiatives

The United States Navy is actively working to make a transition from traditional navigation relying on paper charts to computer-based electronic charting. The Naval Oceanographic Office (NAVOCEANO) is actively supporting this transition with upgrades to state-of-the-art survey ships, instrumentation, and processing equipment. In August 2000, the Navy’s Fleet Battle Experiment - Hotel (FBE-H) provided an opportunity to demonstrate the NAVOCEANO’s ability to rapidly update existing Digital Nautical Chart (DNC®) products with hydrographic survey data and produce an updated field DNC®, a prototype Electronic Navigational Chart (ENC), and seven different Additional Military Layers (AMLs). These digital products and services were delivered to exercise participants within 60 days of the hydrographic survey. Another important objective of FBE-H was to promote awareness of electronic charting issues and current commercial navigation technology.

On 15 November 2000, a Memorandum of Agreement was signed between NIMA and NAVOCEANO under which NAVOCEANO would assume the responsibility to compile specific DNC® libraries. An objective for co-production is to provide quality DNC® products to the Warfighter that meets their high-priority navigational and operational requirements in the shortest possible time. To support immediate military operations, NAVOCEANO may also provide an onboard field version of the DNC® and provide it directly to affected military units. Also, the DNC® Field Chart compilation may be used to produce an ENC in partnership with HYCOOP and foreign host nation hydrographic offices. Such production/co-production would be subject to the terms of separate bilateral international agreements. In late February 2001, NAVOCEANO delivered an updated, larger-scale DNC® Library H509300 for Ingleside, TX to support MCM ships based there. As of this writing, new DNC® libraries are under production for Guam and Saipan to address Pacific Fleet requirements.

Since navigation technology is changing from paper nautical charts to digital electronic charts, NAVOCEANO has implemented major changes to its survey systems, data processing, and chart production systems to support naval operations in the digital age. [13] As part of its mandate to support the Fleet, new capabilities are being established:

- Highly mobile data collection assets capable of supporting immediate Fleet needs. These include the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system and the Fleet Survey Team (FST).

³ Additional information is available at the Navigator of the Navy website: www.hq.navy.mil.

- Rapid processing, editing, and validation of multi-beam sonar and side-scan sonar data using a suite of NAVOCEANO and contractor-developed processing software.
 - Construction in FY2001 of a Survey Operations Center capable of downloading survey data directly from survey ships anywhere in the world.
 - A Digital Nautical Chart (DNC®) co-production program with NIMA for rapid turnaround of digital navigation information from survey to chart delivery for use by the Navy version of the Electronic Chart Display and Information System (ECDIS-N), other ECDIS, and Electronic Charting Systems (ECS).
 - The means to rapidly produce and disseminate battlefield visualization of digital hydrographic and other tactically significant data layers to support ECDIS-N and shipboard Command and Control systems.
- b) select those developments which have a high probability of enhancing NAVOCEANO programs and objectives,
 - c) undertake research and implement these developments to blend emerging technologies with NAVOCEANO's evolving needs, and
 - d) devise new approaches and techniques as required by these developments.

In order to achieve these capabilities, the joint Navy – University of Southern Mississippi program has been instituted.

VI. ECDIS Development Laboratory and Navigation Technology Demonstration Center

The University of Southern Mississippi (USM) holds the leadership role in the marine sciences for the State of Mississippi. In 1986, the University demonstrated its commitment to that mandate by establishing a Marine Science academic and graduate research program at the John C. Stennis Space Center. That program evolved into the USM Department of Marine Science in April 1998. With the assistance of NAVOCEANO, the USM Department of Marine Science has developed a Master of Science degree in Hydrographic Science. The purpose of this new degree program is to provide graduate education in hydrographic science to U.S. Navy employees and others in the field of hydrography. The overall educational objective is to achieve core competency in hydrographic surveying and data production. In this regard, the material covered in the program became the basis for having the NAVOCEANO-USM Joint International Hydrographic Applied Science Program to be certified in April 2000 at the Category A level by the International Federation of Surveyors (FIG) / International Hydrographic Organization (IHO).

In conjunction with the Hydrographic Science program, USM and NAVOCEANO have established a National Center of Excellence in Hydrography (NCOEH). [14] NCOEH will play several roles. It will seek to understand emerging trends in hydrographic science and technology, and modify and advance those trends to provide solutions applicable to NAVOCEANO. In doing so, the Center will:

- a) analyze and assess promising developments in hydrography and related sciences,

NAVOCEANO is expanding these capabilities in a joint effort with USM Hydrographic Science Research Center by establishing an ECDIS Laboratory and Navigation Technology Demonstration Center. In particular, NAVOCEANO wants to implement this capability to provide a full range of electronic chart data products and services for naval war fighters, as well as for civilian, national, and international users. To do so, NAVOCEANO needs to gain a thorough understanding of the capabilities and limitations of current electronic chart systems that can be employed onboard USN vessels.

Starting in September 2001, the ECDIS Development Laboratory is being used to conduct quality assurance and testing of electronic chart products produced by NAVOCEANO and other data providers. It will also be a facility whereby Navy ship personnel can gain an understanding electronic charting technology, as well as learning how to correctly use these products to safely navigate and operate in the shallow littoral areas of the world. Furthermore, the laboratory is envisioned to become an information clearinghouse and demonstration center on available electronic chart products and technological advances in electronic navigation techniques and commercial-off-the-shelf ECDIS and ECS.

The Navigation Technology Demonstration Center will showcase the use of electronic charts and the resulting capabilities commonly used today to avoid groundings and collisions at sea. It would demonstrate the use of tactical digital overlays to provide bridge crews with critical military information affecting safe navigation. Finally, it would focus on understanding the capabilities and limitations of using a wide variety of electronic chart data, produced by both the government and private sector. A particular focus will be on the limitations of using electronic chart data that was digitized from current paper charts compiled from century-old hydrographic survey data.

VII. Looking to the Future

ECDIS and other types of electronic charting systems will lead to dramatic changes in the way vessel navigation is performed. Once fully implemented, electronic chart-related technologies will lead to significant improvements in the safety and efficiency of navigation for all types of vessels operating in the world's increasingly congested ports and waterways.

For naval vessels, ECDIS will enhance all aspects of navigation from initial planning, real-time execution and voyage data recording. Whether the system is designed as NATO Warship ECDIS or ECDIS-N, it will automate many routine navigational functions, transform bridge efficiency, and improve Officer-of-the-Watch warfighting capability. ECDIS should also offer the opportunity for information exchange between ship and shore commands. In the interest of safe navigation for seagoing units or in preparing for the conduct of military operations, both shore and at-sea commands will be able to exchange and use geo-spatial data. Naval vessels will also be able to display additional military layers and other forms of geospatial data superimposed on the electronic chart display. For example, a minehunter will be able to exchange a Mine Warfare AML (Additional Military Layer) with another minehunter tasked to lead an aircraft carrier through a mine danger area.

Since ECDIS is a real-time navigation system, there are also opportunities to improve upon the type of information that deals with the 4th dimension – time! This includes such time-varying information as tides/water levels, currents, ice coverage, weather, and vessel movements. In this regard, the new Navigator of the Navy has a vision of a 3-D Battlespace whereby information and communications between units occurs across all commands and platforms. Called the 4-D Cube Ops Environment, it will be a major evolution in how naval warfare is conducted.

Given the challenges and opportunities that ECDIS involves, it is important that government agencies, industry, education/research organizations, and navigators -- work together!

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