# Integrating GIS, ECDIS and Web-based Marine Information System for Maritime Navigation and Coastal Protection

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**Key words**: Marine Information System (MIS), Geographic Information System (GIS), Electronic Chart Display Information System (ECDIS), Navigation, Light Detection and Ranging (LIDAR), Coastal Zone Management.


## SUMMARY

Over seventy percent of the Earth's surface is covered with water upon which world trade, fisheries, marine transportation and costal populations are relying and require safe navigation and environmental protection. This paper summarizes the principal components of a web-based Marine Information System (MIS); the data formats of electronic nautical chart (ENC), Digital Nautical Charts (DNC®) and raster nautical chart (RNC) for Electronic Chart Display Information System (ECDIS) and safe navigation; the critical infrastructures under protection by coastal management regimes; the recent advances of acquiring hydrographic data by Light Detection and Ranging (LIDAR) for use in geographic information system (GIS) applications; the reliable sources of ENC, DNC and RNC; and the techniques of converting GIS data to ENC or vice versa to expedite the implementation of a MIS.

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## 1. PRINCIPAL COMPONENTS OF MIS, GIS AND ECDIS

A web-based MIS is a computerized information system which facilitates: (1) data storage and maintenance; (2) retrieval of data based on their spatial, temporal, and/or thematic properties; (3) integration of diverse data, for example remote sensing data and field survey measurements and other records; (4) data analysis and visualization; (5) simulation models for prediction of marine parameters (Jacob, et al., 2003). It obtains data via survey instrumentation, GIS and ENC distributors in order to perform the aforementioned functions efficiently and effectively under the World-wide Electronic Navigational Chart Database (WEND) model of the International Hydrographic Organization (IHO). Principal components of a web-based MIS and its communication networks are shown schematically in Figure 1.

GIS has been long recognized as an integral component of the MIS for coastal protection and home-land defense operations. It is essentially a computer-based data management system which can handle vast amount of geo-referenced data to assist decision-making by having the system components of data inputs, metadata management (data storage and retrieval), data manipulation and analysis and data outputs. Typical components of a complete GIS are illustrated in Figure 2. Its input data are addressed as geospatial data of vector or raster objects and attribute data of objects' description (e.g., texts).

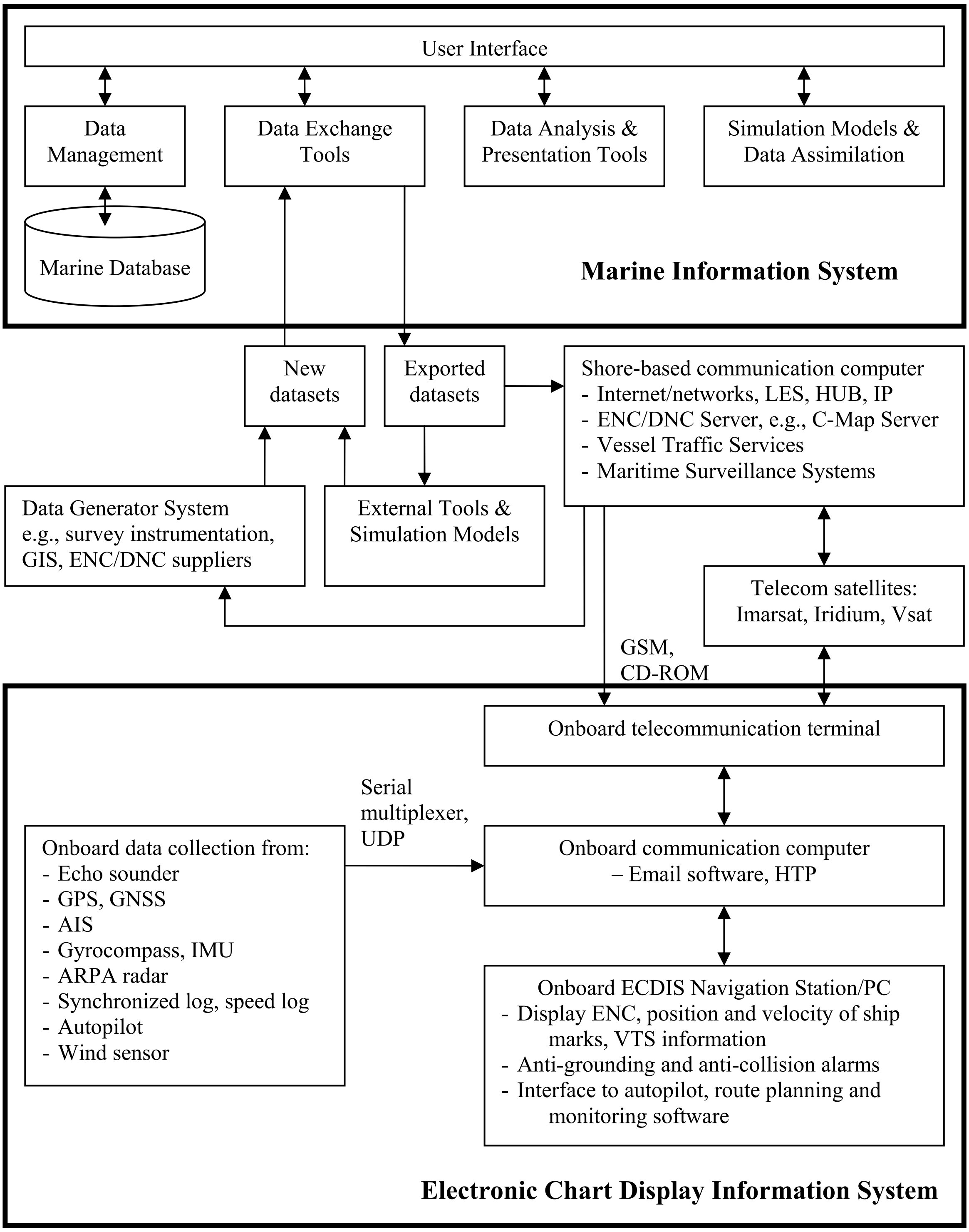


**Figure 1**: Components of the web-based MIS (Jacob, et al., 2003, Fig. 6; Pillich et al., 2003; Ince, 2000; IHO WEND model, 2007; IHO S-63).

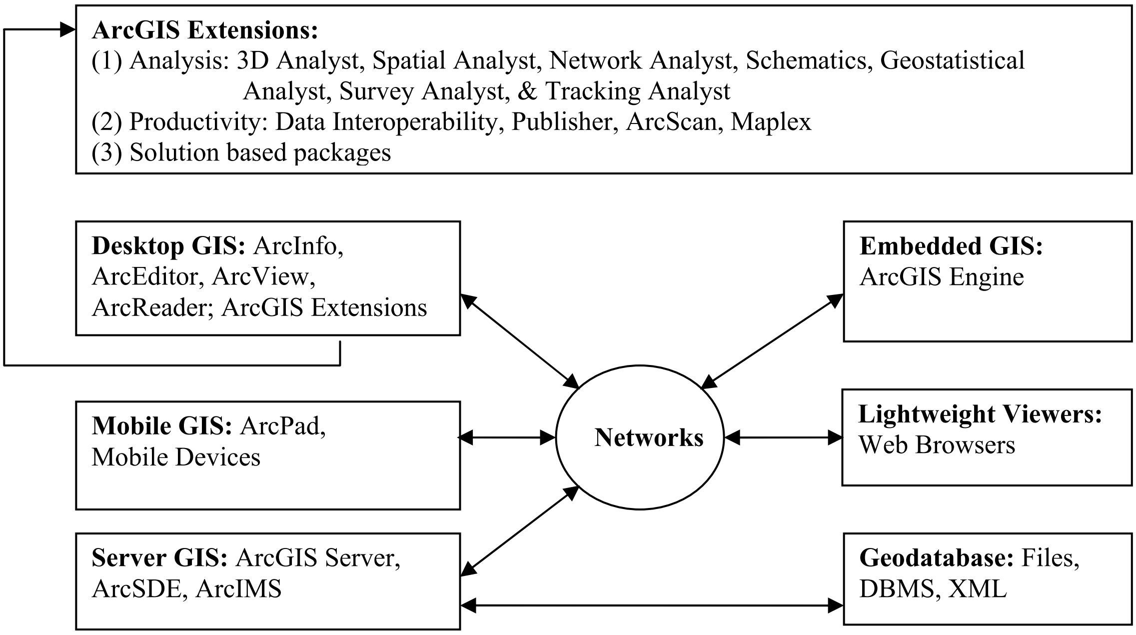


**Figure 2**: A complete GIS by ESRI (www.esri.com, 2007)

According to the code of practice established by the Safety of Life at Sea (SOLAS) Convention and the International Maritime Organization (IMO), all ships must have an approved ECDIS on board with ENCs to be maintained and displayed on the ECDIS. The ENCs must comply with IHO S-52, IHO S-57 and other standards. The hardware of ECDIS must comply with all the calibration tests established by the International Electrotechnical Commission (IEC). Many ECDISs are also capable of displaying the DNCs produced by U.S. National Geospatial-Intelligence Agency (NGA). The DNCs cover the whole world and are intended for GIS and military/security applications. In the absence of ENC and DNC, RNC in bitmap format will be allowed to be used in navigation, which is displayed on Raster Chart Display System (RCDS).

As shown in Figure 1, a true ECDIS is essentially a vector system which displays position, imagery and navigational information received from ship-board sensors on a vector ENC. It has the advantage of interfacing with an Automatic Identification System (AIS), Automatic Radar Plotting Aid (ARPA), Global Navigation Satellite System (GNSS, e.g., GPS) and other sensor data to provide 24-hour real-time positioning, anti-collision and anti-grounding alarms, and autopilot guidance for navigation. It also has application functions for updating and displaying the ENC data, route planning, route monitoring, and recording the ship's past ENC and track logs including date, time, position, direction and speed of the ship. The main advantage of an ECDIS over GIS in general is that it can dynamically display cartographic objects including coastlines and bathymetry and along with the real-time positions and track of other vessels (including the host vessel) within range of an AIS telemetry interface. This computerized system is capable of computing the tracked object's course, speed and closest point of approach (CPA), thereby warning the operator if there is a danger of collision with the other ship or land mass. Thus, the ECDIS is a tool for safe navigation and the prevention of collisions, the dividends of usage being the safety of life at sea, the protection of property and the marine environment. Its primary purpose is as an aid to navigation whereas GIS is not.However, since a true ECDIS is a vector-based charting system, it offers limited interoperability with other GIS formats.

## 2. DATA OF GIS, ECDIS AND MIS FOR COASTAL PROTECTION

The objective of integrating GIS and ECDIS with an MIS is to protect onshore and offshore assets and infrastructure, which if disrupted or destroyed could cause serious damage to health, safety, security and commerce. The implications of which could impact a coastal state's infrastructure, its economic well-being and the effective functioning of government services. Within the scope of a GIS, critical infrastructures can be classified into: energy and utilities (e.g., electricity supply); information and communication systems (e.g., broadcasting stations); finance (e.g., banking system and investment); health care (e.g., hospital); food supply (e.g., agriculture and food safety); water supply and sewage disposal; transportation (e.g., air, rail, road and marine traffic); safety [and security] (e.g., nuclear safety); government services and assets; manufacturing (e.g., chemical industry) (PSEPC, 2004). To aid in the detection of threats to coastal infrastructure posed by pollution and shoreline stability while establishing an MIS for sustainable development of maritime trade, transportation and property rights, the following intelligence mapping programme is recommended by (Barter et al., 2000):

- Mapping of all onshore geology, beach profiles, land use and flora by applying [high resolution] LIDAR surveying methods (eg. Optech's ALTM airborne laser scanning system and LIRIS-3D ground-based laser scanner).
- Mapping of all offshore geophysical objects, [marine] habitat and other marine objects within the [nearshore] marine boundaries using, for example Optech's SHOAL airborne laser bathymeter.
- Mapping and assessment of all engineering structures with the assistance of digital solid models created by LIDAR surveys and reverse engineering software.
- Mapping and analyses of oceanographical and meteorographical data including sampling and analysis of marine and terrestrial water and sediments by Acoustic Bottom Classification (ABC) Survey.
- Socio-economic surveys and public consultation to establish the characteristics of coastal communities.

In areas where LIDAR applications are limited by water depth and/or water clarity, the combined use of multibeam and sidescan sonar systems can provide complimentary high resolution data for mapping bathymetry and seabed classification.

In addition to the above remote sensing and hydrographic techniques, LIDAR techniques based on satellite platform sensors such as elastic-backscatter, differential-absorption, Raman, fluorescence and direct-detection Doppler techniques are recommended to map or monitor atmospheric and meteorographical objects, for examples aerosol particles, water/ice clouds, precipitation, radiation, temperature profiles, windstorms, visibility and industrial emissions (Weitkamp, 2005; Barter et al., 2000).

In addition to National Hydrographic Offices, recognised suppliers of ENCs (in S-57 format) and ECDIS software and hardware are, e.g., Primar Stavanger ENC Service (a distributor of ENCs produced by government HOs and the International Centre for ENCs), C-Map Inc. of Norway and the British Transas Marine Limited. At the time of reporting, 181 object classes are defined in IHO S-57 Object Catalogue, similar to those classes of DNC. DNCs in Vector Product Format (VPF) are supplied by dealers of NGA, which cover the following categories or layers of information for GIS applications, ECDIS and the MIS:
- Cultural Landmarks (human made and land features);
- Earth Cover (shoreline, islands, and other boundaries);
- Environment (current, tides, and magnetic anomalies);
- Hydrography (soundings, bottom characteristics, and depth curves);
- Inland Waterways (canals, rivers, locks, lakes, etc.);
- Land Cover (glaciers, trees, marches, etc.);
- Limits (restricted areas, traffic separation schemes, etc.);
- Aids to Navigation (buoys, lights, beacons, etc.);
- Obstructions (rocks, wrecks, obstructions, etc.);
- Port Facilities (breakwaters, piers, seawalls, etc.);
- Relief (contours and spot elevations);
- Data Quality (source boundaries and information);
- Tile Reference (tile boundary delimiters and information);
- Library Reference (library boundaries and coastal shoreline) (Fishburn and Kimos, 1995).

The last three layers provide source, background and location information (Fishburn and Kimos, 1995). Since 2001, the U.S. National Oceanic and Atmospheric Administration (NOAA) has been offering NOAA ENC®s in S-57 and GIS data formats free of charge to the users over the Internet. But most of the data are converted from raster imagery and may not be valid for navigation operations. In the near future, more oceanographic objects known as Marine Information Objects (MIOs, e.g., meteorological objects) and Additional Military Layer (AML) objects will be developed and added into a new IHO S-100 Object Catalogue to expedite MIS applications (Alexander, 2003; Alexander, et al., 2007).

## 3. INTEGRATION OF GIS DATA AND ENC

The main challenges associated with the integration of GIS and ENC relate to the collection of data (in S-57 format), and the conversion from GIS spatial data format(s) into S-57 object format or vice versa so that, these two categories of data can be assimilated together and applied in spatial analysis, dissemination of findings and decision making in coastal management. We have presented the methods of acquisition and sources of GIS and ENC data in Section 2. Regarding the data conversion, GIS vendors (e.g., CARIS and ESRI) offer the conversion services, software and training to users. For example, the transformation of data from ENC/DNC to GIS or vice versa via ESRI's ArcGIS platform has been both efficient and effective. Another example, (Wan et al., 2005) describes the method of applying a three-dimensional quad-tree data structure for developing ECDIS software that integrates with CARIS HOM/DOM for ENC/S-57 and DNC/VPF production. In this case, despite the disadvantage that a quadtree data structure is shift sensitive in the sense that its space requirements are dependent on the stability of origin or higher hierarchical levels, it is easy to program and implement fast updates and queries of large spatial databases.

## 4. CONCLUSIONS AND FURTHER DEVELOPMENT

In integrating GIS and ECDIS with an MIS, both land and hydrographic data are best collected in ENC (IHO S-57 object format). DNC (VPF format) and a combination of other vector, raster and attribute data can be used to enhance the MIS. LIDAR technology is highly recommended for cost effective, high resolution data acquisition in near shore areas however it may be necessary to integrate high resolution sonar technology to supplement LIDAR coverage. Software to facilitate the interoperability between ENC and various GIS and data base formats is key to presenting information in the MIS to support decisions made by navigators, and persons involved with coastal management. Under the leadership of the IHO, IMO, Fisheries and Oceans Canada, NOAA and other international and national maritime organizations, more oceanographical and meteorographical layers of data (which are classified as MIOs and AML objects) can be added to expand the capabilities of an MIS, to clients concerned with navigational and environmental issues. It is worth considering the potential for the integration of cadastral layers within the MIS to relate mapping and environmental data to a property rights frame work. Presently, the main obstacles are the quality of available source data as well as the cost of acquiring data to be used in the production of ENCs and the availability of training courses on ENC data production and validation. Some government hydrographic offices are still having difficulties in producing ENC data in compliance with IHO S-57 due to the lack of funding and technical expertise.

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## BIOGRAPHICAL NOTES

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