Research on Object-Oriented Relational Database Model and its Utilization for Dynamic Geo-spatial Service through Next Generation Ship Navigation System

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Abstract

This paper aims to develop system architecture and database model dynamically reflecting situational circumstances at sea into ship navigation. It is mainly intended to find how to design dynamic system Electronic Navigational Chart (ENC) and how to utilize it through modeling of the Object Oriented Relational Database. This paper also explores the possibility as well as the limit by realization and enhancement of the concept by a program module of converting actual S-101 ENC raw data to System Electronic Navigational Chart (SENC) model and viewing the outcome.

Keywords: S-100, S-57, ECDIS, e-Navigation, Spatial GIS, next generation navigation.

1 Introduction

Electronic Chart Display and Information System (ECDIS) is the first software driven bridge navigation system that tracking and tracing ships' positions on ENC, digitalized sea map. The navigation system was mandated to equip onboard for a certain level of ships regulated by IMO SOLAS, the International Regulation for Safety of Life At Sea, 1974[5].

The system enables to secure ship's safety by providing safety related information, coastal environment information, weather information, traffic facilities and many others which will be visualized on its display unit. The ENC is the database visualized on the display unit of the navigation system, which must be compliant with the international standard, S-57, S-52 and others by its purposes and be type-approved for its quality assurance.

S-57 is data exchange standard protocol, implemented by International Hydrographic Organization (IHO) in order to enable the national hydrographic offices to transfer their hydrographic data to other HOs, ECDIS manufacturers, mariners and other users. S-57 has been frozen at Ed. 3.1 in November, 2000 after modified as Ed. 3, in order to avoid any unnecessary reluctance for next version and to encourage ECDIS manufacturers without concern for change of standard. S-52 is standard for visualization and presentation on display and also has been frozen at Ed. 5 since 1996. Next edition is now in development by IHO technical working group to be enforced in very near future.

In the meanwhile, advanced GIS technology and ICT convergence trend in the industries are now motivating the maritime users to require more analytical and dynamic presentation of 3D data, submarine topographical map, time serial sea climate change etc. S-100 is the response of IHO in efforts to reflect this ICT-Industry convergence trend, by setting up totally new concept of standard.

S-100 standard is in progress of development aiming to support more effectively industries and users of digital data and its application system. In any way this development of standard will affect inevitably

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the specification and architecture of navigational equipment for future development[4]. In particular new standard specifies not only static data structure as for S-57 but also dynamic structure to manage marine environmental and geographic information database and to flexibly link and share the information between applicable systems. So, static binary file system is now realized to be very limited to manipulate the spatial geographic data in S-100 structure.

This paper proposes an enhanced geo-spatial data model, incorporating with object-oriented database technology and modeling method as an alternative to reflect these technology trend and change of standard.

2 Definition of next-generation ENC and comparison of standards

New standard of next generation Electronic Navigational Chart, IHO S-100 implies existing 2 dimensional spatial geo-data model as well as 3 dimensional spatial model and raster model. Basic geo-spatial data structure is composed of not only ISO/IEC 8211 binary format but also XML.

It expands its application from fundamental navigational purpose to submarine survey, web service and many other value added production and services. The IHO S-100 standard is implemented in order to;

- Magnify a variety of format, product line and user of hydrographic related data
- Provide a variety of space analysis model for route, density etc.
- Diversify web based map service and its platform.
- Secure flexibility and expandability of system by utilizing ISO compatible registry.
- Establish a process of independent update and change of product specification and standard.

To accomplish these purposes IHO S-100 is differentiated from S-57 in many technical aspects. Table 1 depicts the differences.

	S-57 Standard	S-100 Standard
Effective	1996 2010 (overlap for a certain period)	After 2012
Purpose	IMO SOLAS ECDIS	Marine geo-spatial Applications
Latest Version	IHO S-57 ED 3.1X Base Standard & Requirements sustained	IHO S-101, ISO 19100 Profile based S-100 Registry Management
Responsible	IHO	IHO
Data Model	VECTOR 2D	VECTOR2D/2.5D, Raster
Encoded	ISO/IEC 8211 binary	ISO/IEC8211 binary, xml
Attributes	Community dependent, Paper Chart navigation information compiled	A variety of navigational information added to existing electronic charts
Share	Exchange and distribution of data set	Data set exchange and plug & play

Table 1: S-57 and S-100 standard comparison (TTA 2012)

Next generation electronic navigation chart standard, S-100 is categorized into 10 sub-standards and is consist of Registry, Spatial Reference system and Data Encoding. Each sub-standard is referenced to build S-100 based electronic data structure. S-100 ENC data is built on the concept of profiling, which widely taken as in geo-spatial information standards.

Profiling is the conceptual method to select a require module for specified purpose and information community out of multiple base standards and to extend the module to sustain within the standard architecture. It is defined in ISO manual and compliant with ISO 19106 detailed instructions. In result System ENC is constructed as better standardized and in open environmental way than in existing structure, as the SENC follows the next generation ENC standard. While S-57 ENC is presented in fixed and static format, this new S-100 ENC and next generation navigation system geographically.

3 Requirements for dynamic service of next generation ENC

In order to express dynamic marine environment and topography, the next generation navigation system should be differentiated in its electronic chart database structure and system architecture from the existing one, as shown in Figure 1.

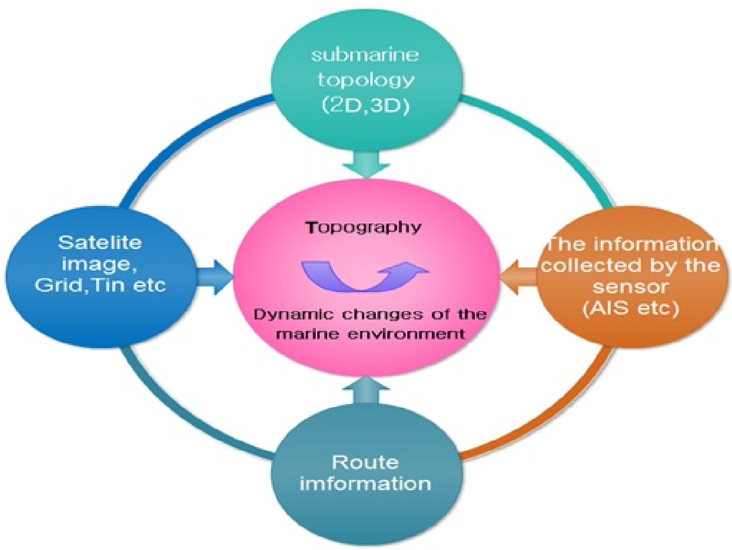

Figure 1: The Concept of Next Generation Electronic Navigational Chart

The S-57 ENC is serviced with its original contents without modification. However S-100 ENC database responds to and reflects navigational circumstances and conditions around mariner's position. In order to accomplish these missions the advanced navigation system requires real time update and immediate visualization of the acquired information in its service, rather than simple access and display of already implemented data source.

For this purpose the ENC database needs smooth and automatic addition, modification and cancellation of data and dynamic transaction process. To meet this requirement System ENC, SENC should be better built on Database system architecture than on simple File base system in terms of system architecture to store and manage the geo-spatial data. In case of land GIS, big database management system, such as Oracle or MS-SQL, together with suitable standards has been widely implemented to manage geo-spatial data especially for their enterprise system. Also third party tool, like post-gis and spatial-lite, capable of managing geo-spatial data on open source database, such as postgresSql or SQLite is being utilized. In land GIS, OGC ST_GEOMETRY and Oracle SDO_GEOMETRY are referenced as their database architecture standard.

Most commercial database management system is constructed on OGC Standard, ST_Geometry, among which is CARIS HPD. It is known to the best marine GIS solution S/W in terms sales performance in world market. ESRI, the best land GIS solution vendor developed in ambition to be more active in marine market PERSONEL Geodatabase to manipulate S-57 standard data on their ST_GEOMETRY structure as shown in Figure 2.

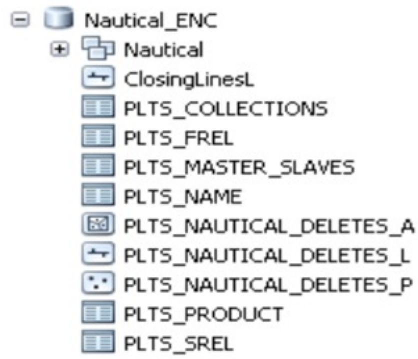

Figure 2: Sample of ESRI Nautical Data Structure[1]
(http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Nautical_data_models
/01060000022v000000/)

These database structures provide multiple users with appropriate system functions both land and sea. However, some technical issues exist in adopting those systems and standards into next generation navigation service.

Firstly easy operation of system is the key issue in next generation navigation. In order to operate ship navigation system running on ENC with existing Geo-spatial data standard, system operator who is capable of managing spatial database and legacy enterprise database system is necessary onboard the ship, which cannot be realized. In that sense, mariners also take responsibility for taking care of system management as an extra work. To lessen their burden on system management, easy rebooting of database system without complicated special command and procedure are essentially needed.

Secondly, consistent transaction and performance should be assured in geo-spatial data service. Conventional database standard puts more emphasis on appropriate conversion of raw file data into standard format for its service operability, so that it implicates multiple processes of data update and modification and in result, to secure the stability in transaction and performance it facilitates user access management function to manage multiple users' accessing and editing of database, such as "Versioning" function of ESRI ArcSDE.

In the meanwhile, the next generation navigation system requires light structured database model than existing geometry model for transaction process, as a variety of sensor data is received, added and updated regularly on real time basis.

Thirdly, easy sharing and linking of information is one of the key factors. The platform of next generation navigation system is expected to grow diversely and to be commercialized in the marine industry; hence it will be considered more important of information to be sharable and linkable among systems.

To meet this end S-100 navigation system requires portability with other system and hardware platform. As S-57 spatial database service by existing vendor only provides standard and service pattern for data storage, individual method was applied to share and link with other platform and system. And identical data structure is consistently necessary on every platform apart from individual user's platform.

Lastly, S-100 support database model and conversion software are of basic necessity. S-57 data is imported into S-100 structure, which has fundamental difference in geo-spatial data structure; SENC is also easily converted between S-100 compatible data structure and original S-100 data.

4 Data Base system structure of next generation navigation system

To clarify the above listed technical issues the solution is proposed to load Object Oriented Relational Database Model on to light sized memory DBMS such as SQLite in the navigation system.

Taking SQLite for instance, it is same database management system as MySQL or PostgreSQL, but is not a server and considerably light-sized database with open source so that is not commercially limited to personal free use[1][2].

It is being freely loaded and run on Android mobile, supplied in library for convenient installation and quick configuration. In addition, it is composed of just one single database file making easy copy and move in a system. And also in general adding more memory increases searching speed, explicitly assuring the effect of hardware enhancement. Figure 3 explains difference in performance of the databases.

	SQLite 3.3.3(sync)	PostgreSQL 8.1.2	MySQL 5.0.18(sync)	MySQL 5.0.18(nosync)
1000 inserts	3.823	4.922	2.647	0.329
25000 inserts transaction Incl.	0.764	16.454	7.833	7.038
25000 inserts index table	1.778	19.236	11.524	12.427
100 searches W/O index	3.153	5.74	2.718	1.641
100 searches text string compare	4.853	6.565	3.424	2.09
inner join W/O index	14.473	0.176	3.421	3.443
Index creation	0.552	0.274	1.159	0.275
5000 searches W/ index	1.872	199.823	3.763	3.725
1000 updates W/O Index	0.562	1.663	1.93	4.656
25000 updates W/ Index	1.883	23.933	16.348	17.383
25000 text string updates W/ Index	1.386	24.672	16.469	15.491
Inserts by search data	1.179	1.091	0.986	0.933
inner join W/ Index	0.371	5.981	0.408	0.603
inner join W/ Text Index	0.383	1.324	0.404	0.558
100 Searches W/ sub-quary	7.877	6.245	16.891	38.447
Cancel W/O Index	0.528	0.336	0.394	0.532
Cancel W/ Index	0.866	0.283	0.541	1.336
drop table	0.138	0.229	0.125	0.058

Table 2: Comparison Sqlite vs other database systems
(http://code.google.com/p/gonando-project/wiki/SQLite3_performance)[3]

General overview of the performance comparison from Figure 3 indicates the SQLite is competitive enough, rather advanced in some tests. In the system architectural aspect SQLite is of ease in copy and manipulation, which makes easy to link next generation navigation data with other platform.

[1]http://ko.wikipedia.org/wiki/SqLite

5 Data Base structure and conversion method of next generation navigation system

The database needs to be constructed on S-100 object structure when the raw S-100 ENC data is converted into System ENC database. In order to design database structure, Object Oriented Relational Data Modeling, which a design method object oriented concept is integrated in relational database, is proposed as a way to store topographic object and dynamic marine environmental data. Figure 3 & 4 features physical and logical model designed in object oriented method.

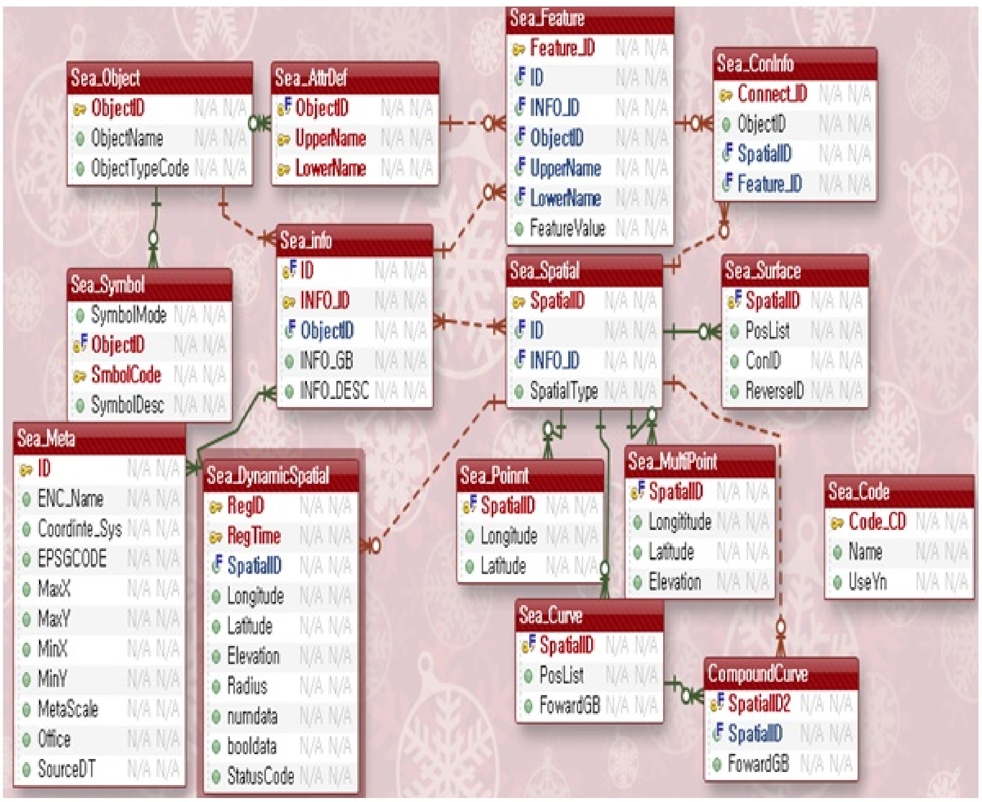

Figure 3: Physical Model of System Electronic navigation Chart

The database model, as shown in Figure 4, comprises marine topographic object information, visualization information, chart meta data information, marine geographic data of point, line and area, object attributes, dynamic marine geo-spatial information etc.

Marine topographic object information and visualization information defines objects presented on electronic chart and symbol and presentation format, where object versus visualization information matches at 1:N in design structure, then it enables presentation of symbol and change of color as per circumstances.

Chart metadata information composes the structural information of the version and scale when the original ENC was produced.

Marine geographic data has the structure to manage the basic objects of point, line and area and comprises point, line, compound curve, surface objects.

Spatial object data information is composed of position fixing information on ECDIS display and spatial array information, mutually referring.

Attribute information relates to attribute field and its value as well as independent reference to refer

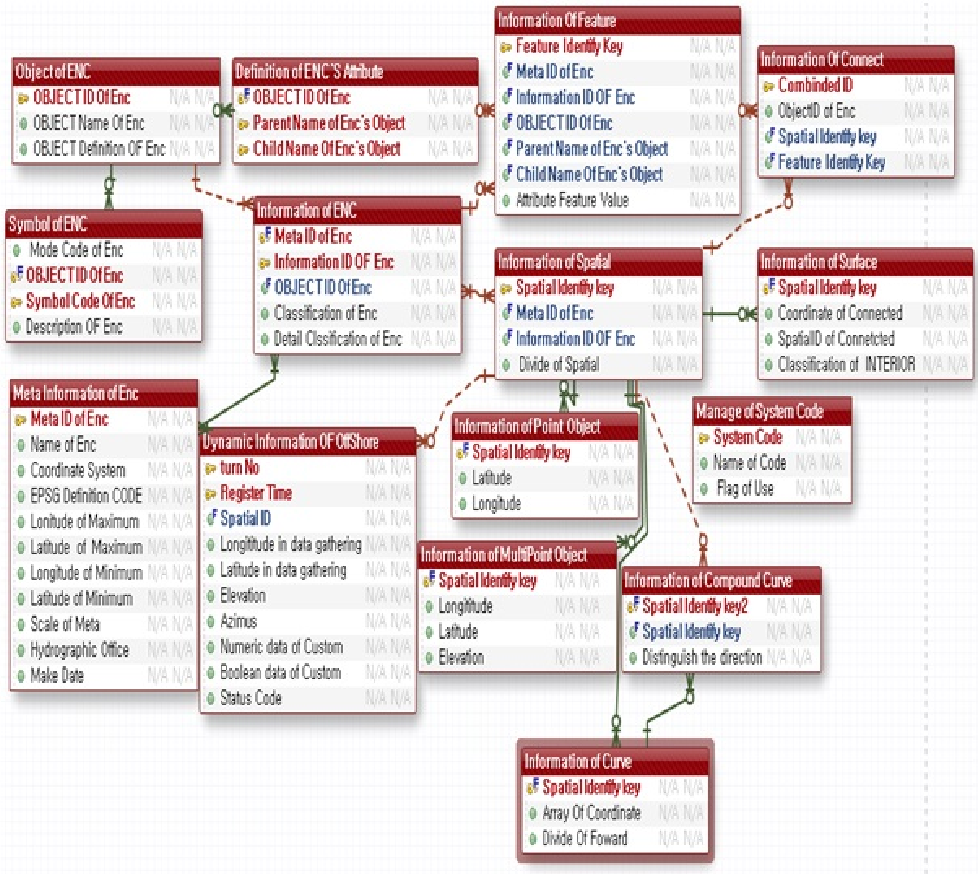

Figure 4: Logical Model of System Electronic navigation Chart

to attributes and spatial information.

Dynamic geo-spatial information is to store position information from various sensors, such as AIS or Automatic Identification System on board, and configuration.

As the structure is designed as above, it is put into the following procedures to physically build database;

1 creation of data storage and accessary information (table, View, Code)

2 analysis of target data to be converted

3 loading of analyzed data onto system

4 converting and storing of loaded data into data base

For the purpose to verify these procedures, as shown in Figure 5 database creation program module was developed.

This module is programmed to analyze S-101 original data, after converted from S-57 format, converted into object oriented relational database structure and stored onto the final destination. The above creation module enables to clarify the result of ENC database through 2D/3D chart viewer and 3D chart in SENC display module, as depicted in Figure 6.

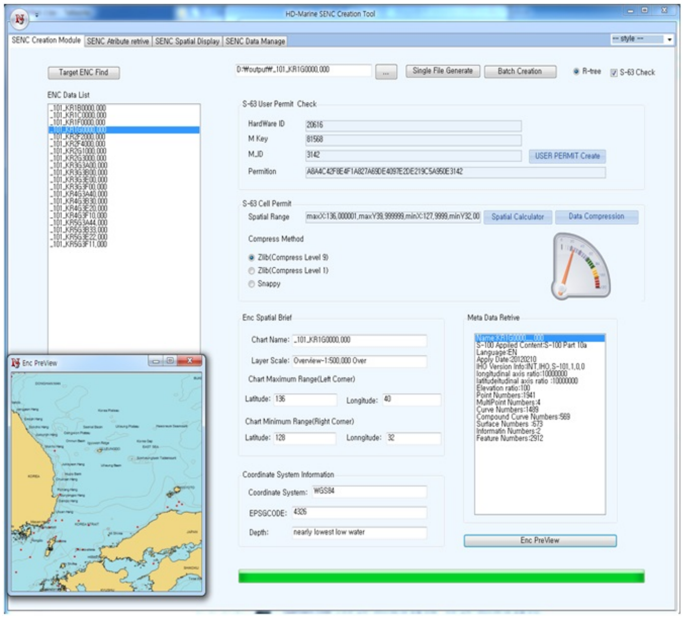

Figure 5: SENC Creation tools based on S-101 Standard

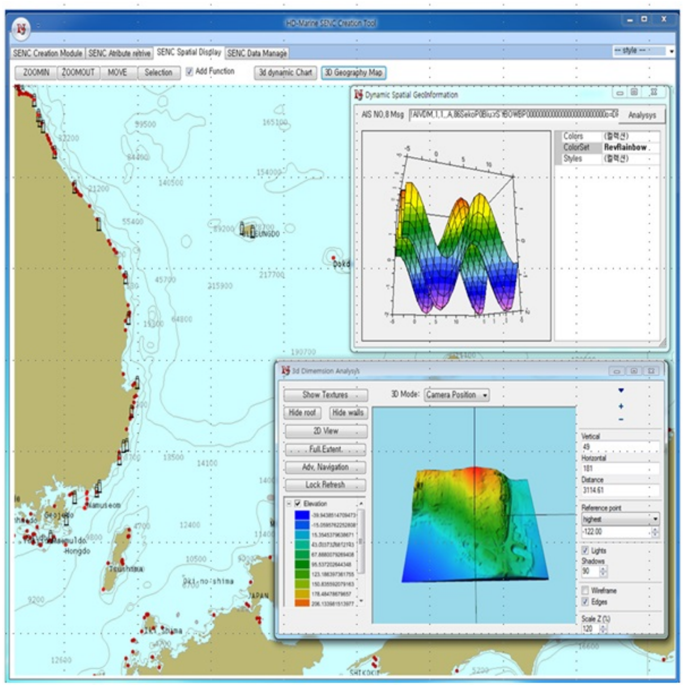

Figure 6: SENC Creation tools based on S-101 Standard

The development explored the possibility of utilization of the program for the purpose to build system ENC database through inquiry and visualization of spatial data by ANSI 92 based standard SQL, without a separate way of calculation of spatial data and viewing facility.

6 Conclusion and next work

Next generation navigation system and its new standard motivate dynamic geo-spatial information service and differentiate system architecture from conventional one. However the current standard only addresses data structure and production specification without moving forward to construction of overall system architecture and database structure.

The eventual goal of next generation navigation system is beyond the level of simple visualization of static chart data, aiming to analysis and integration of both dynamic information and accumulated static marine information. In order to accomplish these objectives, change is inevitable in database structure and system architecture of SENC, which lays basis on next generation navigation.

This paper shows the progress of modeling of System Electronic Navigation Chart (SENC) through object oriented relational database design and the visualization process by adding tentatively the actual S-101 test data into the modeling structure. In result it fulfilled not only the performance specification and requirement of the conventional file system database but also envisioned the possibility of dynamic geographic information service of ECDIS.

The next work is to be done to expand in consistent manner the database model and system architecture by actually loading aboard and analyzing anomalies if occurred and developing solutions, and furthermore to find a way of linking the dynamic geo-spatial data to big data conceptual system. And also it is necessary to enhance the performance of system database through elaborated normalization and optimization process.

References

[1] ESRI, Natuical Data Models. [online]. http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Nautical_data_models/01060000022v000000/.

[2] SQLite. [online]. http://ko.wikipedia.org/wiki/SQLite.

[3] SQLite3 performance. [online]. https://code.google.com/p/gonando-project/wiki/SQLite3_performance.

[4] S. Oh, J. Park, K. Seo, S. Suh, and K. Lee. A Study on Development of Digital Hydrographic Data based S-100. Korean Institute of Navigation and Port Research, May 2007.

[5] SOLAS. International Convention for the Safety of Life at Sea (SOLAS), 1974. List of IMO Conventions, November 1974. http://www.imo.org/about/conventions/listofconventions/pages/international-convention-for-the-safety-of-life-at-sea-(solas),-1974.aspx.

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